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ACADEMIC REVIEW

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Spending, not Sentiment: Analyzing Consumption and Consumer Confidence in Japan's GDP Growth By Ziqian Meng

Abstract

This paper examines two questions regarding Japan's economy since the 1990s: how closely GDP growth is linked to private consumption growth across different macroeconomic regimes, and whether consumer confidence predicts future economic growth. Using quarterly data from FRED, the study estimates regime-specific and pooled OLS regressions of GDP growth on private consumption, investment, exports, and government expenditure. The analysis further evaluates the role of consumer confidence through regime-interaction models and Granger causality tests, including reverse-causality robustness checks.

The results show that private consumption is a significant and consistent driver of GDP across all regimes, although exports become the dominant contributor during several periods. In contrast, consumer confidence exhibits no significant contemporaneous effect on GDP growth once other macroeconomic variables are controlled. Granger causality tests indicate that GDP growth predicts consumer confidence more strongly than consumer confidence predicts GDP growth, suggesting that confidence primarily reflects economic conditions rather than drives them. The main exception is the Abenomics period, during which consumer confidence significantly predicts future GDP growth. Overall, the findings highlight the importance of household consumption in Japan's economic growth while questioning the reliability of consumer confidence as a leading indicator outside a specific policy environment

Introduction

Private consumption has long been a key driver of Japan's economy, accounting for more than half of its gross domestic product (GDP) (Mitsubishi Research Institute). As household spending directly influences aggregate demand, changes in consumption behavior can have significant implications for economic growth. Since the 1990s, Japan has experienced several distinct macroeconomic eras, including the collapse of the asset price bubble, the "Lost Decades" of prolonged stagnation and deflation, the global financial crisis of 2008, and the implementation of Abenomics in the 2010s. More recently, the COVID-19 pandemic and subsequent recovery have further tested the link between household consumption and economic performance. Understanding the relationships between consumption and economic growth is therefore essential for evaluating Japan's long-term economic prospects.

To stimulate growth and overcome persistent economic challenges, the Japanese government has implemented various fiscal and monetary policies, including public spending programs, tax reforms, and large-scale monetary easing. Many of these measures have aimed to encourage consumer spending and strengthen domestic demand. While consumer confidence is often treated as a leading indicator of spending, whether it genuinely predicts growth in Japan remains an open question. Against this background, this research paper investigates two key questions:

1. How closely is Japan's real GDP growth linked to the growth of private consumption, and how has this relationship evolved across different macroeconomic periods since the 1990s?
2. Does the Consumer Confidence Index (CCI) predict future household consumption growth and GDP growth, and has its predictive power changed over time?

Literature Review

Gross Domestic Product (GDP) is commonly measured as the sum of consumption, investment, government expenditure, and net exports. Among these components, private consumption typically represents the largest share of economic activity in advanced economies, including Japan. However, consumption does not necessarily move one-for-one with GDP. There are many hypotheses about the fluctuation of consumer behavior that result in changes in consumption patterns. Friedman's Permanent Income Hypothesis (PIH) implies that a transitory change in income will have little effect on consumption, highlighting that consumption depends on permanent income rather than current income (Friedman). Households therefore smooth consumption over time, maintaining relatively stable expenditure despite temporary income fluctuations. However, evidence from Japan suggests that uncertainty can weaken this mechanism. Studies of Japan's Lost Decades argue that weak household spending was associated with stagnant disposable income, declining household wealth following the growing uncertainty regarding pensions, population aging, and future economic prospects (Vihriälä). As a result, precautionary saving behavior became increasingly important, indicating that consumption may deviate from the predictions of the PIH during prolonged periods of economic stagnation (Carroll).

Consumer confidence provides a complementary perspective by capturing households' perceptions of future economic conditions. Empirical studies find that confidence indicators often possess predictive power, particularly during periods of heightened uncertainty. Consumer confidence can capture precautionary saving motives, sentiment, and expectations that are not fully reflected in conventional macroeconomic indicators. Japan presents a particularly interesting case because many researchers argue that its long-term stagnation reflects structural rather than cyclical factors, including population aging, weak wage growth, and persistently deterred domestic demand (Fukao et al.). Studies have shown that large swings in confidence are often associated with fluctuations in consumption and GDP, and that combining consumer and business survey data can improve forecasts of economic activity (Dees and Soares Brinca). However, this predictive power is not universal: Huang finds the confidence–consumption link varies considerably across countries and crisis episodes, and Japan's structural features (e.g., precautionary saving, aging, and persistent uncertainty) may weaken the channel that operates more reliably in the US and Euro area. Whether Japan's CCI genuinely predicts growth therefore remains an open empirical question.

Methodology

Data Collection

Data series on the following variables are downloaded from the Federal Reserve Bank of St. Louis (FRED)

- **Real GDP:** The inflation-adjusted total value of all goods produced within Japan's economy
- **Real Private Consumption:** Household spending on goods and services adjusted for inflation
- **Real Net Exports:** The difference between exports and imports adjusted for inflation
- **Real Public Investment**: Government expenditure on infrastructure and public capital projects adjusted for inflation
- **Private Residential Investment:** Spending by the private sector on housing and residential property development
- **Private Non-Residential Investment:** Business spending on factories, machinery, equipment, and commercial buildings
- Billions of Chained 2015 Yen, Seasonally Adjusted
- **Public Spending** (Government Final Consumption Expenditure in Japan): government spending on public services, excluding investment expenditure
    - Chained 2010 Yen, Quarterly, Seasonally Adjusted

In addition, Japan's Consumer Confidence Index (CCI) data were downloaded from the OECD through the Federal Reserve Bank of St.Louis (FRED). Since the CCI data were originally reported monthly, they were converted into quarterly observations by selecting the first observation of each quarter. All datasets were then merged by observation date, with quarterly CCI data matched to quarterly GDP data. Any quarters with unmatched observations were excluded from the regression analysis to maintain consistency across variables

Variable Construction

All level variables were transformed into quarter-over-quarter percentage growth rates, such as g_GDP, before analysis. This transformation was conducted for two main reasons. First, growth rates are generally more stationary than level variables, making them better suited to time-series regression and Granger causality analysis. Second, growth rates are unit-free measures, allowing direct comparison across variables that are originally measured using different base years and scales. Furthermore, private non-residential investment (g_Inv) was selected as the investment variable instead of total investment, capturing business capital expenditure decisions more directly, which are likely to respond to changes in consumer confidence and monetary conditions.

We analyse the RQs across different economic regimes characterised by interest rate and inflation:

- Lost decade (1994-1997): A period of prolonged economic stagnation and deflation, characterized by weak growth and declining consumer confidence.
- Post-AFC (1998 - 2007): The recovery phase after the Asian Financial Crisis, marked by low interest rates and gradual economic stabilisation
- Global Financial Crisis (2008-2012): A period of severe external economic shock caused by the global recession
- Abenomics (2013 - 2019): A regime defined by aggressive monetary easing, fiscal stimulus, and inflation-targeting policies.
- COVID (2020-2025): A period characterised by pandemic-related disruption, supply shocks, and heightened economic uncertainty.

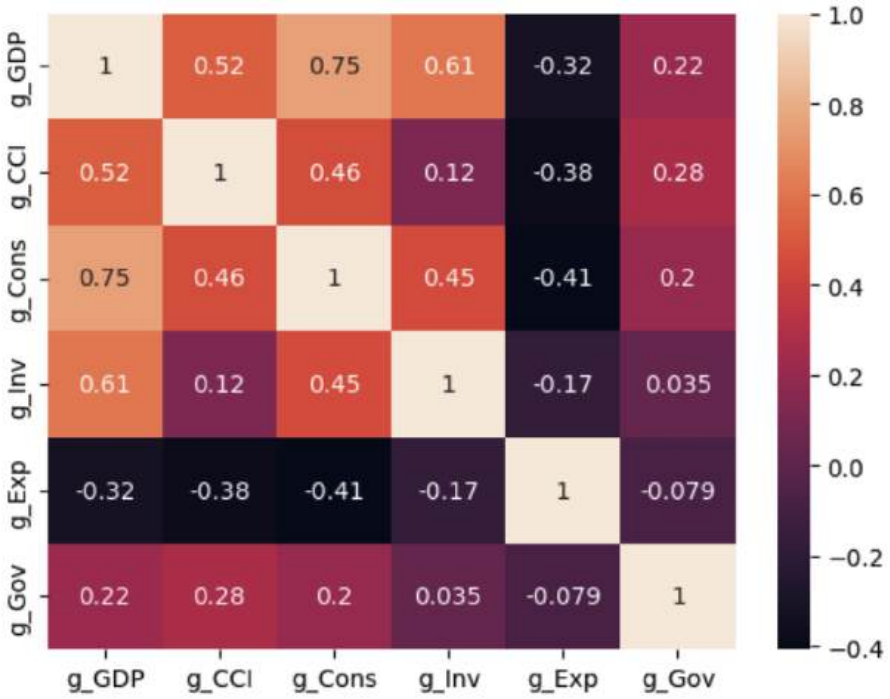
Estimation Strategy

The baseline regression model estimates the determinants of Japan's quarterly GDP growth using the following formula:

$$\mathbf{g\_GDP = \alpha + \beta_1\, g\_Cons + \beta_2\, g\_Inv + \beta_3\, g\_Exp + \beta_4\, g\ Gov + \varepsilon}$$

The model was first estimated separately for each economic regime, then estimated using a pool specification with regime dummy variables (fixed effects). All variables were transformed into quarter-over-quarter percentage growth rates to investigate the dynamic relationship between macroeconomic variables. Taking the differences of each variable in growth-rate form helps ensure stationarity, which is required for valid time-series regression analysis. HAC (Newey-West) standard errors with lag = 1 were applied throughout the analysis to correct for autocorrelation and heteroskedasticity.

Pooled regression is extended by introducing consumer confidence growth (g_CCI) and its interactions with regime dummy variables (Figure 3), replacing private consumption growth (g_Cons) in the specification. This approach allows the effect of consumer confidence on GDP growth to vary across different economic regimes. Additionally, pairwise Granger causality tests were conducted to examine the predicted relationship between g_CCI and g_GDP, as well as between g_CCI and consumption growth (g_Cons). Reverse-direction causality (g_GDP→g_CCI) was also tested as a robustness check, given that consumer sentiment may respond to economic conditions rather than independently driving them. All regressions were estimated in Python using the statsmodels library with HAC robust standard errors throughout, and all code and data sources are available upon request.



(a) Summary statistics

	g_GDP	g_Cons	g_Inv	g_Exp	g_CCI	g_Gov
mean	0.20	0.17	0.29	0.02	0.03	0.43
std	1.22	1.25	2.09	0.58	6.27	0.60
min	-7.21	-7.56	-6.84	-2.97	-31.39	-1.33
25%	-0.19	-0.19	-0.74	-0.19	-3.04	0.05
50%	0.27	0.20	0.48	0.04	0.27	0.40
75%	0.86	0.71	1.50	0.22	2.71	0.77
max	4.99	5.25	6.62	2.89	24.16	2.30

(b) Correlation across variables of interest

Table 1: Summary Stats and Correlation

Results and Discussion

OLS Regression Results

Dep. Variable:	g_GDP	R-squared:	0.525
Model:	OLS	Adj. R-squared:	0.335
Method:	Least Squares	F-statistic:	16.78
Date:	Mon, 08 Jun 2026	Prob (F-statistic):	0.000196
Time:	20:34:09	Log-Likelihood:	-9.1212
No. Observations:	15	AIC:	28.24
Df Residuals:	10	BIC:	31.78
Df Model:	4		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	-0.0785	0.167	-0.469	0.639	-0.406	0.250
g_Cons	0.2959	0.103	2.867	0.004	0.094	0.498
g_Inv	0.1969	0.121	1.625	0.104	-0.041	0.435
g_Exp	-0.1956	0.286	-0.683	0.495	-0.757	0.366
g_Gov	0.3069	0.118	2.607	0.009	0.076	0.538

Omnibus:	1.033	Durbin-Watson:	2.554
Prob(Omnibus):	0.596	Jarque-Bera (JB):	0.668
Skew:	-0.489	Prob(JB):	0.716
Kurtosis:	2.665	Cond. No.	7.29

Notes:

(a) Lost Decade (1994 - 1997)

OLS Regression Results

Dep. Variable:	g_GDP	R-squared:	0.575
Model:	OLS	Adj. R-squared:	0.527
Method:	Least Squares	F-statistic:	17.39
Date:	Mon, 08 Jun 2026	Prob (F-statistic):	6.08e-08
Time:	20:34:09	Log-Likelihood:	-25.968
No. Observations:	40	AIC:	61.94
Df Residuals:	35	BIC:	70.38
Df Model:	4		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	-0.0270	0.092	-0.294	0.769	-0.207	0.153
g_Cons	0.3589	0.099	3.631	0.000	0.165	0.553
g_Inv	0.1922	0.041	4.740	0.000	0.113	0.272
g_Exp	0.7732	0.246	3.145	0.002	0.291	1.255
g_Gov	0.2019	0.114	1.778	0.075	-0.021	0.424

Omnibus:	0.764	Durbin-Watson:	2.443
Prob(Omnibus):	0.682	Jarque-Bera (JB):	0.171
Skew:	0.081	Prob(JB):	0.918
Kurtosis:	3.276	Cond. No.	8.41

(b) Post-Asian Financial Crisis (1998 - 2007)

OLS Regression Results

Dep. Variable:	g_GDP	R-squared:	0.753
Model:	OLS	Adj. R-squared:	0.687
Method:	Least Squares	F-statistic:	14.44
Date:	Mon, 08 Jun 2026	Prob (F-statistic):	5.00e-05
Time:	20:34:09	Log-Likelihood:	-23.450
No. Observations:	20	AIC:	56.90
Df Residuals:	15	BIC:	61.88
Df Model:	4		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	0.0242	0.111	0.218	0.828	-0.194	0.242
g_Cons	0.3790	0.231	1.644	0.100	-0.073	0.831
g_Inv	0.2488	0.128	1.940	0.052	-0.003	0.500
g_Exp	1.1602	0.251	4.614	0.000	0.667	1.653
g_Gov	0.1833	0.162	1.132	0.257	-0.134	0.501

Omnibus:	0.992	Durbin-Watson:	3.023
Prob(Omnibus):	0.609	Jarque-Bera (JB):	0.304
Skew:	-0.296	Prob(JB):	0.859
Kurtosis:	3.119	Cond. No.	4.17

(c) Global Financial Crisis (2008-2012)

OLS Regression Results

Dep. Variable:	g_GDP	R-squared:	0.857
Model:	OLS	Adj. R-squared:	0.833
Method:	Least Squares	F-statistic:	64.10
Date:	Mon, 08 Jun 2026	Prob (F-statistic):	3.90e-12
Time:	20:34:09	Log-Likelihood:	-8.0975
No. Observations:	28	AIC:	26.19
Df Residuals:	23	BIC:	32.86
Df Model:	4		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	0.0767	0.064	1.207	0.227	-0.048	0.201
g_Cons	0.4638	0.054	8.531	0.000	0.357	0.570
g_Inv	0.1691	0.033	5.055	0.000	0.104	0.235
g_Exp	0.8158	0.196	4.170	0.000	0.432	1.199
g_Gov	0.0231	0.128	0.180	0.857	-0.228	0.274

Omnibus:	1.358	Durbin-Watson:	2.168
Prob(Omnibus):	0.507	Jarque-Bera (JB):	1.023
Skew:	0.195	Prob(JB):	0.599
Kurtosis:	2.149	Cond. No.	7.54

(d) Abenomics (2013-2019)

OLS Regression Results

Dep. Variable:	g_GDP	R-squared:	0.979
Model:	OLS	Adj. R-squared:	0.972
Method:	Least Squares	F-statistic:	2377.
Date:	Mon, 08 Jun 2026	Prob (F-statistic):	2.81e-17
Time:	20:34:09	Log-Likelihood:	-5.1828
No. Observations:	17	AIC:	20.37
Df Residuals:	12	BIC:	24.53
Df Model:	4		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	-0.0182	0.084	-0.215	0.830	-0.184	0.147
g_Cons	0.4346	0.055	7.968	0.000	0.328	0.541
g_Inv	0.2012	0.044	4.529	0.000	0.114	0.288
g_Exp	0.8582	0.083	10.347	0.000	0.696	1.021
g_Gov	0.0941	0.072	1.299	0.194	-0.048	0.236

Omnibus:	9.201	Durbin-Watson:	1.632
Prob(Omnibus):	0.010	Jarque-Bera (JB):	6.761
Skew:	-0.932	Prob(JB):	0.0340
Kurtosis:	5.465	Cond. No.	5.71

(e) COVID

Figure 1: Regression Analysis of GDP growth drivers across different economic regimes

The average growth of private consumption (g_Cons) is statistically significant across almost all economic regimes and consistently shows a positive coefficient, indicating that higher consumption growth correlates with higher average GDP growth per quarter. Meanwhile, the significance of the other three components, government spending, investment, and exports, fluctuates across different regimes.

During the Lost Decade (1994-1997), Japan experienced prolonged stagnation caused by the collapse of the asset bubble. Although the consumption growth coefficient is positive and statistically significant (p= 0.004), the coefficient of 0.2959 is the smallest among the five different regimes. Weak consumer confidence and deflation during this specific regime limited economic activity, which explains why private consumption, though statistically significant, only had a moderate effect (Horioka). The low consumption is consistent throughout the regime, showing that households increase buffer saving rather than consumption during recession (Carroll). Government spending (g_Gov) is statistically significant with a coefficient of 0.3069 (p=0.009), showing that fiscal stimulus partially offset weak private-sector demand during stages of stagnation. Investment is not statistically significant (p=0.10), indicating weak corporate activity, most likely due to balance sheet recession and the banking crisis, where firms prioritized debt payment over expansion. Exports played a relatively insignificant role in average GDP growth (p=0.495), suggesting Japan's limited reliance on external demand during this period.

During the Post-Asian Financial Crisis(1998-2007), GDP growth became statistically significant associated with consumption (coef=0.359, p=0.000), investment (coef=0.192, p=0.000), and exports (coef=0.773, p=0.002). The strength of consumer consumption is slightly stronger than in the Lost Decade, indicating a gradual recovery in domestic demand. Although consumption remained significant, its coefficient was considerably smaller than that of exports, suggesting that domestic demand remained relatively weak. This supports studies arguing that Japan's recovery during the 2000s was driven more by external demand than by a sustained revival of household consumption. The high significance of investment reveals that capital allocation and business confidence were improved and restored from the previous regime, which could be attributed to Japan's financial liberalization reformation, such as the Japanese Big Bang Financial reforms in 1996 (Dekle). Government expenditure became statistically insignificant. This finding indicates that growth was increasingly driven by private-sector activity rather than fiscal stimulus.

The Global Financial Crisis (2008-2012) period highlights Japan's vulnerability to external shocks. Exports became the strongest determinant of GDP growth (p=0.000), with a coefficient of 1.1602, while consumption and investment were only marginally significant. Consumption was weakened as heightened uncertainty encouraged households to reduce expenditure and increase savings. Although investment displayed signs of recovery, firms remained cautious amid deteriorating global financial conditions. Government spending is not statistically significant (p=0.257), despite the introduction of stimulus measures such as the Japanese stimulus packages of 2008 (AP), which provided a supplementary budget expected to

be around 14 trillion yen, with proposals for even larger packages up to 25 trillion yen, which would relieve the capital tax burden.

A major structural shift occurred during the Abenomics regime (2013-2019). The ‘Three Arrows’ policy (monetary easing, fiscal stimulus, and structural reform), introduced by Shinzo Abe, aimed to revive domestic demand and end deflation. As a result, consumption (coef=0.464, p=0.000), investment (coef=0.169, p=0.000), and export (coef=0.816, p=0.000) become strongly significant, presenting recovered business confidence, increased household spending, and growing external demand. These changes can be aligned to policies proposed by the Bank of Japan under the Quantitative and Qualitative Easing(QQE) (Kuroda), which lowered interest rates and stimulated borrowing and investment. Government spending(p=0.980) remains statistically insignificant, showing Japan's less reliance on fiscal stimulus compared to the previous regime(Tokuoka) under the consumption-priority fiscal policies.

The Covid Pandemic period (post-2019) exhibits the strongest overall model fit and reveals a similar pattern to the Abenomics era. Consumption (coef=0.435, p=0.000), investment (coef=0.201, p=0.000), and exports (coef=0.858, p=0.000) all exerted a statistically significant effect on GDP growth. The promotion of private consumption can be closely linked to the ultra-loose monetary policy of Quantitative and Qualitative Easing (Bank of Japan, 2021), under which the Bank of Japan maintained ultra-low interest rates and yield curve control, encouraging borrowing and spending by households. It resulted in a structural shift toward a consumption-led economy. This is a substantial increase compared to Abenomics, highlighting stronger dependence on household demand. Investment is still statistically significant (p=0.007) with a coefficient of 0.1941. The significance of investment has continued from the Abenomics period, supported by prolonged low interest rates and continued monetary easing (Bank of Japan). However, exports again displayed the largest coefficient, highlighting the importance of the global trade recovery for Japan’s economic performance. Notably, this regime exhibits the highest explanatory power (R^2=0.979), suggesting that the components of GDP explain 98% of the variance in GDP growth, which means that GDP growth is now more systematically driven by domestic factors, particularly consumption.

OLS Regression Results

Dep. Variable:	g_GDP	R-squared:	0.829
Model:	OLS	Adj. R-squared:	0.817
Method:	Least Squares	F-statistic:	169.9
Date:	Fri, 12 Jun 2026	Prob (F-statistic):	1.33e-58
Time:	13:29:18	Log-Likelihood:	-90.641
No. Observations:	120	AIC:	199.3
Df Residuals:	111	BIC:	224.4
Df Model:	8		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	0.0224	0.130	0.172	0.864	-0.233	0.277
g_Cons	0.4199	0.054	7.729	0.000	0.313	0.526
g_Inv	0.2021	0.042	4.762	0.000	0.119	0.285
g_Exp	0.9271	0.100	9.256	0.000	0.731	1.123
g_Gov	0.1600	0.061	2.628	0.009	0.041	0.279
Post_AFC	-0.0603	0.136	-0.443	0.658	-0.327	0.206
GFC	-0.0425	0.169	-0.252	0.801	-0.373	0.288
Abenomics	-0.0170	0.138	-0.123	0.902	-0.287	0.253
COVID	-0.0713	0.149	-0.479	0.632	-0.363	0.221

Omnibus:	20.533	Durbin-Watson:	2.611
Prob(Omnibus):	0.000	Jarque-Bera (JB):	47.995
Skew:	-0.634	Prob(JB):	3.79e-11
Kurtosis:	5.827	Cond. No.	15.6

Figure 2: Summary of Regression Results with Regime Fixed Effects

The coefficients on the GDP components remain highly significant. Consumption (coef=0.420, p=0.000), investment (coef=0.202, p=0.000), exports (coef=0.927, p=0.000) and government expenditure (coef=0.160, p=0.009) all positively contribute to GDP growth. Among them, exports exhibit the largest coefficient, indicating that external demand is an important driver of GDP growth throughout the sample period. Consumption remains a substantial effect, supporting the view that household expenditure in Japan remains an important source of aggregate demand despite Japan's prolonged economic stagnation.

The dummy variables reinforce the conclusion: none are statistically significant, implying that shifts such as Post-Asian Financial Crisis (p=0.658), Abenomics (p=0.902), Global Financial Crisis (p=0.801), and COVID-19 (p=0.632) did not fundamentally alter the underlying structure of growth. However, all regimes exhibit a negative coefficient on average GDP growth. It indicates a contractionary shock to GDP growth, even if not statistically significant, reflecting its adverse macroeconomic impact.

Overall, the model presents relatively strong explanatory power (R^2=0.829), suggesting that Japan's growth dynamics can be largely explained by these internal components, which confirms that a long-term transition is happening toward a consumption-led and domestically driven economy in Japan.

OLS Regression Results

Dep. Variable:	g_GDP	R-squared:	0.741
Model:	OLS	Adj. R-squared:	0.722
Method:	Least Squares	F-statistic:	67.29
Date:	Mon, 08 Jun 2026	Prob (F-statistic):	4.85e-39
Time:	20:34:10	Log-Likelihood:	-115.60
No. Observations:	120	AIC:	249.2
Df Residuals:	111	BIC:	274.3
Df Model:	8		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	[0.025	0.975]
Intercept	-0.0326	0.079	-0.412	0.681	-0.188	0.123
g_CCI	0.0104	0.045	0.232	0.817	-0.078	0.099
g_CCI:Abenomics	0.0247	0.055	0.453	0.650	-0.082	0.132
g_CCI:COVID	0.0583	0.051	1.149	0.251	-0.041	0.158
g_CCI:GFC	-0.0021	0.048	-0.043	0.966	-0.097	0.093
g_CCI:Post_AFC	0.0308	0.050	0.617	0.537	-0.067	0.129
g_Inv	0.3026	0.034	8.799	0.000	0.235	0.370
g_Exp	0.8457	0.170	4.970	0.000	0.512	1.179
g_Gov	0.2622	0.104	2.526	0.012	0.059	0.466

Omnibus:	1.678	Durbin-Watson:	2.335
Prob(Omnibus):	0.432	Jarque-Bera (JB):	1.339
Skew:	-0.254	Prob(JB):	0.512
Kurtosis:	3.102	Cond. No.	18.1

Figure 3: CCI interactions with regime dummies

Figure 3 examines the relationship between consumer consumption confidence (CCI) and Japan's average growth rate from 1994 to 2025. Significantly, the coefficient for overall CCI growth is small and statistically insignificant (cof=0.010, p= 0.817), suggesting that consumer confidence does not consistently explain long-run GDP growth in Japan. This indicates that changes in consumer confidence sentiment alone were insufficient to influence economic growth across the entire period.

More importantly, none of the interaction terms is statistically significant. The finding indicates that the relationship between consumer confidence and GDP growth did not change significantly across macroeconomic regimes. Although previous literature argues that confidence should become more important during periods of heightened uncertainty because households engage in precautionary spending and adjust spending based on expectations (Dees and Soares Brinca), the regression results do not reflect this hypothesis for Japan. Even during crisis periods such as the Global Financial Crisis and the COVID-19 pandemic, consumer confidence does not exhibit a statistically significant contemporaneous effect on GDP growth.

A possible explanation is that consumer confidence influences GDP indirectly through other components of aggregate demand rather than exerting an independent effect. The figure reveals consistently strong and highly significant coefficients on investment (coef=0.303, p=0.000), exports (coef=0.846, p=0.000), and government expenditure (coef=0.262, p=0.012), which remain the primary drivers of GDP growth throughout the sample. Therefore, the apparent importance of confidence observed in simpler specifications may reflect its correlation with broader economic conditions rather than a direct causal effect on GDP.

Table 2(a): Full sample Granger Causality (1994–2025)

Lag	g_CCI → g_GDP	g_CCI → g_Cons	g_GDP → g_CCI
1	0.0918	1.6931	9.3737***
2	1.0867	0.9292	4.5980**
3	3.0185**	2.4625*	8.3504***
4	2.6238**	2.4020*	7.1814***

*p<0.1 **p<0.05 ***p<0.01

Table 2(a) presents the Granger causality test results examining the dynamic relationship between consumer confidence growth (g_CCI) and GDP growth (g_GDP) in Japan from 1994 to 2025. Each lag represents one quarter of time delay, meaning that lag 1 corresponds to one quarter earlier, while lag 4 represents one year earlier.

For the relationship from consumer confidence to GDP growth, CCI growth significantly Granger-causes average growth of GDP only at lag 3-4 (F=3.0185, F=2.6238; p<0.05). This indicates that changes in consumer confidence approximately four quarters– one year – earlier help predict current GDP growth. The finding implies that consumer expectations may influence future economic activity through a delayed effect on household spending and investment behavior.

In contrast, GDP growth also Granger-causes consumer confidence. The results are highly significant at all four horizons, suggesting that stronger GDP performance will improve consumer confidence three to four quarters earlier. An economic boom may increase employment opportunities and optimism toward future economic expectations, therefore reinforcing consumer sentiment over time.

However, the causality between consumer confidence and consumption growth (g_Cons) remains statistically insignificant across all lags. This result indicates that changes in confidence do not directly influence short-term consumption growth in Japan, possibly due to structural factors, such as precautionary saving behavior, aging population, and long-term economic uncertainty (Horioka).

To sum up, the findings reveal an asymmetric relationship in which GDP growth predicts confidence more strongly and at every horizon than confidence predicts GDP. Meanwhile, consumer confidence appears to influence economic performance over longer periods, while GDP growth simultaneously shapes households' future expectations.

Table 2(b): Does CCI Granger-cause g_GDP within each period?

Lag	Lost Decade	Post AFC	GFC	Abenomics	COVID
1	0.0530	1.3804	0.2674	5.5553**	0.3614
2	0.5587	1.6937	1.9931	4.7196**	0.1484
3		1.1338		4.1003**	
4		1.4253		3.0484*	

*p<0.1 **p<0.05 ***p<0.01

Note: The number of lags tested is capped at 2 for regimes with fewer than 26 quarterly observations to preserve degrees of freedom.

The results show that consumer confidence only significantly predicts GDP growth during the Abenomics period (2013-2019), which was a period of macroeconomic recovery. All four lag lengths are statistically significant, with $p<0.05$ for lags 1-3 and $p<0.1$ for lag 4. This provides strong evidence that changes in consumer confidence preceded changes in economic activity during this period. This result is consistent with the objectives of Abenomics, which sought to stimulate domestic demand and raise inflation expectations through aggressive monetary easing, fiscal support, and structural reforms. Because the policy framework explicitly targeted expectations and confidence, consumer sentiment becomes more closely linked to subsequent consumption and investment decisions. Consequently, confidence functioned as a leading indicator of GDP growth during this regime.

In contrast, the Lost Decade, Post-AFC, Global Financial Crisis (GFC), and COVID periods show no statistically significant causality from CCI to GDP growth across all lags. It means that consumer confidence alone wasn't sufficient to predict economic growth during these periods.

Similarly, although consumer confidence became statistically significant in the earlier regression during crisis periods such as COVID and the GFC, the Granger causality test here suggests that confidence did not consistently predict future GDP growth within those regimes. It implies that confidence may react more immediately to economic conditions rather than operating as a directing indicator.

To conclude, the results suggest that the predictive power of consumer confidence is regime-dependent, which supports the previous conclusion of consumer confidence as a regime-specific factor (Figure 2).

Conclusion

This study examined two questions regarding consumption behavior in Japan since the 1990s: how closely private consumption growth is linked to GDP growth across different macroeconomic regimes, and whether consumer confidence serves as a reliable predictor of future consumption and economic activity. The findings contribute to the broader debate on whether consumer confidence acts as a driver of economic activity or merely reflects underlying economic conditions.

The first key finding is that private consumption remains a consistent contributor to Japanese GDP growth across all regimes. Although export growth became the dominant source of growth during the post-Asian Financial Crisis, Global Financial Crisis, Abenomics, and COVID periods, consumption maintained a positive and statistically significant relationship with GDP growth. Moreover, the consumption coefficient generally increased over time, suggesting that household demand became increasingly important to economic performance. These results support the literature emphasizing the role of domestic demand in Japan's long-run growth trajectory and highlight the importance of household spending despite persistent structural challenges such as the aging society, weak wage growth, and precautionary saving behavior.

The second key finding is that consumer confidence is not a consistently reliable leading indicator of GDP growth. Contemporaneous regressions reveal no significant effect of CCI on GDP growth once investment, exports, and government expenditure are controlled for. Similarly, interaction models indicate that this relationship does not differ significantly across macroeconomic regimes. While full-sample Granger causality tests suggest that CCI predicts GDP growth and consumption growth over longer horizons, regime-specific analysis demonstrates that this predictive power is concentrated almost entirely within the Abenomics period. During the other four regimes, consumer confidence does not significantly predict future GDP growth.

Taken together, these findings suggest that consumer confidence in Japan functions primarily as a reflection of economic conditions rather than an independent driver of growth. This interpretation is reinforced by the strong reverse-causality evidence showing that GDP growth consistently Granger-causes consumer confidence. Furthermore, the contrast between the contemporaneous relationships observed in some specifications and the lack of predictive precedence during crisis regimes suggests that consumer confidence often behaves as a coincident indicator during periods of economic stress.

Several limitations should be acknowledged. First, the regime classifications are necessarily researcher-defined, and alternative dating schemes may produce somewhat different results. Second, the within-regime samples are relatively small, particularly for the Lost Decade, Global Financial Crisis, and COVID periods, reducing the statistical power of the Granger causality tests. Third, while the evidence indicates predictive relationships and potential reverse causality, Granger causality does not establish true economic causation. Identifying causal mechanisms would require structural models, instrumental-variable approaches, or natural-experiment designs beyond the scope of this study.

Future research could extend this analysis by examining disaggregated consumption categories, such as durable and non-durable goods, or by incorporating household-level survey data to better capture heterogeneity in expectations and spending behavior. Structural macroeconomic models could also provide deeper insight into the mechanisms through which consumer confidence interacts with precautionary saving, demographic change, and monetary policy.

Overall, the evidence suggests that Japan's growth experience since the 1990s is best understood as a story of household demand operating within broader structural constraints. Private consumption remains an important pillar of economic growth, but consumer confidence itself is generally more reflective of economic conditions than a force driving them. Only when policy actively shapes expectations, as during Abenomics, confidence will emerge as a meaningful predictor of future economic activity. These findings highlight the importance of distinguishing between household spending and household sentiment when evaluating the drivers of economic growth and designing policies aimed at strengthening domestic demand.

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The Impact of Artificial Intelligence on Operational Efficiency in Modern Businesses: Opportunities, Challenges, and Performance Outcomes By Amira Berzhan

Abstract

Artificial Intelligence (AI) has become one of the most transformative technologies influencing modern business operations. Organizations across industries increasingly adopt AI-driven systems to improve operational efficiency, reduce costs, optimize decision-making, and strengthen competitive performance. This paper examines the impact of artificial intelligence on operational efficiency in contemporary businesses, focusing on automation, predictive analytics, and customer-oriented operational systems. Drawing upon academic literature, industry reports, and real-world business examples, the study evaluates how AI contributes to productivity growth, cost reduction, and process optimization while also addressing implementation challenges and workforce concerns. The findings suggest that AI technologies significantly improve operational performance by increasing efficiency, reducing manual labor, and strengthening strategic decision-making. However, challenges related to implementation costs, ethical considerations, and workforce adaptation remain important concerns. The study argues that artificial intelligence has become a critical factor in shaping business competitiveness in increasingly data-driven and technologically advanced markets.

Keywords artificial intelligence, operational efficiency, business performance, automation, predictive analytics

1. Introduction

Artificial intelligence has rapidly evolved from a theoretical technological concept into a practical business tool used to optimize operations, improve productivity, and strengthen organizational competitiveness. AI refers to systems capable of performing tasks that typically require human intelligence, including learning, reasoning, prediction, and problem-solving (Russell & Norvig, 2021). Businesses increasingly integrate technologies such as machine learning, robotic process automation, and predictive analytics into operational processes to improve efficiency and reduce human error. This transformation reflects growing pressure on companies to operate faster, cheaper, and more effectively in highly competitive global markets. The increasing adoption of AI is closely linked to broader economic and technological developments. According to McKinsey & Company (2023), approximately 55 percent of organizations worldwide have adopted artificial intelligence in at least one business function, a substantial increase compared to previous years. Furthermore, PwC (2022) estimates that AI could contribute approximately $15.7 trillion to the global economy by 2030 through productivity gains, increased efficiency, and enhanced consumer demand. These statistics illustrate that AI is no longer limited to large technology firms but has become increasingly integrated into sectors including healthcare, finance, logistics, retail, and manufacturing.

Operational efficiency has become one of the most important objectives of AI implementation. Operational efficiency refers to an organization's ability to maximize output while minimizing waste, costs, and operational disruptions (Slack & Brandon-Jones, 2019). Companies increasingly use AI to automate repetitive tasks, optimize supply chains, improve forecasting, and enhance customer interactions. However, despite measurable benefits, AI implementation also presents challenges related to investment costs, employee displacement, and ethical concerns regarding data privacy and decision-making transparency. Therefore, this paper evaluates how artificial intelligence affects operational efficiency in modern businesses while assessing both its opportunities and limitations.

2. Theoretical Background

2.1 Artificial Intelligence in Modern Business Operations

Artificial intelligence has become an essential operational tool because of its ability to analyze large amounts of information, automate repetitive activities, and support business decision-making. AI technologies commonly used in business include machine learning, natural language processing, computer vision, and robotic process automation. These systems improve organizational performance by recognizing patterns, predicting outcomes, and optimizing business functions with greater speed and accuracy than traditional approaches (Russell & Norvig, 2021).

AI adoption has accelerated significantly over the past decade. According to IBM's Global AI Adoption Index (2023), approximately 42 percent of enterprises worldwide actively use artificial intelligence in operations, while an additional 40 percent report exploring implementation opportunities. Manufacturing firms increasingly rely on AI-driven predictive maintenance systems, while financial institutions use machine learning for fraud detection and risk assessment. In retail environments, AI-powered analytics improve inventory management and consumer targeting, helping businesses increase efficiency while reducing operational costs. Despite growing adoption, implementation challenges remain substantial. Bughin et al. (2018) note that organizational resistance, high investment costs, and lack of technical expertise often slow adoption, particularly among small and medium-sized enterprises. Concerns regarding cybersecurity and algorithmic bias also create uncertainty, especially when AI systems influence hiring decisions or customer interactions. Nevertheless, increasing investment suggests that AI technologies are increasingly viewed as strategic tools capable of improving operational performance and long-term competitiveness.

2.2 Operational Efficiency and Business Performance

Operational efficiency refers to an organization's ability to produce maximum output with minimal wasted resources, time, and operational cost (Slack & Brandon-Jones, 2019). Efficient organizations reduce inefficiencies while maintaining productivity, quality, and

customer satisfaction. In increasingly competitive business environments, operational efficiency has become a key determinant of profitability and long-term success.

Artificial intelligence directly contributes to operational efficiency through automation, optimization, and predictive capabilities. Deloitte (2022) reports that organizations implementing AI-powered operational systems experience productivity improvements ranging between 20 and 40 percent, depending on industry and implementation scale. In manufacturing, predictive maintenance systems powered by AI have reduced equipment downtime by approximately 30 to 50 percent while extending machinery lifespan by up to 40 percent (McKinsey & Company, 2021). These measurable improvements demonstrate the practical value of AI in improving operational performance.

Business performance also improves when organizations use AI for data-driven decision-making. Predictive analytics enables businesses to forecast demand, manage inventory, and optimize pricing strategies more accurately than traditional forecasting methods. According to Accenture (2022), companies effectively integrating AI into operations may achieve profitability increases of up to 38 percent by improving efficiency and reducing operational disruptions. These findings indicate that operational efficiency and financial performance are increasingly interconnected through technological innovation.

3. Applications of Artificial Intelligence in Business Operations

3.1 Automation and Process Optimization

One of the most important applications of artificial intelligence in business operations is automation. AI-powered automation reduces the need for repetitive manual labor, allowing organizations to improve productivity and reduce operational costs. Robotic process automation is widely used for tasks such as invoice processing, payroll management, inventory tracking, and administrative workflows. Unlike traditional automation systems, AI-driven automation can adapt to changing patterns and improve performance through machine learning (Davenport & Ronanki, 2018).

The economic impact of automation is substantial. According to McKinsey Global Institute (2021), automation technologies could increase global productivity growth by approximately 1.4 percent annually. Furthermore, organizations implementing AI automation report cost reductions ranging between 15 and 35 percent depending on sector and implementation complexity (Deloitte, 2022). For example, logistics companies increasingly use AI-powered warehouse systems to improve inventory movement and reduce delays, improving both operational speed and accuracy.

However, automation also raises workforce concerns. The World Economic Forum (2023) estimates that while automation may displace approximately 85 million jobs globally, it may simultaneously create around 97 million new roles focused on technology management, analytics, and AI supervision. This suggests that while AI may replace repetitive work, it may also transform labor markets by creating demand for new skills and professional adaptation.

3.2 Predictive Analytics and Decision-Making

Predictive analytics represents one of the most valuable applications of artificial intelligence in modern businesses because it enables organizations to make more informed and proactive decisions. Predictive analytics refers to the use of historical data, statistical algorithms, and machine learning models to forecast future outcomes and identify patterns that may influence business performance (Shmueli & Koppius, 2011). Unlike traditional business forecasting methods, AI-driven predictive systems continuously learn from incoming data, improving accuracy over time. Businesses increasingly use predictive analytics to forecast consumer demand, optimize pricing strategies, reduce operational risks, and strengthen supply chain efficiency.

The implementation of predictive analytics has generated measurable improvements across industries. According to a report by PwC (2022), companies using AI-powered predictive systems improve forecasting accuracy by approximately 30 to 50 percent compared to conventional methods. In supply chain management, predictive models help organizations reduce inventory shortages and overstocking costs by analyzing customer demand patterns and external market variables. Retail companies such as Walmart and Amazon use predictive analytics to optimize inventory management and improve delivery efficiency, reducing operational disruptions while increasing customer satisfaction. Similarly, financial institutions increasingly apply predictive algorithms to identify fraud, assess credit risk, and improve financial forecasting accuracy.

The effectiveness of predictive analytics lies in its ability to support strategic decision-making under uncertainty. Rather than relying solely on managerial intuition, organizations increasingly use AI-generated insights to guide investments, production planning, and operational management. However, predictive systems are not without limitations. Poor data quality, algorithmic bias, and inaccurate assumptions may reduce reliability and produce flawed forecasts (Brynjolfsson & McAfee, 2017). Consequently, businesses must combine predictive technologies with human oversight to ensure responsible and effective decision-making.

3.3 Customer Service and Personalization

Artificial intelligence has significantly transformed customer service by enabling businesses to deliver faster, more personalized, and cost-effective interactions. AI-powered systems such as chatbots, virtual assistants, and recommendation algorithms allow companies to respond to customer needs in real time while reducing operational expenses. Natural language processing technologies enable AI systems to understand and respond to customer inquiries, improving both service accessibility and efficiency (Huang & Rust, 2021).

Businesses increasingly rely on AI to improve personalization and customer engagement. Recommendation systems used by companies such as Netflix, Amazon, and Spotify analyze customer behavior to suggest products and services tailored to individual preferences. McKinsey & Company (2021) reports that personalization strategies powered by artificial intelligence may increase company revenues by approximately 10 to 15 percent while simultaneously improving

customer retention rates. Furthermore, Juniper Research (2022) estimates that AI-driven chatbots help businesses save over $11 billion annually by reducing labor costs and improving response efficiency.

Although these benefits are substantial, customer-oriented AI systems also present challenges. Excessive reliance on automation may reduce human interaction and negatively affect customer trust, particularly in situations involving complex issues or emotional communication. Privacy concerns also remain significant because AI personalization depends heavily on data collection and behavioral tracking. Consequently, businesses must balance efficiency gains with ethical responsibility and customer expectations to maintain trust and satisfaction.

4. Case Examples and Comparative Analysis

The impact of artificial intelligence on operational efficiency can be clearly observed through real-world business examples. Companies such as Amazon, Tesla, Starbucks, and JPMorgan Chase demonstrate how AI technologies improve operational performance through automation, predictive analytics, and customer optimization strategies. Although these organizations operate in different industries, they share a common objective of increasing productivity while reducing inefficiencies and operational costs.

Amazon represents one of the strongest examples of AI-driven operational efficiency. The company uses artificial intelligence extensively in logistics, inventory forecasting, and warehouse automation. Amazon's fulfillment centers rely on robotic systems that reduce package movement time and improve inventory accuracy. According to McKinsey & Company (2023), AI-powered warehouse automation has enabled Amazon to reduce fulfillment costs while significantly improving delivery speed. Recommendation algorithms also contribute substantially to operational success, with approximately 35 percent of Amazon's revenue reportedly generated through personalized recommendation systems (McAfee & Brynjolfsson, 2017). Tesla similarly relies on AI technologies to optimize manufacturing processes, predictive maintenance, and autonomous driving systems. The company's factories use AI-supported robotics to improve production precision and reduce waste, contributing to increased manufacturing efficiency.

Starbucks and JPMorgan Chase provide examples of AI implementation outside manufacturing and logistics. Starbucks uses AI through its Deep Brew platform, which personalizes promotions and predicts customer purchasing behavior based on previous interactions. This allows the company to improve operational planning and customer retention. JPMorgan Chase applies AI-powered systems to fraud detection, risk management, and legal document processing. According to JPMorgan internal estimates, AI-supported contract analysis reduced legal document review time from approximately 360,000 hours annually to only a fraction of that workload (Davenport & Ronanki, 2018). These cases illustrate that AI contributes to operational efficiency not only by reducing labor costs but also by improving speed, accuracy, and strategic decision-making across industries.

5. Discussion

The findings of this study indicate that artificial intelligence has become a major driver of operational efficiency in modern businesses. AI contributes to improved productivity through automation, predictive analytics, and personalized customer engagement, enabling organizations to reduce costs and strengthen competitiveness. Businesses increasingly rely on AI technologies to optimize supply chains, improve forecasting accuracy, automate repetitive activities, and support data-driven decision-making. Evidence suggests that organizations implementing AI systems often experience measurable operational improvements, including productivity increases of 20 to 40 percent and substantial reductions in downtime and operational disruptions (Deloitte, 2022).

Despite these advantages, artificial intelligence implementation also presents important challenges. High implementation costs, technical complexity, and workforce displacement remain significant concerns, particularly for smaller businesses with limited resources. Ethical issues related to algorithmic bias, privacy protection, and decision transparency further complicate AI adoption. Moreover, excessive reliance on automated systems may reduce human judgment in situations where contextual understanding and emotional intelligence remain essential. Consequently, organizations must balance technological innovation with ethical oversight and workforce adaptation.

Ultimately, the effectiveness of artificial intelligence depends on how organizations integrate these technologies into broader operational strategies. Businesses that combine AI capabilities with human expertise are more likely to achieve sustainable improvements in efficiency while minimizing associated risks. As technology continues to evolve, artificial intelligence will likely become an increasingly essential component of business operations and strategic competitiveness.

6. Conclusion

Artificial intelligence has fundamentally transformed operational efficiency in modern businesses by improving automation, forecasting accuracy, and customer service. The findings of this study suggest that AI contributes significantly to productivity growth, cost reduction, and improved decision-making across industries. Companies such as Amazon, Tesla, Starbucks, and JPMorgan Chase demonstrate that AI technologies can enhance both operational performance and long-term competitiveness when implemented strategically.

The successful adoption of artificial intelligence requires careful management of challenges related to implementation costs, workforce transformation, ethical concerns, and data privacy. While AI offers substantial operational benefits, organizations must ensure responsible integration supported by human oversight and organizational readiness. As business environments become increasingly data-driven, artificial intelligence is expected to remain a key determinant of operational success and competitive advantage in the future.

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Terrorism: The Evil of the Act or the Identity of the Actor? By Rengin Yaralı

Introduction

"When attacked on civilians it is not anything other than terrorism and its evil rendering any cause irrelevant" is a true but lacking statement. At first glance it appears to be uncontroversial; it aligns with what we are taught by governments, schools, and international law since we were kids. Most people, when asked, would agree targeting unarmed civilians is inherently wrong and a violation of human rights without hesitation. While this statement offers a strong starting point, it ultimately falls short. The real world is far more complex. Does the morality of violence only depend on the victim or does the identity -state or non state- of the actor. Can we uphold a consistent moral standard when states and non-state actors are judged by different measures? The international definition of terrorism itself is contested. The United Nations General Assembly (8th October 2004) defines terrorism briefly as: "Criminal acts -including against civilians- committed with the intent to cause death or serious bodily injury with the purpose to provoke a state of terror or compel a government." (United Nations Office on Drugs and Crime). World leaders have also had some important sayings on terrorism. George W. Bush, after the attacks on 9/11 said that: *"Every nation, in every region, now has a decision to make. Either you are with us, or you are with the terrorists,"* (Voice of America). The president of The Republic of Türkiye Recep Tayyip Erdoğan said: *"Terrorists are puppets. Our goal is a Türkiye without terrorism; we will not compromise on this."* (Sevencan, Berker, and Calli). As you can see governments describe it as something "bad guys" do (Farrell 64). Yet, world leaders have all labelled their adversaries "terrorists" while justifying their own governments' civilian-targeted operations as security measures. This double standard reveals that terrorism is less about what is done and more about who does it. If powerful states can kill civilians and escape the terrorist label, what does that say about our moral consistency?

Defining terrorism and the moral problem

The definition of terrorism changed since its first usage in the 1790s, the French Revolution from today how the FBI defines it (Jenkins). The word terrorism was coined during the French Revolution's Reign of Terror (1793–1794). In the Reign of Terror (Le Gouvernement de la Terreur), a group of rebels called "the Jacobins" used the term when self-reflexively portraying their own actions in the French Revolution (Bishara 4-8). At that time during the Revolution, it was state-centric -terror by the government, not against. Over time, especially in the 20th century, the definition flipped to focus on non-state actors. Today, definitions vary across institutions. The FBI defines terrorism, domestic or international, as the *"Unlawful use of force or violence against persons or property to intimidate or coerce a government or civilian population in furtherance of political or social objectives"*. (Pomerantz).

Philosophical frameworks also shape how we perceive terrorism. Kant (1785) would argue that targeting civilians violates the categorical imperative, as it treats individuals merely

as means to an end rather than as ends in themselves. This absolutist view holds that: “No political or ideological goal can justify the deliberate killing of non-combatants, as it corrupts the very notion of moral law" (Hu). In contrast, consequentialist perspectives introduce a new line of vision to the topic, different from what we morally learn. "The utilitarian perspective evaluates terrorism not by its intrinsic wrongness but by its consequences. Utilitarians ask whether the act prevents greater suffering or is it for the “greater good” (Bentham).
This space of extreme exceptions leads us to one of Michael Walzer’s most controversial arguments in *Just and Unjust Wars,* which is that soldiers and political leaders can override the principle of noncombatant immunity and even kill innocent people -civilians if their political community faces an imminent and existential threat (e.g., the British attack on the Nazism). He called this the ***“supreme emergency”,*** and it continues to be argued even after 4 decades (Fleming 90).

The moral hazard here is that governments exploit these definitions. Powerful governments engaging in mass civilian killings are rarely labelled as terrorists. For example, The United States of America has started its drone warfare with President Barack Obama’s approach to counterterrorism -the act of stopping terrorism- has been his embrace of Unmanned Aerial Vehicles (UAVs) or to target terrorist operatives abroad. The Obama administration has used drones in active theatres of war, such as Afghanistan, but it has also dramatically increased the number of drone attacks launched by the CIA in other countries, such as Pakistan, Yemen and Somalia (Boyle). President Putin has used similar rhetoric in Chechnya and Syria. The Syrian Observatory for Human Rights confirm in their latest figures that Russian air strikes have killed more Syrian opposition fighters than they have Islamic State (IS) group fighters (Hearst). Meanwhile, President George W. Bush declared a *“War on Terror”* where the U.S. military killed thousands of civilians, yet framed these actions as security measures, not terrorism. Thus, moral clarity collapses under the weight of political narratives (Voices & Visions).

When is it morally accepted to attack civilians

Most ethical frameworks argue that it is never morally acceptable to intentionally target civilians. Kant’s deontological ethics condemns such acts as intrinsically wrong: targeting civilians treats people as means to an end, violating the categorical imperative. Civilian immunity is a non-negotiable principle. However, consequentialist ethics such as utilitarianism introduce gray zones. If an act of violence prevents a greater evil -such as stopping genocide- some argue it might be justified (‘Deontological Ethics’).

Walzer argues that British terror bombing of German cities during WWII was a justified response to the threat of Nazism. (Fleming 90). While this looks deeply unsettling, it reveals a scary truth: even when we condemn acts like terrorism, context can shift how we judge them. If states under existential threat can justify civilian targeting, can we completely disregard cause in all other cases?

The *Drone Papers*, based on classified U.S. military documents released to *The Intercept*, reveal stark figures: during one five-month campaign in Afghanistan, nearly **90 %** of those killed

were not the intended targets -logged as EKIA (enemy killed in action)- even if their combatant status was uncertain. The papers also prompted serious moral critique. Signals intelligence (SIGINT), used to identify strike targets, frequently misattributes identity -such as assuming a cell phone owner is a combatant- and later discovering it belonged to a civilian relative. As a result, even "near-certainty" standards touted by policymakers frequently fail in practice, leading to repeated civilian harm despite claims of ethical restraint (The Drone Papers). As from these papers we can see that these attacks have brought the deaths of many civilians. But have we ever seen the act as a terrorism or the ones who commit as terrorists? To give a clear and short answer: **No.** If these drones were thrown by someone other than a state this act would immediately be stamped as terrorism and a shame to society. Therefore, when we say terrorism is "evil," are we referring only to the act, or do we inevitably -and perhaps unconsciously- include judgments about the cause and actor.

The same double standard is also seen in the Israeli and Palestinian conflict. The rivalry between these two countries has been around for decades. We can identify the start as the end of WW2 where to finish the war Israel was created by the UN. But on October 7, 2023 when Hamas's attack on Israeli stormed southern Israeli cities and towns across the border of the Gaza Strip; killing more than 1,300 Israelis, injuring 3,300 and having hundreds of hostages everything went down (Israeli-Palestinian Conflict | Global Conflict Tracker).

Hamas's attack on Israel may meet the definition of terrorism. Before this attack, Hamas also has been involved in rocket attacks, suicide bombings and assaults on Israeli civilians which also fit the evil terrorism definition. However, such violence is often contextualized by supporters as a response to long-standing occupation, displacement, and blockade. Meanwhile, Israel's military response across Gaza has resulted in massive and unprecedented numbers of damage. Hostilities in Gaza had killed 34,535 Palestinians and injured 77,704 between 7 October 2023 and 30 April 2024, according to the Ministry of Health of the State of Palestine, with a further 10,000 missing, presumed buried under rubble. The majority killed and injured were estimated to be civilians, with a large proportion being children and women (OHCHR). These acts are often justified by the Israeli Government as a response to terrorism. Yet, many reports of human rights organizations such as Amnesty International described these actions as potential war crimes, yet the Israeli government framed them as self-defence. This contradiction shows how labels like "terrorism" and "security" are selectively applied depending on political alignment (Amnesty International).

Historical precedents complicate the problem. In 1954 the National Liberation Front (FLN) began a guerrilla war against France and sought diplomatic recognition at the UN to establish a sovereign Algerian state. The FLN used violent tactics, including attacks on civilians, to end French colonial rule -initially branded as terrorism, later viewed as anti colonial revolution ("Algerian War").

The U.S. bombing of Hiroshima on August 6, 1945, killed over 70,000 civilians instantly, the city of Hiroshima was reduced to ash in less than ten seconds and tens of thousands more in the weeks following. Though justified as ending WWII, if a non-state actor had done the same, it

would almost certainly be labelled terrorism (Hersley). Across these examples, a pattern emerges: moral judgment of violence against civilians often hinges not on the act itself, but on the identity and perceived legitimacy of the actor.

Conclusion

The claim that every "attack on civilians is terrorism and is always evil" is in most cases and in theory correct. As we look into the real world, we start to see that not everything goes by theory and our moral definitions. It is not easy to say something when we are not inside. During war, occupation, or resistance; actors often justify their violence through appeals to necessity, defence, or survival blurring the line between terrorism and legitimate warfare. It becomes harder to uphold a consistent moral standard when powerful states avoid the terrorism label while engaging in actions indistinguishable from those condemned by others.

Ultimately, I believe civilians must never be targets, regardless of whether the cause is a state or a non-state actor. If we truly value moral consistency, the same ethical principles must be applied universally. Anything less is not only hypocrisy; it weakens trust in international law and corrodes our sense of justice. Until we stop excusing violence based on who commits it, the cycle of harm will continue fuelled not by truth, but by power. As Mustafa Kemal Atatürk said: Peace at home, peace in the world.

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An Examination of Socioeconomic Standing and its Effect on Academic Performance in Elementary Students By Sienna Squadrito

Abstract

This study examines factors that influence academic performance and the extent to which low socioeconomic status can affect in-school and out-of-school variables that correlate with academic performance. Through a mixed approach, students from a low-income area from a NYC Title 1 Elementary school were asked a series of questions evaluating not only their academic performance and factors affecting academic performance but also their individual feelings about resilience/giving up after failing a class and their willingness to seek help in the face of failure. Among the 76 student respondents, a prevalent factor that contributed to academic success was parental presence/support, which affected academic resilience in failure trajectories. Additionally, parental presence/support affected screen time as a form of entertainment after school. The primary factor determining screen time appears to be parental involvement and rules regulating screen time in the house. This shows another indirect result that parental involvement has on academic performance. Overall, 62% of the sample reported failing at least one of their classes in the past, suggesting a strong relationship between socioeconomic status and academic struggles. Approximately half of the sampled population reported that they did not give up after failing a class. Additionally, 81% of students that stated that they had, in fact, persevered after such a failure also reported they had a parent or guardian at home before or within sixty minutes of their own arrival from school. The most effective way to combat this trajectory is to promote parental involvement in school studies and to teach parents to promote healthy academic boundaries to promote the idea to children of getting help and working towards academic goals. Additionally, interventions can help students address learning issues and create an effective learning environment equal to their counterparts in higher socioeconomic areas.

Introduction

The assumption that in a public school, all kids are equally set up for the same pathway to success is an extremely misguided outlook. A general assumption made is that if all children are set up with the same curriculum and given the same educational materials, they are equally set up for success. This assumption does not take into account many factors, the most influential being socioeconomic status. The difference between an A+ and an F isn't always based on intelligence, and it is evident why. My paper is an analysis of contributing areas to academic success that are affected by socioeconomic standing. “Not only are socioeconomically disadvantaged children more likely to experience disadvantages, they are also more adversely affected by them than their more advantaged peers.” (Buckingham, Wheldall et al. 190) All of these factors fall under the overarching theme of lifestyle. A child’s environment and lifestyle at home are often overlooked as contributors to bad academic performance, since they are at school 6 hours a day. One important consideration is that children are impressionable. They model after

what they know, and the choices they see their parents make become second nature. Looking into the lifestyle of a child shows how academic success can be hindered without a higher family income. “The best indicator of academic achievement is family socioeconomic status.” (Ali, Ullah et al. 35). The involvement of a parent in the child's life and educational motivation is a factor greatly considered in my research. “There is a significance of parental investments and socioeconomic status as a contributor for children's and young adolescents' development throughout several generations.” (Sohr, Scaramella et al. 1047).

Literature Review

An overall analysis of the direct correlation between economic status and school performance in elementary students as a focus group, is an emerging theme that has yet to be examined as a direct result of socioeconomic status. “Socioeconomic differences among low-income and racially minoritized students may be consequential for understanding the dynamics of school choice--especially in high-poverty and racially segregated urban contexts that are often targeted by school choice policies" (Stinger).

The first analysis of lifestyle lies in examining the impact of healthy choices. According to the CDC, lower-income children in the US have a higher rate of obesity compared with higher-income children. This is in direct correlation to the fact that cheaper options for food are typically unhealthy ones. Many low-income families also rely on food stamps, which in most states do not have restrictions on what type of food a person can buy. As a result, in order to make the most of the funds allotted, families may purchase the cheaper, and in most cases, unhealthy option. Another impact on lifestyle is the lack of outdoor play. Many families residing in low-income areas, cite higher crime rates, and as such, are less likely to permit their children to play outside out of concern for their safety. Unfortunately, lack of exercise coupled with a poor diet, will result in a rise in obesity rates, and overall poor health, explaining why low SES (socioeconomic status) families are more prone to obesity. A CDC study states, “There are several possible reasons for the relationship between low family income and lower physical fitness. First, populations with low SES may be more likely to live in low SES communities. Parents from low SES communities have reported higher perceived neighborhood crime and unpleasant neighborhood features compared with those from high SES communities. This concern for safety could make low-SES parents less inclined to let their children play outside, thereby restricting physical activity. Low SES communities may have fewer physical activity facilities, particularly few free activity resources, than high SES communities, thus limiting access to opportunities for physical activity. At an individual level, lower-income families may experience many stressors and barriers to health and, as a result, may place less priority on leisure time physical activity compared with higher-income families. Many leisure activities may also be cost-prohibitive for low-income parents due to membership, participation, or equipment fees.” (Jones-Smith)

Another negative outcome from the lack of physical activity combined with a poor diet is a poorly functioning immune system. Without the proper access to healthy, fresh foods, adequate

physical activity, results in a child being more prone to illness, and therefore, acquiring more school absences. Each time a child is absent from school, they are missing instruction, and falling behind in their curriculum studies, which will ultimately lead to a decline in their academic performance. The United States Department of Education did a study on chronic absenteeism that stated, "Students who were chronically absent in preschool, kindergarten, and first grade were less likely to read at grade level by the third grade. Students who can't read at grade level by the end of third grade are four times more likely to drop out of high school." (Department of Education) This is a prime example of how lifestyle has an effect on school performance, and how not all children are set up for equal success in school.

Yet another important topic to explore is the importance of access to adequate healthcare. A healthy student is a better learner. Acknowledging that poor nutrition, and lack of exercise, leads to a weakened immune system, and therefore makes a child prone to more illnesses, it is equally important to note that children in low income families often do not have access to proper health care. In America, insurance, and your ability to pay for that insurance, drives your access to healthcare. The better the insurance, the more one can access. Therefore, it would then be a valid assumption that a higher-income family, with access to better insurance, would in turn have access to better doctors, and the ability to pay for expensive medications. Lower- income families may decide to avoid the fees at a clinic, and not be able to afford medication, and instead turn to home remedies, avoid the doctor visit, and wait for an illness to pass. As such, that child would then remain at home for a longer period of time, missing more school than a child who had immediate access to proper healthcare and medication. A study conducted by the National Library of Medicine found that the unadjusted odds of chronic absenteeism were found to be 16% higher in children without insurance or with gaps in insurance compared to children with consistent insurance throughout the year. (Ramalingam, Darias, et al. 2) In sum, a child experiencing chronic absenteeism will in turn miss out on crucial instruction, falling behind in the curriculum, resulting in a decline in academic performance. All a result of SES status.

Expanding the lens of study, another area to be considered is the effect an increase in screen time has on academic success. Noting that many low-income families live in areas deemed too unsafe to play outside, the children are then remaining inside, often watching television, or playing games on a school-issued device. Many low-income families have working parents, and therefore the children at home alone, essentially relying upon the screen time on a device to act as a babysitter. The number of children ages 4–17 that spend 4 or more hours of screen time per weekday has increased in percentage since 2003, resulting in much less physical activity. When elementary aged children are spending the majority of their time at home on a screen, and not at home with an adult, they are also less likely to make smart food choices. A child is far more likely to grab a bag of chips or a box of cookies, than venture to make a salad, or other healthy snack. An increase in screen time leads to an increase in poor food choices.

Another negative effect of overuse of screen time is children becoming addicted to the dopamine they acquire from screens. Dopamine is the hormone responsible for driving and

reinforcing habits. The stimuli produced by screens can activate the dopamine reward system in the brain, creating a dopamine feedback loop similar to those found in the brains of nicotine or cocaine users. Becoming addicted to a screen and relying on it for dopamine, will lead to children becoming less focused on schoolwork. The children will then have shorter attention spans, less interest in traditional learning, and consequently lower academic output. Once the student begins to fall behind academically, it creates a snowball effect, in which the decline happens rapidly. In a family of a higher SES, once a child begins to fall behind, they could hire a tutor to provide additional support, but most low-income children don't have access to that luxury. If a child is falling behind, and the family cannot afford a tutor to help them catch up, the child will begin to see more failures than success, and therefore are more likely to lose motivation, and drop out in the future.

Another considerable setback for children coming from a family with a low SES is parental inconsistencies, leading to a lack of parenting and at-home supervision. “Many factors have been hypothesized to link socioeconomic status (SES) to the well-being of children, most of which include variations in the children's and parents' access to financial and social resources or their responses to stressful situations. For children, SES affects well-being at numerous levels, including both family and neighborhood. Children's personal traits, familial traits, and outside support networks all mitigate its impacts.” (Bradley, Corwyn 371). Connecting back to screen time and healthy habits, without parental boundaries that enforce a limited screen time and limit consumption of unhealthy foods, it's almost impossible to motivate children to do so. Limited access to a parent that encourages a child to do homework leads to a child not doing their work, and thus falling behind. Children from low-income families often do not receive the stimulation and do not learn the social skills required to prepare them for school. “Typical problems are parental inconsistency (with regard to daily routines and parenting), frequent changes of primary caregivers, lack of supervision, and poor role modeling. Very often, the parents of these children also lack support.” (Ferguson, Bovaird, Mueller 8) Not having a support system puts the child at a distinct disadvantage from the very beginning of their educational career.

All of these crucial lifestyle factors impacting children from low SES families, result in the children struggling with learning and eventually dropping out of school, as a result of a disadvantage they have no control over. The easiest way to try to combat this and to even out the difference in how children learn based on the income they grew up living with is early intervention. “Interventions act to advance a child’s development through a range of supports and services. Their underlying goal is to develop the skills lacking in children that have already developed in other children who are of a similar age. There is general agreement that interventions should be data-driven and that assessments and interventions should be closely linked.” (Ferguson, Bovaird, Mueller, 8) It's evident that if we try to provide low-SES children with the resources they need to succeed, that their peers have access to, they can be just as successful as a child from a higher SES. Teaching parental figures how to make changes to the child’s environment and promote healthy habits can also be a key to unlocking every child’s full potential.

Hypotheses

Hypothesis 1: Elementary school students residing in a household whose income falls below the poverty line are less likely to demonstrate higher academic success than those who live in more affluent conditions.

Hypothesis 2: Student resilience in the face of academic failure is affected by parental/caregiver support and presence after school.

Hypothesis 2a: There is a significant relationship between parental presence and academic performance in elementary school students.

Gap

The gap that exists within my research lies with my participant population, elementary school students. Additionally, there is a lack of significant research on the direct correlation between academic success and the socioeconomic status of elementary school students. As such, my results will be impactful, drawing on the effect socioeconomic status has on children's developmental years in the areas of reading, spelling, writing, critical thinking, and contextual learning skills. I specifically set out to find out if children of low family income are set up with a research-backed curriculum and Department of Education services, will they achieve academic success?

Methods: Participants and Procedure

From October to December 2024, 76 students from ages 7 to 11, in 2nd to 5th grade, all in attendance at the same NYC Title 1 elementary school, were asked to complete an approximately 5-minute-long survey anonymously to investigate the effect socioeconomic status (students with a profile indicating their household falls below the poverty line) had on elementary school students' academic performance. Students were measured on their socioeconomic status based on their qualifications for free lunch, which is an indicator that that student's household falls below the poverty line. Only students qualified for the survey were excused from class for the approximate time for the survey in order to complete it. While collecting data, no potentially identifying information was collected, including gender or ethnicity, due to Department of Education regulations. This did limit avenues of analysis while collecting data on participants. Informed parental and student consent forms were handed out to participants via Google Forms to complete prior to their completion of the survey. The study contained informed parental and student consent forms. The study proposed minimal risk to participants; however, participants disclosed that if they felt uncomfortable answering any questions in the survey, they should immediately cease participation. The study contained a debriefing form that asked students not to discuss the content of the survey to prevent compromising the integrity of the study. The students ranging in the set ages were asked questions that sought to analyze the extent to which circumstances outside of school, compounded by socioeconomic status, affected school performance, their feelings about school,

and, in turn, themselves. Specifically, analysis of health choices, screen time and extracurricular activities, healthcare access, school absence, and parental presence and supervision.

Instruments: Quantitative

Purpose	Author/Date	Sample Questions
Evaluates the extent to which student incorporates fruits and vegetables into daily meal	Sienna Squadrito , 2024.	“On a scale of 1-5, how many days per week are fruits and vegetables included in your daily meals?”
Evaluates the students’ amount of time spent outside per week	Sienna Squadrito, 2024.	“On a scale of 1-5, how many days per week do you play outside?”
Examines health concerns that caused an extended absence in participants in the prior school year	Sienna Squadrito, 2024.	“Last school year, how many times did you get a cold or other viral sickness serious enough for you to miss at least one day of school?”
Examines the extent of screen time for participants per week.	Sienna Squadrito, 2024.	“On a scale of 1–5, how often are you resorting to a screen/TV for entertainment after school?”

Instruments: Qualitative

Purpose	Author/Date	Sample Questions
Evaluated the student’s academic performance	Sienna Squadrito, 2024.	“Have you ever failed a class? If so, what class?”
Examines participant’s personal reason for academic struggle.	Sienna Squadrito, 2024.	“Why, in your opinion, did you struggle in that class?”
Examined willingness to incorporate a tutor in case of academic struggle	Sienna Squadrito, 2024.	“Would you ever consider getting a tutor for said class?”
Evaluated parental/parental figure presence after school, translated into hours the student is left alone without a caregiver.	Sienna Squadrito, 2024.	“Do you have at least one parent/ sitter /childcare professional/family member at home when you return from school? If so, what time do they get home“?
Examines student resilience in face of academic failure	Sienna Squadrito, 2024.	“Have you ever considered a class hard and given up due to how much you struggled? What was the main reason that made you quit or not quit?" (Please explain.)
Evaluates the extent of extracurricular activities the student is involved in	Sienna Squadrito, 2024.	“What extracurricular activities—clubs or sports—are you currently involved in?”

A NYC DOE administrator independently rated my qualitative variables. When there was a disagreement, we discussed it and came to a consensus.

Variables

Independent (x)	Dependent (y)	Covariates
Parental Involvement/Parental Supervision or Presence of Support	Academic performance	Presence of Noted Illness
Student Resilience in the Face of Adversity	*Student Resilience in the Face of Adversity*	Access to Healthcare
Screen Time/Usage		
Extracurricular Activities		
Healthy Food Choices/Habits		
Reasons for School Absence		

Student resilience in the face of adversity serves as both an x and y variable in this model. It mediates an indirect relationship between parental involvement & academic performance.

Results

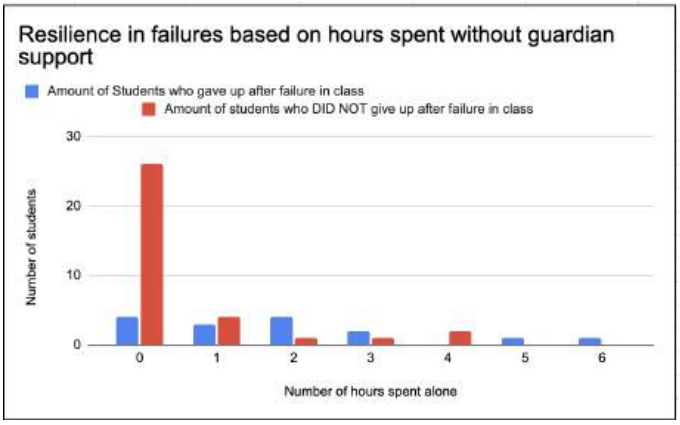
I. Hypothesis 1: Elementary students residing in a household whose income falls below the poverty line are less likely to demonstrate higher academic success than those who live in more affluent conditions.

The data from my survey, which was composed of 76 respondents, resulted in 62% of respondents stating that they had failed a class. Because my respondents were composed of students falling below the poverty threshold, the percentage of failures among students confirms my hypothesis.

II. Hypothesis 2: Student resilience in the face of academic failure is affected by parental/caregiver support and presence after school.

Those who failed a class but also noted that they had a parent or caregiver present at home indicated resilience and specifically stated that they did not give up when they failed said class. In all responses, resilience rates had a direct correlation to parental presence. Those students who noted having support at home were more likely to persevere in the face of adversity. Conversely, those who stated they were home alone for several hours without a parent/guardian were more likely to give up and report feelings of defeat after facing academic setbacks. There is 93% confidence in my regression model that as the hours the student is left alone after school without a caregiver/parental figure present, increase, the resilience of the student after failing a class decreases ($r=.281$, $p<.001$, $r^2=.079$). Almost 8% of the variance in student resiliency is predicted by the number of hours they spend after school without parent or guardian support.

Graph 1



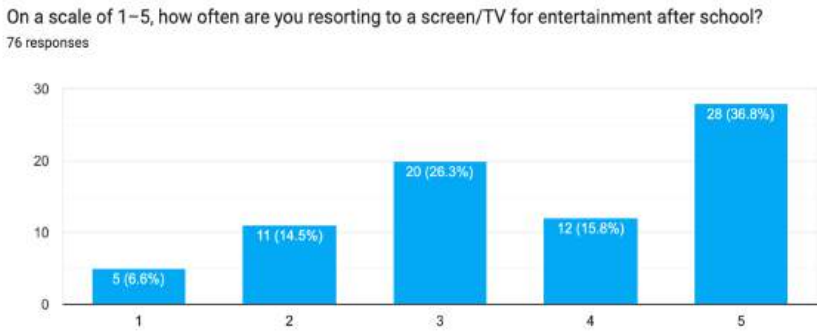
III. Hypothesis 2a: There is a significant relationship between parental presence and academic performance in elementary school students

Data compiled from my survey demonstrated that 62% of respondents stated they had failed a class. Approximately half of the sampled population reported that they did not give up after failing a class. Additionally, 81% of students that stated that they in fact persevered through a failure of a class also reported they had a parent or guardian at home within or before the hour that they got home from school.

IV. Non hypothesized results : Screen Time

My survey results showed that the majority of students relied on screen time as their sole source of entertainment after school more than 3 days per week. The students who reported less parental involvement and support at home also stated they spent increasingly more time on their devices than those who had parental presence at home after school. Out of the 76 respondents, 52% of respondents rated a 4 or 5 on a scale of 1-5 for how often they resorted to a screen after school for entertainment.

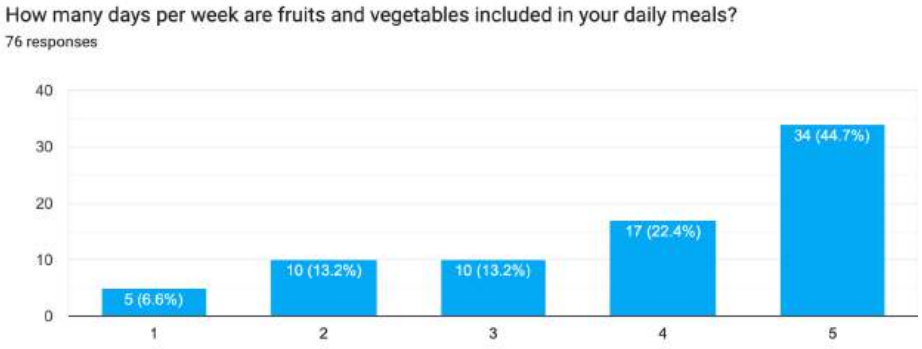
Graph 2



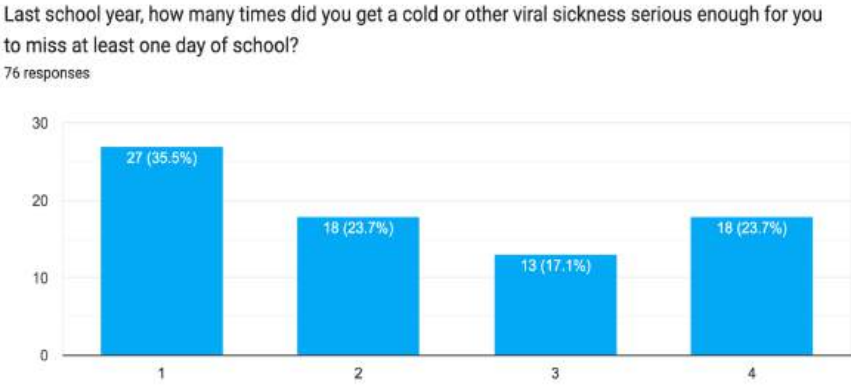
V. Non hypothesized results: Healthy habits

A positive account from my survey showed that due to the programs established in schools to promote and instill healthy habits, students reported a healthy amount of consumption of fruits and vegetables in the majority of respondents. In order to maintain physical health, schools in the New York City Department of Education are required to provide 60 minutes of daily physical activity through physical education, recess, and other programs, such as "Move to Improve." Schools encourage healthy meal choices by ensuring each student's meal includes several required food components, such as fruits, vegetables, grains, meat or meat alternatives, and milk. The DOE's implementation of healthy foods promotes a weekly intake of fruits and vegetables for a growing child, as displayed through the survey. As a result, viral illnesses were less prevalent in survey respondents, displaying the importance of school intervention to promote healthy habits in low socioeconomic areas.

Graph 3



Graph 4



Discussion

In conclusion, the variable that established the most discernible correlation to academic failure was parental presence. While parental involvement didn't affect the degree of grades the children earned, it showed a promise of resilience, a desire among the students to continue to try in their classes despite a failure in a subject. Additionally, screen time was a major distraction among students at home. The staggering amount of time students spend using screen time as entertainment is an obvious factor in academic failure. The main reason for resorting to screen time is parental involvement and lack of rules regulating screen time in the house. This shows another indirect result that parental involvement has on academic performance. Additionally, my hypotheses were confirmed through my survey results. Elementary students residing in a household whose income falls below the poverty line are less likely to demonstrate higher academic success than those who live in more affluent households. Student resilience in the face of academic failure is affected by parental/caregiver support and presence after school. Lastly, There is a significant relationship between parental presence and academic performance in elementary school students.

My data shows importance in my field of research because it shows that low SES status has a significant negative impact on student academic achievement, healthy lifestyle choices, positive self image, and persistence in the face of adversity. If I were to continue my research, I would conduct a comparative study of elementary school students from a high socioeconomic status area, and add gender and ethnicity population sampling. One significant limitation on my study was my inability to collect gender and ethnicity sampling due to Department of Education regulations. I also was limited in the area of interpreting the qualitative answers children gave. To combat this limitation, I had a Department of Education administrator independently rate my qualitative variables, which overall helped me to learn how to interpret results. I would also explore the extent to which student resilience in the face of academic adversity changes based on socioeconomic standings and, additionally, how differences in parental presence show promise for student resilience in a high socioeconomic area. Finally, I would like to explore the impact to which interventions could help close the gaps that my study identified. Specifically, while one cannot change the SES status of the students that were studied, could interventions help close the gap between the students of polarized SES status, creating a more level playing field and making academic success more achievable.

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Should We Use GLP-1 Analogs to Treat PCOS?
By Leila Lotfi, Laila Khonsori, Lily Talakoub

Abstract

GLP-1 Receptor agonists have an integral role in the treatment of insulin resistance. PCOS is a global multi-system metabolic disorder leading to infertility, obesity, and diabetes; however very few treatments have been proposed to treat the underlying insulin resistance that is responsible for its systemic morbidity. We suggest the use of GLP-1 agonists in the treatment of PCOS to help a world-wide systemic disease and its long term complications.

Glucagon-like peptide or GLP-1 medications have revolutionized how type 2 diabetes and obesity are treated. While GLP-1 was discovered over two decades ago, it has gained major attention due to its effectiveness in controlling blood sugar and promoting weight loss (Nauck & Meier, 2019). However we are now understanding the effect of these medications on long term metabolic and skin diseases particularly the multi-organ disease of PCOS. We would like to propose the benefits of GLP-1 analogs for the treatment of PCOS particularly in the global health environment where access to infertility and skincare treatments are limited or cost-prohibitive.

GLP-1 is a hormone that is naturally produced in the small intestine shortly after food is consumed, especially carbohydrates or fats. It is produced in response to meal intake by endocrine intestinal cells. It belongs to a group of hormones called incretins, which are responsible for helping the body respond to food. Once released into the bloodstream, GLP-1 acts as a chemical messenger to several organs, helping regulate metabolism. It plays a particularly important role in the pancreas , where it increases insulin production but only when blood sugar levels are high. This function helps the body use glucose efficiently without causing dangerous drops in blood sugar (Drucker, 2018).

In addition to their anti-inflammatory and regenerative functions, GLP-1 receptors in the skin help maintain the skin's barrier function and protect against cellular stress. For instance, in keratinocytes, GLP-1R activation can encourage healthy turnover of skin cells and support the repair of the epidermis and dermis after damage (Lim et L., 2022). In fibroblasts, these receptors may help regulate the balance of collagen production and breakdown, which is essential for wound healing and preventing scarring or skin thinning. Additionally, GLP-1R may influence how the skin responds to hormonal and immune signals. Because the skin is an immunologically active organ, GLP-1R signaling can help balance the immune response, preventing both excessive inflammation and immune suppression (Tseng et al., 2020). GLP-1R activity may also affect sebaceous glands and skin hydration indirectly by modifying insulin and hormone levels systemically, which could explain why some patients on GLP-1 drugs report improvements in

Leila Lotfi National Cathedral School Washington DC USA Leilalotfi77@gmail.com
Laila Khonsori Stone Ridge School Bethesda, MD USA
Lily Talakoub MD Mclean Dermatology and Skincare Center McLean, Virginia lilytalakoub@gmail.com (unaffiliated)

skin texture or reduced acne. As research continues, dermatologists and endocrinologists are beginning to explore the therapeutic potential of targeting GLP-1 receptors not just for blood sugar control, but as a pathway to improve skin health and treat complex dermatological conditions linked to metabolism and inflammation.

Polycystic Ovary Syndrome (PCOS) is a multi-organ hormonal disorder that affects millions of women. The hormonal disruption caused by PCOS not only affects women's menstrual cycles and fertility, but also the skin causing not only physical discomfort but also emotional distress (Escobar-Morreale, 2018).

While the exact cause of PCOS remains unknown, research has shown that insulin resistance leads to an abundance of androgens which plays a large role in its development. When a woman struggles with high levels of insulin it can cause ovarian cysts. The multiple cysts release the male hormone testosterone. While a woman's body naturally contains a small amount of androgens, an excess of it can be considered unhealthy, and causes PCOS symptoms (Azziz et al., 2016).

A few of the PCOS symptoms are cystic acne, hirsutism (excess hair growth in areas where men typically grow hair) because androgen prompts sebaceous glands to produce more oil and hair follicles to produce darker and more coarse hair. While these are some of the common symptoms PCOS can also increase the risk of long-term health issues that extend beyond the skin and reproductive system. By the age of 40, 10% of women with PCOS go on to struggle with type 2 diabetes. Hyperinsulinemia due to insulin resistance is caused by higher levels of androgens and puts PCOS patients at a higher risk of getting type 2 diabetes (Legro et al., 2013).

PCOS also increases the risk of heart disease as high insulin levels cause high cholesterol, high triglycerides, and fats in the blood leading to clogged arteries which increase the chances of heart attack and stroke. High blood pressure is also commonly seen in PCOS because the blood vessels often become inflamed, making it harder for the heart to pump blood (Wild et al., 2010).

Fertility problems are another major issue. In order for a woman to ovulate, she must contain enough estrogen and progesterone hormones. When a woman's hormones are dominated by androgens produced from ovarian cysts, ovulation can not happen (Goodarzi et al., 2011).

The growing understanding of how GLP-1 and its receptor agonists function has opened new doors in the treatment of complex metabolic disorders beyond type 2 diabetes and obesity. PCOS, a hormonal disorder that affects millions of women, is deeply intertwined with many of the same biological pathways that GLP-1 targets, particularly insulin resistance, hyperinsulinemia, and chronic inflammation. Given this overlap, GLP-1 analogs represent a powerful and promising treatment option for PCOS and its related complications (Li et al., 2022).

One of the most compelling reasons to consider GLP-1 analogs for PCOS is their ability to address multiple aspects of the condition simultaneously as a metabolic regulator. They improve insulin function, reduce inflammation, balance hormones, decrease appetite, enhance cardiovascular health, and even support emotional and psychological well-being through effects

on dopamine pathways in the brain (Severinsen & Jensen, 2020). This whole-body approach is valuable when symptoms are interconnected and treatment must be comprehensive. By addressing the root metabolic imbalances that drive PCOS, GLP-1 analogs offer not just symptom relief, but the possibility of long-term improvement particularly in the global health environment where access to infertility and skincare treatments are limited or cost-prohibitive.



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I would like to submit a short review about the use of GLP-1 agonists in the treatment of Poly Cystic Ovarian Syndrome. This is a new topic and the treatment of PCOS has routinely been oral contraceptive pills even though insulin resistance is the cause of the disease.

PCOS is an under-treated but prevalent disease with significant co-morbidities. It has however been treated solely with birth control pills which only halts some of the progression of the infertility associated with it but not the other symptoms of the disease. GLP-1 agonists are routinely available and can treat the underlying cause, however it is not being used in clinical practice.

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From Captivating Exposés to Humanitarian Advocacy: Charting Nellie Bly's Shift from Sensational Reporting to Social Reform By Iris Chen

Abstract

Nellie Bly is widely remembered as the daring pioneer of stunt journalism who went undercover to conduct dangerous investigations and embarked on a record-breaking journey around the world. However, this reputation ignores the significant transformation that Bly underwent throughout her career, specifically regarding her writing style and focus. This paper argues that Bly's writing evolved from sensational investigative reporting centered on exposing individual injustices to journalism focused on humanitarian advocacy, social reform, and human rights. Drawing from Bly's newspaper articles, books, and historical scholarship, the paper examines how her experiences as a journalist, an industrialist, and a war correspondent, along with the historical events occurring around her, reshaped both her rhetorical style and her understanding of journalism's purpose. Bly's shift can be traced from her early dramatic first-person narratives and undercover investigative exposés to her later writing that increasingly emphasized moral responsibility and humanitarian action on behalf of women, children, laborers, and those affected by war. This evolution reflected not only Bly's personal experiences but also broader changes in American journalism during and after the Progressive Era, as reporters increasingly viewed journalism as a tool for social reform.

Introduction

In most people's minds, the name "Nellie Bly" conjures up daring images: a brave woman who wasn't afraid to speak out, a plucky female journalist who proved her strength in a male-dominated field, and a daredevil who accomplished what others thought was impossible. Bly defied the stereotypes forced upon women in the 19th century, establishing herself as an outspoken advocate and powerful reformer. Historians have also traditionally remembered her as the pioneer of stunt journalism, emphasizing her daring undercover investigations and record-breaking journey around the world. Yet, she was more than that: she was also an inventor, a novelist, and an entrepreneur (Norwell and Brandman). She was a bold writer with an unapologetic style who portrayed the struggles and issues of the time with a clarity that other journalists lacked. Bly spent her life fulfilling her responsibility as a journalist and an advocate. Throughout her career, she fought for the rights of the oppressed, particularly young, working-class women. However, as Bly's career progressed, she stayed committed to her responsibility to promote human rights, but her mindset and rhetoric experienced a dramatic shift. While Bly's stunt journalism achievements undoubtedly transformed American journalism, they often overshadow the ideological evolution that occurred during the latter half of her career. Nellie Bly's writing style and focus evolved from investigative, exposé-style articles to pieces centered more around social advocacy and humanitarian causes, reflecting her own experiences with the historical circumstances of the time and her change in perspective as a woman who advocated for societal reforms and human rights in the 19th century.

Early Career

Nellie Bly was born Elizabeth Jane Cochran on May 5, 1864, in Cochran's Mills, Pennsylvania, and was nicknamed "Pink" (Henry 88). When she was six, her father died and her mother, Mary Jane Cochran, was forced to remarry John Jackson Ford, a violent alcoholic and abusive husband (Kroeger, *Daredevil, Reporter, Feminist* 9-15). When Cochran finally sued Ford for divorce, a fourteen-year-old Pink testified at the court proceedings, and the violence she witnessed as a child shaped the strong beliefs about justice and women's rights she would hold into the future (Kroeger, *Daredevil, Reporter, Feminist* 19-20).

Bly's entrance into writing wouldn't occur until 1885, when a fiery letter she wrote in response to a sexist article landed her a job at the *Pittsburg Dispatch* (Kroeger, *Daredevil, Reporter, Feminist* 15-38). She wanted to write about topics that mattered to her, including women's rights and social inequality. Her first piece was titled "The Girl Puzzle", where she spoke about the struggles of lower-class women and argued that girls were just as capable as boys. "Instead of gathering up the 'real smart men'", she wrote, "gather up the real smart girls, pull them out of the mire, give them a shove up the ladder of life" (Lonely Orphan Girl). The *Dispatch* was where Nellie Bly acquired her pseudonym in 1885: a misspelling of Stephen Foster's famous song, "Nelly Bly" ("Nellie Bly"). At the time, it was considered inappropriate for women to write, so many female writers – including Bly – relied on pen names.

Bly was often relegated to articles of the "women's sphere". As an ambitious young journalist, she was discontent with being pigeonholed into writing solely on "women's issues" like fashion and gardening (Bly, "Hose in Style"; Bly, "Wraps for Cool Evenings"). In an attempt to escape the monotony, she took an assignment as a foreign correspondent in Mexico, where she stayed for five months reporting on government corruption (Bly, *Six Months in Mexico*). The experience gave Bly the chance to investigate and write on complex social and political issues and increased her awareness of the change she could create with her words. But despite her adventurous sojourn in Mexico, she was still stuck as a "women's sphere" reporter. After just nine months, Bly decided to leave the *Dispatch*, restless and dissatisfied with her assignment to the society pages. Her passion for justice and feeling of responsibility towards the underserved led her to New York. She wrote one last note to one of her colleagues before her departure, stating, "I have gone to New York. Look out for me" (Lepere).

NY World

In 1886, all of the papers located on New York City's Newspaper Row were male-dominated. After six months of searching, Nellie Bly had yet to find an editor to hire her. In 1887, Bly marched into the office of the *New York World* and proposed a list of story ideas focused on underserved and underrepresented communities. Intrigued by her risky and daring proposals, Joseph Pulitzer, the owner of *The World*, commissioned her to report undercover from the New York City Lunatic Asylum (Norwood and Brandman). Determined to establish herself as a respected journalist, Bly agreed and checked into a women's boardinghouse, where she feigned insanity (Bly, *Ten Days in a Mad-house* 10-20). Despite the possible dangers, Bly's

determination to uncover the mistreatment of the women lent her the courage she needed to face the cruel abuses at the asylum. Her convincing act of madness at the boardinghouse led Judge Patrick G. Duffy to declare her insane and place her in Bellevue Hospital. Eventually, physicians at Bellevue sent her to Blackwell's Island – a small island on the East River that held New York City's asylum, prison, and almshouses (Bly, *Ten Days in a Mad-house* 43-46; "Blackwell's Island (Roosevelt Island), New York City"). Bly spent the next ten days suffering under brutal conditions and harsh treatment that she described in her newspaper stories. The public was appalled at the beatings and ice-cold baths administered by the physicians and were shocked to discover that many patients were sane lower-class women whose societal disadvantages, including language barriers, had them unfairly placed into the asylums by neglectful family members (Bly, *Ten Days in a Mad-house* 50-53). Bly was eventually released by an attorney from the *New York World*, and her articles garnered outrage and attention upon publication (Paranick). Her risky investigative approach to journalism was a strategy for the young, spunky writer to prove her ability to the doubtful men in the field and to draw attention to her work and the important topics she covered. The personal writing style of Bly's stunt reports allowed readers to connect to the story on a more intimate and emotional level, and her exposés carried her ardent support of women and their rights. The injustices she revealed brought public attention to the people's responsibility to help vulnerable groups, and as a result, the asylum was investigated and reformed (Widra).

Bly quickly became a sensation, and she continued going undercover to expose secrets that she would relate to readers with a first-person writing style. During one particular investigation, Bly posed as a woman wanting to buy a child to infiltrate New York City's sinister market of baby trafficking. "I bought a baby last week, to learn how baby slaves are bought and sold in the city of New York," she wrote. "Think of it! An immortal soul bartered for $10" (Bly, "Nellie Bly Buys a Baby"). Her other exposés investigated the harsh working conditions for factory girls, the predatory actions of a man favored by the police, and even the corruption and bribery present within the New York legislature in Albany (Bly, "Girls Who Make Boxes"; Bly, "Infamy of the Park"; Bly, "King of the Lobby").

Nellie Bly's fame stemmed from her reputation as a stunt reporter who took risks to get her desired story. Her articles focused mainly on underserved communities, especially women and children, though she often reported only on the situation at hand and not on the larger movements and contexts behind the issues she was describing. Bly relied on using elements of shock, surprise, and vivid imagery to capture readers' attention and interest. Her daredevil persona was further solidified when she took her famous 1890 trip around the world in an attempt to beat the record set by the main character of Jules Verne's book *Around the World in 80 Days*. In a series of articles eventually published as *Around the World in 72 Days*, Bly completed what most people thought was impossible – she circumnavigated the globe in just seventy-two days and set a world record, disproving all of the men who believed that no one, much less a woman, would be able to achieve such a feat (Bly, *Around the World in 72 Days*). Soon after, however, her anger at *The World*'s underwhelming response to her impressive accomplishments

fueled her decision to leave the newspaper and the world of journalism (Kroeger, *Daredevil, Reporter, Feminist* 185).

Brief Hiatus, Return, and Marriage

Nellie Bly's first hiatus lasted only three years, most of which she spent writing fiction for the *New York Family Story Paper* (Kroeger, *Daredevil, Reporter, Feminist* 186; Bly, "Little Luckie"). In her absence, Newspaper Row saw an increase in female reporters, many of whom were inspired by Bly and imitated her stunt girl reporting style (Kroeger, *Daredevil, Reporter, Feminist* 192). Bly's trailblazing career opened the journalism industry to more women and motivated them to challenge gender norms in the workspace.

In 1893, Bly returned to *The World*, where she was offered a job by the new editors (Kroeger, *Daredevil, Reporter, Feminist* 200-201). She continued to speak out on the public's responsibility to address social inequity. When the Pullman Strike broke out in 1894, Bly was deployed to Chicago, preparing to denounce the strikers. However, she found herself sympathizing with them instead. This was contrary to popular opinion at the time, and Bly's strong sense of responsibility to the poor workers propelled her to write from the workers' perspectives (Walt 264). "Before I had been half a day in Pullman, I was the most bitter striker in town," she asserted (Bly, "Cheers for Nellie Bly"). When other papers blamed the strikers for burning "hundreds of freight cars" in Chicago, Bly gathered and published evidence that proved the destruction was caused by arsonists hired by Pullman to disparage the workers (Walt 264). Bly largely stood alone in her support of the strikers, showing her unshakable dedication to advocating for laborers' rights. Her writing style evolved as well, as her focus slowly began to switch from entertaining stunts to advocacy. Bly's report on tenement housing further exemplified this gradual shift, as she expressed outrage at the horrific conditions and held the Trinity Corporation accountable for its poor treatment of its tenants (Bly, "In Trinity's Tenements").

Despite her evolving writing style, Bly's career began to decline, as she clashed with editors at *The World* and struggled to find stable positions at other newspapers. To everyone's surprise, in April of 1895, she abruptly retired from journalism and eloped with Robert Livingston Seaman, a seventy-year-old millionaire industrialist and owner of the Iron Clad Manufacturing Company (Kroeger, *Daredevil, Reporter, Feminist* 258). When Seaman died in 1904, Bly became one of the leading female industrialists as the president of her husband's steel-container manufacturing company (Apollo Area Historical Society). Inspired by her responsibility to uphold the ideals of workers' rights, she introduced welfare reforms for her employees. However, after multiple incidents of swindling and fraud, the company went bankrupt (Norwood and Brandman).

The failure of the company prompted Bly to return to journalism, and she began writing for the *New York Evening Journal* (Kroeger, "She Did It All" 14). During this period, Bly's writing was geared towards advocacy and social justice, and she adopted a proactive approach towards the topics she cared about. In 1913, Bly attended a large women's suffrage rally in

Washington D.C. – two days before the presidential inauguration of Woodrow Wilson – and reported passionately on what she called a "unity of womanhood". Her glowing portrait of the courageous demonstrators praised their determination to fight for the right to vote and the responsibilities they took on to increase independence and equality for the women of the future (Bly, "Suffragists Won the Capital"). Bly's article on the inauguration further exhibited her expanded writing perspective, as she boldly asked, "Will you and I ever see a woman stand there and take the oath of office?" (Kroeger, *Daredevil, Reporter, Feminist* 376). At the same time, Bly faced pressing financial issues from the collapse of her company and traveled to seek aid from a wealthy friend in Vienna. Around the time of Bly's departure, Austria declared war on Serbia, and World War I had begun (Kroeger, *Daredevil, Reporter, Feminist* 385).

Later Career

The outbreak of war sparked Nellie Bly's feeling of responsibility as a journalist, and she became the first female war correspondent to report from the Eastern Front (McDonough). She traveled with Austro-Hungarian troops to battlefields near the town of Przemyśl and spent a full month in the trenches of both the Russian and Serbian war zones. Her descriptions of the harrowing conditions highlighted the brutality of the war, and she wrote passionately about the catastrophic consequences on the soldiers and civilians (Bly, "Sees Maimed"; Bly, "War-Rent Przemysl"). "I think with fainting heart of the thousands of weary, sick, hungry men lying in mud trenches," she wrote, "Not thousands but millions of them. I try to realize what it all means – the untold, indescribable suffering of millions of the world's best men: and when I say millions of men I must multiply those millions by ten to count the wives, children, parents and sweethearts and relatives who are suffering untold mental agony" (Bly, "Second Daring Trip"). Her rhetoric relied more on emotional appeals and moral reasoning rather than the elements of shock and surprise of her early career.

Bly's determination to reveal the horrors of war led her to experience the horror firsthand. Her time in the trenches was marked by near-constant din of grenades, gunfire, and exploding shells. Though she reported with the Austro-Hungarians, she empathized with the devastation on all sides and expressed her deep regrets for all soldiers and nations involved. Bly was especially horrified to discover the brutal conditions for wounded soldiers; they were often left for days or weeks on end without anyone to help them (Bly, "On the Battlefield"). Her gruesomely detailed accounts of war scenes in the trenches and hospitals gave American readers a first-hand glimpse into the Great War and likely helped fuel anti-war sentiments (Otto).

Over time, Bly had become more and more of an outspoken advocate for the causes she believed in. While she hadn't actively pursued any reforms after publishing her madhouse exposé, she now took an active role in helping Austrian orphans and widows, appealing to the American public to raise funds for the Austrian cause (Pace). Her writing reflected her expanded perspective, and her reports continued to move towards humanitarianism and advocacy, zooming out to capture the larger pictures she had failed to capture during her earlier career. Even as resentment against the Central Powers grew in America, Bly continued to fight for the rights and

welfare of all the women and children impacted by the war (Kroeger, *Daredevil, Reporter, Feminist* 422).

When the war ended, Bly returned home to New York and continued to write and raise awareness about people's responsibilities to support disadvantaged groups. She would remain an outspoken advocate for women and children for the rest of her life, and promoted humanitarian efforts in her articles, especially for orphaned children (Bly, "Scarlet Letter Child"). Her support for women's suffrage would contribute to the ratification of the 19th Amendment, which gave women the right to vote (Pace). On January 27, 1922, Nellie Bly died at the age of 57, leaving behind a long-lasting legacy of courage and a relentless advocacy for equality ("Nellie Bly, Journalist").

Conclusion

Throughout Nellie Bly's long and illustrious career, her writing style and focus gradually grew to encompass more humanitarian causes, and began to lean towards social advocacy. This was a clear evolution from her earlier reporting days, where she went undercover and wrote captivating articles focused on her dangerous experiences tackling individual instances of injustice. Bly's experiences as an industrialist, labor advocate, suffragist, and war correspondent broadened her perspective, and the struggles she witnessed inspired her to stand against inequality and to view journalism as an instrument for humanitarian action. Her fierce advocacy for human rights, including those of women, laborers, and children, encouraged the public to take responsibility and help vulnerable groups, and the injustices she exposed paved the way for many reforms, including the investigation and eventual reform of the New York City Lunatic Asylum and the ratification of the 19th Amendment.

Bly opened the traditionally male-dominated profession of journalism to women, but she also proved that female journalism could extend beyond society papers and sensational exposés. Her reporting helped improve conditions for marginalized communities, advance support for women's suffrage, and inspire future generations of investigative journalists. Bly's transformation also reflected larger changes occurring within American journalism during the late nineteenth and early twentieth centuries, and her investigative exposés exemplified the muckraking techniques of Progressive Era journalists who sought to inspire change. However, her later reporting demonstrated that journalists, especially female journalists who were working to establish their careers, could move beyond exposing corruption to actively shaping public discussions about reform, equality, and human rights. Bly and other journalists increasingly challenged readers to consider their own responsibility toward vulnerable populations, including women, laborers, immigrants, children, and communities devastated by war. Their resilience and courageous pursuit of social justice brought many reforms and changes that have lasted until today. Nellie Bly's enduring legacy demonstrates that the most influential journalism does more than inform the public – it challenges society to confront injustice and inspires people to build a more equitable world.

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Why In Vivo Editing May Matter More Than Personalized Ex Vivo Therapy
By Bansari Patel

Abstract

From its initial lab discovery in 2012, CRISPR gene editing progressed to an approved gene-editing medicine from the FDA in a span of just over a decade. The various forms of gene editing are moving so quickly that they are often grouped together under the umbrella of one single success story. Beyond editing accuracy, what separates these tools is whether they can be delivered into the body and manufactured at scale.

To date, one of the most successful cases has been the story of Casgevy for sickle cell disease and beta-thalassemia, which proved that gene editing could be life-changing. Each treatment requires one patient at a time, having their edited cells collected, edited, checked for off target effects, and returned to the patient. More advanced delivery methods such as in vivo editing can deliver the editor within the body. This is harder to design, but could potentially be done as an off-the-shelf therapy. This is being tried in a genetic heart disease (transthyretin amyloidosis) and in an inherited eye disease, and there is an example of such a therapy being made for an individual child. Over time, what gene editing is worth to public health will depend as much on delivery and access as it will on molecular precision.

Background

Historically, genetic conditions have been treated indirectly. For example, someone with sickle cell disease may have been given blood transfusions, pain relief, or other therapies to reduce its symptoms. A child with a metabolic genetic disease may have been given special dietary supplements or enzyme replacement therapy. While these treatments may help correct damage, they cannot reverse the disease-causing DNA mutation. CRISPR changed that conversation by providing scientists with a precise method of targeting DNA at will.

The rapidity of this progress is extraordinary: the CRISPR-Cas9 system was discovered to be a programmable DNA-cutting tool in 2012, with the first CRISPR-based medicine receiving US FDA approval in December 2023 (Jinek et al. 816; "FDA Approves First Gene Therapies"). And not all the CRISPR milestones have the same importance: Some therapies are built from cells taken from each patient, while others try to deliver the editor into patients more broadly.

It compares the two models. The authors consider the clinical effect, delivery, manufacture, cost/access and ethical governance of the two models. The main conclusion is that, while ex vivo models such as Casgevy show somatic CRISPR can be used successfully in the clinic, the in vivo model is a better model for the future because it is easier to manufacture, distribute and have a large-scale public health impact.

How CRISPR-Cas9 Works

The simplest form of CRISPR-Cas9 is composed of two parts: a DNA-manipulating

enzyme known as Cas9 and a short RNA molecule known as guide RNA that is designed to find a specific sequence in the genomic DNA the scientists want to manipulate. Once the guide RNA binds with a DNA target, Cas9 can bind to it. This is a key feature of CRISPR: rather than modifying the enzyme, one can change the guide RNA to target a new site.

To enable cleavage to the right site, Cas9 must first identify the presence of a short DNA sequence known as a protospacer adjacent motif (PAM) which is located next to the target site. For Cas9 from the bacterium Streptococcus pyogenes (spCas9), this is most commonly a short stretch of DNA that contains NGG (where N is any DNA base). While this requirement determines where Cas9 can act throughout the genome, it also determines which DNA sites can be targeted in this way.

Once Cas9 has cleaved the target double-stranded DNA, the cell's DNA repair machinery will repair the cut, most frequently by non-homologous end joining (NHEJ), the fast but error-prone repair mechanism that directly joins broken DNA ends together. It also repairs the break by modifying a few DNA letters to knock out the gene, or the template can be used to perform homology-directed repair (HDR) to fix it. Because HDR is less efficient than NHEJ and can only be performed when the cell is dividing, science and medicine often choose to disable the gene because it is easier than correcting the mutation.

Beyond Cutting: Base Editing and Prime Editing

Standard approaches using CRISPR-Cas9 center on repairing double-stranded breaks. While a powerful tool, double-stranded breaks also lead to safety concerns. A double-stranded break may also lead to undesired insertions, deletions, and chromosomal rearrangements at the target site (Kosicki et al. 765). This concern has prompted the development of tools to edit DNA without fully cutting both DNA strands.

Another technique called base editing uses a modified form of a Cas protein and a chemical editing enzyme to convert one letter of DNA into another, for example converting C to T or A to G. Prime editing was first described in 2019. Engineered Cas9 combined with reverse transcriptase and gRNA will then bind to the desired target and introduce the new sequence information (Anzalone et al. 149).

This is particularly important for new modalities since their in vivo editing is less amenable to post-sorting of cells (as would be done in ex vivo therapy where modified cells are screened for editing efficiency and returned to the patient). Therefore, chemistries that are safe and predictable are desirable to reduce the burden of screening on the actual patient.

Somatic Editing and the Germline Boundary

The focus of this paper is on somatic editing, where the patient's non-reproductive cells are modified by changing their DNA sequences. Such changes are unique to the treated individual and will not be heritable, and in this sense somatic gene editing fits the ordinary goal of medicine: treating one patient for one patient's disease.

Germline editing is different as it edits the eggs or sperm or the very early embryo. The

edit would therefore be in every cell of the future person and all their descendants. So germline editing, although destined to be applied to those who cannot consent, is only one of a larger set of ethical issues. The therapies we discuss here - Casgevy, in vivo transthyretin amyloidosis editing, retinal editing, the baby CPS1 therapy - are somatic therapies. The question is no longer whether we should be editing the human germline. Rather, the question is which model of somatic editing can help the most patients.

The Central Comparison: Ex Vivo vs. In Vivo Editing

Ex vivo editing	In vivo editing
1. Remove patient cells 2. Edit cells in the lab 3. Test cells -> 4. Prepare patient -> 5. Return edited cells	1. Create a canonical editor 2. Push it into the body 3. Editor reaches target tissue -> 4. Cells are edited inside the patient.
Main example in this paper: Casgevy	The two principal examples in this paper are NTLA-2001 and EDIT-101

Figure 1. The basic process difference between ex vivo and in vivo CRISPR therapy.

Criterion	Ex vivo model	In vivo model
Where editing happens	Outside the body in the collected cells of patients.	Inside the body, after delivery to the target tissue.
Clinical advantage	Cells can be edited and quality checked before being returned.	The same product may in principle be given to many patients.
Main limitation	Tailored manufacturing, chemotherapy conditioning, and specialized centers.	Challenges include poor delivery to target tissues, immune response to editing systems, and assessing editing.
Scalability	Difficult to scale because each treatment is a custom process.	Potentially more scalable, since they can be mass-produced.
Ethics	Access and affordability.	Safety, consent, and evidence standards for editing inside the body.

Table 1. Comparison framework used in this paper.

Casgevy: A Clinical Triumph with a Scale Problem

The first clinical use of CRISPR was for a gene therapy called Casgevy, exagamglogene autotemcel or exa-cel. In December 2023, the U.S. Food and Drug Administration approved it for sickle cell disease ("FDA Approves First Gene Therapies") and soon afterward for transfusion-dependent beta-thalassemia. Both of these conditions are hemoglobinopathies, which are caused by mutations that affect the structure of the hemoglobin molecule that carries oxygen in blood.

Casgevy does not repair the genetic mutations that are responsible for sickle cell disease or beta-thalassemia syndromes; rather, it is designed to edit a regulatory element that helps control the production of the protein BCL11A in hematopoietic stem cells that suppresses fetal hemoglobin production after birth. Casgevy prevents this repression, leading to production of

fetal hemoglobin, which acts as a functional replacement for defective adult hemoglobin.

The clinical results reported have been very promising, with the majority of evaluable patients in the sickle cell trial not experiencing any VOEs requiring hospitalization within twelve months of the treatment (Frangoul et al. 1649). Because most of the evaluable patients in the beta-thalassemia study were able to attain periods of transfusion independence (Locatelli et al. 1663), this finding was considered a major medical advance for patients who had endured frequent painful episodes, repeated transfusions or high-risk, customary BMT procedures.

The problem is not whether Casgevy works. The problem is how it is made and delivered. Casgevy is an ex vivo therapy. The patient's blood stem cells must be harvested, edited, and tested in the laboratory, and only then returned to the patient after chemotherapy is given to make room in their bone marrow. As a result, making Casgevy available to patients is more like providing individualized medical treatment than a normal drug on a shelf.

The process is therefore a manufacturing model with an immutable ceiling: treating the next patient does not make the next course of therapy much cheaper or easier, because their cells need to be re-manufactured. Casgevy thus shows that personalized CRISPR cures or ameliorates disease. It does not show that personalized CRISPR can or will reach the millions who might benefit from gene editing.

In Vivo Editing: The Scalable Model, but Not the Easy One

In vivo editing (or in body editing), is editing happening inside the body rather than removing cells, editing them and putting them back into the body. It is more technically demanding than ex vivo editing, because the editor has to get to the right tissue, the right cells, edit enough of the right cells, and not cause catastrophic damage. However, this might be more possible if this were a standard product rather than a custom made item for every patient.

An example of a proof of concept is NTLA-2001 for transthyretin amyloidosis, an inherited condition in which misfolded transthyretin produced by the liver amasses and damages organs including the heart and peripheral nerves. NTLA-2001 delivers the CRISPR components in lipid nanoparticles, and it has been found that these amass predominantly in the liver. Here, the editor was able to disrupt the gene encoding a disease-causing protein for transthyretin with a single infusion, producing an 80% decrease (Gillmore et al. 493). This result is important in that it showed that systemic in vivo CRISPR editing can work in human patients.

In another example, EDIT-101 is being studied for treating a form of genetic blindness called CEP290-associated retinal degeneration. In this case, the CRISPR system was injected subretinally into the photoreceptors. While these did not produce cures, they did lead to important improvements in vision (Pierce et al. 1972). Due to the level of access, along with the relative ease of delivering gene therapies to the eye, it remains a likely starting point for in vivo gene editing.

In an infant CPS1 case (2025), (Musunuru et al.) physicians used a patient-specific base-editing therapy to treat an infant with a severe CPS1 deficiency, which is a serious metabolic disorder. Although this case is unique in that the base-editing therapy was specifically

designed and manufactured in a matter of months for just that infant, this case should not be considered as a primary model for treatment of common diseases. It did, however, combine in vivo delivery with personalized manufacturing, which could be a strategy for very rare diseases, though not necessarily easily scaled for more common diseases affecting millions.

Examining the Evidence

These examples appear to teach different lessons through the lens of the extreme clinical benefit that they show: Casgevy shows strong clinical benefit efficacy in sickle cell disease and beta-thalassemia, not in the democratized personalized ex vivo manufacture that the other studies show. NTLA-2001 shows safety, in vivo editing and reduction of expression of pathogenic liver genes with a single dose, but not in every tissue. Although the phenotypic benefit of in vivo local editing of the retina by EDIT-101 for some patients is encouraging, it remains unclear whether the retina is a generally treatable tissue, and whether therapeutic editing of other tissues (outside liver and retina) would be feasible or informative. The infant case of CPS1 illustrates how rapidly a custom base-editing therapy can be developed for that urgent single patient. It doesn't prove this is a scalable model for common disease, but together the two cases at least establish a strong claim of feasibility, and a weaker claim of scalability.

Constraints: Delivery Is the Bottleneck for Scale

Another problem is off-target mutations, in which DNA is altered outside of where it was intended, either in complementary DNA or in close proximity to the desired target. This can be minimized by computationally predicting the target, screening the whole genome, or using engineered high fidelity (HF) enzymes. Cleavage does not always produce a clean deletion; unwanted deletion of larger stretches of DNA or more complex rearrangements may occur (Kosicki et al. 765). In some cell types, CRISPR-induced DNA damage may trigger the p53 pathway, possibly leading to selection of cells with deficiencies in DNA-damage response (Haapaniemi et al. 927).

Delivery of the editor is often the primary obstacle to medical utility. No matter how good the editor is, it results in little medical utility if it cannot be delivered to the proper cell types. This is one reason why initial efforts at in vivo delivery are focused on the liver, where lipid nanoparticles naturally circulate and amass. Getting to the muscle, brain, lung, or blood stem cells in the body is much harder.

This delivery problem is a key motivation for ex vivo editing, where blood-forming stem cells are selectively removed, edited in the lab, and put back in the patient; this is difficult and expensive, but avoids the unsolved problem of getting your editors into your stem cells, inside the patient. So in that sense, ex vivo therapy is not foolish or outdated, and may be the best option for some tissues. The question is whether it should be regarded as a prototype for future scales.

Another common issue in in vivo genome editing is the immune response. Because Cas9 is derived from bacteria, some individuals have immune responses to Cas9 proteins (Charlesworth et al. 249). That is even more important in vivo, where the editor enters directly

into the human body. In ex vivo therapy, the editing machinery can be handled relatively easily in the laboratory, never descending into the body. This is one of the real advantages of the ex vivo model.

Cost and Access: Why the Model Matters

The public-health benefit of a drug is limited when that drug is unavailable to patients. Casgevy is estimated to have a U.S. list price of 2.2 million dollars per patient (Gardner). The cost of the drug is high. However, in certain health care systems the one-off manufacturing costs are justified by the high cost of treating a person with a lifetime of serious sickle cell disease, despite the capital costs being incurred in one lump and manufacture needing to occur for each patient.

Unfortunately, one major downside of this ex vivo model is that generalizability is only possible in hospitals that practice stem cell harvest, specialized manufacturing, chemotherapy conditioning, tolerance of side effects, and engraftment follow-up: delivery of this type of therapy could be concentrated in wealthy health systems and medical centers. This is unfortunate because sickle cell disease is most common in areas least likely to have transplant-based medical infrastructure such as sub-Saharan Africa (World Health Organization, "Sickle-Cell Anaemia").

Even a standardized in vivo product will not necessarily overcome all access barriers (for example it might remain expensive or still require medical supervision), but it has the potential to reach scale more easily. Production at scale, wider distribution and falling prices can mean more people can access the product. The access argument is not separate from the science, it is built into the difference between personalized and standardized treatment.

Bioethical Dimensions

Ethical concerns surrounding somatic editing are thought to be more straightforward than those for germline editing, as the patient is treated for their own disease, but questions of safety and evidence of benefit, informed consent and, ultimately, whether to regulate the procedure through the US Food and Drug Administration or the European Medicines Agency are still present. A further concern relates to how such an unproven and irreversible treatment is only available to the wealthy.

The dilemma has been illustrated with respect to infant CPS1: on the one hand, a clinical trial cannot be done about a therapy designed for one patient, but on the other hand, trials are not always feasible, due to the rarity of the disease and the fragile condition of the baby. The parents' problem, of having to make a choice before the baby is treated and incapacity to consent, does not mean that the treatment was a mistake, but that one-patient therapies face unique evidence and consent issues.

When editing in the germline, the germline boundary is even more strict. In 2018, He Jiankui announced editing embryos to become twin girls, to modify the CCR5 gene to confer immunity to HIV. Internationally, this edit was condemned as heritable, not medically motivated, secret and uncontrolled. He has been jailed in China (Normile). However, the case shows that

somatic therapy is not in the same ethical category as germline editing.

Another aspect of justice is equity. CRISPR therapies can be expensive, and if only a small number of wealthy patients can access the therapy, it is likely that inequality of health will be perpetuated, even while individual patients benefit. Justice will not only depend on the safety and specificity of the CRISPR technology, but also on its delivery and manufacturing model.

Conclusion

Casgevy's data suggest that somatic gene editing would provide important clinical benefit to patients who suffer from serious inherited blood disorders. In vivo studies have been done to establish the ability of editors to work inside the body, particularly in the liver and eye. In the case of CPS1, a specific edit was carried out on the patient, and it may be possible that other ultra-rare disorders could be treated this way as well.

Each of these accomplishments is a separate story, with its own models, and its own future. Though powerful and clinically translatable, personalized ex vivo editing is difficult to manufacture, expensive, and infrastructure-driven. Scalable in vivo editing is less mature, with major delivery and safety barriers, but has a manufacturing logic for wider applications in public health.

The future of CRISPR medicine, however, will not depend only on the discovery of new and improved gene editors. The fate of the gene editor as a therapeutic will also depend on whether it can be effectively delivered to the intended tissue, manufactured as a regulated product, and made accessible to people. So precision is important, but precision without scale will leave genome editing as an extraordinary therapy for the few rather than a transformative medicine for the many

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The Development of a UV-Powered Water Purification System Using Graphene-Based Filters for the removal of Azo Dyes in seawater By Jessica Abraham and Miley Liu

Abstract

By the end of 2024, over 300,000 tons of azo dyes were discharged into industrial wastewater, introducing carcinogenic and mutagenic compounds into aquatic ecosystems and potential drinking water sources. Conventional treatment methods such as reverse osmosis require high energy input and generate secondary wastewater, highlighting the need for more sustainable purification strategies. This study developed a UV-activated seawater filtration system using a graphene oxide–activated carbon–titanium dioxide (GO–AC–TiO_2) nanocomposite membrane reinforced with chitosan and multi-walled carbon nanotubes (MWCNTs) to remove methylene blue (MB) and methyl orange (MO). Activated carbon provided porous adsorption sites, graphene oxide introduced oxygen functional groups for dye interactions, and chitosan supplied protonated amine groups that electrostatically attracted negatively charged contaminants. Under UV-A irradiation, TiO_2 generated reactive oxygen species that oxidized dye molecules, while MWCNTs improved electron transport and reduced charge recombination. Eighty-one filter formulations were tested across seven trials for flow rate, turbidity reduction, and dye removal. The fastest filtration occurred at 10:90 GO–AC + 3 wt% TiO_2 + 1 wt% chitosan (6.3 ± 0.4 mL/s). Dye removal reached 94 ± 2% for MB and 91 ± 3% for MO. A univariate test ($p < 0.05$) and Scheffé comparisons confirmed that filter composition significantly influenced performance. The optimized formulation 10:90 GO–AC + 5 wt% TiO_2 + 3 wt% chitosan + 2 wt% MWCNTs showed the best balance of adsorption, photocatalysis, and filtration stability, demonstrating the potential of graphene-based nanocomposite membranes for scalable and sustainable dye remediation in water systems.

A. Rationale

By the end of 2024, over 300,000 tons of azo dyes were discharged into marine and freshwater systems, with more than half entering drinking water supplies (Islam et al., 2025). Azo dyes, characterized by azo linkages (-N=N-) between aromatic structures, are extensively employed in textile manufacturing due to their chemical stability and color fastness. However, this stability imparts environmental persistence, and their reductive degradation can generate carcinogenic aromatic amines such as benzidine (Chung, 2016). In aquatic environments, azo dyes elevate chemical oxygen demand, weaken light penetration, inhibit photosynthetic activity, and introduce toxic intermediates into potable water sources.

The urgency of this contamination is increased by global water insecurity, with 4.4 billion individuals lacking access to safely managed drinking water. Conventional treatment strategies such as sediment filtration and reverse osmosis, exhibit significant limitations: insufficient removal of dissolved organics, high energy demand, and generation of secondary waste streams (Dvorak & Skipton, 2013; Wenton & Khoiruddin, 2016). These constraints show the need for more energy-efficient and chemically targeted remediation technologies.

Therefore a UV-driven seawater purification system is proposed incorporating graphene-based filtration media. Taking advantage of graphene's high surface area and electron mobility, the system integrates adsorption with photocatalytic degradation, facilitating oxidative cleavage of azo bonds under UV irradiation. This approach aims to enhance dye removal efficiency while minimizing environmental and energetic costs (Limsakul, 2024).

An emerging strategy in advanced water purification involved UV-driven photocatalysis using TiO_2-based nanocomposites. $TiO_2$is an n-type semiconductor with a bandgap of ~3.0-3.2 eV, enabling UV absorption and generation of electron-hole pairs. These charge carriers initiate redox reactions that produce reactive oxygen species (ROS), including hydroxyl and superoxide radicals, which oxidize organic contaminants, dyes and microbes (Sheth et al., 2022; Tasisa et al., 2024). Integrating TiO_2 with graphene-based materials enhances photocatalytic efficiency by improving surface area and charge separation while reducing electron-hole recombination.

Graphene oxide (GO), a chemically oxidized derivative of graphene, contains oxygenated functional groups that increase hydrophilicity and dispersibility (De La Fuente, n.d.). When assembled into membranes, GO forms layers of nanochannels that enable rapid water transport while rejecting hydrated ions via size exclusion and electrostatic repulsion (Sabin Civil Engineering, 2020). However, GO membranes may swell in aqueous environment, reducing selectivity.

Activated carbon (AC) complements GO by providing a highly porous, high-surface-area structure capable of adsorbing organic pollutants, heavy metals, and dyes through π–π interactions, hydrogen bonding and Van der Waals forces (Heidarinejad et al. 2020).

While GO and AC primarily function as adsorbents, TiO_2 provides photocatalytic degradation. Under UV irradiation, TiO_2 oxidized adsorbed contaminants, regenerating adsorption sites and enabling a self-cleaning mechanism that enhances stability (Tayel et al., 2018; Ying et al., 2020).

Carbon nanotubes (CNTs) further improve system performance by enhancing electrical conductivity, mechanical strength and water flux. Acting as electron sinks, CNTs suppress charge recombination in photocatalytic systems and facilitate rapid water transport through smooth, hydrophobic nanochannels (Aslam et al., 2021). Together, GO, AC, TiO_2, and CNTs create a synergistic filtration platform that integrates adsorption, size exclusion, and photocatalytic oxidation. When powered by solar-driven UV irradiation, this composite system offers an energy-efficient and scalable approach for azo dye degradation and seawater purification.

Han (2021) demonstrated graphene's strong photothermal properties, including broadband absorption, thermal stability, and high conductivity. By encapsulating graphene nanosheets with a zeolitic imidazolate framework (ZIF), they enhanced light absorption and thermal localization, achieving 98% solar-to-thermal and 96% solar-to-vapor conversion efficiencies–substantially outperforming pure graphene (Han et al., 2021)

Schmidt (2023) developed a regenerable graphene-based household filter that removed heavy metals at efficiencies 3-65 times greater than conventional AC, maintaining performance up to ~600 bed volume at 15 ppb (Schmidt et al., 2023).

Yangyang (2022) engineered a MOF-801@GO-PDMS membrane achieving 29.24 kg m^{-2}

h^{-1} vapor flux with 99.99% salt rejection, demonstrating graphene oxide's stability under desalination conditions (Yangyang, 2022).

While these studies demonstrate the efficiency, regenerability, and scalability of graphene-based systems, long-term performance under natural environmental conditions and removal of complex organic contaminants remain underexplored. Most investigations focused primarily on salt or heavy metals rather than persistent organic dyes. This study addresses these gaps by developing a sustainable UV-driven purification system integrating graphene-based components to enable photothermal and photocatalytic removal of azo dyes from seawater, advancing scalable solutions for water scarcity. The alternate hypothesis was that the addition of MWCNTs would enhance the ability of the GO-AC filter for dye degradation. The null hypothesis was that with the reinforcement of MWCNTs, there would be no change in the performance of the filter.

B. Procedures

All of the below protocols were completed by the competition entrant.

Experimental Overview

All trials lasted for 1 week, and readings were taken daily. This study aimed to evaluate the performance of GO and MWCNT's filters. Readings were taken for a week to allow for the assessment of the immediate and long-term effects of the filters. The experimental setup included assessing the water flow rate, durability, turbidity, and ability to remove MO and MB from seawater. Water flow rate was measured in milliliters per minute (mL/min) to assess the efficiency of water passage through the filter. Next, durability was measured by assessing the physical integrity of the filter material and its ability to maintain performance using data obtained from the number of cycles the filter is able to withstand. Furthermore, turbidity, MO, and MB was measured using nephelometric turbidity units (NTU) to determine the cleanliness of the filtered water. Percent removal was calculated to determine how much of the substance was able to be filtered out. Through these measurements, it was possible to determine how the filter performed and how sustainable it was for purification. The independent variable of this study was the type of filter being used: a TiO2-GO-AC filter, a TiO2-GO-AC filter with the addition of MWCNTs, or a normal filter from lab supply. The dependent variable of the study was the ability of the filter to remove azo dyes after passing through the filter, the turbidity, the water flow rate, and the durability of the filter. The control group was the normal Brita filter. All of the conditions during testing, as well as the products used, were held constant during experimentation. **M**

Phase 1

1.1 The preparation of Activated Carbon Powder

Marineland premium activated carbon was utilized; however, this activated carbon initially had a grain size of approximately 0.5 mm and therefore required further reduction to a particle size less than 0.075 mm. To obtain this, a clean and fully dried coffee grinder was placed

under a fume hood with the sash lowered. The activated carbon was then added and ground until a fine, uniform powder was obtained (Reza et al., 2020). The resulting powder was subsequently sifted, transferred into a labeled container, and stored for later use.



Figure 2: Preparation of activated carbon ground from 0.5 mm to 0.075 mm under a fume hood, sifted, and stored for use (Picture taken by student researchers 2025 using a chromebook camera).

1.2 Creation of Graphene Oxide-Activated Carbon (GO-AC)

To create the graphene oxide-activated carbon, 0.4 wt% graphene oxide and activated carbon powder were used. The ratio of the amount of GO and AC that was used differed, as a pilot study was conducted to determine the ratio that would give the best results. The weight ratios included 10:90, 20:80, and 25:75 GO: AC by weight. For a 20:80 ratio, 0.8g of AC powder was used, and 50 mL of GO dispersion. To prepare this composite, the amount of AC powder needed was weighed, transferred into a clean 100 mL beaker, and 50 mL of DI water was added. This mixture was then mixed with a magnetic stirrer for 2-3 minutes to disperse the particles. The mixture was allowed to settle briefly for 1-2 minutes. The vacuum filtration apparatus was then constructed, and filter paper was placed down. The AC-water mixture was poured into the funnel, vacuum suction was applied to draw off the liquid, and once the water was gone, a new 30 mL portion of DI water was slowly added over the AC again. This step was repeated 3-5 times until the water ran clear. The filter paper with the AC powder was then transferred to a clean glass container with no lid on top and dried in an oven at 60-80℃ to remove moisture that can interfere with dispersion (4-6 hours). Next, the AC powder was added slowly to the GO dispersion. Magnetic stirring occurred for at least 1-2 hours to allow the GO sheets to wrap with the AC particles. The suspension was then sonicated for 10-30 minutes at a temperature below 30-40℃ to break up clumps of AC and exfoliate GO further (Rathnayaka et al., 2025). After the suspension was created, because GO is stable at a pH of 6-8, the pH of the GO-AC suspension was then measured. For adjustments needed to raise the pH, 0.1M of NaOH was slowly added dropwise while stirring, and the pH was measured after each drop. To lower the pH, 0.1M of HCl was slowly added dropwise while stirring.



Figure 3: Activated carbon was washed using a hand-held vacuum filtration pump and dried before mixing with graphene oxide (Picture by student researcher 2025).

1.3 The addition of TiO_2 and Chitosan into GO-AC

To create a GO-AC-TiO_2 solution, a pilot study was conducted where a range of 3-5 wt% TiO_2 concentrations was used. The TiO_2 was weighed out for each target wt% and was then dispersed in 10 mL of deionized water. The dispersion was sonicated in pulse mode (5 seconds on and 5 seconds off) for 7 minutes using an ice bath to maintain a temperature below 40 ℃. Immediately after, the TiO_2 dispersion was slowly added into the GO-AC suspension dropwise over 10 minutes under continuous magnetic stirring. Stirring was maintained for an additional 30–60 minutes at room temperature (Nellaiappan et al., 2021). The pH of the mixture was then adjusted to 7 and allowed to equilibrate for 10–15 minutes.

To further improve the membrane's stability to help strengthen the incorporation of MWCNT's and to help prevent it from being released into the environment over time, chitosan was incorporated into the GO-AC-TiO2 slurry before casting. Chitosan was incorporated into the GO-AC-TiO_2 slurry before casting. A pilot study was performed where a range of 1-3 wt% concentration of chitosan was used. To prepare the chitosan stock, a 1 wt% solution was prepared by dissolving chitosan powder in 1% v/v acetic acid (0.174 M) under stirring until fully dissolved in a fume hood (3-6 hours). Since 1-3 wt% of the total solids are being used, the corresponding volume of the stock solution was added dropwise into the stirred GO-AC-TiO_2 suspension and mixed for 15-30 minutes (Lu et al., 2004). The slurry pH was adjusted to a pH of 6 to maintain chitosan solubility and ensure good dispersion before casting.



Figure 4: The addition of TiO_2 dropwise into the GOAC-TiO_2 slurry (Picture by student researcher 2025).

1.4 Creation of the Filter and Neutralization

The method that was utilized to cast the filter was membrane casting via vacuum filtration. For vacuum filtration casting, the MCE was placed on the filter base of the vacuum filtration apparatus ensuring that there were no wrinkles or air bubbles beneath it. The support membrane was wet with DI water to prevent the GOAC-TiO_2 slurry from penetrating unevenly. Then, the slurry was poured into the funnel to allow the slurry to spread evenly over the surface. The vacuum pressure was gradually increased (up to 0.05–0.1 MPa), and a constant suction rate was maintained so the DI water was removed evenly. Strong suction was avoided initially, as this could have caused cracking. Filtration was continued until the top surface appeared matte and there was no visible liquid remaining, which usually took around 4-5 days. During this process, the GO sheets self-assembled into stacked layers, held together primarily by van der Waals forces and hydrogen bonding. Activated carbon particles became physically trapped within these layers and occupied the interstitial spaces, preventing GO restacking. This contributed to additional adsorption sites. TiO_2 nanoparticles integrated into the structure by forming hydrogen bonds with the oxygen-containing functional groups and by physically adsorbing onto the high-surface-area pores of AC. After filtration, the vacuum was carefully released, and the wet membrane was kept submerged in DI water to prevent tearing and wrinkling. Following vacuum filtration casting, the wet membrane was placed in a beaker with the MCE still under it to neutralize the membrane and remove any residual acidity from acetic acid before crosslinking. DI water was added slowly from the side of the beaker until just enough was in the beaker to cover the membrane. The membrane was let sit for 10-15 minutes to allow diffusion of acidic residues into the water. The pH of the rinse water was checked using a pH meter. If the water was still acidic, new DI water replaced the old one, and this step was repeated until the pH was at 7.

To crosslink this membrane with genipin to enhance mechanical strength and reduce swelling during filtration use, a 0.5 wt% genipin aqueous solution was prepared by dissolving the genipin in DI water under magnetic stirring until fully dissolved (15–20 minutes). The solution pH was then adjusted to 7. The neutralized wet membrane was then transferred into the genipin solution using tweezers, and the beaker was covered to minimize contamination and was left at room temperature for 24 hours. A visible blue coloration appeared as the genipin reacted with chitosan. After crosslinking, the membrane was removed and rinsed thoroughly with DI water several times (3–5 times) to remove unreacted genipin. Then, the membrane was fully submerged in DI water in a sealed container at 4 °C until use to prevent dehydration and cracking.

For the final assembly, the hydrated membrane was to be put into a syringe. First, the membrane was carefully taken out of the sealed container with both MCE's still attached to it. The membrane was placed on the flange and then the plunger was used to slowly push the MCE to the bottom of the barrel. The syringe had no needle attached to the bottom of it. The utilization of a syringe as the filter container of the membrane was practical as it allowed for a steady holder container for the water waiting to pass through the filter.

Phase 2

2.1 The addition of Multi-walled Carbon Nanotubes

The addition of MWCNTs to a GO-based filter can enhance its properties, such as mechanical strength, conductivity, and adsorption capacity. To reinforce the GO-AC-TiO_2 composite, MWCNTs were incorporated before membrane casting. For a 10g total-solids batch, 0.1-0.2g MWCNTs (1-2 wt%) was added dropwise into the membrane. Clumps were common because MWCNTs are hydrophobic, meaning they naturally repel water and form into large clumps due to strong van der Waals forces. The mixture was sonicated in an ice bath using a probe sonicator in pulse mode (5 seconds on and 5 seconds off) for a total of 3-8 minutes to ensure deagglomeration while minimizing MWCNT shortening and structural damage. The well-dispersed MWCNT suspension was then added and the MWCNTs were forming ��-�� interactions with the graphene sheets. Some hydrogen bonding occurred between the MWCNT surface groups and the oxygen-containing groups on GO. TiO_2 adsorbs onto the MWCNTs, promoting a stronger composite (Gangu et al., 2019). After this GOAC-TiO_2-MWCNT solution was created, and the filter was created as it was before the MWCNTs were added into the solution.

2.2 UV Usage

Ultraviolet (UV) light was employed in order to activate TiO_2 to generate reactive oxygen species (ROS); this process is known as photocatalysis. Photocatalysis occurred because when TiO_2 is exposed to UV light, it becomes energized and creates ROS, reactive oxygen species, and examples of that are hydroxyl radicals and superoxide ions. ROS key reactions are TiO2 + hv to $e^- + h^+$. These ROS are efficient in degrading impurities in water, such as organic contaminants, bacteria, and viruses. The inner region of the filtration chamber was coated with the TiO_2-based composite filter, which makes it effective in purification. During experimentation, a UV-A lamp from Vernier was placed over the filter so that the system was kept under constant light, facilitating photocatalysis. A UV-A probe was placed 1 foot away from the UV-A Lamp to keep the intensity uniform for each trial. Using UV light is optimal and ideal because it is a chemical-free and cost-efficient process of purification. TiO_2 is also extremely stable and is not readily degraded so therefore, it is environmentally sustainable for applications in the water treatment process.

Phase 3: Filter Testing

3.1 Measuring the turbidity

Turbidity was assessed using a Vernier turbidity sensor. The Vernier Turbidity Sensor was connected to the LabQuest 2 prior to use. The sensor was calibrated using a 100 NTU calibration standard and distilled water. For the first calibration point, the 100 NTU standard vial was wiped with a Kimwipe to remove any fingerprints and inserted into the turbidity sensor with the arrow

on the vial aligned with the arrow inside the sensor. After the voltage stabilized, 100 NTU was entered as the known value. For the second calibration point, a clean vial was filled with distilled water, wiped clean and inserted into the sensor with proper arrow alignment and 0 NTU was inputted once the voltage stabilized (Vernier Science Education, 2025). Once the calibration was complete, one of the vials was filled with the appropriate amount of seawater mixed with bentonite powder. This solution was created by adding 50 g of bentonite powder into 300 mL of seawater. The vial was wiped and placed into the sensor where the measurement was taken down in units of NTU. Then, the liquid from the glass vial was put into the filter to remove any contaminants. The product of this was then added into another clean vial for testing again. The percent removal was calculated using the equation: (Inflow-Outflow)/Inflow x 100.

3.2 Water Flow Rate

Water flow rate through the filter was measured with the use of a stopwatch to measure the amount of time required for 400 mL of water to successfully pass through the filter. The measurements were placed into the formula "Flow Rate = Volume/Time (mL/min)". The purpose of this step was to observe for any changes in membrane activity, leaks, or changes in structural integrity.

3.3 Azo Dye Testing

The filter was tested to determine how well organic contaminants could be removed from seawater through the process of photocatalysis. The membrane was tested using methyl orange (MO) and methylene blue (MB), which are model azo dyes. A 100 mg/L concentrated MO and MB stock solution was prepared in deionized water and diluted to a 1:10 ratio to prepare the 10mg/L working solution. 200 mL 10 mg/L were charged into the test filter setup for every test and passed through the filter under a UV-A light from 10-15 cm above the chamber. Before the lamp was turned on, however, the solution was passed through the dark to allow for natural adsorption to happen, which took 10 minutes, and also a 10 mL sample to be a baseline labeled "time 0". Once that was complete, the UV lamp was turned on, and 5-10 mL samples were collected in 5, 10, 20, and 30 minutes. Each sample was filtered by syringe and then scanned on a spectrometer at 464 nm, which was the MO and MB adsorption maximum. The formula followed was $\%\text{Removal} = (1 - A/A_0) \times 100$, where A_0 is the absorbance at time 0 after dark adsorption and A is the absorbance at each time point. Controls included MO and MB without a filter under UV (photolysis control), MO and MB with a filter but no UV (adsorption control), and MO and MB with UV and a plain MCE membrane (matrix control). Once completed, the waste particles were put into a labeled container (Limsakul et al, 2024). The percent removal was calculated using the equation: (Inflow-Outflow)/Inflow x 100.

3.4 Absorbance Spectrum

An absorbance spectrum of the two dyes (methylene blue and methyl orange) were measured to determine how much light was absorbed at different wavelengths. A

spectrophotometer was used to record the electromagnetic radiation absorbed by the sample across the relevant wavelength range, and this allowed for the comparison of intensity at each wavelength (Zuehlsdorff et al., 2019).

3.5 Beer's Law Plot

A Beer's Law plot was created to create a calibration curve for each dye sample. Known concentrations were prepared and their absorbance values were measured. The absorbance was then plotted against concentration to generate a linear relationship. The R^2 value indicated how well the calibration curve fit into a straight line, therefore values closest to 1 illustrated a strong linear relationship. The slope of the line represented how much absorbance changed per unit concentration.

3.6 Assessing the Durability

A major component is to create a sustainable water-filtration system, so long-term effectiveness was determined. To determine this, after water flowed through the filter daily for a week, structural integrity was assessed. The number of cycles were noted down, and the amount of time it took for the filter to be unable to produce any more clean water. If there were any signs of physical degradation, such as the filter breaking or the filter being completely saturated, that indicated that the lifespan was over.

Also, if the salinity of the water continued to increase. This helped indicate how often the filter would need to be replaced in the real world and allow for adjustments to the filter's structure.

3.7 Data Analysis

All of the data was completed on IBM SPSS v. 28. The statistical test used was a univariate test to analyze a single variable at a time to describe its distribution. Water flow rate, turbidity, and dye removal were each all analyzed, respectively. A post-hoc Scheffe test was conducted after the univariate test to determine which specific group means differed while controlling for Type 1 errors. Significance was shown with a p value less than 0.05. Bar graphs were made to compare distinct categorical data sets and show numerical data across groups.

3.8 Data Collection

Data was collected in a notebook every day in the morning, and measurements included details about the volume of water that has been purified over a certain period of time. The data was divided by date and time of measurement. The data revolved around the volume of water purified in mL and the duration of filtration. Since the study aimed to determine sustainability, the start and end times were determined to calculate the total time in hours and minutes that the filter lasts. This was all quantitative data; qualitative data was taken about the appearance of the filtered water, such as being clear, and the condition of the membrane.

3.9 Disposal

To dispose of the filter, it was treated as hazardous solid waste so it was collected, sealed, a ity.

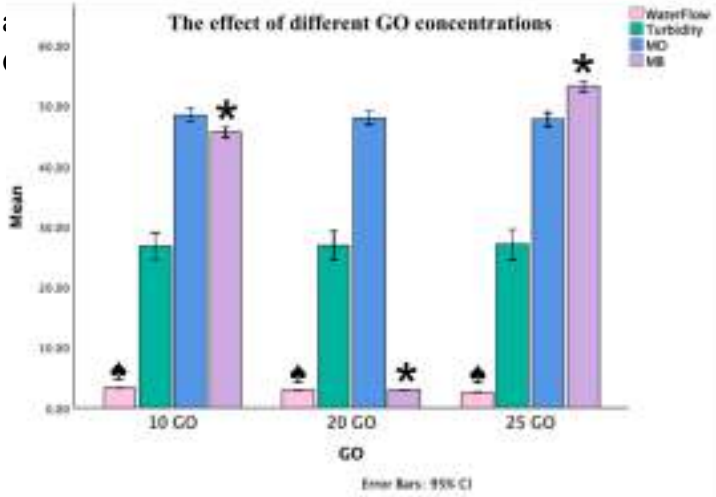


Figure 5: The effects of different GO concentrations on water flow rate, turbidity, MO and MB (n = 21, N = 588) (*, ♠, ♥ show significance with a p-value less than 0.05) (Graph made by competition entrants, 2026)

A Scheffe post-hoc analysis revealed that GO concentrations significantly influenced water flow rate and MB removal. For water flow rate, 10% GO is significantly different from 20% GO ($p<0.001$) and 25% GO ($p<0.001$). For MB removal, 10% GO differed significantly from 20% significantly from 25% GO ($p = 0.008$). MO removal and turbidity reduction did not show statistically significant differences among GO concentrations.

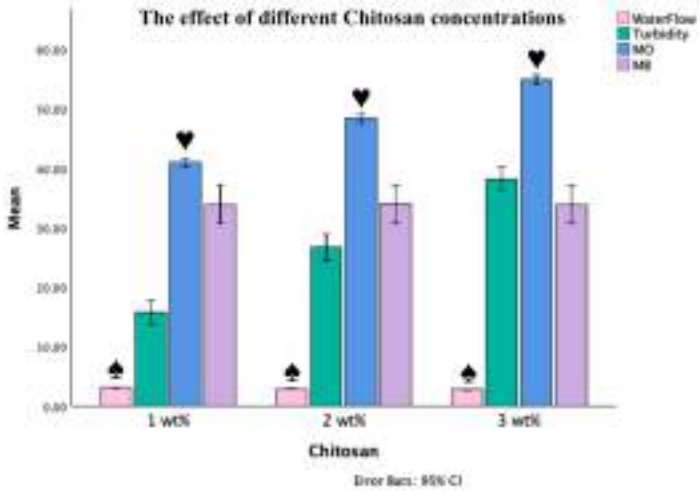


Figure 6: The effects of different Chitosan concentrations on water flow rate, turbidity, MO and MB (n = 21, N = 588) (*, ♠, ♥ show significance with a p-value less than 0.05) (Graph made by competition entrants, 2026)

Scheffe post-hoc testing showed that chitosan concentrations significantly influenced water flow and MO removal. For water flow, 1 wt% chitosan differed significantly from 2 wt% chitosan ($p<0.001$) and 3 wt% chitosan ($p<0.001$), and 2 wt% chitosan also differed significantly from 3 wt% chitosan ($p<0.001$). For MO removal, 1 wt% chitosan differed significantly from 2 wt% chitosan ($p<0.001$) and 3 wt% chitosan ($p<0.001$), while 2 wt% chitosan also differed significantly from 3 wt% chitosan ($p<0.001$). MB removal and turbidity reduction showed no statistically significant differences between chitosan concentrations.

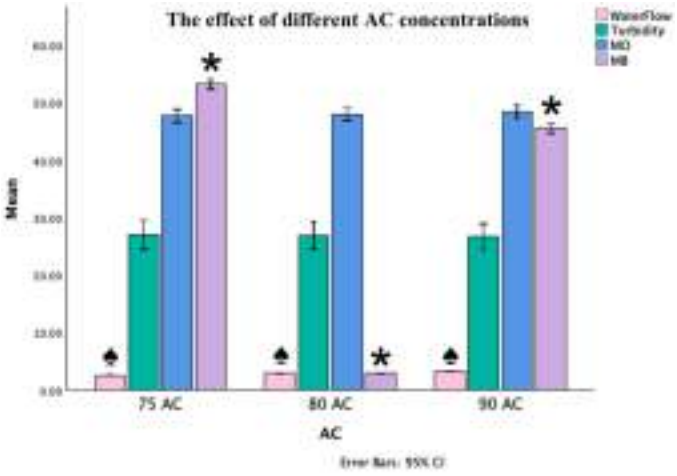


Figure 7: The effects of different activated carbon concentrations on water flow rate, turbidity, MO and MB (n = 21, N = 588) (*, ♠, ♥ show significance with a p-value less than 0.05) (Graph made by competition entrants, 2026)

Scheffe post-hoc analysis indicated that AC concentrations produced statistically significant differences in water flow rate and MB removal. For water flow rate, 75% 11 AC differed significantly from 80% AC ($p<0.001$) and 90% AC ($p<0.001$), and 80% AC differed significantly from 90% AC ($p<0.001$). For MB removal, 75% AC differed significantly from 80% AC ($p=0.008$) and 90% AC ($p<0.001$), while 80% AC also differed significantly from 90% AC ($p<0.001$). MO removal and turbidity reduction showed no significant differences between AC concentrations.

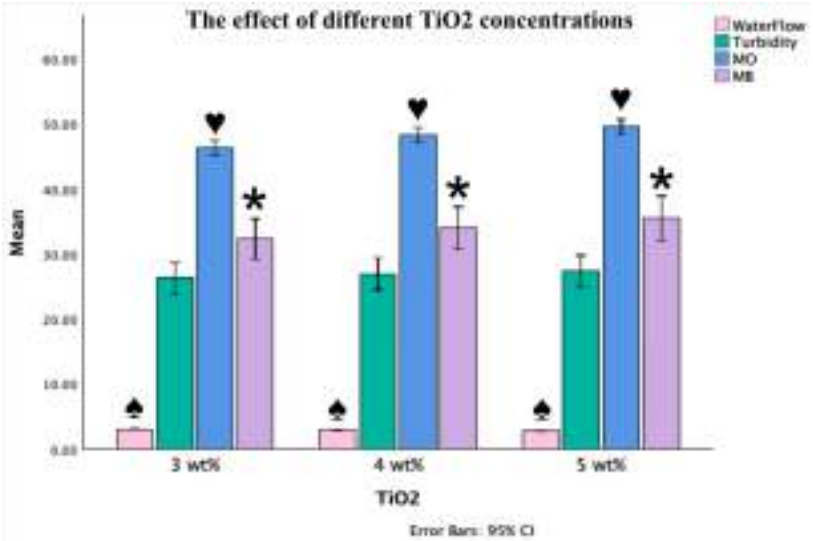


Figure 8: The effects of different titanium dioxide concentrations on water flow rate, turbidity, MO and MB (n = 21, N = 588) (*, ♠, ♥ show significance with a p-value less than 0.05) (Graph made by competition entrants, 2026)

A Scheffe post-hoc test demonstrated that TiO_2 concentrations significantly affected water flow rate, MB and MO removal. For water flow rate, 3 wt% TiO_2 differed significantly from 4 wt% TiO_2 ($p = 0.017$) and 5 wt% TiO_2 ($p<0.001$) and 4 wt% TiO_2 differed significantly from 5 wt% TiO_2 ($p=0.009$). For MB removal, 3 wt% TiO_2 differed significantly from 4 wt% TiO_2 ($p=0.002$) and 5 wt% TiO_2 ($p<0.001$), while 4 wt% TiO_2 TiO_2 also differed significantly from 5 wt% TiO_2 ($p=0.004$). For MO removal, 3 wt% TiO_2 differed significantly from 4 wt% TiO_2 ($p=0.004$) and 5 wt% TiO_2 ($p<0.001$).

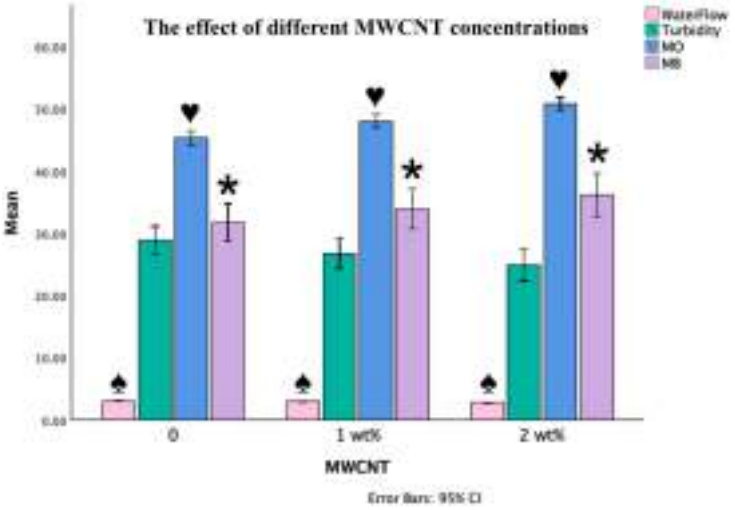


Figure 9: The effects of different multi-walled carbon nanotube concentrations on water flow rate, turbidity, MO and MB (n = 21, N = 588) (*, ♠, ♥ show significance with a p-value less than 0.05)
(Graph made by competition entrants, 2026)

A Scheffe post-hoc analysis indicated that MWCNT concentrations significantly affected water flow rate, MB and MO removal. For water flow, 1 wt% MWCNT is significantly different from 2 wt% MWCNT ($p<0.001$). For MB removal, 1 wt% MWCNT is significantly different from 2 wt% MWCNT ($p<0.001$). For MO removal, 1 wt% MWCNT is also significantly different from 2 wt% MWCNT ($p<0.001$). Turbidity reduction did not show statistically significant differences among MWCNT concentrations.

C. Discussion

The purpose of this study was to test different ratios of materials to create a UV-driven water purification system that could most effectively remove azo dyes from sea water. The experimental results demonstrated that filter composition plays a critical role in determining overall purification performance which supports the engineering goal of optimizing material ratios to improve adsorption, photocatalytic degradation and filtration stability. Different formulations optimized different performance metrics, demonstrating that no single material ratio maximized every variable independently. Since the optimized formulation demonstrated improved dye removal efficiency compared to the base filter, the alternate hypothesis that MWCNT reinforcement would enhance filtration performance was supported, while the null hypothesis was rejected. Statistical comparison between filter compositions confirmed that these differences were significant, with multiple pairwise comparisons producing p-values less than 0.05. This indicated that variations in material ratios produced measurable changes in filtration performance rather than random variations. Overall, the results indicated that carefully balancing GO-AC structure, chitosan-mediated adsorption, and TiO_2-MWCNT photocatalytic activity produced the most effective filtration performance for removing azo dyes from seawater.
For water flow rate, the fastest filtration was observed in the formulation 10:90 GO-AC + 3 wt% TiO_2 + 1 wt% Chitosan with no MWCNT reinforcement. Statistical comparisons indicated that filters with higher AC concentrations produced significantly greater flow rates than filters containing higher GO fractions (mean difference = 1.36 units between 90% AC and 75% AC

formulations, $p < 0.001$). All ratios had a significant effect on the water flow rate. This formulation performed best because it contained the highest AC composition while maintaining moderate GO content and minimal polymer binder. Yue's study in 2024 supports this finding as during his research on the use of TiO_2/AC nanocomposites for degrading MB from wastewater, the composite with 3 wt% TiO_2 showed the highest photocatalytic activity, achieving a dye degradation efficiency of 99.6% within 100 minutes under natural light irradiation (Yue, 2024). A greater AC concentration would be more beneficial for water flow rate because AC contributed a highly porous structure with extensive micro and mesopore networks that facilitated rapid water transport. In contrast, GO tends to form stake lamellar sheets that would narrow interlayer channels when present at higher concentrations. Chitosan was also at the lowest due to its ability to coat pore surfaces and partially fill void spaces, while TiO_2 and MWCNTs would have occupied internal pore volume and increased transport resistance. Thus, the highest permeability occurred when the membrane composition minimized structural densification while retaining enough GO to maintain mechanical integrity. This explained the observed trend that higher AC content and lower concentrations of GO, chitosan, TiO_2 and MWCNTs favored faster filtration. On the other hand, filters containing higher GO and chitosan fractions likely showed slower flow due to increased channel constriction and polymer bridging between graphene layers.

For turbidity removal, the most effective formulation was the 25:75 GO-AC + 5 wt% TiO_2 + 3 wt% Chitosan + 1 wt% MWCNT reinforcement. Statistical analysis confirmed that increasing chitosan concentration significantly improved turbidity reduction compared with filters lacking chitosan (mean difference = 800 NTU relative to 0 wt% chitosan, $p < 0.001$). It was shown that once the nanomaterial was added, increasing the concentration does not significantly improve turbidity removal, suggesting how the system reaches a saturation or adsorption equilibrium. Turbidity in this system was caused by suspended bentonite particles which remained dispersed in seawater because of their small size and negatively charged surfaces. Effective removal therefore depended on adsorption and particle aggregation mechanisms rather than photocatalytic degradation which is why not as much TiO_2 was needed. The high AC composition likely increased the available surface area for physical particle capture within the porous matrix. The higher chitosan concentration likely enhanced turbidity removal through electrostatic interactions as chitosan contains protonated amine functional groups that become positively charged in aqueous environments and can attract negatively charged clay particles. This interaction most likely promoted particle bridging and aggregation, causing small suspended particles to form larger flocs that were more easily trapped within the membrane. The relatively low GO concentration likely prevented excessive channel narrowing, which may have reduced clogging and allowed particles to penetrate deeper into the adsorption network rather than accumulating only on the membrane surface.

For MB removal, the strongest formulation was 25:75 GO-AC + 5 wt% TiO_2 + 2 wt% Chitosan + 2 wt% MWNCTs. Pairwise statistical comparisons showed that increasing TiO_2 concentration significantly improved MB degradation, with mean differences of approximately

20.82 units between 0 wt% and 5 wt% TiO_2 formulations ($p < 0.001$). Since MB is a cationic dye, meaning that it is positively charged in aqueous solutions, there would have been a promoted electrostatic attraction between the membrane and MB molecules due to the oxygen-containing functional groups on GO surfaces such as carboxyl and hydroxyl groups that typically carry negative charges. AC further enhanced adsorption through the ��-�� interactions between the aromatic rings of MB and graphitic carbon structures. The high TiO_2 concentration likely increased photocatalytic activity under UV illumination by generating electron-hole pairs that produced ROS such as hydroxyl radicals. These radicals are highly reactive and likely drove the photocatalytic degeneration of Mb molecules.The addition of MWCNTs likely improved this process by facilitating electron transport within the nanocomposite, reducing electron-hole recombination, and increasing the lifetime of reactive charge carriers.

For MO removal, the most effective formulation was 10:90 GO-AC + 5 wt% TiO_2 + 3 wt% Chitosan + 2 wt% MWCNTs. Statistical testing indicated that higher chitosan concentrations significantly improved MO removal efficiency (mean difference = 21 units between 0 wt% and 3 wt% chitosan formulations, $p < 0.001$). Increasing MWCNT significantly improves MO removal ($p<0.001$). For AC, 75-90% were statistically the same. MO is an anionic dye, meaning that it carries a negative charge in aqueous solutions. Unlike MB, MO is less strongly attracted to GO surfaces because GO can also carry negative charge. Instead, chitosan likely played the more dominant role in MO capture since the protonated amine groups of chitosan provide positively charged sites that can strongly attract negatively charged dye molecules through electrostatic interactions. Higher chitosan concentrations therefore improved MO adsorption. AC likely contributed additional adsorption capacity through hydrophobic interactions and pore-based pasture, which is particularly important in saline environments where ionic strength can weaken electrostatic interactions. Once MO molecules were adsorbed near the membrane surface, TiO_2-driven photocatalysis likely contributed to their degradation . MWCNTs likely enhanced this photocatalytic process by improving electron transfer and increasing catalytic efficiency.

The 20:80 GO-AC + 4 wt% TiO2 + 3 wt% chitosan + 2 wt% MWCNT filter had the best durability. This was because durability relies on GO stacking to hold activated carbon together and prevent cracking during filtration. The 10:90 ratio filter was too fragile and powder based leading to the filter to break and erode over cycles. On the other hand the GO is too high for the 25:75 filter leading to the layers stacking too tightly and creating clogging and brittle filters. This was why the 20:80 filter was optimal as it gave enough reinforcement without excessive stacking.

When overall performance across all metrics was considered, the formulation 10:90 GO-AC + 5 wt% TiO_2 + 3 wt% Chitosan + 2 wt% MWCNTs appeared to provide the best overall performance and balance. Statistical comparisons showed that this formulation consistently outperformed several other filters across multiple performance metrics with significant differences observed in dye removal efficiency ($p < 0.05$). This configuration combined strong adsorption capacity from AC, effective electrostatic dye capture from chitosan and enhanced

photocatalytic degradation from the TiO_2-MWCNT system. The moderate GO fraction likely preserved membrane structure and adsorption sites without excessively restricting water flow. In contrast, filters optimized for a single performance ability often sacrificed performance in others. For instance, highly porous filters optimized for flow rate did not capture particles or dyes as efficiently, while membranes with extremely dense structures improved turbidity removal but reduced permeability and increased clogging risk. The optimized formulation therefore represented the most effective compromise between adsorption capacity, membrane permeability, electrostatic attraction, and photocatalytic activity.

These trends shown were consistent with previous research on graphene-based membranes. For example, what Han found in 2021 supports the trend that incorporating graphene-based materials increased photothermal performance; this means that the combination of high light adsorption and heat conductivity are essential for transforming sunlight into vapor and heat (Han, 2021). Furthermore, Schmidt's study in 2023 aligns with the current one as graphene-based adsorbent removed heavy metals much more efficiently than regular activated carbon and was durable (Schmidt's, 2023). Yangyang's findings in 2022 also align with the trends found in this study as high water flow led to complete salt rejection and it was found that graphene oxide was stable and efficient (Yangyang, 2022).

Despite these promising findings, several limitations remained. The experiments were conducted under controlled laboratory conditions using model contaminants rather than real industrial wastewater, which may contain additional dissolved compounds that influence adsorption or catalytic reactions such as a complex mixture of dyes, dissolved salts, organic compounds, and heavy metals. As a result, the adsorption and degradation mechanisms observed in this study may behave differently in more chemically complex environments. To address this, the optimized filter compositions can be tested using real textile wastewater or synthetic wastewater mixtures that more closely remember industrial discharge conditions.

Another limitation involved the evaluation of long-term membrane durability and fouling behavior. Since the study focused on comparing 81 different nanocomposite formulations, filtration cycles for each individual filter was limited. In practical applications, filtration membranes must maintain structural stability and removal efficiency over extended use. Accumulation of particles and organic contaminants within membrane pores may eventually reduce permeability and catalytic efficiency. Previous studies of photocatalytic membranes have suggested that regeneration methods such as UV-assisted self-cleaning or chemical washing can restore adsorption capacity and reduce fouling. In 2016 Roso also found that membranes containing both TiO2 and graphene had higher photoctalytic activity compared to membranes with only TiO2. (Roso, 2016). Thus, in the future, there could be more of a focus on evaluating long-term filtration cycles and investigating regeneration techniques that allow the membrane to maintain performance over repeated use.

The membrane structure itself was also not directly characterized using advanced imaging techniques. While the observed filtration trends suggested that factors such as pore structure, particle aggregation, and catalyst distribution influenced performance, the nanoscale

morphology of the membranes was not directly visualized. Techniques such as scanning electron microscopy (SEM) or transmission electron microscopy (TEM) could provide valuable insights into how GO layering, AC pore networks and TiO_2 nanoparticle distribution influence membrane structure and transport pathways. The incorporation of these characterization methods in future studies could allow researchers to better correlate structural features with filtration performance and thus further optimize the nanocomposite design.

While the current study demonstrated that optimizing GO-AC-TiO_2 nanocomposite composition significantly improved turbidity and azo dye removal efficiency, additional research is needed to evaluate long-term stability, structural characteristics and performance under real-world wastewater conditions. Further investigation into membrane regeneration, structural characterization, and testing with complex wastewater matrices would help strengthen the understanding of how these nanocomposite filters perform in practical applications. Overall, the findings from this study demonstrate the strong potential of optimized graphene-based nanocomposite membranes as effective and sustainable technologies for improving future water purification systems.

D. Conclusion

This study investigated how varying compositions of GO-AC-TiO_2 nanocomposite membranes reinforced with chitosan and MWCNTs influenced the removal of azo dyes from seawater. The findings demonstrated that filter composition strongly affected purification performance, demonstrating how adsorption, electrostatic interactions, and photocatalytic degradation work together with the nanocomposite system. While different formulations optimized different performance aspects, the result showed that incorporating MWCNTs generally enhanced dye removal efficiency by improving photocatalytic activity, supporting the alternate hypothesis and rejecting the null hypothesis. Some findings were notable in that certain filters that maximised adsorption did not necessarily produce the highest overall performance, emphasizing the importance of balancing membrane structure, catalytic activity, and permeability. These results help address the research gap identified in previous studies, which often focused on graphene-based membranes for salt and heavy metal removal rather than persistent organic dyes. By integrating GO, AC, chitosan and TiO_2 photocatalysis within a single filtration design, this study demonstrated how material optimization can improve dye removal efficiency in saline environments while maintaining practical filtration performance. It offers a multifunctional purification approach that could potentially reduce reliance on energy-intensive treatment technologies such as reverse osmosis. By addressing the removal of persistent organic dyes in seawater conditions, this study contributes to ongoing efforts to develop more sustainable and scalable technologies for protecting water resources and improving global water quality. Overall, the results suggest that carefully engineered nanocomposite membranes have strong potential to advance more sustainable and effective approaches for treating dye-contaminated water.

E. Future Studies

Future research could extend this study in several ways to further improve graphene-based water purification systems. First, future experiments could evaluate the optimized GO-AC-TiO_2 nanocomposite filters using real industrial wastewater from textile or dye manufacturing facilities. Testing the filters under these more realistic conditions would help determine whether the observed mechanisms remain effective in practical applications and could provide valuable insight into how the system performs in large-scale treatment environments. A second study would be to investigate long-term membrane durability and regeneration methods. Over repeated filtration cycles, contaminants may accumulate within the membrane pores, potentially reducing adsorption capacity and photocatalytic activity. Future studies could examine whether regeneration techniques such as UV-assisted self-cleaning, chemical washing, or thermal treatment can restore filter performance and extend membrane lifespan. Understanding regeneration behavior would be essential for determining whether these nanocomposite membranes can function as sustainable and cost-effective filtration technologies in real-world water purification systems.

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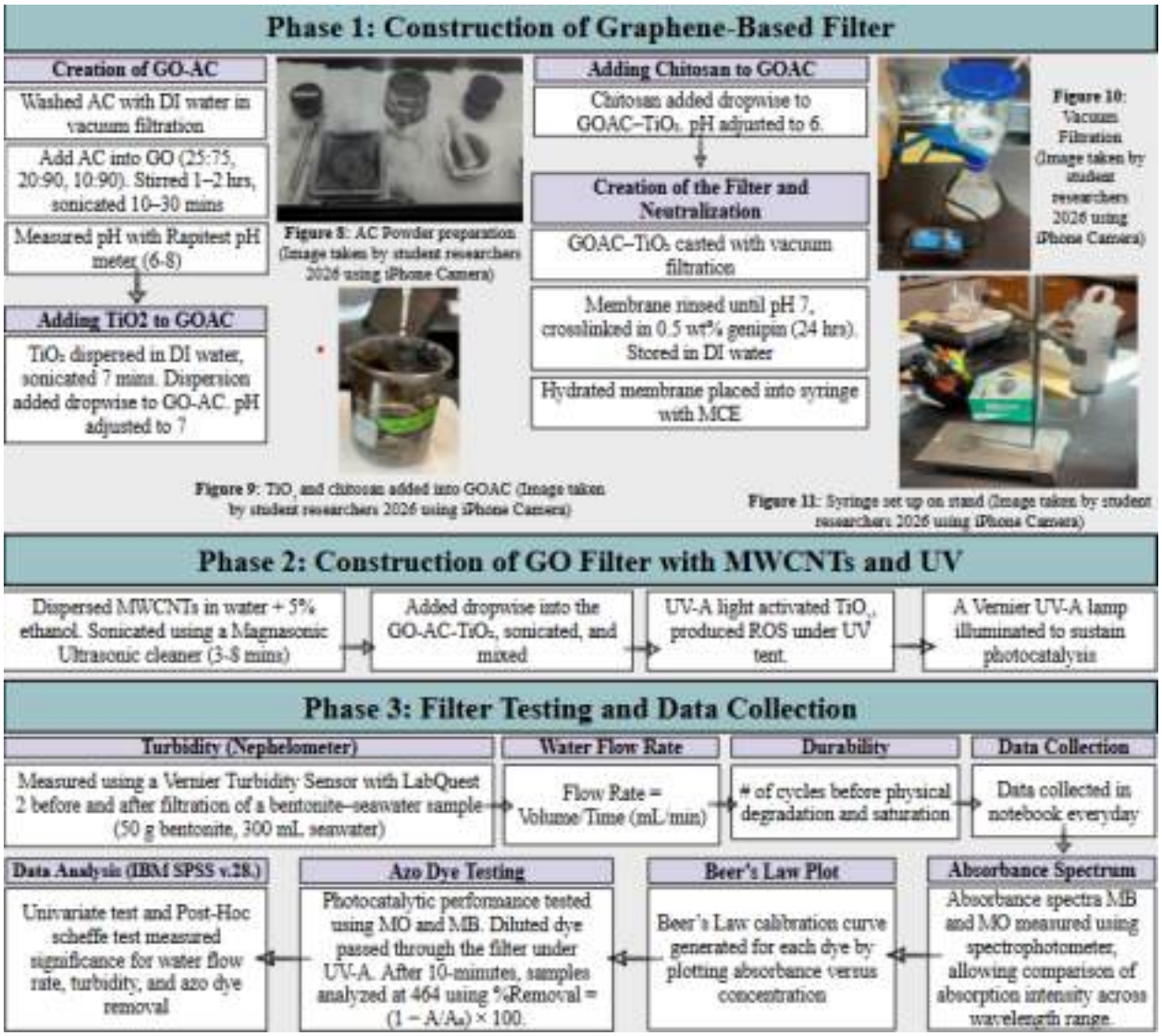
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Methodology flow chart (Created by Researchers, 2026)

Climate Change and the Spread of Infectious Diseases: A Threat Multiplier for Global Health By Saket Lingamallu

Abstract

Climate change is not only an environmental problem. It is also a public-health challenge because temperature, rainfall, humidity, and extreme weather can change where infectious diseases spread. This review focuses on dengue and malaria, two mosquito-borne diseases that respond to similar climate conditions but have followed different recent global trends. Dengue has surged to record highs, while global malaria incidence has fallen over the past two decades because of public-health interventions such as bed nets, spraying, diagnosis, and treatment. This contrast shows why climate change should be understood as a threat multiplier rather than a single cause of disease. Laboratory evidence strongly shows that temperature affects mosquito survival, biting, and pathogen development. However, real-world disease patterns are also shaped by urbanization, travel, sanitation, vaccines, surveillance, and health infrastructure. Climate change is therefore best understood as a force that redraws disease risk across regions, creating new risks in some places while reducing suitability in others. Because disease burden depends on both climate and human action, surveillance, vaccination, vector control, clean water systems, and emissions cuts can still reduce harm.

Background

The idea that climate shapes human disease is ancient. Hippocrates, writing around 400 BCE in On Airs, Waters, and Places, urged physicians to study the seasons and local environment when trying to understand patterns of sickness. What is new today is the speed and scale of climate change caused by human greenhouse-gas emissions. Global average surface temperatures have risen by roughly 1.1 to 1.2 degrees Celsius since the pre-industrial period, and scientists can now trace how this warming affects pathogens, vectors, and human hosts.

The most thorough synthesis of this evidence is the Intergovernmental Panel on Climate Change Sixth Assessment Report, usually called IPCC AR6. Its health chapter states that climate hazards are increasingly contributing to adverse health outcomes in many regions and that the net health impacts are largely negative (IPCC 1045). A major study by Camilo Mora and colleagues reached a similar conclusion by a different route: it found that 58 percent, or 218 out of 375, of known human infectious diseases have been aggravated by at least one climatic hazard at some point (Mora et al. 869). That number is striking, but it should be interpreted carefully. It counts possible aggravation; it does not prove how often climate worsens each disease, how large the effect is, or whether climate is the main driver of the global disease burden.

The projected human cost is still substantial. The World Health Organization estimates that between 2030 and 2050, climate change is expected to cause about 250,000 additional deaths per year from undernutrition, malaria, diarrhea, and heat stress alone. The WHO also notes that 3.6 billion people already live in areas highly vulnerable to climate change ("Climate Change and Health"). These numbers are serious, but they hide major differences across diseases

and regions. Some diseases are likely to expand, some may shift location, and some may be shaped more by health systems than by temperature itself.

This paper is a narrative review that prioritizes IPCC and WHO syntheses along with peer-reviewed studies on climate-sensitive infectious disease. It uses dengue and malaria as the main case studies because both are mosquito-borne and temperature-sensitive, yet their recent global trajectories differ in important ways. This paper argues that climate change changes where and when infectious diseases can spread, but real outbreaks and disease burdens are often shaped just as much by urbanization, public-health infrastructure, and disease-control programs. For that reason, climate change is best understood as a threat multiplier rather than a stand-alone cause.

Two evidence levels organize the review. The first is mechanistic evidence, which comes from controlled studies of how climate variables affect pathogens and vectors. For example, laboratory studies can measure how temperature changes the time a virus needs to develop inside a mosquito. This evidence is usually strong because it can be isolated and repeated. The second is ecological evidence, which comes from real-world associations between climate and disease outcomes, such as outbreak counts, range maps, and long-term trends. This evidence is important but harder to interpret because many non-climatic factors change at the same time. The distinction matters: a mechanism can be well established even when the size of its real-world effect is uncertain.

The strong tier: temperature and the biology of transmission

The strongest part of the climate-disease argument is biological. Many pathogens and their vectors are ectothermic, meaning their body temperature and metabolism depend on the surrounding environment. Decades of laboratory work show that temperature affects mosquito survival, biting frequency, and pathogen development. A key concept is the extrinsic incubation period, or EIP. The EIP is the time a pathogen needs to develop inside a vector before that vector can transmit it. Within a viable range, warmer temperatures shorten the EIP, so an infected mosquito can become infectious faster and may transmit the pathogen to more hosts during its lifetime (Mordecai et al. 1690). Experimental work on dengue confirms this pattern: as temperature rises, the incubation period of dengue virus inside Aedes albopictus mosquitoes becomes shorter (Xiao et al.).

Temperature does not increase transmission indefinitely. Transmission rises up to an optimal range and then falls when conditions become too hot for the vector or pathogen. Mordecai and colleagues found that mosquito-borne disease transmission varies strongly with temperature and peaks between about 23 and 29 degrees Celsius. Dengue and Zika have higher optima, near 29 degrees Celsius, while malaria peaks lower, around 25 degrees Celsius (Mordecai et al. 1690). This pattern is central to the paper. Warming can increase transmission in places that are currently too cool, but it can reduce suitability in places that become too hot. Climate change therefore does not raise disease risk everywhere in the same way. It redraws the map of risk.

Temperature also interacts with other climate variables. Mosquitoes need standing water to breed and humid air to survive. The IPCC links dengue transmission with high confidence to temperature, relative humidity, and rainfall (IPCC 1062). Extreme weather creates additional pathways. Heavy rainfall and flooding can increase diarrheal disease, while floods and storms can displace people into crowded conditions where infections spread more easily (Mora et al. 871). Over longer time scales, climate-driven shifts in animal ranges may increase contact between species that do not normally meet. One model projects roughly 300,000 first encounters between species and about 15,000 new cross-species viral transmission events by 2070 (Carlson et al. 555). These mechanisms are biologically plausible, but they are not all equally certain. A laboratory measurement of the EIP is stronger evidence than a long-term projection about future viral spillover.

Dengue and malaria: why the contrast matters

Table 1. Comparison of dengue and malaria as climate-sensitive diseases

Disease	Mechanistic climate link	Major non-climatic drivers	Recent broad trend	Best-supported claim
Dengue	Strong temperature sensitivity; Aedes mosquitoes thrive in warm, humid urban environments.	Urbanization, international travel, water storage, mosquito breeding containers.	Strong rise in reported cases, including record global levels in 2024.	Climate likely amplifies dengue risk, but recent case growth cannot be attributed to climate alone.
Malaria	Strong temperature sensitivity; Anopheles transmission peaks at a lower temperature than dengue.	Bed nets, indoor spraying, rapid diagnosis, artemisinin-based treatment, drug resistance.	Long-run global decline with local shifts into some higher-altitude or urban areas.	Climate may redistribute malaria risk even when public-health intervention reduces the total burden.

Dengue: a disease on the rise

Dengue is the clearest case of climate change worsening infectious-disease risk. A viral infection spread by Aedes mosquitoes, it has risen dramatically in a single generation. Cases reported to the WHO increased from about half a million in 2000 to a historic high in 2024, when the organization recorded more than 14.6 million cases and more than 12,000 deaths ("Dengue and Severe Dengue"). The Region of the Americas accounted for more than 90 percent of cases, with Brazil alone reporting more than ten million ("Dengue - Global Situation").

Dengue's biology is part of the reason. Its Aedes vectors thrive in warm cities, and dengue virus has one of the highest thermal optima in Mordecai and colleagues' study, near 29 degrees Celsius (Mordecai et al. 1690). In many populated tropical and subtropical regions, current temperatures are below that optimum, so warming can push transmission conditions closer to the range where dengue spreads most efficiently. Ecological projections fit this

mechanism. One projection cited by the IPCC concludes that dengue risk will increase across Asia, Europe, and sub-Saharan Africa, potentially placing an additional 2.25 billion people at risk by the end of the century (IPCC 1063). Another study projected that more than six billion people could live in areas at risk of dengue by 2080 (Messina et al. 1508).

These projections should be read carefully. They estimate future exposure to climatically suitable conditions; they are not direct predictions of case counts. The dengue surge is real, but attributing it mainly to climate would overstate the evidence. Oliver Brady, a co-author of a major dengue projection, has cautioned that climate change is likely to contribute to dengue expansion, while population growth and urbanization will play a larger role in shaping who is at risk (qtd. in "More than Six Billion"). The decades of dengue growth were also decades of rapid tropical urbanization, increased international travel, and expanded water storage in containers where Aedes mosquitoes breed. A balanced conclusion is that warming creates more favorable conditions for dengue in many regions, but urbanization and infrastructure strongly shape whether that suitability becomes an actual disease burden.

Malaria: a disease in retreat

Malaria complicates any simple claim that warming automatically worsens mosquito-borne disease. Malaria is caused by Plasmodium parasites carried by Anopheles mosquitoes, and it follows the same general temperature biology as dengue. But its thermal optimum is lower, around 25 degrees Celsius (Mordecai et al. 1690). If climate were the dominant driver of recent global malaria trends, we would expect incidence to rise overall. Instead, global malaria incidence has fallen substantially over the past two decades because of insecticide-treated bed nets, indoor spraying, rapid diagnostics, and artemisinin-based treatment. This shows that public-health intervention can outweigh climate pressure at the population level.

Climate change can still leave a signal inside that broader decline. The IPCC reports with very high confidence that malaria risk has shifted to higher altitudes as the climate warms (IPCC 1062). The East African highlands illustrate the point. These regions have historically been cool enough to limit malaria, which means they sit on the cold side of the temperature optimum. Warming can therefore open new territory for transmission. Mercedes Pascual and colleagues documented significant warming at four highland sites between 1950 and 2002 and argued that mosquito populations can amplify the biological effects of warming (Pascual et al. 5829). A later study of the Ethiopian highlands estimated that roughly 27 million people, about a third of the country's population, could live in areas of elevated malaria risk under high-emissions scenarios (Lyon et al.).

Even here, the evidence is contested. Simon Hay and colleagues analyzed the same East African highland sites and reported that temperature, rainfall, vapor pressure, and months suitable for Plasmodium falciparum transmission had not changed significantly. They attributed the malaria resurgence instead to drug resistance and weakening control programs (Hay et al. 905). This disagreement is not a weakness in the paper's argument; it is part of the argument. At

the ecological level, separating a climate signal from changing treatment, resistance, poverty, land use, and public-health capacity is genuinely difficult.

Malaria therefore supports the same threat-multiplier framing as dengue, but in a different way. Climate change is not raising malaria risk everywhere. It may expand risk upward into cooler highlands or into new urban settings, while public-health programs reduce transmission in many historic malaria regions. A further concern is Anopheles stephensi, an invasive urban mosquito that is spreading through African cities and could make malaria better adapted to dense urban environments (Samuel et al.). The most careful conclusion is that climate change can redistribute malaria risk, but human intervention remains a major determinant of the total disease burden.

Beyond the flagships: water, ticks, and emerging threats

The same two-level logic applies beyond dengue and malaria. Waterborne diseases are one example. Cholera, caused by Vibrio cholerae, is linked to warm coastal waters and poor sanitation. In Bangladesh, cholera risk has been reported to rise two- to fourfold in the weeks after a five-degree spike in water temperature (Mason). The disease is now in a global resurgence, and the WHO classified the cholera upsurge as a Grade 3 emergency, with sixty countries reporting cases in 2024, up from forty-five the year before ("Cholera Upsurge"). In eastern and southern Africa, the 2023-2024 surge was driven by droughts, cyclones, and floods that overwhelmed sanitation systems (UNICEF). Climate can favor the pathogen and worsen water conditions, but cholera outbreaks still track poverty, displacement, and broken water infrastructure very closely.

Other pathogens are also shifting with warming. Vibrio vulnificus, a dangerous bacterium found in warm coastal waters, appears to be moving poleward as coastal waters warm. Infections along the U.S. Atlantic coast have risen over recent decades and often cluster after hurricanes push warm, brackish water inland (Archer et al.; Lartey). Lyme disease shows a similar redistribution pattern in temperate regions. Ixodes ticks are expanding northward as temperatures rise, and tick spread across Canada has accompanied a two- to three-degree rise in land-surface temperature (Sambado et al.). U.S. health departments report roughly 89,000 Lyme cases per year, but the true figure has been estimated closer to 476,000 (Kugeler et al. 619). West Nile virus also follows a temperature curve, with transmission peaking between roughly 23 and 26 degrees Celsius (Shocket et al.).

Some emerging threats are more speculative. Valley fever, caused by the soil fungus Coccidioides, is projected to expand as drought-prone conditions spread; one model estimated that its endemic U.S. range could more than double by 2100 (Gorris et al.). Candida auris, a multidrug-resistant fungus that emerged on multiple continents around 2009, may be linked to thermal adaptation, meaning that warming could have selected for heat tolerance that helped the fungus infect humans (Casadevall et al.). Climate-driven animal range shifts may also increase viral spillover between species (Carlson et al. 555). These are worth watching, but they are still hypotheses to test rather than settled conclusions.

Complexity, confounders, and competing explanations

The central challenge is that a real biological mechanism can coexist with a population trend that moves in a different direction. Dengue has surged, but not only because of climate. Malaria has declined, but not because the climate stopped mattering. The effect of warming is filtered through urban growth, housing, water systems, travel, income, vaccines, drug resistance, and vector-control programs. This is why the paper avoids a climate-determinist explanation. Climate matters, but it rarely acts alone.

The temperature optimum also complicates the accounting. Because mosquito-borne transmission drops when temperatures become too hot, warming may reduce suitability in some of the hottest regions while increasing suitability in cooler regions. A defensible claim of net harm must therefore consider both increases and decreases in risk rather than counting only places where disease suitability worsens. This does not mean the threat is minor. It means the threat is uneven. Climate change raises the probability and geographic suitability of many diseases, but any specific outbreak still depends on other causes.

This balanced framing matches the IPCC's broader conclusion. The IPCC finds that adverse health impacts are increasing, while also emphasizing that proactive adaptation can reduce many risks and even avoid some of them (IPCC 1041). Holding both points together is not fence-sitting. It is the most accurate way to represent the evidence. Climate change expands the conditions under which diseases can spread, but policy and public-health systems help determine whether those risks become large outbreaks.

Responses: surveillance, vaccines, and mitigation

If climate change is a threat multiplier, then its disease burden is not fixed. Surveillance and early-warning systems are the first line of defense. The IPCC identifies disease surveillance, early-warning systems, and vaccine development as important adaptation tools (IPCC 1041). Climate-informed forecasting is already being used for diseases such as cholera, and satellite-based systems can forecast Vibrio risk along some U.S. coasts. By the end of 2023, fifty countries had formally assessed their health vulnerabilities to climate change, up from eleven the year before (Romanello et al. 1870).

Vaccines and vector-control tools are another major response. In 2021 the WHO recommended RTS,S/AS01, the first malaria vaccine. In October 2023, it recommended a second vaccine, R21/Matrix-M, which demonstrated roughly 75 percent efficacy at sites with highly seasonal transmission over twelve months and can be manufactured in large quantities at relatively low cost ("WHO Recommends R21"). For dengue, the Wolbachia method has also shown promise. This method infects mosquitoes with a bacterium that blocks viral transmission. In a randomized trial in Indonesia, Wolbachia-infected mosquito deployments reduced dengue cases by 77 percent and hospitalizations by 86 percent (Utarini et al.).

The most fundamental response is still mitigation. Because Mora and colleagues identified more than one thousand pathways linking climate hazards to disease, they argue that the breadth of the problem shows the need to reduce greenhouse-gas emissions at the source

(Mora et al. 874). Emissions cuts can also bring immediate health benefits by reducing air pollution. A One Health approach, which links human, animal, and environmental monitoring, helps here because many emerging diseases begin where ecological change, animal movement, and human exposure meet.

Conclusion

Dengue and malaria lead to a conclusion that neither disease could support alone. The biology linking warming to mosquito-borne transmission is strong: temperature affects mosquito survival, biting, and pathogen development. But the two diseases have moved in different directions in recent decades. Dengue has surged, while malaria has declined globally because of major public-health interventions. That contrast shows that climate change is an amplifier, not the only author of infectious-disease trends.

The signature of climate change is not a uniform increase in every disease everywhere. It is a redrawing of the risk map. Cooler highlands, temperate coasts, and some urban environments may become more suitable for transmission, while regions that become too hot may lose suitability for certain vectors. Whether those changing risks become large disease burdens depends on surveillance, sanitation, vaccines, vector control, access to care, and emissions policy.

This distinction matters because it leaves room for action. If disease burden is jointly determined by climate and human action, then it can be changed. The same decades that saw warming also saw major progress against malaria. Stronger surveillance, vaccination, vector control, clean water infrastructure, and emissions cuts can reduce the danger of climate-sensitive disease. The burden will fall hardest on low-income populations that have contributed least to the emissions causing climate change, so the issue is one of justice as well as epidemiology. The diseases of a warming world are not a fixed outcome but a challenge that timely, equitable, and evidence-based action can still meet.

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How Personality Is Associated with the Mental Health of Adolescents By Xinge Ye

Abstract

Adolescence is a critical period for both personality development and mental health. During these years, young people form identities, build relationships, respond to academic and social pressure, and develop patterns of emotional regulation. This review examines how personality is associated with adolescent mental health by focusing on three connected questions: what shapes personality during adolescence, how Big Five traits are related to mental health outcomes, and how maladaptive personality patterns can become clinically significant. Research suggests that adolescent personality develops through an interaction of genetic tendencies, family relationships, peer experiences, school environments, and broader social contexts. Among the Big Five traits, neuroticism is most consistently linked to anxiety, depression, low confidence, and social difficulties, while conscientiousness, extraversion, agreeableness, and openness may support resilience in different ways. The review also considers personality disorders and dissociation to show that personality and mental health are not separate topics; they develop together through biological, psychological, and environmental processes. Overall, the evidence suggests that personality is not destiny. Because adolescence is a flexible developmental period, early support from families, schools, and mental health professionals can help adolescents build healthier coping skills, stronger relationships, and more stable self-understanding.
Keywords: adolescence, personality, mental health, Big Five, personality disorders, dissociation

I. Introduction

Adolescence is one of the most important periods for understanding mental health because it is a time of rapid biological, cognitive, emotional, and social change. During these years, young people are not only adjusting to school pressure, changing friendships, family expectations, and future planning; they are also forming a more stable sense of who they are. The Centers for Disease Control and Prevention reported that, in the 2023 Youth Risk Behavior Survey, 39.7 percent of U.S. high school students experienced persistent feelings of sadness or hopelessness, and 28.5 percent reported poor mental health (CDC). These numbers show that emotional distress among adolescents is widespread. They also raise an important question: why do some adolescents experience stronger distress than others when they face similar challenges?

One answer is personality. Personality shapes how adolescents interpret events, respond to stress, regulate emotions, build relationships, and understand themselves. Two students may face the same academic pressure or friendship conflict, but their reactions can be very different. One student may ask for support and make a plan, while another may withdraw, blame themselves, or become overwhelmed. These different reactions are not random. They often reflect personality traits that influence coping, confidence, and social behavior.

Personality is commonly understood as a relatively stable pattern of thoughts, feelings, motivations, and behaviors, even though it can still change through experience. The Big Five model describes personality through five broad traits: neuroticism, extraversion, openness,

agreeableness, and conscientiousness (McCrae and John). These traits help explain everyday differences in emotional sensitivity, social behavior, curiosity, cooperation, and self-control. In adolescence, these traits are still developing, which makes personality especially important for understanding both risk and resilience.

This paper argues that adolescent personality and mental health are deeply connected. Personality does not cause mental health outcomes by itself, but it shapes the way adolescents experience stress, seek support, manage emotions, and respond to their environments. First, this review explains how adolescent personality is shaped by biology and social experience. Second, it examines how specific personality traits, especially neuroticism, relate to mental health outcomes. Third, it discusses how maladaptive personality patterns may become clinically significant. Finally, it uses dissociation and Dissociative Identity Disorder as a carefully limited case study to show how severe adversity can affect identity development. Together, these sections show that personality is not destiny, but it is a powerful pathway through which adolescent experiences influence mental health.

II. What Shapes Personality During Adolescence

Personality development during adolescence cannot be explained by one single cause. Research consistently shows that personality develops through the interaction of biological tendencies and lived experience. Adolescents may inherit certain temperamental tendencies, such as emotional reactivity or sociability, but those tendencies are shaped over time by families, peers, schools, and cultural expectations. Caspi, Roberts, and Shiner argue that personality development is best understood through both stability and change: early dispositions matter, but life experiences can reinforce, weaken, or redirect them.

Adolescent development itself is a major influence. During adolescence, young people experience changes in self-awareness, abstract thinking, emotional intensity, independence, and social roles. Backes and Bonnie describe adolescence as a period of major opportunity because the brain and social identity are still developing. Hill and Edmonds also emphasize that identity formation, maturation, and social role investment are central to personality development in adolescence. As teenagers take on more responsibility at school, in friendships, in families, and in future planning, their traits may become more visible and more organized. For example, academic expectations can strengthen conscientiousness, while new social experiences can shape extraversion, agreeableness, and emotional stability.

Genetics also play a role, but genetic influence does not mean personality is fixed. Briley and Tucker-Drob found that genetic and environmental influences both contribute to personality continuity across development. Krueger, Johnson, and Kling similarly explain that personality development reflects both inherited differences and environmental experiences. This interaction matters because it prevents an oversimplified view of personality. A teenager may have a natural tendency toward sensitivity, caution, sociability, or persistence, but the environment determines how that tendency is expressed. Supportive environments may help a sensitive adolescent

become reflective and empathetic, while unstable or rejecting environments may make the same sensitivity more closely connected to anxiety or self-doubt.

Family relationships are especially important. Hartup and Van Lieshout argue that adolescent personality change is shaped by early temperament, parent-child relationships, attachment security, sibling relationships, peer acceptance or rejection, and broader social stressors. Milenkova and Nakova also identify family upbringing, parental warmth, self-esteem, autonomy, and peer relationships as major influences on adolescent personality. These sources show that personality develops through daily interactions with important people. Warm, consistent relationships can support emotional regulation and self-confidence, while harsh criticism, instability, or rejection can make adolescents more vulnerable to negative self-image and emotional distress.

Peers and schools also shape personality. Adolescents spend much of their lives in school, where they encounter achievement pressure, social comparison, belonging, competition, and new forms of independence. Tetzner, Becker, and Bihler found that learning environments can influence Big Five trait development in adolescence, especially conscientiousness. This finding is important because school is not only a place where personality is expressed; it is also a place where personality can be shaped. A supportive school environment may help adolescents become more responsible, connected, and confident, while an isolating or highly stressful environment may reinforce insecurity or avoidance.

Overall, personality in adolescence should be understood as dynamic rather than fixed. Biological tendencies, family relationships, peer experiences, school settings, and cultural pressures all interact to shape the traits that adolescents carry into adulthood. This developmental flexibility is important for mental health. The same period that makes adolescents vulnerable to stress also makes them responsive to support, guidance, and healthy relationships.

III. Personality Traits and Mental Health Outcomes

Personality is strongly connected to mental health because it influences how adolescents experience emotions, interpret stress, and choose coping strategies. Mental health is not shaped only by what happens to a person; it is also shaped by how the person understands and responds to what happens. For this reason, personality traits can help explain why some adolescents develop anxiety, depression, low confidence, or social difficulties while others show greater resilience under similar circumstances.

The clearest connection appears in neuroticism. Neuroticism refers to a tendency to experience negative emotions such as worry, sadness, fear, irritability, and emotional instability. Adolescents high in neuroticism may be more likely to interpret ordinary challenges as threatening or overwhelming. They may also have more difficulty calming themselves after stress. Kang and colleagues studied 12,007 participants from the British Household Panel Study and examined how Big Five traits related to three mental health dimensions: depression and anxiety, loss of confidence, and social dysfunction. They found that neuroticism was positively associated with all three mental health problems (Kang et al.). This evidence supports the idea

that emotional instability is one of the strongest personality-related risk factors for poor mental health.

Other traits can be protective. Conscientiousness is linked to organization, planning, responsibility, and self-control. These qualities can support mental health by helping adolescents manage assignments, maintain routines, and solve problems before they become overwhelming. Extraversion may also support well-being because adolescents who are more socially outgoing may be more likely to express feelings and seek support from others. Agreeableness can reduce conflict and support healthier relationships, while openness may help adolescents adapt to change and consider new perspectives. Kang and colleagues found that extraversion, agreeableness, conscientiousness, and openness were negatively related to some mental health problems, suggesting that these traits may protect well-being in different ways (Kang et al.).

Personality also influences coping style. Salehinezhad explains that personality characteristics affect emotional well-being, coping, and vulnerability to psychological difficulties. When adolescents face stress, those high in neuroticism may be more likely to overthink, avoid problems, or focus on negative feelings. These responses can intensify distress over time. In contrast, adolescents high in conscientiousness may use planning and problem-solving, while extraverted adolescents may reach out to friends, family members, or teachers. Open adolescents may be more willing to try new strategies or reinterpret a situation. These differences show that personality affects mental health not only through emotion, but also through behavior.

Self-image is another pathway between personality and mental health. Adolescence is a period when identity and self-esteem are still developing, so adolescents may be especially sensitive to criticism, failure, rejection, or comparison. Kang and colleagues found that personality traits were connected to loss of confidence, not only to anxiety and depression. This is important because confidence can influence school performance, relationships, and willingness to seek help. A teenager high in neuroticism may interpret a poor grade as proof of personal failure, while a more conscientious or emotionally stable teenager may treat the same grade as a problem to solve.

Recent research also suggests that personality and internalizing mental health problems may overlap in complex ways. Soodla and colleagues examine the relationship between personality traits and internalizing psychopathology, including anxiety and depression, using multi-informant data. Their study suggests that emotional instability, worry, and sensitivity may not simply predict internalizing symptoms; they may also share underlying features with those symptoms (Soodla et al.). This means the relationship between personality and mental health is not always a simple cause-and-effect relationship. In some cases, traits and symptoms may develop together and influence each other across time.

Overall, personality traits shape adolescent mental health through emotional reactivity, coping behavior, self-confidence, and relationships. High neuroticism appears to increase vulnerability to distress, while conscientiousness, extraversion, agreeableness, and openness may support resilience. These findings do not mean that a teenager with high neuroticism is destined

to experience poor mental health. Instead, they show that some adolescents may need more support in learning emotional regulation, flexible thinking, and healthy coping strategies.

IV. When Personality Patterns Become Maladaptive

The connection between personality and mental health becomes especially clear when personality patterns become rigid, extreme, and harmful. Personality disorders are not the same as ordinary personality differences. A teenager can be shy, careful, emotional, or independent without having a disorder. Personality patterns become clinically concerning when they are persistent, inflexible, cause significant distress, or interfere with daily functioning and relationships. MedlinePlus explains that personality disorders affect how people think, feel, behave, and relate to others. The American Psychiatric Association similarly describes personality disorders as enduring patterns that create problems in self-functioning and interpersonal functioning (Robitz).

Personality disorders are important for this review because they show how normal personality traits can become maladaptive. Very high neuroticism may contribute to emotional instability, fear of rejection, or intense anxiety. Very low agreeableness may be connected to conflict, distrust, or difficulty maintaining relationships. Extremely high conscientiousness may become harmful if it turns into rigid perfectionism or excessive control. In this way, personality disorders can be understood as extreme and inflexible versions of patterns that also exist in normal personality development.

Adolescence is a sensitive period for understanding personality disorders because identity, emotional regulation, and relationships are still developing. Sharp, Vanwoerden, and Wall argue that adolescence should be viewed as an important period for the development and identification of personality pathology rather than as a stage in which such concerns should be ignored. Shiner makes a similar argument by connecting personality disorder development to normal personality development in childhood and adolescence. He explains that personality disorder symptoms can appear before adulthood and can be linked to real impairment in relationships, school functioning, and emotional control (Shiner). These findings challenge the idea that adolescent personality problems are always just temporary phases.

The development of personality disorders is not caused by personality alone. Gabbard emphasizes that biological, psychological, and social influences are deeply connected in personality disorders. This means that temperament, brain development, family relationships, peer experiences, and stress all interact. For example, an emotionally sensitive adolescent may learn healthy coping skills in a supportive family or school environment. However, if that same sensitivity is combined with chronic rejection, unstable relationships, or intense stress, the adolescent may become more vulnerable to emotional dysregulation and interpersonal difficulties.

Because adolescent personality is still developing, early support matters. Therapy can help young people understand emotional patterns, communicate more effectively, manage stress, and build healthier relationships. Supportive families and schools can also reduce risk by

strengthening self-esteem, emotional regulation, and belonging. The goal is not to label adolescents too early or treat personality as fixed. Rather, the goal is to notice persistent, harmful patterns early enough to offer support before those patterns become more severe and long-lasting.

V. Trauma, Dissociation, and Identity Development

Dissociative Identity Disorder offers a useful but limited case study for thinking about personality, identity, and mental health. It is important to state clearly that DID is not classified as a personality disorder; it is a dissociative disorder (American Psychiatric Association). However, DID is relevant to this review because it involves serious disruption in identity, memory, and the sense of self. It shows how severe adversity can affect the development of self-understanding, emotional regulation, and psychological continuity.

Dissociation is a psychological process in which a person becomes disconnected from thoughts, emotions, memories, surroundings, or identity. In ordinary life, mild forms of dissociation can happen during stress or distraction. In severe clinical forms, dissociation can become disruptive and impair functioning. Putnam explains that dissociation in children and adolescents must be understood developmentally because young people are still forming a coherent sense of self. When early experience is highly overwhelming and repeated, identity development may be disrupted rather than integrated in a typical way.

The connection between DID and adolescent mental health is significant because the roots of dissociative disorders often appear in childhood or adolescence. Brand and colleagues describe dissociative disorders as closely connected to trauma, treatment needs, and broader mental health difficulties. Loewenstein also notes that dissociation is often misunderstood, which can delay accurate diagnosis and appropriate care. For adolescents, misunderstanding can be especially harmful because symptoms may be mistaken for attention problems, mood instability, or ordinary teenage behavior. DID also shows why personality and mental health should not be separated too sharply. Earlier sections of this paper showed that personality develops through the interaction of biology, relationships, and environment. Dissociation demonstrates an extreme version of the same principle: when a young person develops in an unsafe or overwhelming environment, the organization of identity and emotion can be affected. The International Society for the Study of Trauma and Dissociation emphasizes that treatment for DID focuses on safety, stabilization, trauma-informed care, and gradual integration of functioning rather than sensationalized ideas about identity.

Including DID in this review does not mean that DID is common or that ordinary personality differences lead to dissociation. Instead, DID helps clarify a broader point: mental health problems can affect not only mood and behavior, but also identity and self-understanding. For adolescents, whose identities are still developing, supportive relationships, early intervention, and trauma-informed care are especially important.

VI. Implications and Conclusion

The research reviewed in this paper shows that personality and adolescent mental health are closely connected. Personality is shaped by biology, family relationships, peer experiences, school environments, and broader social contexts. At the same time, personality shapes how adolescents respond to stress, regulate emotions, understand failure, build relationships, and seek support. This two-way relationship makes personality one of the most useful frameworks for understanding why adolescents differ in vulnerability and resilience.

The Big Five traits provide a clear way to understand this relationship. Neuroticism is most consistently linked to anxiety, depression, low confidence, and social difficulties. Conscientiousness, extraversion, agreeableness, and openness can support mental health by encouraging planning, social support, cooperation, and flexibility. However, these traits should not be treated as permanent labels. Adolescence is a flexible developmental period, which means traits can be strengthened, redirected, or supported through healthy environments and interventions.

This review also shows that personality patterns become more concerning when they are rigid, extreme, and harmful to everyday functioning. Personality disorders demonstrate how normal traits can become maladaptive when they interact with stress, unstable relationships, or limited support. Dissociation and DID further show that severe adversity can disrupt identity development itself, even though DID is not a personality disorder. Together, these topics illustrate that personality and mental health develop through connected biological, psychological, and social processes.

The practical implications are important for parents, educators, clinicians, and policymakers. Adults who work with adolescents should not view mental health only as a set of symptoms. They should also pay attention to the personality patterns that shape how young people cope with stress and relate to others. A teenager who is highly anxious or emotionally reactive may need support in emotion regulation and self-compassion. A teenager who is socially withdrawn may need safe opportunities for belonging. A teenager who is perfectionistic may need help developing flexibility and self-worth beyond achievement.

Future research should continue to examine how personality interacts with cultural background, school climate, family relationships, and digital environments. More attention should also be given to early intervention, because adolescent personality is still developing and may be more open to change than adult personality. Understanding personality is not about predicting a fixed future for adolescents. It is about identifying pathways of risk and resilience so that young people can receive the support they need.

Ultimately, personality is not destiny. Some adolescents may be more vulnerable to mental health difficulties because of their personality traits, but traits are shaped by experience and can change over time. When adolescents have access to supportive relationships, healthy school environments, and appropriate mental health care, they can build stronger coping skills, more stable self-understanding, and greater resilience. Understanding the connection between personality and mental health is therefore not only an academic question. It is a foundation for helping young people grow into healthier, more flexible, and more confident adults.

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The Prescription Pandemic By Anastasia Samy

Abstract

There is already so much focus on illicit drugs that no one ever considers that there are ways to misuse substances that are completely legal and even encouraged to be used. Millions of people each year misuse prescriptions which snowballs into an addiction. This can then lead to overdose deaths. This is such a serious problem that can impact anyone at any moment and it deserves more attention towards it. This research paper discusses the root causes of prescription misuse. I also describe the effects that prescription misuse has on an individual. It concludes with discussing different prevention and treatment options that can be beneficial to people struggling. The main causes for prescription misuse is the overprescribing of prescriptions, the need to relieve pain, the need to feel good or get high, and peer pressure. The three main effects include health problems, deteriorating mental health, and making you unfit to take care of others and yourself.

“Don’t do drugs, stay in school” is a phrase that almost every kid has heard multiple times throughout their childhood. This phrase conjures an image of poorly lit alleys and the sly trading of illegal, illicit drugs and money. This, however, is not usually the case. Drug misuse has often been portrayed in the media as this shady and secretive operation that could never occur among common individuals. Even though illegal drug misuse is a large problem, there is another one that has been sitting under our noses this whole time: prescription misuse. Prescription misuse is the use of any prescription medication in a way not intended by the doctor. This can range from injecting your prescriptions in some backwards alley to get a high to borrowing an aspirin from your friend for a headache. Most everyday misuses aren't even seen as misuses because it doesn't seem as drastic as the media portrays it. In a survey conducted with a wide range of people, it was found that an alarming number of them, specifically males and people of a younger age demographic, were less able to identify PDAs, or instances of prescription drug abuse (Shupp). Studies like these prove how essential it is to spread awareness and information about prescription misuse to help people to stop doing it, and even prevent it from happening in the first place.

There is a wide variety of prescription medications out there that are being misused and abused daily, but the main focus of this research will be on opioids, as they are becoming an increasingly larger problem in today's world. The use of opioids was first recorded 3,000 years ago in texts from ancient Egypt. These texts described a “phenomenon of human beings using opium—an extract of a common flower called the poppy—for both inducing a feeling of euphoria and reducing pain (ODfree).” Over time other similar, organic substances were discovered and abused until the 1900s when physicians figured out how to synthetically make opioids. These are the opioids that can be prescribed and, if used incorrectly, abused. Opioids specifically stimulate areas in the spinal cord, brain, and digestive tract to block specific chemicals that allow us to feel pain, which is one reason it is so heavily misused. Another thing

they can do is cause a temporary high, a feeling of euphoria or happiness, which is a second reason for its increased misuse. Because of this, opioids can become highly addicting, and due to technological advancements, “an amount smaller than a grain of sand, can kill a person of any size, weight, age, or degree of health (ODfree).” This is why it is so important to spread information about opioids so we can stop the addiction before it happens. And even more important than stopping an addiction we can stop overdoses which are the “leading injury-related cause of death in the United States (CDC).”

The three main causes of opioid misuse are the availability of prescriptions, the need for pain relief or temporary happiness, and the presence of peer pressure and stigma. These factors lead to a dependence on the medication which leads to health risks and an increased chance of death. This dependence can also lead to addiction which can affect their relationships and the people around them. The first cause is the availability of prescriptions which can sometimes occur because of overprescribing. Overprescribing is when a doctor prescribes too much of a medication to the point where the patient is either taking more than they should, or they have extras lying around. Joseph Samy, a pharmacist that I interviewed, provided some insight by explaining that sometimes, for example, after a surgery, doctors will need to prescribe very powerful opioids to keep the patient's pain under control. But what some doctors don't take into account is that, as time goes by, the pain will decrease and so will their need for strong painkillers. Some doctors don't take into account the flexibility of prescribing opioids and instead the patient can end up dependent on them. Another potential consequence is that the patient does not end up taking ht medication and now has dangerously strong opioids remaining unused and are not properly disposed of. This can then result in the opioids ending up in someone else's hands, which is another negative outcome of overprescribing. When asked about from whom they receive their prescriptions from, 34.37% of young adults said they received them from friends or family (Ford). This overprescribing issue has been occurring for years, for example, “from 1999 to 2008 alone, there was a fourfold increase in prescription opioid sales, associated with a fourfold increase in deaths attributed to prescription opioids (Judd)” This shows that an increase in the availability of prescription opioids is directly correlated to deaths from those very same prescription opioids. And as previously mentioned above, the patients who are getting prescribed these medications aren't the only ones at risk. For example, “62% of teenagers say they choose to abuse prescription drugs because they’re easy to get from parents’ medicine cabinets(NCDAS).” This goes to show that having extra medication lying around is not only dangerous to the patient but also to the people around them. Not carefully managing or even disposing of your medication can have disastrous consequences on the people around you. There are many selfish reasons, including money which was mentioned above, for why doctors overprescribe. In the same study conducted by Judd, it was found that physicians in rural areas were more likely to overprescribe medications so that the patients would have to drive all the way to them and waste both of their time. It is completely irrational reasons like these that should encourage us to not only spread awareness about the causes of prescription misuse so that they

can be easily recognized, but also prevent the overprescribing from happening in the first place. Only when you are aware of the problem can you take the first steps to solving it.

The other main reason for abusing prescription opioids is usually cited to be wanting to relieve pain or get high. This is an especially dangerous reason because it can result in a cycle of dependency which can lead to addiction. If you take medication to relieve pain, there is a high chance that you will become dependent on it because it allows you to feel good, and once it stops working, you want to take more to keep that happy, pain-free feeling. However, the more you get lost in that haze, the harder the pain hits you when it comes back. Over time your tolerance will increase, forcing you to increase the dosage for you to actually feel something. This endless cycle can result in addiction, health risks, mental health issues, or even death. “65.7% of painkiller abusers report using the drug to relieve physical pain” while “just 11.3% of painkiller users misuse the drug to feel good or get high (NCDAS)”. This shows that a majority of people do it for the same reasons and if we could spread information to that demographic and explain the risks of what they are doing and provide regulatory measures and a safer alternative, all 65.7% of those people don't have to be at such a high risk for addiction and overdose. Another thing that can occur is the mixing of substances to increase the feeling you get when you take them, which can be especially dangerous (Mayo Clinic). The third cause of prescription misuse is peer pressure and underlying stigma. In a study done in 2025, it was found that “American Indian youth were more likely to use opioids if they had more friends pressuring them to use illicit drugs. Similarly, Nalven et al. [15] also found greater peer substance use was associated with greater likelihood of both lifetime and past-30-day opioid misuse among American Indian adolescents (Asante).” This shows the direct correlation between peer pressure and opioid misuse. Spreading awareness about the effects of prescription misuse will be able to push back against peer pressure. If we can prevent the succumbence to peer pressure we will be able to prevent the greater likelihood of lifetime misuse that follows. Another reason why social influence is so dangerous is stigma. Multiple different articles state that social or even self stigma is a major cause in the lack of treatment for opioid misuse. “Stigma toward substance use disorders reduces treatment seeking and recovery efforts of persons who could most benefit from services. This is particularly true for opioid use disorder (OUD) stigma, which in recent years has likely fueled the overdose epidemic (Yaugher).” This same source also tells us that storytelling is an important tool to understanding and therefore reducing stigmas so people can have easier access to treatment. Allowing people to share their stories can help overcome this stigma and encourage other people going through the same thing to seek treatment. Spreading awareness of subconscious stigma can help people become aware of it and take the necessary steps to eradicate it.

With all of these drastic causes come drastic effects. Not only does prescription misuse affect you physically, it can also affect you mentally and can affect the people around you. “Side effects of painkiller abuse include seizures, a weakened immune system, an increased risk of heart disease, apnea (stop breathing), coma, and death (NCDAS).” This goes to show that even if you don't accidentally overdose you still have an increased risk of dying due to related health

risks. And the unhealthier you are, the less work you'll be able to do, and the less you can do to provide for yourself and anyone that depends on you. In addition to physical risks, " A 2022 systematic review reported that among people with OUD, the prevalence of current depression was 36.1%, anxiety was 29.1%, attention-deficit/hyperactivity disorder was 20.9%, PTSD was 18.1%, and bipolar disorder was 8.7%. (Santo)" Even if these effects aren't physical, all of these mental disorders increase your risk of sucicide which becomes infinitely easier when you are addicted to opioids. Spreading information about what comes after the temporary lapse in pain and sadness is crucial to preventing all of these life altering, and in some cases, life ending, effects. The situation becomes even worse when it is a parent who is addicted. "Children may not be taught basic life skills. ... These children are more likely to skip school, have antisocial behaviours (like being aggressive), or have other unhealthy behaviours (like an eating disorder) (Alberta Health Services)." Not being there for your children could also later have them turn to substance abuse to deal with the childhood neglect because it was the only example they had growing up. Even if we can't get to the adults, we should at least try to stop these kids from going down the same path.

This issue is so important because it impacts a devastating number of people and its audience spans all demographics. Starting from age 12, "3.1% (or about 8.7 million people) reported misusing prescription pain relievers in the past 12 months (2021 DT) (NIDA)." Of those people, "an estimated 1.8% (or about 5.0 million people) had a prescription opioid use disorder in the past 12 months (2021 DT 5.1). (NIDA)." And in that same year "approximately 16,706 people died from an overdose involving prescription opioids (NIDA)" This is only a fraction of the statistics about prescription misuse. There are so many other branches of medication out there that are also being misused and those people may not even know the damage they are doing. What if they don't have access to this kind of information? How are they supposed to be educated if no one bothers to put that information out there in an easily consumable format. Any correct information is better than no information at all. It truly would display our societies deepest flaws if we continue to let people die from a lack of knowledge.

That being said, it's not like we have to start from scratch. There are already foundations in place that can be built upon, and problems that have already been solved, which gives us hope for the future. For example, people used to get their prescriptions from multiple doctors so they could have enough to fulfill them. At the time, the doctors had no way of knowing that that patient had already gotten multiple of the same prescription. Now, there is software that allows the doctors to check the patients prescriptions before giving them anything. In addition, preaddiction tactics are being implemented to stop the addiction before it takes over. In an article titled "Time To Start Talking about Pre-Addiction," Dr. Volkow, the Director of the National Institute on Drug Abuse at the National Institutes of Health, explains how people can seek help before they hit "rock bottom" and how beneficial it would be to begin implementing treatments before a person becomes fully addicted. Going back to stigma, the same article by Shupp as mentioned above suggests that "primary prevention efforts through education might put the most emphasis on helping the general public correctly identify PDA symptoms, rather than in

attempting to reduce PDA stigma directly." This provides us with an alternative route, so not only can we focus on preventing the problem itself, we can also prevent the stigma that stops them from seeking help. There are so many different entrances and paths to stopping, preventing, and lessening prescription misuse, and it is crucial that we start utilizing them.

My action plan includes starting a podcast where each episode is an interview with a person who's seen or interacted with prescription misuse. The goal is to spread awareness and share information to close the knowledge gap and reduce the number of people misusing prescriptions. I also plan on contacting small and large pharmaceutical companies alike to install more medication drops on kiosks. They are places to safely dispose of prescriptions with no questions asked. This allows patients to dispose of any unnecessary medication so that it does not fall into the wrong hands. Providing people with different ways to protect themselves and prevent future misuse is the best way to chip away at this global issue.

In conclusion, prescription misuse, specifically opioids, affects a large number of our population in extremely detrimental ways by targeting their physical and mental health as well as the people around them. There are many ways we could stop the problem from the root, such as decreasing the availability of prescriptions, finding safer alternatives to relieving pain, and identifying and expelling peer pressure through the sharing of information. Not only do we have multiple options to pursue, but we also have foundations to build on to significantly decrease this problem that's capable of taking so many lives.

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Addiction & Mental Health, Alberta Health Services. "Addiction in the Family." Myhealth.alberta.ca, 18 May 2022, myhealth.alberta.ca/Alberta/Pages/addiction-in-the-family.aspx.

This network showcases trusted, easy-to-use health and wellness resources from Alberta Health Services and Alberta-based partner organizations. All of its information comes from health experts and is accurate and up to date. This article explains many things. One thing it explains is how an addiction can develop. It also provides information on how addiction can affect a family."A person's addiction usually has a negative impact on the family, which can lead to conflict and fighting between family members." It also narrows its focus on the children specifically. This relates to my project because misusing prescriptions can lead people to become addicted to them. Once they get addicted, it stops only affecting them and starts affecting the people around them. This information will help prove how many people misusing prescription eventually impacts.

Asante, Samuel, et al. "An Examination of the Relationship between Social Support Networks and Opioid Misuse among American Indian/Alaska Native Populations: A Systematic Review." Healthcare, vol. 13, no. 16, 21 Aug. 2025, p. 2072, mdpi-res.com/healthcare/healthcare-13-02072/article_deploy/healthcare-13-02072.pdf?version=1755772317, https://doi.org/10.3390/healthcare13162072. Accessed 13 Oct. 2025.

"This systematic review addresses the disproportionate impact of the opioid epidemic on American Indian and Alaska Native (AI/AN) populations by examining the socio-ecological and social network factors that influence opioid use and misuse." This study focuses on the correlation between peer pressure from friends and family and the misuse and abuse of prescriptions. It was found that, if they are surrounded by people who frequently abuse prescriptions, they are more likely to abuse prescriptions themselves.

Centers for Disease Control and Prevention. "About Prescription Opioids." Overdose Prevention, 8 May 2024, www.cdc.gov/overdose-prevention/about/prescription-opioids.html.

This is an official website of the United States government and was written June 10, 2025 meaning that the information it provides is accurate and up to date. This article describes prescription opioids, when they can become a problem, and the risk of overdose. This correlates to my research because it shows the steps that are taken before it becomes an addiction. It is also related to my research because it emphasizes the significance of this issue through statistics about overdose deaths.

Ford, Jason A., et al. "Friends and Relatives as Sources of Prescription Opioids for Misuse among Young Adults: The Significance of Physician Source and Race/Ethnic Differences." Substance Abuse, 11 July 2019, pp. 1–8, https://doi.org/10.1080/08897077.2019.1635955.

The authors of this study are all incredibly reliable as they have medical degrees and are experts in their fields. It is also an official website of the U.S. government. This study

was taken to see where people get the prescriptions they misuse. This article supports my research by providing information about the source of prescription misuse. By identifying the source, it can be possible to stop it early on. Stopping people from receiving their prescriptions will stop them from misusing and eventually abusing them.

jpennington. “History of Opioids.” ODFree.org - Mississippi Overdose Data, Prevention & Treatment, odfree.org/history-of-opioids/.

This article has many official and credible program partners and gets its information from government websites. It includes information about the origins and development of opioids which is crucial to my research. It is important to explain where opioids originated from and how they have evolved to what they are today to understand the addictive properties and affects.

Judd, Duncan B, et al. “The Opioid Epidemic: A Review of the Contributing Factors, Negative Consequences, and Best Practices.” Cureus, vol. 15, no. 7, 10 July 2023, www.ncbi.nlm.nih.gov/pmc/articles/PMC10410480/, https://doi.org/10.7759/cureus.41621.

This website is a journal of medical science and this specific article is about the opioid epidemic. This article is very credible because it has been peer reviewed by professionals. This article helps with “identifying the contributing factors and negative consequences as well as best practices for healthcare providers in managing the crisis.” This is important because it contributes to any information I have about the consequences while also providing practices for prevention that are already occurring. It can also help support my action plan because the practices are in the same vein.

Mayo Clinic. “Prescription Drug Abuse - Symptoms and Causes.” Mayo Clinic, 2022, www.mayoclinic.org/diseases-conditions/prescription-drug-abuse/symptoms-causes/syc-20376813.

This website is a very credible source as it is an organizational website and its entire staff of writers are all certified and have medical degrees. This includes pharmacists which is extremely relevant to the topic of the article. This article includes a multitude of important research. It defines what misusing a prescription is, “the use of a prescription medicine in a way not intended by the prescriber,” and it describes some of the ways one could go about that. It also lists detailed signs and symptoms that would allow you to identify who is misusing prescriptions and what kind. It also provides possible causes for the misuse, including wanting “to feel good or get high, to relax or relieve tension, [and] to ease pain.” It also explains some effects specific medications have on a person. It closes with prevention techniques. This supports my research by defining the problem and ways to prevent it and even spot it before it's too late. It also reveals causes which can allow us to go to the root of the problem and stop it from happening in the first place.

National Institute on Drug Abuse. “What Is the Scope of Prescription Drug Misuse in the United States?” National Institute on Drug Abuse, June 2020,

nida.nih.gov/publications/research-reports/misuse-prescription-drugs/what-scope-prescription-drug-misuse.
The author is the National Institute on Drug Abuse and it is a very credible research report as it is a government website and they are a national organization dedicated to all things related to drug abuse. The statistics provided are also recent as they come from 2021-2022. The contents of this research report include statistics about the misuse of prescriptions in the U.S. in regards to age, education, and type of drug, including tranquilizers, opioids, and stimulants. It also provides information on overdose deaths. For example, "in 2021, approximately 16,706 people died from an overdose involving prescription opioids." This supports my research because I need to prove how large of a problem is the misuse of prescription opioids. Statistics about who uses them and how many people overdose because of them can be used to help solve/prevent the issue.

"Prescription Drug Abuse Statistics [2025]: Opioids, Fentanyl & More." NCDAS, 3 Oct. 2025, drugabusestatistics.org/prescription-drug-abuse-statistics/. Accessed 17 Oct. 2025.
The author for this article is an organization named National Center for Drug Abuse Statistics. They are a government organization and their data is extremely reliable because they are the original source. They survey the entire nation and update their data yearly. This article is a collection of prescription abuse statistics. It included causes and effects for this abuse. It also included information about how much specific medications are abused. It also provides general data such as "45.8% of American adults used a prescription drug – legally or not – within the past 30 days." This relates to my research because by providing numerical evidence about the prevalence of this problem, I can prove how important a solution is. This research also allows me to explain the effects of misusing prescriptions which will make people think twice before doing so.

Samy, Joseph, a pharmacist, interviewed by Anastasia Samy
Joseph has been a pharmacist for over 21 years and has not only worked in the United States but also in Egypt, which gives him a unique perspective on prescription misuse outside of the country. He now co-owns a pharmacy with his wife and was able to give me some insight on the issue of doctors overprescribing. He also made me aware of software that has reduced doctor shopping, which is an act of going to multiple doctors to get multiple prescriptions.

Santo, Thomas, et al. "Prevalence of Mental Disorders among People with Opioid Use Disorder: A Systematic Review and Meta-Analysis." Drug and Alcohol Dependence, vol. 238, no. 1, 1 Sept. 2022, p. 109551, www.sciencedirect.com/science/article/abs/pii/S0376871622002885, https://doi.org/10.1016/j.drugalcdep.2022.109551.
This article is very reliable because it has multiple authors and 105 citations. It relates to the effects part of my project because it describes what mental disorders are prominent in the same people who have an opioid use disorder. This strengthens my case for the

importance of this topic because a poor mental health not only negatively affects you but also the people around you.

Shupp, Robert, et al. “Recognition and Stigma of Prescription Drug Abuse Disorder: Personal and Community Determinants.” BMC Public Health, vol. 20, no. 1, 22 June 2020, https://doi.org/10.1186/s12889-020-09063-z.

This article is reliable because it comes from an organization and has multiple expert authors. This relates to the peer pressure part of my research because pressure from society can cause people to misuse opioids to fit in and stigma can keep them from seeking help. Being able to identify which demographic groups are aware of stigma can help narrow down the audience of this research.

Yaugher, Ashley C., et al. “Understanding Stigma through the Lived Experiences of People with Opioid Use Disorder.” Drug and Alcohol Dependence, vol. 249, 1 Aug. 2023, p. 110873, www.sciencedirect.com/science/article/abs/pii/S0376871623011110, https://doi.org/10.1016/j.drugalcdep.2023.110873. Accessed 4 July 2023.

This article directly correlates to my action plan because if we can get people to share their experiences with prescription misuse and the ensuing stigma then we can allow people going through the same things to connect with each other. Spreading awareness and each other can help people find support. Increasing the availability of these testaments can let people know that they are not alone and that there are ways to overcome this struggle.

Microplastic Pathways in Human Physiology By Samar Singh

Abstract

Microplastics are small plastic particles that are increasingly present in the environment due to the breakdown of larger plastic waste and the widespread use of synthetic materials. Their growing presence in food, water, air, and cosmetic products has raised concerns regarding human exposure and potential health effects. This review paper investigates how microplastics enter the human body and examines their possible physiological impacts. The research paper was conducted through a review and analysis of various sources, including peer-reviewed journal articles and reports related to microplastic exposure and human health. The findings show that microplastics primarily enter the body through ingestion, inhalation, and dermal contact. Research indicates that exposure may affect multiple biological systems, including the digestive, immune, respiratory, and circulatory systems, potentially causing inflammation and disruption of gut microbiota. Smaller particles may also enter the bloodstream and circulate throughout the body through the use of cosmetics on the skin. The paper concludes that human exposure to microplastics is largely unavoidable due to their widespread environmental presence, and further long-term research is required to better understand their effects on human health and to support environmental policies aimed at reducing plastic pollution.

Keywords

Microplastics, Environmental impact, Human health impacts, Exposure pathways, Pollution, Food and Water Contamination

1. Introduction

Microplastics refer to very small plastic elements, which are normally smaller than five millimeters, and are either a product of the degradation of bigger plastic materials or microscopic plastic manufacturing products such as synthetic fibers and industrial additives (World Health Organization). Microplastics have been steadily increasing in concentration across the planet due to the widespread use of plastic in modern life and the plastic's durability against natural degradation (Wright and Kelly). The disturbing thing about microplastic pollution is its invisibility in terms of the fact that one cannot see the plastic elements in the environment and in people's bodies, and yet they are steadily increasing in concentration in both the environment and people's tissues and fluids (Campanale et al.). Microplastic pollution has recently been found in people's bodies in a rather revealing connection between pollution and health (Leslie et al.). Microplastics are a source of serious concern in the present day due to their longevity in the environment and the way in which they end up dispersing in diverse ecosystems (Wright and Kelly). When regular plastic waste breaks down in the presence of sunlight, mechanical, and other natural forces, it breaks down into innumerable microplastics, which end up in the air, water, and soil (Prata et al.). Moreover, microplastics are also known to bind with various toxic substances, heavy metals, and other harmful materials present in the environment, acting as

vectors in food chains (Campanale et al.). Not only does the use of microplastics affect the diversity of the planet, but it also has the potential to transfer the contaminants present in the environment to human life (Smith et al.).

Microplastics enter the human body through various routes, and it is hard to avoid contact with them. An important source of microplastic entry into the human body is ingestion, as microplastics have been identified in drinking water, seafood, salt, fruit, and vegetables (Cox et al.; World Health Organization). Another source of ingestion is breathing, which is caused by plastic fibres discharged from synthetic clothing, dust, and pollution (Prata et al.). Microplastics have also been identified in human blood, urine, and breast milk, assuming that the microbeads have entered the human body and are circulating within it, as opposed to the previous assumption that they are eliminated (Leslie et al.; Ragusa et al.). Such sources point towards the human interaction with microbeads being a continuous process that starts at a basic everyday life source (Ee et al.).

After the microplastic is ingested, it has the possibility of reacting with the biological systems within the human body, raising concerns for human health. Research has suggested the possibilities of adverse reactions of microplastics to the human body, causing cellular damage and oxidative stress (Wright and Kelly). Microplastics have also been known to have the possibility of hampering the human gut microbiota (Ee et al.). Additionally, one must note that plastics have the possibility of containing or absorbing chemicals like Bisphenol A and phthalates, which have been proven to have the possibility of being endocrine disruptors (Campanale et al.). Though human conclusive evidence is not available, the possibility of increased human health risks due to such factors has opened channels for further human health studies (Ee et al.).

Although microplastic detection is increasing in the human body, there are still several unknowns with regard to the long-term physiological impacts microplastic particles can cause to the human body (World Health Organization). The differences in particle sizes, shapes, and compositions pose a threat to conducting standardized research (Wright and Kelly). This review paper explores the impact of microplastic exposure on human physiology, focusing on how microplastics enter the body, interact with biological systems, and contribute to potential health outcomes.

2. Methodology

The research aim of this paper is to examine how microplastics enter the human body and how exposure to microplastics may affect human physiology (Savchuk). This paper also focuses on identifying major exposure pathways as well as analysing their potential impacts on important bodily systems (Lee et al.).

2.1 Pathways of Exposure

a. Ingestion

The primary pathway through which microplastics enter the human body is ingestion. Microplastics are consumed through contaminated food and drinking water, including seafood, salt, fruits, and vegetables (Lee et al.). Smaller particles such as nanoplastics are capable of crossing the intestinal barrier and entering the bloodstream, thereby increasing internal exposure (Lee et al.).

b. Inhalation

Airborne microplastics are inhaled during normal respiration. These micro-particles originate from household dust, tyre wear, air pollution, and synthetic clothing fibres (Lee et al.). Many of these small particles are able to penetrate lung tissue and may enter the circulatory system, increasing the risk of systemic exposure (Lee et al.).

c. Dermal Exposure

Dermal exposure occurs through direct contact with microplastics present in cosmetics, exfoliants, and synthetic fabrics (Lee et al.). Although the skin acts as a protective barrier, extremely small particles or plastic-associated chemicals may enter the body through hair follicles or damaged skin (Lee et al.).

2.2 Effects on Human Physiology

a. Digestive System

When microplastics enter the body through ingestion, they may affect the digestive system by causing inflammation and irritation in the gastrointestinal tract (Lee et al.). Research suggests that microplastics may disrupt gut microbiota, which plays a crucial role in metabolism, digestion, and immune regulation (Lee et al.).

b. Immune System

The immune response is activated when microplastics are recognised as foreign particles. This immune activation can lead to inflammation and oxidative stress, contributing to an immune system imbalance with prolonged exposure (Lee et al.).

c. Circulatory and Respiratory Effects

Inhaled microplastics can cause lung irritation and cellular damage within the respiratory system (Lee et al.). Smaller particles that enter the bloodstream may circulate throughout the body and interact with vital organs such as the heart and liver, raising concerns about long-term physiological effects (Lee et al.).

3. Discussion

3.1 Pathways of Exposure

Microplastics enter the human body via several routes of exposure, including ingestion, inhalation, and dermal contact. These major routes demonstrate how deeply microplastics have become embedded in everyday life, as exposure frequently occurs unconsciously through routine activities such as eating, breathing, and contact with consumer goods, including makeup and skincare products (Savchuk; Lee et al.). The pathways discussed here are important for assessing microplastic accumulation and their potential interactions with human physiology (Lee et al.). The main route of exposure of microplastics to humans is believed to be ingestion. Microplastics have been identified in a wide range of foods and beverages, including seafood, drinking water, salt, fruits, and vegetables (Cox et al.; World Health Organization). The presence of microplastics in food and beverages is associated with contaminated water sources, agricultural practices, and food processing methods (Cox et al.). While many ingested microplastics pass through the intestinal system, smaller particles, particularly nanoplastics, are believed to cross the intestinal barrier and enter the bloodstream (Lee et al.). The detection of microplastics in human feces and blood samples indicates that ingested microplastics not only cause exposure but also distribute within the body (Leslie et al.). Ingested microplastics may also affect the gut microbiota, potentially altering digestion and immune function, although the extent of these effects remains under investigation (Campanale et al.).

Another significant but less visible route of exposure is inhalation. Microplastics are present in both indoor and outdoor air, originating from sources such as the breakdown of synthetic textile fibers, tire wear, industrial emissions, and household dust (Prata et al.). Individuals are therefore exposed to airborne microplastics during normal respiration, with exposure levels generally higher in urban environments and indoor spaces (Prata et al.). Inhaled microplastics may become lodged in the upper respiratory tract, while smaller particles can reach deeper lung tissues (Prata et al.). Studies suggest that inhaled microplastics are associated with respiratory irritation, inflammation, and oxidative damage to lung cells (Wright and Kelly). Smaller particles are also believed to translocate from the lungs into the bloodstream, potentially affecting organs beyond the respiratory system (Wright and Kelly).

Dermal exposure occurs through direct contact between microplastics and the skin, particularly through the use of cosmetics, exfoliants, and synthetic clothing fabrics (Lee et al.). Although the skin acts as an effective protective barrier, research indicates that very fine microplastics or plastic-associated chemicals may enter the body through hair follicles or damaged skin (Campanale et al.). Compared to ingestion and inhalation, dermal exposure is considered a less significant route; however, absorbed plastic additives may still influence bodily functions, including hormonal and immune regulation, following systemic absorption (Campanale et al.).

Taken together, ingestion, inhalation, and dermal contact highlight the largely unavoidable nature of human exposure to microplastics. These exposure routes do not operate independently but instead contribute to continuous, low-level exposure throughout an

individual's lifetime (Lee et al.). Understanding these pathways is essential for evaluating the potential health risks associated with long-term microplastic exposure.

3.2 Effects on Human Physiology

a. Digestive System

The digestive system is one of the most affected parts of the body because ingestion is the main route by which microplastics enter the human body (Cox et al.; World Health Organization). Microplastics are ingested from food and drinking water contaminated by them, and they may come into contact with the stomach and intestines, probably irritating and inflaming these organs (Lee et al.). Larger microplastic particles normally pass through the digestive system and exit the body, whereas the smaller ones, especially nanoplastics, sometimes can remain longer in the gut or even cross the intestinal wall (Lee et al.). The gut microbiota, considered important for digestion, metabolism, and immune function (Campanale et al.), has been shown in several studies to be perturbed by microplastics. Such a disturbance can affect normal digestion and gut health. Even though much evidence relies on laboratory and animal studies, such findings raise several concerns about the long-term effects of chronic exposure to microplastics on human digestive health(Lee et al.).

b. Immune System

Microplastics may have a further impact on human health, such as on the immune system. The immune system is capable of identifying the presence of microplastics and may attempt to get rid of them from the body (Lee et al.). An example is when there is inflammation and oxidative stress, especially when exposure to microplastics happens on multiple occasions over a long period of time (Wright and Kelly). Overexposure to microplastics may impair the immune system and reduce its normal functioning. Additionally, it may carry a variety of harmful substances such as heavy metals and endocrine-disrupting chemicals, such that when they get inside the body, they may trigger immune responses (Campanale et al.). Although empirical evidence on human health is unavailable, current studies indicate that the immune system is a vital point of worry when looking into human health effects of exposure to microplastics (Ee et al.).

c. Circulatory and Respiratory Effects

Additionally, microplastics can also affect the respiratory and circulatory systems. This effect can be attributed to the inhalation of microplastics. During the normal course of breathing, people inhale microplastics into their respiratory system. In the respiratory system, microplastics accumulate. However, particles that are larger accumulate in the upper respiratory tract, while those that are smaller accumulate deeper in the lungs, leading to damage, inflammation, and irritation of cells (Wright and Kelly; Prata et al.). Therefore, studies indicate that microplastics, especially the very small ones, can even enter the bloodstream after accumulating in the lungs. Then, they can lead to changes in all organs, including the heart and liver (Leslie et al.). When

microplastics are detected in the bloodstream, this shows that the effect of microplastics is not restricted to the respiratory system (Leslie et al.).

4. Conclusion

This review paper's main findings are about how microplastics enter the human body through multiple pathways, including ingestion, inhalation, and dermal contact. Many people ingest these microplastics through food, makeup products, and airborne particles such as dust and synthetic fibres. Ingestion is the most significant pathway of exposure because microplastics have been detected in seafood, salt, fruits, vegetables, and drinking water. Many of these nanoparticles may cross the intestinal barrier and enter the bloodstream, which increases the internal exposure. The microplastics may affect several biological systems in the body. Many researchers have found that microplastics can interact with multiple systems, including the digestive, immune, respiratory, and circulatory systems. These interactions can cause irritation, inflammation, and cellular stress. They can also disrupt the gut microbiota and the immune response. Gut microbiota are essential for digestion, but any interference between microplastics and gut microbiota can escalate tensions in the body. The immune system may react to the microplastics as foreign particles, causing a heavy reaction from the body. Many studies have shown that microplastics can circulate within the body, potentially reaching different organs. These implications show how human exposure to microplastics is unavoidable because microplastics are present everywhere, and they pose long-term health risks. More scientific research is needed, as future studies should focus on understanding the long-term effects of microplastics and especially on how they interact with human biological systems. The policy and environmental action may also be required while reducing plastic pollution and improving waste management, which could help limit microplastic exposure and protect both environmental and human health.

Table 1: Summary of the system affected and key findings of the paper

Theme	System Affected	Possible Human Impact	Key Finding	References
Theme 1 **Pathways of Exposure**	Digestive system, Respiratory system and the Skin	Caused to the prolonged exposure through ingestion, inhalation, and dermal contact	Microplastics enter the body mainly through contaminated food, water, airborne particles and contact with synthetic products such as makeup, making exposure largely unavoidable in everyday life	Lee et al.; Cox et al.; Prata et al.; Campanale et al.
Theme 2 **Effects on Human Physiology**	Digestive system, Immune system, Respiratory and circulatory systems	Inflammation, oxidative stress, disruption of the gut microbiota, respiratory irritation and possible circulation of particles to organs	Microplastics can interact with biological systems that interact with our bodies and may affect the gut health, immune responses, lung tissue and potentially other important organs through the bloodstream transport.	Wright and Kelly; Leslie et al.; Campanale et al.; Lee et al.

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Prakrithi Sathi: Exploring Generative AI in Community and Home Gardening
By Shanmukh Sriram Chintapalli

Abstract

Prakrithi Sathi is a student-developed gardening assistant designed to simplify plant care for beginners through an intuitive conversational interface. This paper documents the evolution of the application from a rule-based keyword-matching system to a Generative AI-powered solution capable of processing both text and image inputs. The system integrates a Django-based web application with a structured SQLite database containing over 200 plant disease records, and an OpenAI GPT-4o-powered AI model to provide accurate, context-aware, and eco-friendly plant care recommendations. Users can interact using natural language, upload plant images, or combine both modalities for enhanced diagnosis. Three interaction modes are supported: text-only database search, image-only AI analysis, and a combined text-and-image mode. The study evaluates both approaches across five parameters — cost, accuracy, flexibility, hallucination risk, and response speed — demonstrating that Generative AI significantly improves accessibility and user experience compared to traditional rule-based approaches. By bridging the gap between expert botanical knowledge and everyday users, Prakrithi Sathi demonstrates the potential of AI-driven tools in promoting sustainable, chemical-free gardening practices and empowering beginner gardeners and communities.

1. Introduction

Gardening has long been one of humanity's most instinctive and rewarding hobbies. From ancient kitchen gardens to modern urban balconies, the urge to grow and nurture plants is deeply rooted in human culture. In recent years, this interest has seen a significant revival, particularly among young and first-time gardeners in cities who are turning their terraces, backyards, and balconies into tiny gardens as a way to connect with nature, grow their own food, and contribute to a healthier environment. This enthusiasm is frequently accompanied by a critical gap in knowledge. Beginner gardeners, unfamiliar with the science of plant health, often feel overwhelmed by the volume of information on the internet and frequently resort to chemical pesticides and fertilisers without understanding their correct application and side-effects. This sometimes leads to burned roots, damaged foliage, the unintended destruction of beneficial insects such as bees and ladybugs, and in more serious cases, contamination of local soil and groundwater. The very act of trying to care for a plant can, without proper guidance, cause more harm than good.

It is within this context that the recent advances in Artificial Intelligence (AI) and Generative AI present a remarkable and timely opportunity. GenAI refers to a class of AI systems capable of understanding, reasoning about, and generating human-like responses to complex inputs — whether those inputs are text, images, audio, video, or a combination of these. Unlike traditional software that follows rigid, pre-programmed rules, GenAI systems learn from vast amounts of real-world data and can respond to new, unpredictable situations with a

flexibility that closely mirrors human expertise. Applied to the domain of gardening, this means that a beginner who does not know the name of a disease, cannot identify a pest, or simply notices that something looks wrong with their plant, can now receive intelligent, personalized, and safe guidance — instantly, and in plain language they can understand.
This paper explores the intersection of Generative AI and beginner gardening and community through the lens of **Prakrithi Sathi** — a student-developed, open-source gardening assistant application built at Sri Kumaran Children's Home, CBSE, Bangalore, during the academic year 2025–26. The name itself, drawn from Sanskrit, translates meaningfully to *"Nature's Companion"* — a perfect description for an application whose core aim is to place expert plant care knowledge within the reach of anyone who needs it.

The vision for Prakrithi Sathi is to bridge the gap between human concern for nature and expert botanical knowledge. At its heart, it's not just a database; it's a digital companion for gardeners and farmers, designed to demystify the complexities of plant health through intuitive conversation. The core concept centres on accessibility and empowerment (Django Based Web Application). Instead of forcing users to navigate complex scientific catalogues, the platform allows them to describe their observations in their own words —like a friend seeking advice (Conversational Chat Bot. By centralizing knowledge on diseases and treatments (SQLite Database), it transforms from a simple reference tool into a proactive support system that helps users protect their greenery. Furthermore, the Prakrithi Sathi includes a community and stewardship layer. By distinguishing between those seeking help (regular users) and those curating the knowledge (Admins), it ensures that while the interface remains simple for the user, the wisdom behind it remains verified and high-quality.

2. Literature Survey

The development of Prakrithi Sathi was informed by a review of prior research in technology-assisted plant disease identification and agricultural advisory systems. Existing literature reveals a range of approaches, each with distinct strengths and limitations, collectively shaping the design decisions underlying this application.

Mohanty et al. (2016) demonstrated the application of Convolutional Neural Networks (CNNs) to image-based plant disease detection, achieving accuracy exceeding 99% on the PlantVillage dataset. However, the study acknowledged a significant performance gap when the model was applied to real-world field photographs under uncontrolled conditions, as opposed to the clean, standardised images used during training. This limitation highlighted a critical challenge in translating laboratory-grade models to practical, field-level deployment — a consideration that directly influenced the design goals of Prakrithi Sathi.

Building on classification-based work, Fuentes et al. (2017) proposed an object detection framework capable of not only identifying disease types but also spatially localising the affected regions within tomato plant images, thereby providing users with more precise diagnostic information. Separately, Kumar et al. (2012) introduced Leafsnap, a mobile computer vision system designed for species identification by everyday users rather than botanical specialists.

While Leafsnap represented an important step toward accessible plant technology, its scope was confined to species recognition and did not extend to disease diagnosis, a gap that Prakrithi Sathi seeks to address.

Kamilaris and Prenafeta-Boldú (2018) conducted a comprehensive survey of deep learning applications in agriculture, noting that despite high reported accuracy figures, the majority of these systems lacked accessible, natural-language interfaces for non-expert users. Most required image inputs in specific formats or assumed familiarity with technical terminology, creating a usability barrier for the very communities these tools aimed to serve. This finding strongly motivated the development of a conversational chatbot interface in Prakrithi Sathi, one that allows users to describe plant problems in their own words without any prerequisite technical knowledge. Complementing this, a report by the Food and Agriculture Organization of the United Nations (FAO, 2021) confirmed the practical viability of rule-based chatbots for delivering agricultural advisory services in multiple countries, validating the conceptual foundation of a conversational plant care assistant.

A pivotal contribution to the field came from Brown et al. (2020), whose work on GPT-3 demonstrated that large language models could respond to expert-level queries across diverse domains without task-specific training. The concept of prompt-guided behaviour — whereby a general-purpose language model is directed through carefully constructed instructions to act as a domain specialist — forms the architectural basis for the Generative AI component of Prakrithi Sathi. Rather than developing a custom model trained exclusively on plant disease data, the application leverages GPT-4o with domain-specific prompt engineering, making it both resource-efficient and highly capable for a student-developed project.

Taken together, this body of literature traces a clear trajectory in the evolution of AI-assisted plant care: from rigid rule-based systems, through image classification and object detection models, to the current frontier of conversational AI powered by large language models. Prakrithi Sathi draws on this progression, integrating the reliability of a structured database, the visual diagnostic capability of a multimodal AI model, and the accessibility of a natural-language interface — combining these elements into a cohesive tool suitable for beginner gardeners without any technical background.

3. Journey of Prakrithi Sathi

Prakrithi Sathi began as a Django-based web application built on Python, featuring a conversational chatbot interface backed by a structured SQLite database of plant diseases, symptoms, causes, treatments, and prevention strategies. Users could log in, type a description of their plant problem, and receive matching guidance retrieved through a keyword-based search across the database. The application also featured a role-based system: regular users could access the chat interface, while administrators could manage the plant disease knowledge base — adding, editing, or removing records — and manage user accounts. This architecture, while functional and thoughtfully designed, operated entirely within the boundaries of what had been manually entered into the database. Its intelligence in the database was, in essence, the limited

knowledge of the application creator and the terminology used by specialists. To enhance the capability of this application and overcome the limitation, Prakrithi Sathi has been integrated with Generative AI – specially choosing OpenAI Model (gpt4o) which has the ability to analyse text as well as Images. It can now support three modes of interaction:

1. Text Only Mode with Database Search
2. Image only Mode with GPT4o
3. Image and Text combining 1 and 2 above

A user may describe their plant problem in text alone, as they would in a message to a friend. They may upload a photograph of their struggling plant and let the Generative AI examine it visually, identifying symptoms such as leaf discolouration, wilting, fungal spots, or pest damage that the user themselves may not be able to name. Or they may do both simultaneously — combining a written description with a photograph to give the AI the fullest possible picture of the situation, much as one would show both a photo and explain the context to a doctor. In all three modes, the AI is guided by carefully written **prompts** that constrain its responses to safe, natural, and beginner-appropriate recommendations — ensuring that the power of Generative AI is channelled responsibly.

This paper documents the design, architecture, and capabilities of both versions of Prakrithi Sathi, examines the role of Generative AI in transforming the application's diagnostic ability, and reflects on the broader potential of AI-assisted tools in making sustainable, chemical-free gardening knowledge universally accessible. In doing so, it contributes to a growing body of work exploring how Generative AI can be applied not just in large-scale industrial or academic settings, but in the everyday lives of ordinary people — beginning, quite literally, with the plants on their windowsill.

4. Concept In Action

This section describes the user-flow and role-based access control architecture of Prakrithi Sathi — the rules that govern who can access the system, what they can do, and how each interaction is handled. To make these technical concepts accessible, the architecture is explained through an analogy. The whole process within Prakrithi Sathi is represented by the state-flow diagram as Figure 1. Imagine a zoo with a single entrance gate. No matter which part of the zoo you want to visit — the lion enclosure, the reptile house, the cafeteria — you have to buy a ticket and show it at the gate first. Nobody sneaks past. Prakrithi Sathi's login page is exactly this gate. Your username and password are your ticket. If you do not have them right, you cannot use this application

Right after the gate, there's a staff member who looks at your ticket and hands you one of two things. Regular visitors get a **tourist map** — it shows the animal exhibits, the paths, the feeding times. Staff members get a **staff keycard** — it opens enclosures, back corridors, and the management office. You don't choose which one you get. The staff member checks your ticket

and decides. This is exactly what Prakrithi Sathi's role check does the moment you log in — tourist map for regular users, staff keycard for admins.

Now imagine each animal enclosure has a big information board outside it. You walk up, read about the animal's species, diet, habitat, and health needs. The Prakrithi Sathi chat is this information board system — except instead of you walking to the right enclosure, you just shout the name of the animal and the nearest board lights up automatically. Type "tomato" and the app instantly pulls up all the diseases, symptoms, causes and treatments related to tomatoes — like five enclosure boards lighting up at once, all relevant to what you asked.

The clever part is that the search isn't rigid. If you say "yellow leaves" instead of "Early Blight," the app still finds the right boards — because it searches the descriptions too, not just the names. It's like the zoo recognising you're looking for a big cat even if you said "striped animal" instead of "tiger."

Behind every great zoo is a team of zookeepers who decide which animals are housed, what information goes on the boards, and who is allowed inside. Visitors never see this office. But without it, the boards would be outdated, wrong animals would be in wrong enclosures, and the whole zoo would fall apart.

The Admin Dashboard in Prakrithi Sathi is this zookeeper's office. Admins can add new plant disease records — like introducing a new animal to the zoo. They can edit existing information — like updating a board when an animal's diet changes. They can delete entries — like removing a board for an animal that's no longer there. And they can manage users — deciding who gets a tourist map and who gets a staff keycard.

Every zoo keeps a detailed registry of all its animals — species, age, health history, feeding schedule, enclosure number. This registry is stored in files that only the staff can update, but the information boards for visitors are all pulled from it. Prakrithi Sathi's SQLite database is this registry. Every plant disease entry — plant name, symptoms, cause, treatment, prevention — lives in this registry. When you chat and ask about tomatoes, the app runs to this registry, finds all tomato-related entries, and puts them on your screen. The chat is just a friendly window into the registry.

You visit a zoo and never think about the water pipes, electrical wiring, feeding schedules, or the roads that connect every enclosure. But without all of that invisible infrastructure, the zoo simply wouldn't function. Django, the web framework powering Prakrithi Sathi, is exactly this. It routes you to the right page, checks your login, talks to the database, and sends back the right response — all invisibly, all instantly, every single time you click something. A responsible zoo doesn't just let you wander out through a hole in the fence. There's a proper exit — a turnstile that registers you've left, so the headcount stays accurate and no one can use your ticket again. Prakrithi Sathi's logout works the same way. It doesn't just close your window — it formally ends your session on the server, invalidating your access completely. Someone picking up your phone right after couldn't waltz back in, because your ticket has already been stamped and discarded.

Figure 1: State Flow Diagram of Prakrithi Sathi

5. Database and Data Collection

The entire database of Prakrithi Sathi is organised around two distinct **sets of tables** that serve completely different purposes — the **People** and the **Knowledge Tables**. One controls who gets access to the system. The other stores what the system actually knows. Figure 2 shows the Entity Relations Diagram

Figure 2: Entity Relationship Diagram

5.1 The People Tables

The People related Tables is a network of interconnected tables that together answer two questions about every person in the system — who are you, and what are you allowed to do?

At the centre of this set sits the **auth_user** table. Every person who can log into Prakrithi Sathi has exactly one record here, storing their username, hashed password, email, name, and a set of flags. The is_superuser flag grants unrestricted access, is_staff grants admin dashboard access, and is_active determines whether the account is currently usable. Timestamps for last_login and date_joined round out each user's profile.

Branching outward from auth_user is the permission system. The **auth_permission** table lists every possible action that can be performed in the system, while **django_content_type** catalogues every model that exists in the database. Together they define the complete universe of possible actions. The **auth_group** table then bundles these permissions into named roles, and **auth_group_permissions** connects groups to their specific permissions. Finally, **auth_user_groups** links individual users to their groups, completing the chain from a specific person to a specific set of allowed actions.

Two supporting tables complete the People Set of Tables. The **django_admin_log** maintains a full audit trail of every create, update, or delete action an admin performs, recording who did what and exactly when. The **django_session** table manages live access — creating a session record when a user logs in and deleting it when they log out, validating every page request in between.

5. 2 The Knowledge Tables

Where the People Set of Tables is a complex web of interconnected tables, the Knowledge Set of Tables is deliberately the opposite — a single flat standalone table called **PrakrithiSathiApp_plantdisease** with no foreign keys and no relationships to any other table.

Each record in this table represents one specific disease affecting one specific plant, containing seven fields — a unique id, the Plant name, the Disease name, observable Symptoms, the biological Cause, the recommended Treatment, and Prevention advice. This is the table the chat interface reads from every time a user submits a message. The application splits the user's input into keywords and simultaneously searches the Plant, Disease, and Symptoms fields, ranks the results by how many fields matched, and returns the most relevant entries as a response. This is the primary table for the application's gardening data Plant disease mapping. It includes the following fields:

- id: A unique identifier for each record.
- Plant: The name of the plant.
- Disease: The specific disease affecting the plant.
- Symptoms: Physical signs used to identify the issue.
- Cause: The underlying reason or pathogen for the disease.
- Treatment/Prevention: Solutions and methods to fix or avoid the problem

The effectiveness of the Prakrithi Sathi chatbot is fundamentally rooted in the integrity of its underlying database, specifically the PrakrithiSathiApp_plantdisease table. Because this table serves as the "knowledge engine" for the entire application, the transition from AI-generated raw data to a verified, high-quality "encyclopedia" is a critical requirement for the project's success and needs to scan large encyclopedia Using OpenAI's prompting data has been generated and stored in respective table. Figure 3 shows the prompt and Figure 4 shows the sample data ingested into Prakrithi Sathi

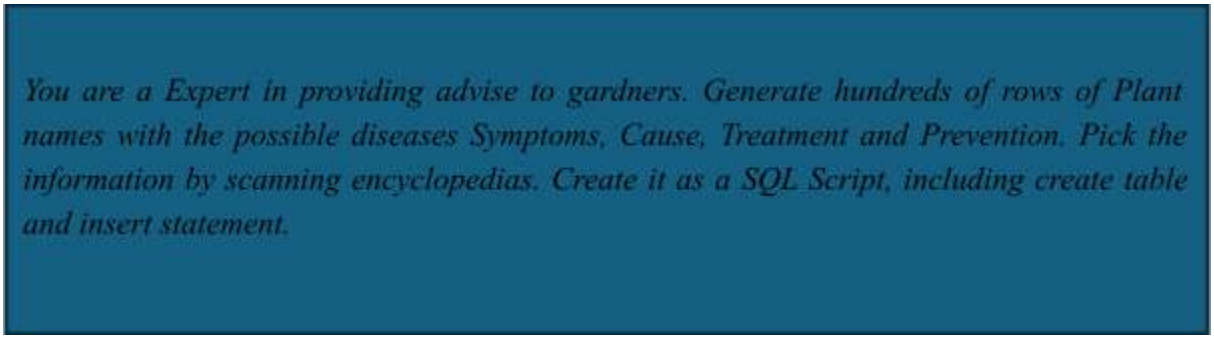


Figure 3: Prompt for Generating the Data



Figure 4: Sample Plant Disease Database

The two sets of tables have no direct database relationship between them. What connects them is the application layer. The People Tables acts as the gatekeeper — verifying identity and role before any request reaches the Knowledge Set of Tables. If authentication passes, the query goes through. If not, the user is redirected to login. One set of tables manages trust. The other

stores and serves knowledge. Together they form the complete data architecture of Prakrithi Sathi.

6. Two Algorithms – Description Text And Image Analysis

Prakrithi Sathi Operates under two algorithms

- Rule Based Approach
- Generative AI Approach

6.1 Rule Based Approach

The rule-based approach in *Prakrithi Sathi* is designed to provide accurate and reliable plant disease diagnosis by using structured logic instead of probabilistic or generative methods. In this approach, the system processes user input in a systematic manner and retrieves information strictly from a predefined database. This ensures that the responses are consistent, explainable, and based only on verified data.

When a user interacts with the chatbot, they typically enter a query describing their plant and its symptoms, such as "tomato leaves turning yellow with spots." The system first takes this input and performs text preprocessing. This involves converting the input into a standard format, such as lowercase, and then splitting the sentence into individual words or tokens. This step is important because it allows the system to analyze each meaningful component of the query separately. After tokenization, the system begins keyword identification. It scans the individual words to detect relevant terms such as plant names (e.g., tomato, potato) and symptom-related words (e.g., yellowing, spots, wilting). These keywords act as the basis for searching the database. The system then applies predefined rules and conditions to determine how the database should be queried.

The next stage is database matching. The system compares the extracted keywords against fields in the database, particularly plant names and symptom descriptions. Each match contributes to a match score, which reflects how closely a database entry corresponds to the user's query. For example, if both the plant name and multiple symptoms match, the score will be higher than a partial match.

Once all possible matches are evaluated, the system performs ranking of results. The entries are sorted based on their match scores, and the highest-ranked result is selected as the most relevant diagnosis. This ranking mechanism ensures that even if the user's input is not perfectly structured, the system can still identify the closest possible match.

After selecting the best match, the system retrieves the corresponding details from the database, including the disease name, symptoms, causes, treatment methods, and preventive measures. These results are then presented to the user in a clear and structured format.

If no suitable match is found, the system does not attempt to guess or generate an answer. Instead, it follows a fallback mechanism by either asking the user for more specific details or indicating that the information is unavailable. This prevents incorrect outputs and maintains the reliability of the system.

Overall, the rule-based approach in *Prakrithi Sathi* is deterministic, transparent, and efficient. It relies on logical conditions, keyword matching, and scoring rather than machine learning or generative techniques. As a result, it ensures that all outputs are grounded in existing data, making the system trustworthy and suitable for practical use in plant care.

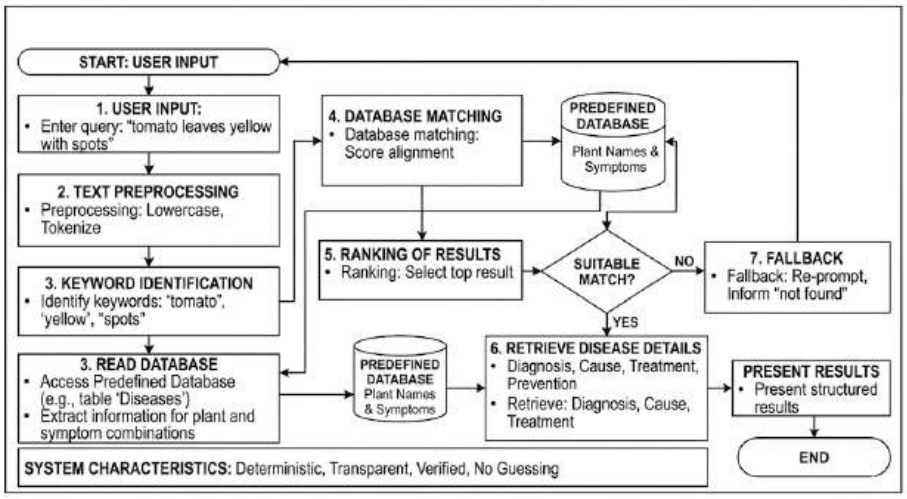


Figure 5: Flow chart for Rule Based Approach

6.2 Generative AI based Approach

The upgraded version of Prakrithi Sathi uses a Generative AI-based approach to provide intelligent, dynamic, and context-aware solutions for plant care. Instead of relying solely on keyword-based searches, the system leverages advanced AI models to understand user queries and generate meaningful outputs in real time.

In this approach (Figure 6), the application functions as an interactive assistant where users can describe their plant-related concerns in natural language. The user may also upload an image of the affected plant to enhance the accuracy of the analysis. This capability allows the system to process both textual and visual inputs, making it more versatile and effective in identifying plant issues.

When a user submits a query, the system collects the input data, which includes the text description and any uploaded image. Along with this, a carefully designed system prompt (Figure 7) is included. This prompt guides the AI model to respond in a specific manner, such as focusing on eco-friendly solutions, providing clear explanations, and avoiding harmful or excessive chemical recommendations. The prompt acts as an instruction set that ensures the responses remain relevant, safe, and aligned with the purpose of the application.

The collected input is then sent to the OpenAI API, where the Generative AI model processes the information. The model uses natural language understanding to interpret the user's concern and, if an image is provided, analyzes visual features such as leaf discoloration, spots, or texture changes. By combining these inputs, the model forms a contextual understanding of the problem.

Based on this understanding, the AI generates a response that includes a possible diagnosis, likely causes, and suggested treatments. The response is not limited to fixed answers but is dynamically created, allowing it to address a wide variety of plant issues. The solutions are typically structured in a clear and user-friendly format, often including step-by-step guidance and preventive measures to avoid future problems.

The generated response is then sent back to the application and displayed in the chat interface. This creates a seamless conversational experience, where users can ask follow-up questions and receive further clarification. The interaction feels natural and intuitive, similar to speaking with an expert.

Additionally, the Generative AI approach enables continuous improvement. As the AI model is trained on vast amounts of data, it can provide insights across a broad range of plants and conditions. The system can also be enhanced over time by refining prompts, incorporating user feedback, and integrating additional contextual data such as weather or location.

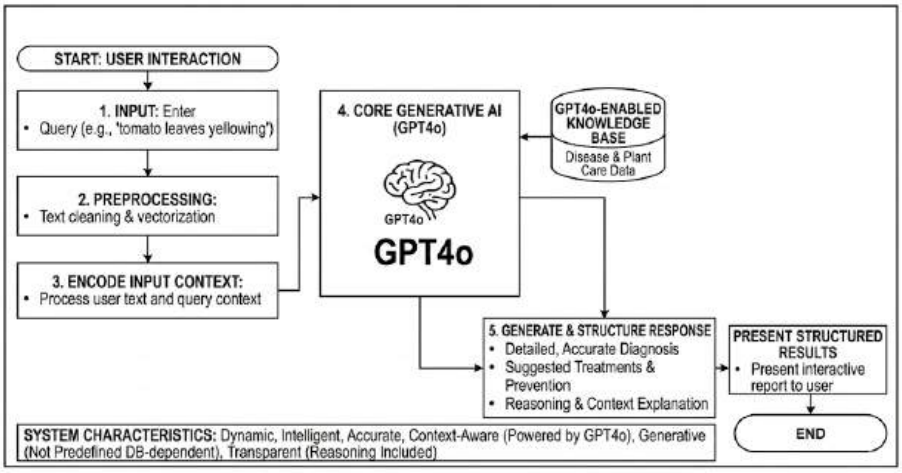


Figure 6: Flow chart of Generative AI Approach



Figure 7: Prompt for AI Generated Responses

6. 3 Comparison of the two Approaches

The Prakrithi Sathi system implements two distinct approaches for plant disease diagnosis: the rule-based approach and the Generative AI-based approach. Both methods aim to assist users in identifying plant problems and suggesting solutions, but they differ significantly in terms of cost, accuracy, flexibility, side effects, and response speed. This comparison also refers to the output representations shown in Figures 8 and 9, where Figure 8 corresponds to structured rule-based outputs and Figure 9 represents AI-generated conversational outputs.

One of the primary differences lies in cost and token usage. The rule-based approach operates entirely on a local database and predefined logic, meaning it does not incur any external API costs. Once the system is developed, the operational cost remains minimal regardless of usage. In contrast, the Generative AI approach relies on API calls to models such as those provided by OpenAI. Each request consumes tokens based on input size (text + image) and output length. As usage increases, the cost scales proportionally. Therefore, while the rule-based system is cost-efficient and predictable, the Generative AI system introduces variable operational expenses depending on user activity.

In terms of accuracy, the rule-based system provides highly reliable results when the user input matches entries in the database. Since it retrieves verified and predefined data, the output is consistent and free from ambiguity. This is reflected in Figure 8, where the output is structured into fixed categories such as disease, symptoms, causes, and treatment. However, its accuracy drops when the input does not closely match stored patterns. On the other hand, the Generative AI approach demonstrates strong contextual accuracy. As seen in Figure 9, the output is more descriptive and tailored to the user's query. It can interpret variations in language and even incorporate visual cues from images. However, because it generates responses probabilistically, there is a possibility of minor inaccuracies or overgeneralizations.

Flexibility is another area where the two approaches differ significantly. The rule-based system is inherently rigid, as it depends on predefined rules and database entries. It cannot handle unseen queries effectively and may fail when the user provides incomplete or unusual input. In contrast, the Generative AI system is highly flexible. It can process natural language queries of varying complexity, understand context, and even engage in follow-up interactions. The conversational output format shown in Figure 9 highlights this adaptability, as it allows the system to provide detailed explanations and suggestions beyond fixed templates.

When considering side effects, the rule-based approach is generally safer and more controlled. Since it only retrieves stored information, there is no risk of generating misleading or fabricated responses. This makes it highly dependable in critical scenarios. The Generative AI approach, while powerful, may occasionally produce incorrect or non-specific recommendations due to its generative nature. These unintended outputs, sometimes referred to as hallucinations, can be mitigated through prompt design and validation mechanisms but cannot be entirely eliminated.

Finally, the speed of response varies between the two systems. The rule-based approach is typically faster because it performs simple operations such as keyword matching, scoring, and

database retrieval. These processes are computationally lightweight and executed locally, resulting in near-instant responses. In contrast, the Generative AI approach involves sending requests to an external API, processing by a large model, and returning the generated response. This introduces network latency and processing time, making it slightly slower than the rule-based system. However, the difference may not be significant in practical usage, especially with optimized infrastructure.

Parameter	**Rule-Based Approach**	**Generative AI Approach**
Cost / Token Usage	No API cost, fixed and minimal	API-based, cost increases with token usage
Accuracy	High for known cases, deterministic	Context-aware but probabilistic
Flexibility	Limited to predefined rules	Highly flexible and adaptive
Side Effects	No hallucination, fully controlled	Possible hallucinations or minor inaccuracies
Speed of Response	Very fast (local processing)	Slightly slower (API + model processing)

Table 1: Comparison of Rule Based and Generative AI Approaches

In summary, the outputs in Figures 8 and 9 clearly demonstrate the contrast between structured, deterministic responses and dynamic, conversational outputs. The rule-based approach excels in reliability, cost efficiency, and speed, while the Generative AI approach offers superior flexibility, contextual understanding, and user interaction.

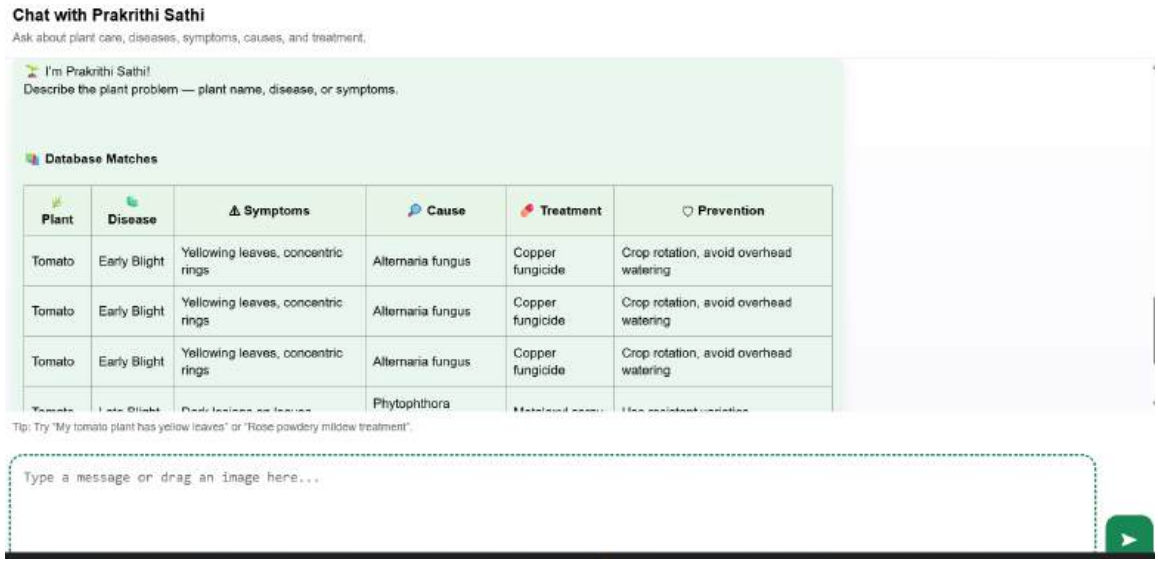


Figure 8: Output of Rule Based Approach *(Query: yellow leaves on tomatoes)*

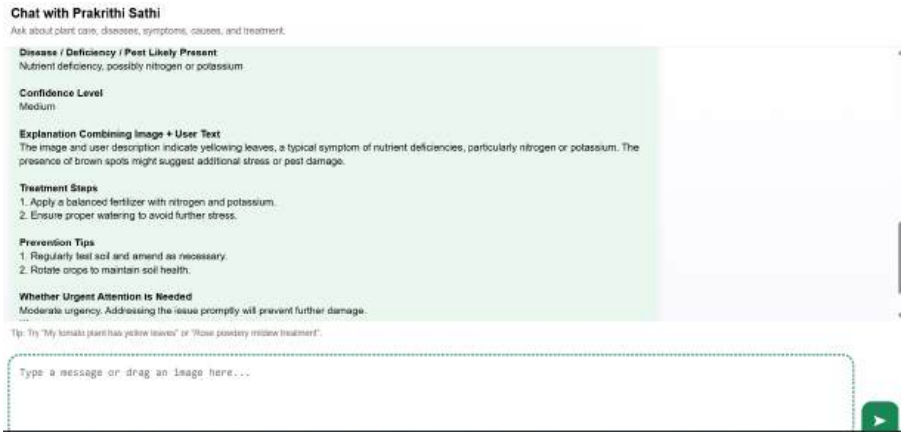


Figure 9: Output of Generative AI based approach(*yellow leaves on tomato + image*)

7. Conclusion

Prakrithi Sathi represents a meaningful step toward integrating modern artificial intelligence with everyday environmental practices such as home and community gardening. As discussed throughout this paper, the application successfully evolves from a structured, rule-based system into a more advanced, Generative AI-driven assistant capable of understanding and responding to complex user inputs. This transformation significantly enhances the system's ability to assist users who may lack formal knowledge of plant diseases or terminology, making plant care more accessible and less intimidating.

The rule-based system, built on a well-organized SQLite database and Django framework, provides a strong foundation of reliability and consistency. It ensures that responses are derived from verified information and presented in a structured format. However, its dependence on predefined data limits its ability to handle unfamiliar queries or diverse user expressions. The integration of Generative AI addresses this limitation by enabling the system to interpret natural language, analyze plant images, and generate context-aware responses dynamically. As illustrated through Figures 8 and 9, the transition from rigid, structured outputs to conversational, adaptive responses marks a significant improvement in user interaction and diagnostic capability.

Another important contribution of this project lies in its emphasis on safe and eco-friendly recommendations. By guiding the AI through carefully designed prompts (Figure 7), the system ensures that users receive practical advice that minimizes environmental harm, avoiding excessive reliance on chemical treatments. This aligns technological advancement with the broader goal of sustainable living.

Despite its advantages, the Generative AI approach introduces challenges such as dependency on external APIs, cost considerations, and the possibility of occasional inaccuracies. However, these limitations can be mitigated through prompt engineering, validation mechanisms, and hybrid integration with the rule-based database.

In conclusion, Prakrithi Sathi demonstrates how Generative AI can transform a simple informational tool into an intelligent digital companion. It highlights the potential of AI in

democratizing knowledge, supporting sustainable practices, and enhancing user engagement. Future developments can further expand its capabilities, making it a valuable resource for gardeners, farmers, and environmentally conscious communities.

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Sleep Deprivation and Subject-Specific Academic Recall in Adolescents: Evidence From a Multiday Memory Assessment By Nathaniel Chan

Abstract

Sleep deprivation is a pervasive issue among adolescents and has been associated with weakened memory consolidation and impaired academic performance. While previous research has established a relationship between sleep and academic performance, limited research has examined how sleep deprivation affects academic subjects differently. This study investigates how sleep deprivation affects STEM and humanities subject performance in adolescents and explores the impact of weekend recovery sleep and motivational factors on academic performance. This study used a mixed-methods approach combining survey data with a two-day memory recall assessment. The survey collected data on sleep habits, academic performance, and recovery sleep patterns. The memory assessment measured immediate and delayed recall of STEM and humanities material adapted from standardized academic content. The results of the study indicated that STEM subjects are more negatively impacted by sleep deprivation than humanities subjects. Additionally, subject preferences influenced recall outcomes, and weekend recovery sleep was associated with improved academic performance. These findings highlight the importance of promoting sleep hygiene habits and have implications for educational policies and school scheduling.

Introduction

Nearly three out of every four adolescents fail to obtain the recommended amount of nightly sleep, even though sleep is an integral component of human health necessary for optimal physical and mental functioning as well as for learning, memory consolidation, and academic success (Dwivedi; Lowe et al.; Banks and Dinges). Sufficient sleep facilitates memory consolidation, concentration, working memory, problem-solving abilities, and brain maturation, which is especially essential for adolescents (Wang et al.; Garcia et al.; Huberman and Poe). As a result, the American Academy of Sleep Medicine and National Sleep Foundation both recommend that adolescents aged 13-18 obtain 8-10 hours of sleep per night for optimal health and functioning (Dwivedi; Wang et al.; Garcia et al.; Banks and Dinges).

That being said, many adolescents do not get enough sleep, with approximately 73% of high school students reporting sleeping for less than 8 hours per night (Garcia et al.; Perez-Lloret et al.). Furthermore, the average sleep duration of high school students is 6-7 hours on school nights, and the average bedtime is 2:30 a.m. (Dwivedi; Garcia et al.; Hershner and Chervin). Additionally, college students also suffer from sleep deprivation, with over 70% reporting getting less than eight hours of sleep per night and experiencing tiredness or sleepiness frequently (Garcia et al.; Hershner and Chervin).

Chronic sleep deprivation is frequently experienced due to medical conditions, sleep disorders, puberty, work demands, social and domestic responsibilities, homeostatic changes, early school start times, and lifestyle (Banks and Dinges; Wang et al.; Dewald et al.).

Physiologically, adolescents and young adults tend to have a delayed circadian clock, which occurs during puberty, causing adolescents to be less tired at night (Hershner and Chervin). Another major cause of sleep deprivation is the increased evening use of electronic devices, which is closely associated with reduced sleep duration and poorer sleep quality (Wang et al.; Garcia et al.).

Sleep deprivation has been associated with cognitive impairment, motor vehicle accidents, anxiety, hyperactivity, early mortality, elevated risk for metabolic disorders, including obesity, type-2 diabetes, cardiovascular disease, depression, and psychiatric disorders (Phillips et al.; Banks and Dinges; Perez-Lloret et al.; Garcia et al.). Moreover, current findings consistently demonstrate that insufficient sleep negatively impacts memory consolidation processes, attention regulation, and executive functioning (Dwivedi; Wang et al.; Seoane et al.; Dewald et al.). On this note, sleep is essential for learning and efficient memory consolidation of both declarative/explicit knowledge and nondeclarative/implicit skills (Seoane et al.; Cunningham et al.). For this study, declarative memory will be examined in more depth.

However, sleep deprivation may be especially detrimental to certain academic subjects. Academic performance is not a uniform construct; different subjects engage distinct cognitive skills and mental processes (Wang et al.). The impact of sleep duration on adolescents' academic performance varies across different subjects. Subjects such as mathematics and science, which require high levels of cognitive processing, are especially dependent on adequate sleep (Wang et al.). Compared to math and science, language-based subjects (such as English) are less sensitive to sleep deprivation.

Thus, there is a growing debate about whether sleep deprivation impacts STEM and humanities memory recall to the same degree. And as a result, addressing the academic consequences of sleep deprivation may need to differ across subjects. This study synthesizes the existing literature on sleep deprivation and academic recall across STEM and humanities subjects and on the biological and societal implications. To investigate this discrepancy, this study will: 1) explore the memory consolidation process and memory types involved in both humanities and STEM subjects, 2) evaluate past empirical research supporting the differing effects of sleep deprivation on subjects, and 3) review proposed solutions to sleep deprivation and how these strategies may need to consider subject-specific contexts. Thus, this paper aims to answer the question: How are memory consolidation and academic performance affected by sleep deprivation in adolescents, and do these relationships differ between STEM and humanities subjects?

Literature Review

The Memory Consolidation Process

Empirical evidence demonstrates an association between sleep and the consolidation of memory, which is required for executive functioning, including abstract reasoning, goal-directed behavior, and creative processing (Dewald et al.). While sufficient sleep increases cognitive

functions, sleep deprivation impairs them (Lin et al.). In general, sleep acts as an offline mode of brain processing and the active system consolidation of memory, in which newly encoded memories become redistributed to other neuron networks for long-term storage (Born and Wilhelm). Sleep is required before learning to prepare the brain for encoding and after learning to consolidate memories and strengthen the brain's ability to change and adapt, accelerating synaptic strengthening and learning efficiency (Huberman and Walker; Lin et al., 2025). In fact, in sleep studies, sleep-deprived groups showed a 40% reduction in memory formation compared to the control group (Huberman and Walker).

FMRI studies have provided evidence that sleep transfers memories from the hippocampus to the neural cortex, enhancing long-term memory consolidation (Huberman and Walker; Born and Wilhelm). Events experienced during wakefulness are initially encoded in neocortical networks and in the hippocampus (i.e., medial temporal lobe structures) (Born and Wilhelm). Following sleep deprivation, there was a reduced recording of hippocampal activation and transfer to the prefrontal cortex (Dwivedi). Furthermore, fMRI studies showed significant reductions in hippocampal activation during memory encoding tasks and decreased functional connectivity between hippocampal and prefrontal regions in sleep-deprived compared to well-rested adolescents (Dwivedi; Banks and Dinges; Dewald et al.; Seoane et al.).

Memory Types

Long-term memory is divided into declarative/explicit memory and non-declarative/implicit memory (Born and Wilhelm). Declarative memory is further broken down into semantic memory, which refers to general knowledge, and episodic memory, which refers to individual events consciously experienced during wakefulness (Born and Wilhelm). While short-term or working memory (semantic) holds a limited amount of information for short periods of time, the episodic memory system has near-unlimited capacity (de Almeida et al.). These differences can explain why declarative memory is far more affected by sleep deprivation than procedural or implicit memories. Past studies have shown that students subjected to normal sleep had significantly higher scores for declarative memory retrieval than those subjected to sleep deprivation (El Tellawy et al.).

Sleep Deprivation and Academic Performance

Specifically, findings revealed a significant negative effect of sleep deprivation on cognitive processing for executive functioning (−0.324), sustained attention (g = −0.409), and long-term memory (g = −0.192) (Lowe et al.). In summary, sleep quality and quantity both contribute significantly to learning outcomes, with effects mediated through memory consolidation pathways (Dwivedi). Sleep experts have also identified a negative relationship between sleep disruptions and academic achievement, with students experiencing sleep disruptions showing lower grades and reduced cognitive functioning (Garcia et al.; Lin et al.; Seoane et al.). In fact, the risk of failing one or more years of school doubled in poor sleepers (Perez-Lloret et al.). Alarmingly, surveys have found that each hour of sleep loss is associated

with a 0.21 decrease in GPA (Dwivedi; Leak et al.; Phillips et al.; Hershner and Chervin). In summary, numerous studies demonstrate that students who struggle to attain the recommended amount of sleep perform worse academically compared to students who get adequate sleep.

Discrepancies Between STEM and Humanities Recall

Although there is a consensus that sleep deprivation affects academic performance, there is less understanding of how different subjects are affected by sleep deprivation. Preliminary studies hypothesize that sleep deprivation reduces adolescents' math performance, as sleep directly affects problem-solving, logical reasoning, and inferential skills (Wang et al.). Additionally, STEM subjects involve high levels of abstraction, requiring students to engage in complex deduction and reasoning at advanced cognitive levels, abilities that are severely compromised by insufficient sleep (Wang et al.). Past studies have found a correlation where each hour of sleep loss was associated with a 0.15-point GPA reduction in mathematics and science courses (Dwivedi).

Although insufficient sleep can impair humanities memory, especially in processing vocabulary and grammatical rules, language and arts subjects generally rely more on long-term accumulation and mastery, capacities that are not entirely dependent on short-term sleep duration (Wang et al.). In fact, a free recall memory study showed that free recall of words is not a sensitive task to sleep deprivation effects, corroborating that sleep deprivation does not affect short-term verbal memory or episodic memory significantly (de Almeida et al.). However, prolonged sleep insufficiency still leads to declines in language comprehension and expression abilities, specifically in analyzing complex passages (Wang et al.). These findings suggest that sleep's impact is more pronounced in cognitively demanding subjects such as mathematics and science (Wang et al.).

The Recovery Sleep Debate

Studies found that longer durations of weekend sleep are associated with higher GPAs (Leak et al.). High-school students in the United States who slept 7 hours on weekdays and weekends displayed poor academic performance, but this effect was not observed in students who extended their sleep duration on weekends (Leak et al.). Another study found that recovery sleep preserves and restores memory functioning to the level seen in typically rested individuals, as recovery sleep led to improved performance compared to sleep-deprived participants who remained awake (Cunningham et al.). Other studies, however, have found that weekend recovery sleep was insufficient to fully compensate for weekday sleep deprivation and was ineffective for performance recovery (Dwivedi). These findings are significant as sleeping in on weekends may lead to a significant improvement in cognition, memory consolidation, and academic performance, but further studies are warranted.

Research Gaps

The current literature reveals several significant gaps regarding the relationship between sleep deprivation, memory consolidation, and academic performance in adolescents. First, most studies examine overall GPA rather than subject-specific memory recall and accurate and realistic course material, limiting our understanding of how sleep affects different academic disciplines. Secondly, current studies focus on laboratory-based cognitive recall tasks rather than curriculum-aligned and standard assessments involving math, science, vocabulary, reading comprehension, and historical recall. Thirdly, there is limited research that combines self-reported sleep and academic behaviors with objective recall assessments, particularly studies comparing STEM and humanities performance within the same population.

Finally, existing research often overlooks motivational factors, study habits, and subject preferences that may influence academic outcomes independently of sleep duration. Other confounding variables include classroom environment, learning style, socioeconomic background, and prior academic achievement (Garcia et al.; Hershner and Chervin). Moreover, many studies indicate that sleep-dependent consolidation of memory is motivationally driven, and sleep duration cannot be the only indicator for academic performance (Garcia et al.; Seoane et al.). Hence, further studies are needed to evaluate the effect of sleep deprivation on other variables such as working memory or motivation (Perez-Lloret et al.).

These inconsistencies highlight the need for a study that examines sleep deprivation alongside motivational and academic variables rather than relying solely on sleep duration as the only contributor to academic performance. Thus, this study aims to address multiple major gaps in the existing literature. These gaps include the lack of subject-specific recall research, the lack of research connecting student subject preferences to academic outcomes, no consensus on the effectiveness of weekend recovery sleep, and the limited integration of sleep data with objective memory assessments. While sleep deprivation is widely recognized as a contributor to impaired cognition and academic performance, this study prioritizes an adolescent-centered and subject-specific approach to better capture how sleep deprivation influences different forms of declarative memory and academic recall. Thus, this study aims to 1) investigate how sleep deprivation affects memory consolidation and academic recall in adolescents through surveys and a two-phase memory assessment, 2) compare whether STEM recall is more vulnerable to sleep deprivation than humanities recall, and 3) evaluate whether weekend recovery sleep influences academic memory performance.

Methods & Findings

This project aims to address these gaps by combining a survey with a two-phase memory test. This approach is stronger than surveys alone because it combines perceived outcomes (students' beliefs about sleep and academic performance), behavioral data (i.e., sleep duration, fatigue, study habits), and objective recall data (memory test scores). While surveys provide insight into students' sleep habits, fatigue levels, academic preferences, and perceptions regarding memory performance, the memory assessment provides objective evidence of recall ability. Through combining subjective and objective measures, the study reduces bias and allows

cross-validation across different forms of evidence. This design directly aligns with the research question because it measures behavioral factors associated with sleep deprivation and actual test results.

This survey was designed to efficiently gather data from students in middle school, high school, and college regarding their weeknight and weekend sleep duration, academic standings, average fatigue, and subject-specific preferences. The memory test will quantitatively compare memory drop-offs between STEM and humanities material and the degree to which sleep duration is associated with STEM and humanities memory recall. The mixed-methods approach will 1) investigate how sleep deprivation affects memory consolidation and academic recall in adolescents, 2) compare whether STEM recall is more vulnerable to sleep deprivation than humanities recall, and 3) evaluate whether weekend recovery sleep influences academic memory performance. This mixed-methods approach directly addresses the study's research question. Comparing self-reported sleep data with objective recall outcomes enables the study to evaluate both the overall academic effects of sleep deprivation and whether certain subjects demonstrate greater vulnerability than others.

Variable Type	Variable	Measurement
Independent Variable	Weeknight Sleep Duration	5 or fewer, 6-7, 7-8, 8-9, 9+ hours
Independent Variable	Weekend Sleep Duration	5 or fewer, 6-7, 7-8, 8-9, 9+ hours
Independent Variable	Weekend Recovery Sleep	Extra sleep duration in comparison with weeknights
Dependent Variable	STEM Recall Difficulty	Likert Scale
Dependent Variable	Humanities Recall Difficulty	Likert Scale
Dependent Variable	Immediate STEM Test Score	Number of correctly recalled STEM questions
Dependent Variable	Immediate Humanities Test Score	Number of correctly recalled humanities questions
Dependent Variable	Follow-up STEM Test Score	Number of correctly recalled STEM questions
Dependent Variable	Follow-up Humanities Test Score	Number of correctly recalled humanities questions
Control Variable	Baseline STEM Motivation	Likert Scale
Control Variable	Baseline Humanities Motivation	Likert Scale

Figure 1: The table below summarizes the key operationalized variables measured in this study

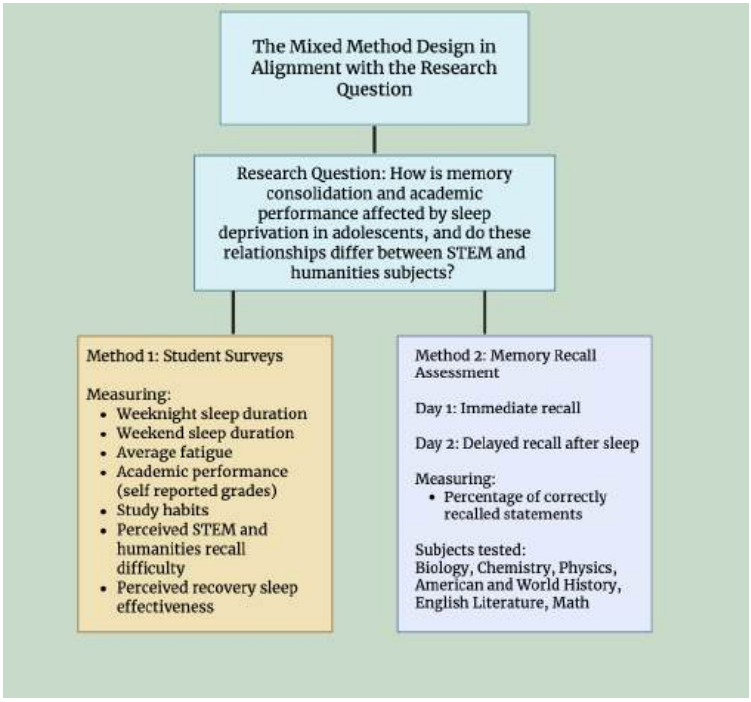
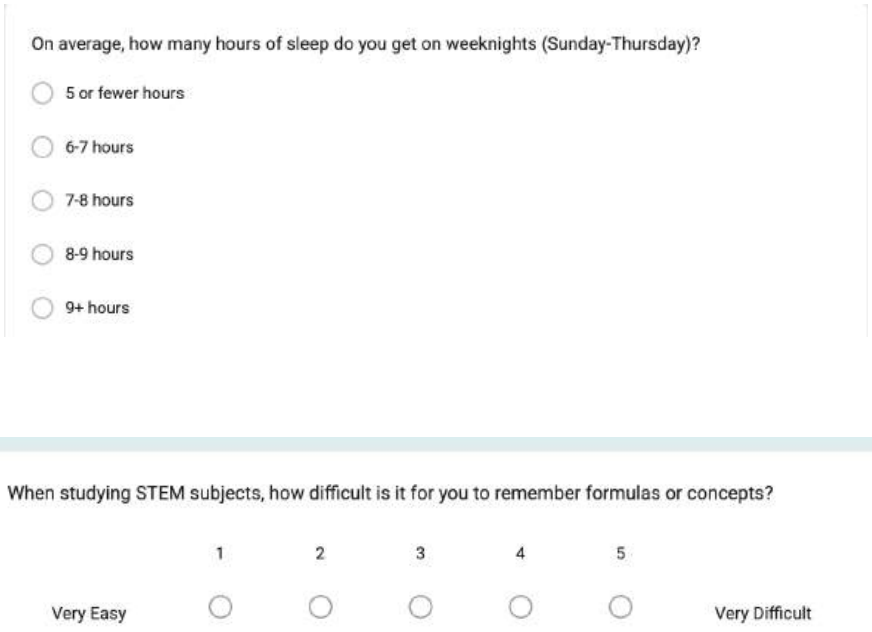


Figure 2: A flowchart breaking down the research design and alignment with the research question

Surveys

A structured, anonymous survey was developed to collect self-reported perspectives on sleep habits, sleep deprivation, recovery sleep, memory recall, and academic preferences. This survey incorporates Likert scales (ranging from 1: strongly disagree to 5: strongly agree) and multiple-choice questions to ensure standardized results. Key topics included were repeatedly referenced in the current literature.

Participants included middle school students, high school students, college students, and graduate students. Survey administration was conducted through a combination of personal, professional, and cold contacts. The survey was administered electronically through the secure online platform Google Forms, and respondents were presented with an informed consent statement outlining the study's purpose, voluntary participation, anonymity, and data storage procedures. Respondents were required to record their age range as either an adult (18+) or a minor (11-17). Adult (18+) participants were provided a condensed informed consent form with an agree/disagree statement after reading the terms and conditions of the study. Minors (ages 11-17) were required to have a parent or guardian review and sign the terms and conditions. A similar informed consent form was created for the memory assessment. Demographic information, including the respondent's occupation and age, was collected at the start of the survey. The survey received a total of 362 responses.



Figures 3 and 4: Two sample questions from the administered survey. These questions utilized a mix of both Likert scales and multiple-choice questions.

The first set of questions was centered around sleep habits (*e.g., on average, how many hours of sleep do you get on weeknights? (Sunday-Thursday*). The next section was focused on academic performance *(e.g., what are your typical grades?)* and preferences meant to measure motivational factors (*e.g., which subjects do you usually perform best in academically?*). The last set of questions focused on memory (*e.g., which type of recall is easy for you?)* and sleep recovery *(e.g., if applicable, do you think increased sleep on the weekend improves your academic performance during the week?).* Each of these categories covers areas that connect sleep deprivation to subject-specific academic performance but has been under-researched in the current literature.

Survey Analysis

To start, the raw, unfiltered survey data was exported to a Google Sheet. Data was anonymized and listed in a random order on the Google Sheet to mitigate bias. Of the questions asked in the survey, the Google Sheet highlighted topics including the average amount of sleep on weeknights and weekends, average course grades, average fatigue scale, and relative STEM and humanities enjoyment, which were used in further steps. Non-highlighted boxes indicated either insufficient data or answers that came from identifying questions, such as age or occupation.



Amount of Sleep (Weeknights)	Grades	GPA
6-7 hours	Mostly A's	3.5–4.0
5 or fewer hours	Mostly A's	3.5–4.0

Figure 5: The image illustrates a section of how the survey data was organized. In this section, the highlighted boxes indicate columns that will be used for graphing and drawing conclusions.

Next, the chosen data sets were grouped based on similar themes, with the left-hand columns representing the x/independent variables and the right-hand columns representing the y/dependent variables. These paired variables were informed by the research aims and gaps in the literature and were operationalized for graphing. Specifically, variables including average fatigue and grades utilized Likert scales ranging from 1 to 5 in order to quantify values.



Enjoy STEM Yes: 3 Unsure/Maybe: 2 No: 1	Difficulty Recalling STEM Material Very Easy: 1 Very Difficult: 5	Enjoy Humanities Yes: 3 Unsure/Maybe: 2 No: 1	Difficulty Recalling Humanities Material Very Easy: 1 Very Difficult: 5
3	2	1	4
3	1	2	2

Figure 6: An example of two sets of related values that will be graphed in a scatterplot.

Finally, this study utilized the built-in Google Sheets chart function to graph scatterplots and generate lines of best fit from the provided data. For some questions, including "which subject is more affected by sleep deprivation" and "does weekend recovery sleep improve academic performance," pie charts were used instead to measure response frequencies.

Survey Findings

Figures 7 to 9 focus on sleep deprivation and subject-specific memory recall. The findings support the hypothesis that sleep deprivation disproportionately affects STEM-related recall compared to humanities recall.

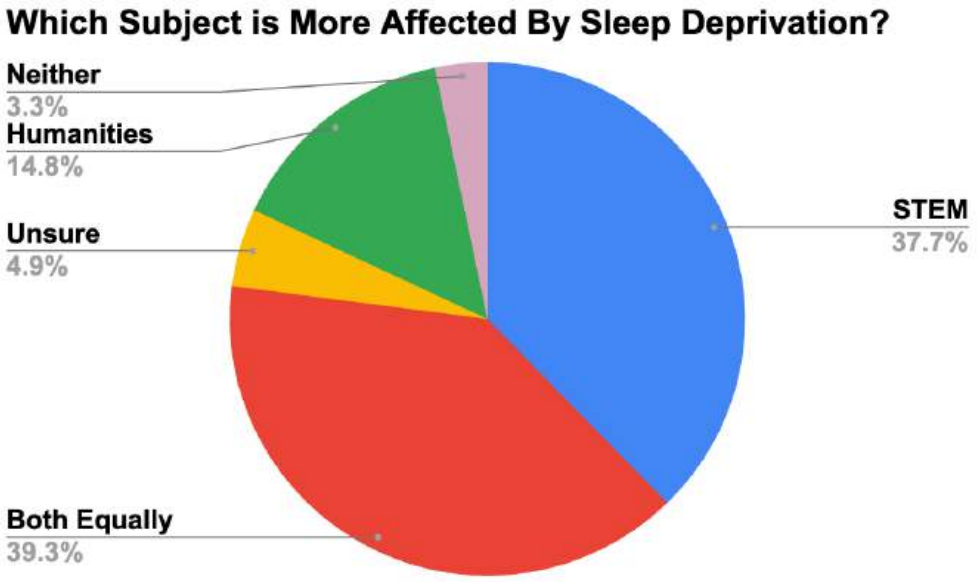


Figure 7: Respondents more frequently identified STEM subjects as being more negatively affected by sleep deprivation than humanities subjects. These findings are consistent with preliminary findings proposing that STEM subjects are more vulnerable to sleep deprivation due to a higher reliance on executive functioning, logical reasoning, and complex problem-solving processes.

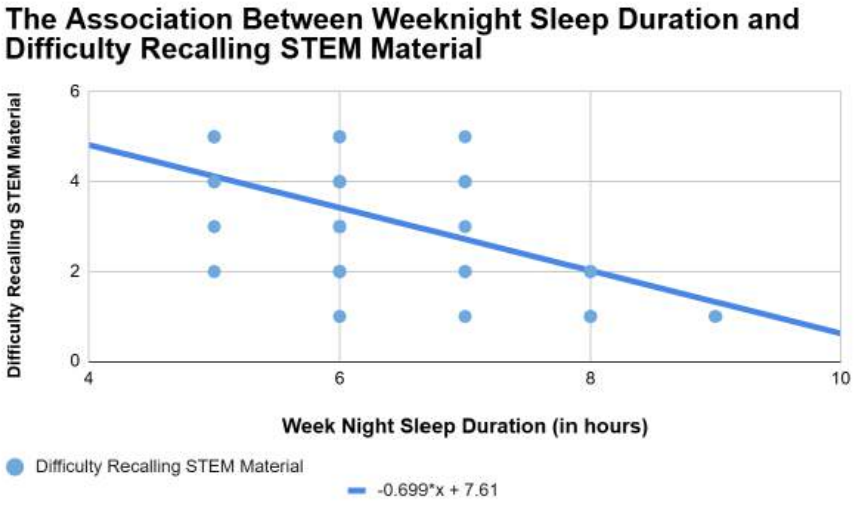


Figure 8 examines the relationship between weeknight sleep duration and difficulty recalling STEM material. The graph shows a negative relationship, indicating that shorter sleep duration is correlated with increased difficulty recalling formulas and scientific concepts. This suggests that STEM performance is highly dependent on adequate sleep.

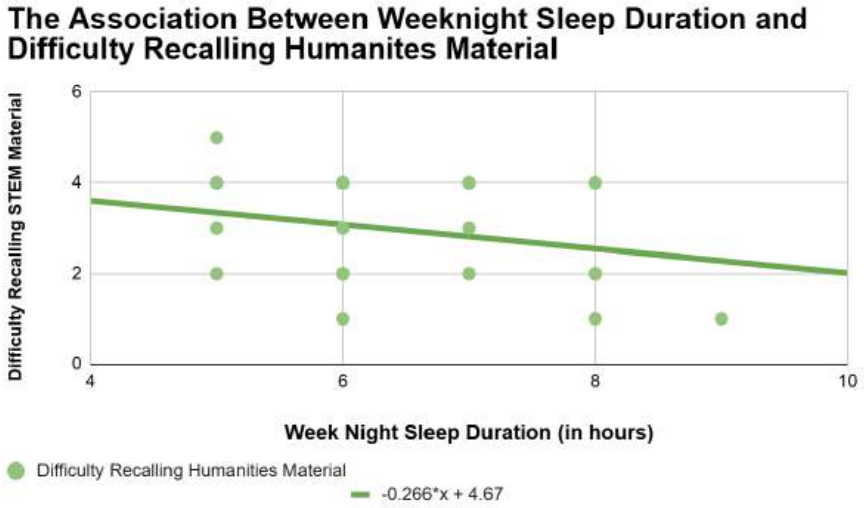


Figure 9 evaluates the relationship between sleep duration and difficulty recalling humanities material. Although the graph still demonstrates a relationship between reduced sleep and increased recall difficulty, the trend appears less pronounced than in the STEM graph.

While the slope of Figure 8 (STEM) was -0.699, the slope of Figure 9 (humanities) was only -0.266, which is substantially weaker. This supports prior research suggesting that humanities subjects rely more heavily on accumulated long-term knowledge and verbal comprehension, whereas STEM subjects require more active executive processing and working memory. Figures 10 and 11 examine the influence of prior subject preferences and motivation on recall difficulty across STEM and humanities subjects.

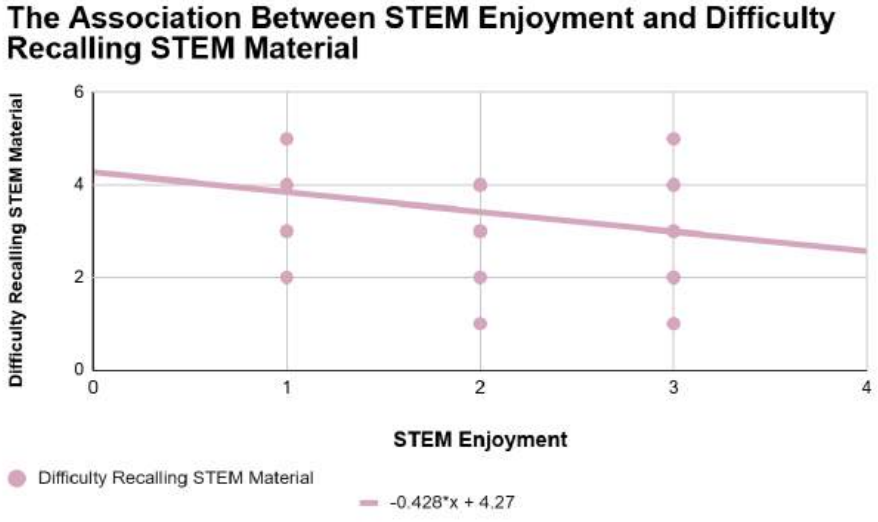


Figure 10: Students who reported greater baseline enjoyment of STEM subjects generally experienced less difficulty recalling STEM material.

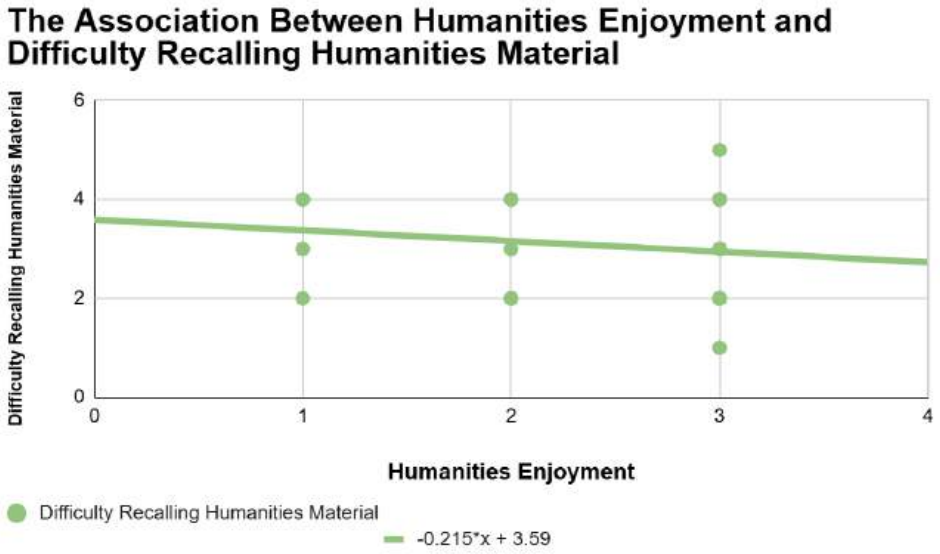


Figure 11: Students who preferred humanities subjects reported lower levels of humanities recall difficulty. These findings help address a key research gap: motivational and subject preferences may influence academic performance, regardless of sleep duration.



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Figure 12: There is a slight positive relationship between additional weekend sleep and higher grades. This suggests that weekend recovery sleep may partially alleviate the cognitive effects of weekday sleep deprivation.

Overall, the survey findings support the current literature connecting sleep deprivation with impaired cognition and academic performance. The results provide preliminary evidence that STEM recall may be more vulnerable to sleep deprivation than humanities recall. However, a few of the observed relationships were moderate, indicating that additional factors, including motivation, study habits, and prior academic preference, likely contribute to subject-specific academic performance alongside sleep duration.

Memory Recall Assessment

In conjunction with the administered surveys, a two-day optional memory recall assessment was administered. This test was meant to address the limitations of self-reported survey responses designed to measure declarative memory performance across subject domains (STEM vs. humanities) under varying sleep conditions. This test also aimed to address the research gap of a few studies that directly compare subject-specific memory performance.

The test was structured to take place over two days. The day-one diagnostic test took a total of 10 minutes, with a 1-minute pre-administration questionnaire, a 4-minute encoding phase, a 1-minute distraction phase (to prevent short-term memory recall bias), and a 4-minute immediate recall phase. The day-two test would resume the following day after a typical night of sleep. This follow-up test only included a 4-minute recall stage of the same material from day 1.

Prior to testing, participants were asked the following question (on average, how many hours of sleep do you get on weeknights (Sunday-Thursday)?) in order to establish a baseline sleep duration. Additionally, participants were asked to submit a nickname or alias in order to compare test scores across days while preserving anonymity.

After completing the identifying questions, participants were exposed to a series of STEM and humanities statements. Subjects included Math, Biology, Chemistry, Physics, History, and Literature. Specifically, each participant was presented with three STEM formulas, three STEM facts, three vocabulary words, three historical facts, and a short reading passage. Specific topics tested included photosynthesis, chemical bonding, the definition of the derivative, the displacement formula, and ancient trade routes. The testing material was sampled from the SAT and AP exams (AP Biology, AP Chemistry, AP World History, AP US History, AP Literature, AP Physics 1, AP Calculus AB). The memory assessment received a total of 140 responses. To minimize content-specific bias, questions were selected from multiple STEM and humanities disciplines rather than a single subject area. Although ensuring perfect difficulty equivalence cannot be guaranteed, this approach is intended to provide a broader measure of subject-specific recall.

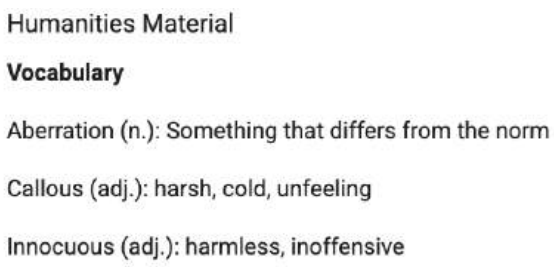


Figure 13: Sample test statements as they were presented in the memory assessment.

Following a one-minute distraction phase to ensure participants weren't simply relying on short-term memory, they were asked to recall as much material as they could. Participants were asked to manually type answers to questions based on the material presented earlier.

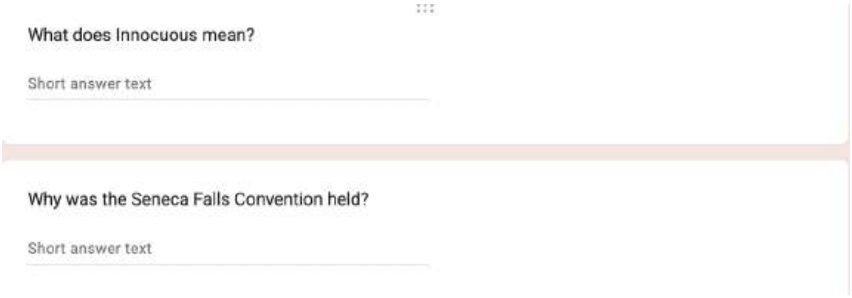


Figure 14: A set of questions asked in the second section of the memory assessment

The following day, participants retook the memory recall test to evaluate the effects of sleep on memory consolidation and academic recall. They were presented with the same questions as on the first day.

Memory Assessment Data Analysis

Similar to survey analysis, memory assessment results were first exported from Google Forms to a Google Sheet. In this Google Sheet, each question asked on the test was listed in a separate column. Boxes were highlighted in green, denoting a correct answer, and red, denoting an incorrect answer. The total number of correct answers per respondent was then marked in a designated column. This process would be repeated for day 2, and aliases were used to pair day 1 and day 2 results while preserving anonymity.

Next, the number of correct questions was divided by the total number of questions per section. For instance, a STEM score of 5 out of 6 would be recorded as an 83, while a 4 out of 7 on the Humanities section would be recorded as a 57. The average hours of sleep on weeknights were then compared to these percentages to generate scatterplots and lines of best fit. STEM and humanities scores were compared with the average weeknight sleep duration.

For comparing day 1 STEM results to day 2 STEM results and day 1 humanities results to day 2 humanities results, a separate column was created. Day 1 results were listed in the left-hand columns, and day 2 results were listed in the right-hand columns. A table was generated to compare score changes for each subject over the two days.

Memory Recall Assessment Results

Figures 15 to 17 summarize the memory assessment results comparing sleep duration to subject-specific recall performance and measuring changes in declarative memory retention across the two-day testing period. Unlike the survey findings, which relied on self-reported perceptions of recall difficulty, the memory assessment provides objective quantitative evidence of how sleep duration relates to subject-specific memory performance. In summary, the findings suggest that insufficient sleep was more associated with reduced STEM memory recall than humanities memory recall.



Figure 15: The relationship between average weeknight sleep duration and the percentage of STEM questions answered correctly during the memory assessment. The scatterplot shows a positive relationship between sleep duration and STEM recall accuracy, indicating that participants who reported longer average weeknight sleep generally performed better on STEM-related memory tasks. The tasks were designed to assess declarative recall and cognitive processing. The upward slope demonstrates that STEM performance may be strongly correlated with hippocampal-dependent consolidation and executive functioning processes that are vulnerable to sleep deprivation. This finding also aligns with the survey results, indicating that participants perceived STEM recall as more negatively affected by insufficient sleep.

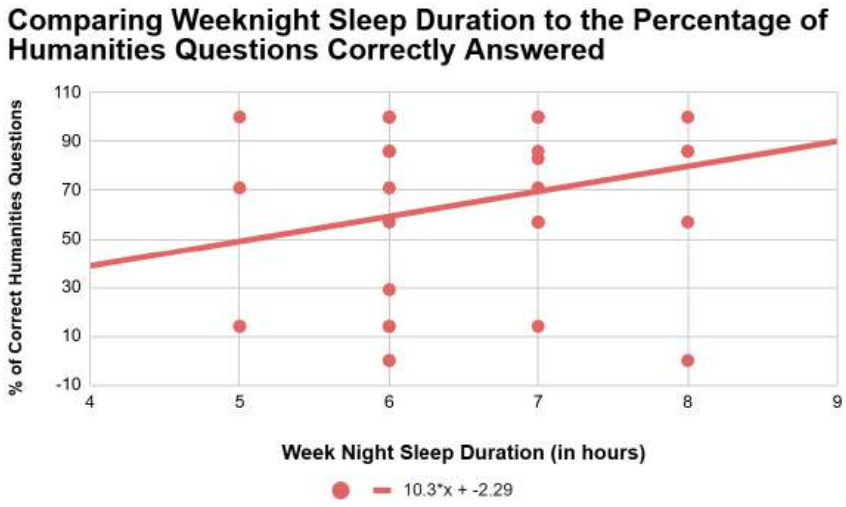


Figure 16: The association between average weeknight sleep duration and the percentage of humanities questions answered correctly. As opposed to the STEM results, the relationship appears significantly weaker, suggesting that humanities recall was less directly influenced by differences in sleep duration. While the slope of Figure 15 (STEM) was 25.8, the slope of Figure 16 was only 10.3.

The trendlines indicate that increased sleep duration was not as strongly associated with changes in humanities recall performance as it was for STEM. These findings support the study's hypothesis and preliminary literature, which argue that humanities subjects rely more heavily on accumulated semantic knowledge, which may be less impaired by sleep deprivation. These graphs suggest an association between reduced sleep duration and lower STEM recall performance, supporting the hypothesis that STEM subjects may be more vulnerable to sleep deprivation than humanities subjects.

Subject	Day 1 Mean Percentage of Questions Correctly Answered	Day 2 Mean Percentage of Questions Correctly Answered	**Change in Mean Percentage of Questions Correctly Answered**
STEM	76.2 %	47.3%	**-28.9%**
Humanities	65.7 %	65.7 %	**0 %**

Figure 17: A comparison of the mean recall across days one and two for both subject groups. STEM recall showed a significant decline between days one and two, decreasing from a mean score of 76.2% on day one to 47.3% on day two, a 28.9% decrease in correct responses. Meanwhile, humanities recall remained relatively stable across both testing days. The mean score of day one was 65.7%, which was the same for day two. This consistency suggests that humanities material may be less dependent on sleep duration.

Overall, the memory assessment findings provide objective support for the observed survey trends. These findings strengthen the argument that sleep deprivation does not impair all academic memory equally and that subject-specific cognitive demands significantly influence vulnerability. That being said, these findings should be interpreted cautiously due to the relatively small sample size and potential confounding variables such as baseline subject familiarity and differences in study habits. Nevertheless, the results provide evidence that adolescent sleep deprivation may disproportionately weaken STEM-related academic recall.

Discussion & Conclusion

The purpose of this study was to investigate how chronic sleep deprivation affects memory consolidation and academic performance in adolescents and whether these relationships differ between STEM and humanities subjects. Specifically, this project aimed to 1) examine how sleep deprivation influences declarative memory and academic recall through surveys and a two-phase memory assessment, 2) compare whether STEM recall is more vulnerable to sleep deprivation than humanities recall, and 3) evaluate whether weekend recovery sleep influences academic memory performance. To address these aims, this study utilized a mixed-methods approach combining survey responses with memory recall assessment data.

The study's findings contribute to a new understanding of the field of sleep research. Specifically, this study argues that sleep deprivation does not impair all academic recall ability

equally. The results suggest that STEM recall is more vulnerable to sleep deprivation than humanities recall. Both survey and memory assessment results illustrate stronger negative associations between sleep deprivation and STEM memory performance. This pattern suggests that STEM learning may be more vulnerable to disruptions in memory consolidation, supporting the argument that sleep deprivation does not impair all academic performance equally. These findings support and add to the existing literature arguing that STEM subjects significantly rely on executive functioning, logical reasoning, working memory, and abstract cognitive processing, which are heavily impacted by sleep deprivation (Lowe et al.). While previous studies frequently examined overall GPA, this study compared STEM and humanities recall directly within the same participant population. The results provide evidence that academic performance should not be viewed as a single uniform outcome.

Conversely, humanities recall remained stable, suggesting that these subjects rely more on accumulated semantic knowledge that may be less vulnerable to sleep deprivation. The stability in humanities recall supports the hypothesis that humanities subjects may be less vulnerable to sleep deprivation than STEM subjects. Nevertheless, the humanities questions may have been less cognitively demanding or easier than the STEM questions, which would impact results. Furthermore, participants may have had greater prior exposure to vocabulary, historical concepts, and reading comprehension, which would allow them to rely more on preexisting knowledge rather than newly consolidated memories.

The findings also provided insights into motivational and behavioral confounding variables. Motivational variables significantly impacted recall performance. Respondents who were more interested in STEM experienced less difficulty recalling STEM material, and vice versa for the humanities. This supports prior literature suggesting that sleep duration cannot be the only contributor to academic performance (Garcia et al.). Survey findings also indicated that there was a slight positive correlation between additional weekend sleep and higher grades, aligning with studies suggesting that recovery sleep may partially restore cognitive functioning and memory performance (Cunningham et al.; Leak et al.). Recovery sleep should not be viewed as a substitute for consistent sleep habits, but the results indicate students may experience measurable academic benefits from additional weekend sleep, warranting further investigation into its effectiveness as a real-world intervention.

Implications & Recommendations

These findings have significant implications for policymakers, school administrators, teachers, parents, students, and researchers. Specifically, these findings contribute to broader discussions surrounding adolescent health, educational equity, and school policy. Firstly, the findings support the recommendation of adequate sleep, particularly for cognitively demanding STEM subjects. To address this issue, later school start times may be effective and have been widely suggested among the scholarly community (Dwivedi; Hershner and Chervin; Leak et al.). These findings emphasize the importance of better aligning school start times with adolescent circadian rhythms to reduce the effects of sleep deprivation and improve academic performance.

Furthermore, the results of this study argue that schools and policymakers should reconsider the timing of cognitively demanding coursework and assessments. Administering assessments at suboptimal times of the day may impair performance, especially in STEM courses that require higher levels of executive functioning (Dwivedi). Since STEM subjects are more vulnerable to sleep deprivation, schools should avoid scheduling STEM examinations during early morning periods when students are most likely to experience the greatest effects of sleep deprivation.

In addition to policy changes, sleep hygiene education should be a top priority among educators and parents. Prior literature has argued that improved sleep hygiene practices may benefit adolescents and learning outcomes (Hershner and Chervin). In fact, students enrolled in STEM-heavy coursework may particularly benefit from sleep interventions compared to students enrolled primarily in humanities courses. These interventions could include limiting nighttime electronic device use, encouraging consistent sleep schedules, and increasing awareness regarding the cognitive consequences of chronic sleep deprivation.

Limitations

Despite this study's contributions to the literature on sleep deprivation, memory consolidation, and adolescent academic performance, several limitations must be acknowledged. Firstly, the survey relied on self-reported data, such as average sleep duration, academic performance, fatigue, and study habits. While self-reporting helped expand the survey's reach and increased the response rate, self-reported measures are inherently vulnerable to recall bias, response bias, and subjective interpretation. Respondents may have overestimated or underestimated their sleep duration or fatigue, especially given that this survey was administered during final exam season. Moreover, participants' perceptions regarding whether STEM or humanities subjects were more affected by sleep deprivation may have been influenced by personal experiences and subject preferences. Likert scales were used to standardize results, but the responses still remain subjective. Secondly, future studies should incorporate statistical analyses, including correlation coefficients, regression models, confidence intervals, and statistical testing (p-values), to determine whether observed differences between STEM and humanities recall are statistically significant.

Additionally, controlling for confounding variables associated with academic performance proved to be challenging. While this study attempted to account for motivational factors and subject preferences, other factors, including classroom environment, study strategies, stress levels, socioeconomic background, and baseline intelligence, are also at play (Garcia et al.; Hershner and Chervin). For instance, students with better organizational skills may excel despite reduced sleep. Similarly, early risers may be more motivated or organized, or students with late-night preferences may be unable to wake up earlier (Hershner and Chervin). On this note, Wang et al. argue that higher-achieving students may demonstrate greater resilience to short-term sleep deprivation, allowing them to fall back on acquired learning strategies and prior knowledge.

The study's short duration also limits the interpretation of the findings. Although the two-day memory assessment design achieved its goal of collecting adequate responses, the results may not account for long-term sleep habits. The current findings may underestimate the cumulative cognitive and neurological effects associated with chronic sleep deprivation over time. Thus, future longitudinal studies are needed to determine whether chronic sleep deprivation produces larger impacts on memory consolidation and academic performance in adolescents.

Lastly, this study cannot establish causal relationships between sleep deprivation and subject-specific academic outcomes. External variables, including mental health, stress, nutrition, family environment, school quality, and time-management skills, may have contributed to the observed relationships. As a result, the findings should be seen as an association between sleep deprivation and memory recall rather than definitive evidence that insufficient sleep alone causes decreased STEM performance.

Future Directions

Future research should address the methodological limitations present throughout this study. Firstly, future studies should incorporate significantly larger and more representative participant populations across different geographic regions, socioeconomic groups, and educational settings. This would strengthen the reliability of findings and allow researchers to examine differences, including variations by grade level, academic achievement, gender, and socioeconomic status. Specifically, future studies should investigate whether lower-performing students experience greater cognitive vulnerability to sleep deprivation than higher-achieving students, as proposed in the existing literature (Wang et al.).

Next, future research should incorporate more objective physiological measures of sleep rather than relying solely on self-reported sleep duration. These experiments could utilize actigraphy watches, sleep-tracking devices, electroencephalography (EEG), and polysomnography. Because memory consolidation is strongly associated with SWS, measuring biological sleep architecture directly may provide better insights into how specific sleep stages influence subject-specific academic recall. Likewise, longitudinal research designs could lead to more conclusive results. While this study examines recall over two days, longitudinal studies could follow adolescents over a period of months or years, which would help provide a more comprehensive understanding of how chronic sleep deprivation influences academic trajectories over time. Moreover, longitudinal studies would allow researchers to evaluate whether policy interventions, such as delayed school start times, produce measurable benefits.

Another important aim for future research should involve exploring different forms of memory other than declarative memory. Future investigations should compare how sleep deprivation affects procedural memory, emotional memory, working memory, creativity, and problem-solving ability across academic disciplines. Additional studies should also investigate whether semantic memory and episodic memory are equally vulnerable to sleep deprivation.

Finally, future studies should evaluate interventions designed to improve adolescent sleep and academic performance. Although this study presents later school start times, sleep hygiene

education, and recovery sleep as possible solutions, more experimental studies are needed to evaluate which interventions produce the greatest improvements in cognition and learning outcomes. These recommendations directly address several research gaps identified, including the limited study of subject-specific recall, the lack of objective sleep measures, and the debate around recovery sleep. Future studies can build upon these findings and provide a more comprehensive understanding of how sleep influences memory across academic disciplines. By integrating biological, neurological, social, and educational perspectives, future research can provide more comprehensive strategies for addressing the adolescent sleep deprivation crisis and improving long-term cognitive health and academic success.

This study provides evidence that sleep deprivation does not affect all forms of academic recall equally. Across both survey responses and objective memory assessments, STEM-related recall demonstrated greater sensitivity to reduced sleep duration than humanities recall. These findings suggest that academic disciplines relying heavily on executive functioning, working memory, and complex reasoning may be particularly vulnerable to the cognitive consequences of sleep deprivation. Despite motivational factors, prior knowledge, and study habits also contributing to academic performance, the results reinforce the critical role of sleep in memory consolidation and learning. As adolescent sleep deprivation continues to be a widespread public health concern, educators, policymakers, and families should prioritize strategies that promote healthy sleep habits and support optimal cognitive functioning.

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Design and Evaluation of SpineAlign: A Wearable Posture Monitoring Device for Scoliosis Management By Jeanne Brigit Judy

Abstract

Bad posture is prevalent in today's society as technology is starting to consume individuals, playing part in diseases such as scoliosis. However, good posture can improve the condition of specific scoliosis conditions. My research paper revolves around a device I engineered called SpineAlign, which targets bad posture and alerts the user when their posture isn't neutral. By using two gyroscopes that sense angle changes, and an Arduino, this device beeps if the difference of angles measured initially and the newly measured angles exceed a threshold of 10 degrees for leaning, 12 degrees for slouching, or 7 degrees for hip tilts. This device sends the data to a local host website that generates charts to record user data. After a week of pilot study, the average leaning left angles of two participants decreased by 1.123 degrees per day, the leaning right decreased by 1.095 degrees per day, and the slouching decreased by 0.408 degrees per day. Additionally, according to the bar chart, slouching events were more prevalent. Results show the device was highly efficient in reducing leaning angles, and moderately efficient in reducing slouching angles. Hip tilt measurements were also not recorded because of the rigidity of structural support the device was mounted on. Without the structural support, hip tilts can be accurately measured, so in future prototypes, the device will be mounted on a flexible item. This pilot study shows how SpineAlign can be a cost-effective device, used to improve bad posture, ultimately reducing functional/degenerative scoliosis, and helping to manage side effects of structural scoliosis.

1. Introduction

"Each year, 442,900 office visits, 133,300 hospital visits, and 17,500 emergency room visits are made by children with scoliosis" ("Scoliosis Statistics"). Throughout the world, these statistics are very real, not only to children, but to all ages affected by scoliosis. Many are forced to undergo expensive and dangerous surgeries while others are confined to wearing an uncomfortable brace their whole life. Scoliosis is the abnormality of the curvature of the spine, leading to further complications such as hip tilt, shoulder imbalance, and back pain. If this abnormality is so harmful to individuals, why aren't there efforts to try and prevent and eliminate scoliosis? Why do some medical experts claim "there is no cure" instead of encouraging practices to help with this situation? All these questions may be left unanswered, but there is something that scoliosis is rooted within. Something that is not given enough importance due to our everyday lifestyle. Something that is heavily overlooked but just may be a life line for patients with scoliosis. This is a concept very familiar with individuals, yet treated so insignificantly: posture. A research study from the National Library of Medicine shows "relations between desk heights and the risk of AIS for the first time…producing new evidence of associations between postural habits and AIS risks" (Yang). Despite scoliosis being deemed incurable, posture plays a crucial role in the intensity of the spinal curve implying that

maintaining good posture can be beneficial to patients with scoliosis, as well as preventive in some cases.

2. Background

Maintaining a good posture helps relieve any pain associated with scoliosis and the spinal curve. Enduring pain every day due to the abnormality of one's spinal curvature isn't ideal. Luckily, posture plays a great role in relieving that pain by relieving the muscles. "The consistent alignment of your body can relieve the pressure on your spine and nerves, reducing muscle spasms and overall discomfort" (Philips). Posture plays a key role in how our spine curves. It helps the muscles align, and nerves relax, and the spine to retreat back to its natural state. Most of the pain and discomfort that patients with scoliosis experience comes from tensed muscles and pinched nerves. Good posture can stretch out those muscles as well as the spine to minimize the painful side effects. The more good posture is practiced, the more stretched and aligned your muscles and spine will be, relieving pain. Additionally, the back muscles will be strengthened allowing for more spinal support ("Yoga for Scoliosis: 4 Poses to Try"). The greater the spinal alignment, the greater the pain relief due to the greater structural support. However, the opposite can occur if posture is not maintained. "[P]oor posture uses high amounts of energy, which means our bodies need to rest for longer to recover" ("Posture and Positioning"). To add to the importance of maintaining good posture, if the opposite is done, the body has to pay great prices. The worse the posture, the more the pain. Additionally, "[p]oor posture can put a strain on the body causing pain and muscle tightness or weakness and can even change the way you move, meaning you aren't able to move as much or in a variety of ways" ("Posture and Positioning"). The main cause of pain is tightness and inflexibility. Poor posture induces these aspects into one's life, increasing the intensity of the pain. In order to maintain a healthy spine, one's back must remain flexible and strong, achievable with good posture, but out of reach with poor posture. Good posture helps establish long-term muscular strength that helps contradict the damaging pull of gravity, something causing the progression of scoliosis curves. Though many may not believe it, posture truly does play an important role in helping patients of scoliosis by relieving their pain, something most patients have to endure inevitably.

Good posture can also maintain spinal health and muscle imbalances, which are two key factors for scoliosis. Other than inflexibility, and weakness of muscles, another cause of scoliosis includes the joints of the spine. "As the spine ages, wear and tear on the spinal discs and joints can result in scoliosis" ("Scoliosis Stretches"). Like always, posture can help prevent the wear and tear of the spinal discs as it "can positively impact the alignment of the back" ("Scoliosis Stretches"). Maintaining posture helps keep the spine aligned and the joint aligned, negating the "inevitable" effects of aging. Likewise, posture can help with muscle imbalances which can also lead to complications such as scoliosis. "Specifically, the side that curves outward (called the convex side) often becomes overactive, while the side that curves inward (the concave side) is typically weaker and underactive" ("Strength Training with Scoliosis"). By maintaining proper posture and the alignment of the spine, the individual can reduce their muscle imbalance by

allowing both sides of the back to grow and strengthen equally. The more aligned one's back is, the more aligned the muscles are, allowing for the elimination of muscle imbalances. This helps mitigate further complications such as hip tilts and shoulder imbalances, often associated with scoliosis. By increasing the alignment of the spine to keep the spinal joints healthy, and by aiding muscle imbalances, posture is continuously shown to be vital for managing scoliosis.

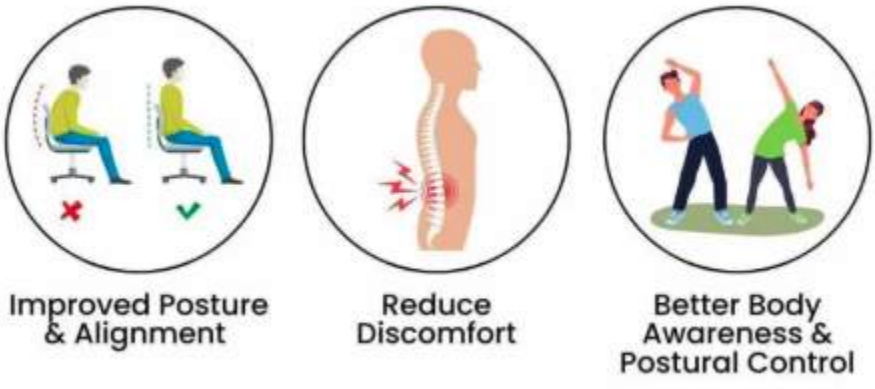


Figure 1: Benefits of Good Posture

Despite the many amazing benefits to posture and scoliosis, there are some limits to be acknowledged. There are three main categories for scoliosis: idiopathic, structural, and functional scoliosis. Idiopathic scoliosis is when there is no known cause for the curvature of the spine and it isn't reversible. Structural scoliosis "involves spinal rotation in addition to the side-to-side curvature of the spine. This type of scoliosis affects the spine's structure and is considered permanent unless the spine receives treatment" (Baaj). There are many types of structural scoliosis including neuromuscular scoliosis due to muscular dystrophy, congenital formed in the embryo, and degenerative which is due to the degrading of the spine. (Baaj). Functional scoliosis "results from a temporary cause and only involves a side-to-side curvature of the spine (no spinal rotation). The spine's structure is still normal" (Baaj). Posture can aid with functional scoliosis as it is temporary. It can help with pain, muscle flexibility, and spinal alignment. Posture can also help prevent or slow down degenerative scoliosis because it can reduce wear and tear of the spinal discs due to spinal aging. However, there are some areas where posture cannot be useful to eliminate the curvature, but can be used to manage the pain and muscle imbalances. Many treatments such a Schroth therapy help maintain posture for these reasons, so that the patients can relieve their pain even if they are unable to remedy the curvature. According to a study done on Schroth Therapy, the results indicated "Schroth Exercise treatment added to standard care (observation or bracing) reduced asymmetry measurements in AIS" (Mohamed). Despite the limitations of posture's ability to help scoliosis patients, it has a great impact on any situation, small or big, making it an important unnoticed factor of life.

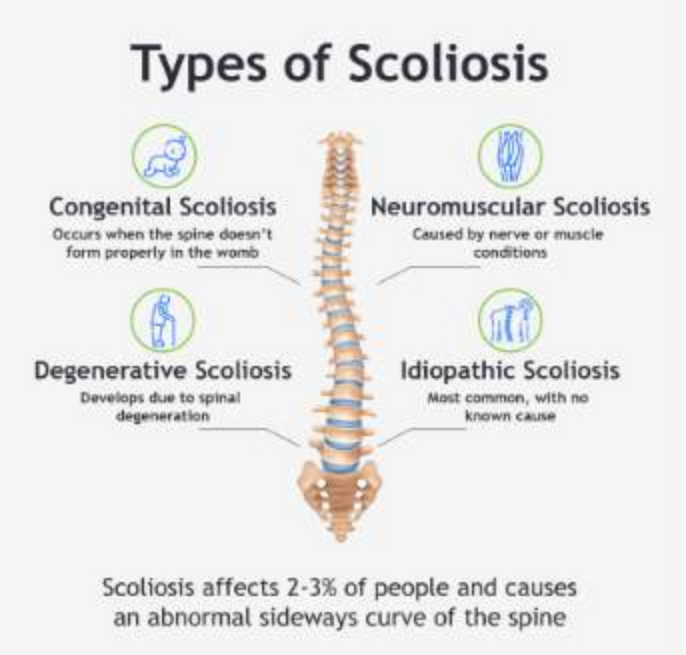


Figure 2: Types of Scoliosis

There have been numerous attempts to fix this problem which include wearable posture correctors made by companies such as AlignMed and BetterBack. All of these posture braces allow the user to sit straight for the time that brace is being used. However, since most of these braces are deemed flexible enough to induce comfort, they also allow for slight misalignments and slouching. If one wants to maintain their posture for a prolonged period of time, getting used to slightly slouching can be detrimental to prolonged results. That is why a device that alerts the user of bad posture is more beneficial than a simple brace. This device of my creation, SpineAlign, allows the user to maintain their posture as it alerts them whenever they lean or slouch the slightest. Though there are some prototypes available to the public that work accordingly, the cost and reliability are detrimental factors. SpineAlign, on the other hand, is reliable, as it shows the user their posture progress on a website and is cost-effective, made with simple materials. Additionally, most prototypes only alert the user when they slouch, but scoliosis can affect the lower back as well, which is why SpineAlign monitors one's hip tilt in addition to leaning and slouching.

SpineAlign is centered with an Arduino Uno, the motherboard that processes all information. It is connected to two MPU6050 inertial measurement unit sensors, also known as gyroscopes, that detect the pitch and roll angles. Additionally, a buzzer is implemented to alert the user when the angle from the MPUs passes a certain threshold. The reason for the implementation of two MPUs is so that one can monitor the upper back for leaning and slouching, while the other can monitor the lower back for a hip tilt. Depending on the curvature of the spine, the cobbs angle can be a curve in the lower back or the upper back, making it crucial to monitor both. Instead of implementing a vibrator, a buzzer is deemed to have a more piercing sound, prompting the user to correct their posture rapidly as possible to cease the noise.

In future prototypes, the user will be able to control what sound they want to play, allowing for user comfort and benefit. As for the programming aspect, this device is made for anyone taking into account unique natural curvatures of the spine. To address this aspect, the device reads an initial angle measure, and then compares the newer measurements to the initial angles. If the difference exceeds a certain threshold, the device will alert the user until good posture is maintained. This allows the user to set a certain posture they want to maintain initially, allowing the device to adapt to each individual's needs and desires. Once the device has been calibrated to the user's natural spinal alignment, it sends live data to a website where the user can see their weekly progress, daily summaries, and the distribution of each action, allowing them to track their improvement over time.

3. Methodology

3.1 Initial Design

In order to design my posture corrector, I created an initial CAD on OnShape. My intent was to have the bands come out in 3 places to attach onto the user. The 2 box-shaped figures would be where the 2 MPU-sensors would be sheltered as well as the Arduino board.

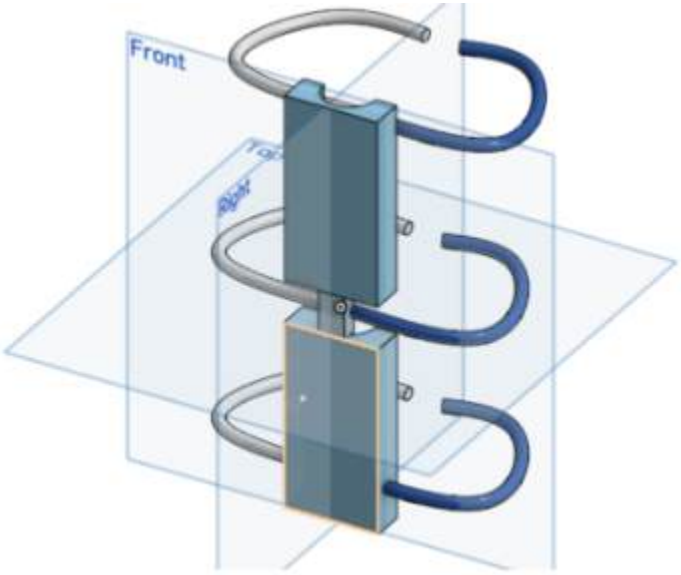


Figure 3: Initial design made with OnShape.

3.2 Improved Final Design

I chose a different design to what I CADED and formed an image depicting the prototype. This prototype involved using gyroscope (MPU sensors) that detect angle changes placed on the upper back and lower back. The Arduino board will be in the center mounted on the wearable brace.

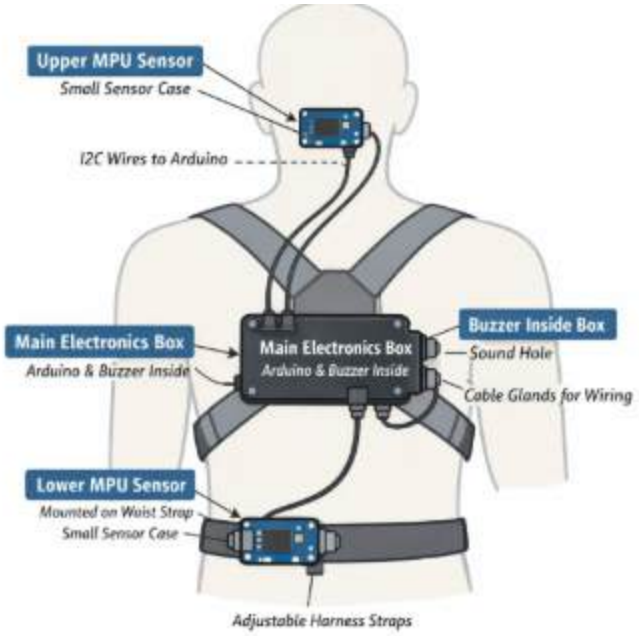


Figure 4: Final design with modifications and improvements.

3.3 Circuit Diagrams

Then I created the circuit diagram as to where to wire the MPU sensors to the Arduino board as well as the buzzer. This helped me map exactly where the wires would be soldered in the next step.

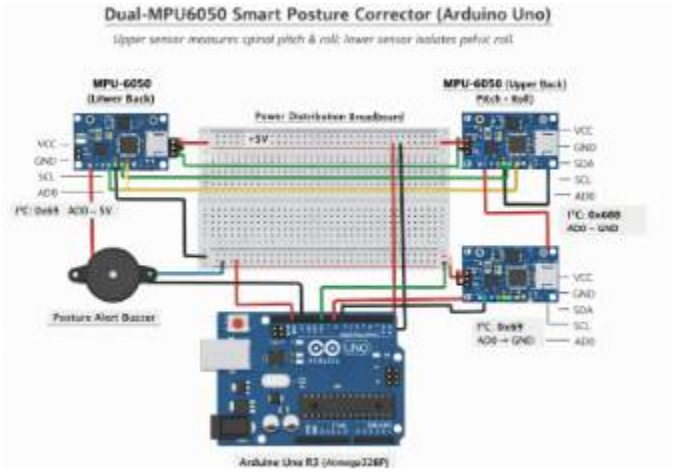


Figure 5: Circuit diagram

3.4 Electricals and Circuit Board Testing

Consequently, I tested the circuit diagram with a breadboard, wires with male/female ends, 2 MPU sensors, a buzzer, and the Arduino Board. This allowed me to validate and confirm my design before soldering it permanently.

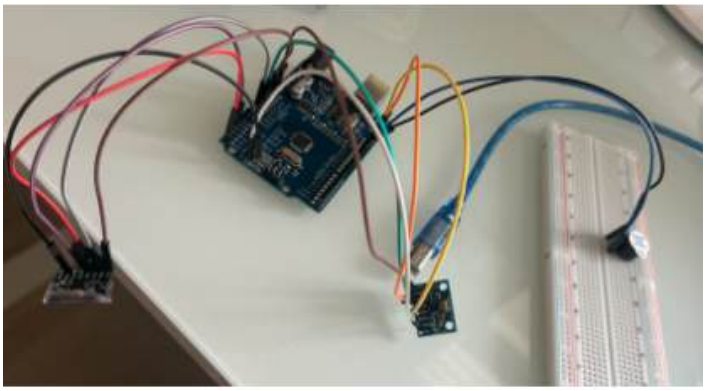


Figure 6: Circuit Board Testing

3.5 Programming and Debugging

I then programmed the buzzer to make sounds if the MPUs were tilting over a threshold angle using Arduino IDE. In order to find the threshold angles for leaning, slouching, and hip tilt alerts, I tested different angles on myself.

```
if (rollDiff > 10 && abs(rollDiff) > abs(pitchDiff)) {

  // User is leaning to the right
  leaning = "right";
  badPosture = true;
}
else if (rollDiff < -10 && abs(rollDiff) > abs(pitchDiff)) {

  // User is leaning to the left
  leaning = "left";
  badPosture = true;
}

// Slouch detection:
// Detects forward/backward bending using pitch difference.
// Only triggers if pitch movement is greater than roll movement.
if (abs(pitchDiff) > 12 && abs(pitchDiff) > abs(rollDiff)) {

  // User is slouching
  slouching = true;
  badPosture = true;
}

// Hip tilt detection:
// Compares current left sensor roll angle to calibrated baseline.
if (abs(rollLFiltered - rollL0) > 7) {

  // Uneven hip alignment detected
  hipTilt = true;
  badPosture = true;
}

// Prevent simultaneous lean + slouch classification:
// If leaning is already detected, ignore slouch detection
// to avoid conflicting posture states.
if (slouching && (leaning == "right" || leaning == "left")) {
  slouching = false;
}
```

Figure 7: Main If-Statement Algorithm

3.6 Soldering and Final Design

Once the code and circuit worked as intended, I soldered the wires onto the Arduino board and MPU gyroscope sensors. During this meticulous process, I ran into some soldering problems since the Arduino board was extremely small. Once all soldering was done, I placed the sensors in protection containers, covered the wires with insulation piping, and attached the device onto the wearable brace.



Figure 8: Final product mounted on wearable brace

3.7 Website Creation and Data Collection

I developed a website using REACT and VITE as well as AI assisted coding to store my data (http://localhost:5173/). How it works is that the Arduino IDE sends a JSON through a web serial number, then using VITE and local storage, when the website receives the data, it generates the live graphs, 3D models and daily summaries. To test this device, every day, I will place this device on my back and record my posture angles as leaning or slouching using this website.

4. Results

After the one week pilot study, the device showed some promising results and some not so promising results. Two participants were asked to wear this device for 4 hours each day for a week, as their data was recorded on the website. After a week, the first 16 year-old scoliosis participant's, leaning left angles decreased at an average rate of change of 0.625 degrees per day, while the leaning right angles decreased at a rate of 1.43 degrees per day. In total, the left angles decreased by 4.3° and right angles decreased by 9.1°. The second 40 year-old participant's left

angles decreased at an average rate of 1.62 degrees per day, while the right angles decreased by 0.76 degrees per day. In total, the left angles decreased by 8.6° and the right angles decreased by 9.4°. Despite the major improvements in the leaning angles, the slouching angles for the first participant stayed constant for the majority of the week except for a slight decrease of 0.236 degrees per day and a total improvement of 1.2°. The second participant had a slight decrease of 0.58 degrees per day and a total improvement of 3.5°. Accordingly, the bar chart on the website showed that slouching was more prevalent than leaning left or right for both participants.

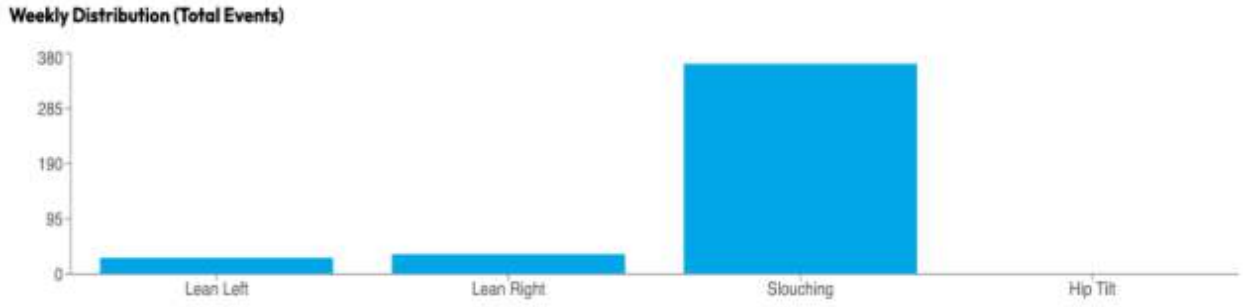


Figure 9: Distribution of events for participant 1 generated through the website

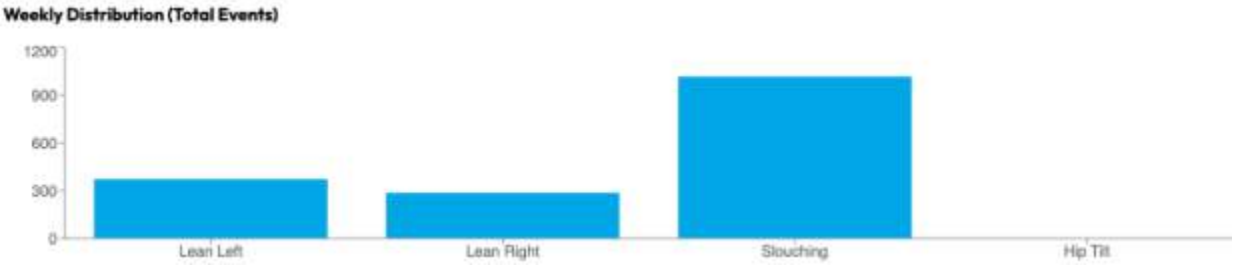
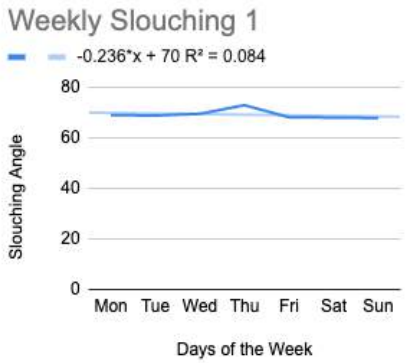


Figure 10: Distribution of events for participant 2 generated through the website

A)



B)



C)



D)



Figure 11: Weekly Leaning and Slouching Angles for participant 1 + 2 made through website

5. Limitations

This study, however, did have its limitations. I was restricted to two participants, over a one week long period with no control group because of the time constraints to enter in the Alameda County Science and Engineering Fair. Even if the two participants reported positive benefits, it doesn't take into account all possible outcomes, but it showcases what may be possible with this device. Some other limitations may include device interference.

6. Discussion

These results suggest that the device may be able to improve posture by reducing leaning greatly and slouching slightly. The extremely little change in slouching angles can be explained by a sensor error. When a leaning angle is detected, slouching is also detected due to the inefficiency of the pitch and roll measurements of the MPUs. Since slouching is alerted every time leaning is alerted in addition to slouching solely, it explains why slouching is more prevalent within the data. In future prototypes, this will be eventually solved by making the device more sensitive to certain conditions, allowing it to distinguish between slouching and leaning. Additionally, due to the rigidity of the item that the device is mounted on, a hip tilt is not being detected efficiently. Without the rigid support, the MPU successfully detects a hip tilt when it is placed on the back, so in future prototypes, a flexible support will allow it to do so freely. Even though the device was not able to reduce slouching or detect a hip tilt due to its rigidity, it was extremely efficient at reducing leaning which helped the user maintain their posture even without the device, ultimately achieving its principal goal. Based on this feedback and analysis, newer prototypes will be able to detect hip tilt despite the support it is using and improve slouching angles, allowing it to be a cost-effective product.

7. Conclusion

This study investigated how efficient the posture corrector SpineAlign would be in improving one's posture with the goal of one day benefiting patients with scoliosis by using MPUs and an Arduino. The results indicate how the device was able to decrease the leaning left and right angles by 1.123 degrees per day and 1.095 degrees per day, respectively (the average of both participants are stated here). However, it only decreases the slouching angles by an average of 0.408 degrees per day. These findings propose that the device was efficient in improving leaning angles but not as much for slouching angles, suggesting that the device can be used to improve one's long term posture. Ultimately, improving one's posture can help relieve pain, ease tension, strengthen the muscles, remove muscular imbalances, allow for a healthier spinal alignment, and even improve specific types of scoliosis such as functional and degenerative scoliosis. In the future, this device should be more flexible to detect hip tilts, and more sensitive on the upper MPU for efficient slouch detection, as those were the two problems encountered in this study. In addition to mitigating current problems, I aspire to create an advanced prototype that will not only detect posture misalignments, but put pressure on the user's back to align the spine using motors and/or tension. I will make this device something that requires no effort to use, especially when the user doesn't have to fix their posture themselves. This device will also evolve into a more portable and easy to wear device so more users will be willing to put it to use.

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Better Sensor or Just Newer? Resting Heart-Rate Agreement Between Two Apple Watch Generations and a Finger Pulse Oximeter By Shrihan Ananthu

Abstract

Wrist-worn devices such as the Apple Watch have increasingly substituted for clinical instruments for everyday heart-rate (HR) monitoring, yet their optical estimates remain less direct than electrical measurements. This study compared resting HR agreement between two Apple Watch generations, the Series 9 (2023) and the Series 3 (2017), and a SmartHeart finger pulse oximeter (FPO), and asked whether agreement has changed across hardware generations. Twelve healthy, seated participants were each measured with an Apple Watch and the FPO simultaneously on the same arm 5 readings per device were averaged. Six participants used the Series 9, and the other six used the Series 3. The agreement was evaluated using signed mean difference (bias), mean absolute error (MAE), relative error, Bland-Altman analysis, and comparison against the oximeters' stated measurement tolerance. Both watch generations read slightly higher than the FPO at rest, and the two devices showed nearly identical average bias (Series 9, +1.67 BPM; Series 3, +1.55 BPM). The generations are separated in consistency rather than in average offset. The Series 9 produced tight agreement (95% limits of agreement +0.17 to +3.17 BPM; all six readings above the FPO), whereas the Series 3 produced wide, bidirectional disagreement (limits -3.93 to +7.03 BPM). At rest, both generations tracked the FPO closely on average, but the newer hardware was substantially more accurate. The differences in participant composition between the two groups, the small sample, and the absence of an electrocardiographic reference device limit the certainty of claims about improvement across generations.

Introduction

A decade ago, checking a heart rate on the go meant putting a finger on a wrist and looking at a clock. Today, it means a glance at a watch. Since the Apple Watch debuted in 2015, wrist-worn devices have moved from fitness novelties to devices people trust increasingly more for health decisions, monitoring resting heart rate, blood oxygen, and even single-lead electrocardiograms (Apple). As these functions have grown, so have questions about whether the measurements are good enough to act on. However, the stakes aren't small; a heart-rate reading that is wrong can mask a real cardiac signal or manufacture a false one.

The Apple Watch estimates heart rate using photoplethysmography (PPG), in which a green light-emitting diode (roughly 540 nm) illuminates the skin and a photodetector measures fluctuations in reflected light as blood volume rises and falls with each heartbeat (Seshadri et al.) A finger pulse oximeter works on a similar optical principle but at the fingertips instead of the wrist, where higher perfusion and lower motion generally make the signal more stable. For this reason, oximeters are common in clinical settings, though they also estimate rate optically rather than electrically (“Pulse Oximetry”). Neither device measures the heart's electrical activity

directly. That difference matters for interpreting any comparison between them, because the real gold standard for heart rate is the electrocardiogram (ECG), not a second optical device.

Current research consistently shows that wrist PPG is reliable at rest but degrades during movement. In a study of more than fifty adults measured against clinical ECG, Bent and colleagues reported an Apple Watch mean absolute error of roughly 1.8 BPM at rest, with errors increasing during motion and varying with skin perfusion and pigmentation (Bent et al.). Alfonso and colleagues, comparing wrist devices against ECG across lying, sitting, standing, and walking, found near-perfect agreement while participants were still and as activity increased, with the Apple Watch outperforming a competing wrist monitor (Alfonso et al.). However, data in a clinical population brings up a concern that is easy to miss. When Seshadri and colleagues compared the Apple Watch Series 4 against hospital telemetry in fifty patients, the overall agreement was only moderate (correlation = 0.7), and the authors explicitly warned against relying on the watch for heart-rate monitoring in patients with arrhythmias such as atrial fibrillation (Seshadri et al.). In other words, “accurate at rest in healthy people” and “accurate everywhere” are not the same claim.

There were two main gaps that motivated this study. First, most validation tests benchmark the watch against an ECG. Rarely do any compare it against the finger pulse oximeter that an ordinary person is more likely to own. Second, the question of whether the watch's optical hardware has actually improved across generations is rarely tested head-to-head. Therefore, this study compared resting heart-rate agreement between an Apple Watch Series 9 and an Apple Watch Series 3, each against the same SmartHeart finger pulse oximeter, and asked the following question: at rest, how closely does each generation agree with the oximeter, and does the newer model agree more closely? Because no ECG reference was available, it was framed as an agreement study rather than an accuracy validation; therefore, the hypotheses were that (1) both watches would agree with the oximeter within a few BPM at rest, and (2) the Series 9 would agree more closely than the Series 3.

Methods

This study was made using a method-comparison design. Each participant's resting heart rate was measured at the same time by an Apple Watch and a finger pulse oximeter, and the readings were compared to determine agreement. The sections that follow describe the participants and how the sample was characterized, the two devices and their manufacturer specifications, the measurement procedure, and the methods used to quantify agreement.

Participants

Twelve participants were measured in a single high-school classroom session. Six were measured with an Apple Watch Series 9 and six with an Apple Watch Series 3. Most participants were ages 15-17, with one adult aged 47. The Series 9 group consisted of five males and one female participant, while the Series 3 group consisted of one male and five female participants. All participants were healthy and remained seated throughout. A pre-study survey characterized

the sample further. All twelve provided informed consent to participate; self-reported race was predominantly Asian (ten of twelve), with two White participants; and self-reported activity ranged from moderate (five participants) to active (seven), with none reporting sedentary. Participants also rated their skin tone on the ten-point Monk Skin Tone scale, with responses spanning roughly from Monk 3 to Monk 8 (light-medium to dark). Because the questionnaire was anonymous, these characteristics describe the sample as a whole and are not linked to watch-group assignment. Participant identities were not recorded in the dataset, and the individuals are reported here only as Participant 1-6 within each group.

Devices

Two wrist-worn devices were evaluated: The Apple Watch Series 9 (released 2023) and the Apple Watch Series 3 (released 2017), both of which estimate heart rate using green-LED photoplethysmography (Seshadri et al.). The readings were compared against a SmartHeart finger pulse oximeter (Veridian Healthcare), a fingertip transmittance device that reads heart rate optically from the pulsatile blood-column signal and is widely used as a convenient point-of-care monitor ("Pulse Oximetry"). The manufacturer specifies a pulse-rate accuracy of ±2% or ±2 digits ("SmartHeart Pulse Oximeter"). Across the 63-99 BPM range observed in this study, the ± 2 digit term is the binding tolerance, which corresponds to roughly ± 2 BPM. Like the watch, it estimates heart rate optically rather than electrically, and the true reference for heart rate remains to the electrocardiogram. Its stated tolerance is used below to assess whether watch and oximeter differences surpass the reference instruments' own measurement uncertainty.

Procedure

All measurements were taken in one sitting in the same classroom and under consistent room temperature and lighting. Each participant wore the Apple Watch and the finger pulse oximeter on the same arm at the same time, so that both devices recorded the same heart rate simultaneously. Simultaneous measurement was chosen so that normal beat-to-beat variation in heart rate couldn't be mistaken for disagreement between devices. The watch band was fitted snugly at a moderate tightness, neither too loose nor too tight. The watch was worn on the wrist, with the oximeter clipped to a finger on the same hand. The right or left hand was not formally standardized or specified.

Five readings were taken per device for each participant. Each Apple Watch reading was obtained by opening and closing the heart-rate application. Each oximeter reading was obtained by removing and reattaching the device to the same finger. Reopening the application and reattaching the oximeter between readings was done to capture short-term measurement variability rather than a single instantaneous value. The five readings per device were averaged to result in 2 averages for both the oximeter and watch per participant.

Analysis

For each participant, the averaged oximeter value and the averaged watch value were compared. The agreement was quantified in the following four ways: (1) signed mean difference (bias), calculated as watch minus oximeter, which captures systematic over or underestimation and its direction; (2) mean absolute error (MAE), the average magnitude of disagreement regardless of the direction; (3) relative error, the difference expressed as a percentage of the oximeter reading; and (4) Bland-Altman analysis, the standard method for comparing two measurement techniques, which measures the difference between devices against the mean of the two devices and reports the mean bias and 95% limits of agreement (bias ±1.96 standard deviations) (Bland and Altman). Reporting both signed bias and absolute error is mandatory, as a device can show a small average bias while still being unreliable if its errors are large but cancel out in opposite directions. In addition, each group's per-participant differences were interpreted against the oximeter manufacturer's stated tolerance (±2 BPM across this heart rate range). The Series 9 and Series 3 groups were analyzed separately.

Results

Both Apple Watch generations read slightly higher than the finger pulse oximeter at rest, and their average offsets were almost identical. The Series 9 showed a mean bias of +1.67 BPM (MAE 1.67 BPM, mean relative error = 2.5%), and the Series 3 had a mean bias of +1.55 BPM (MAE 2.58 BPM, mean relative error = 3.5%). On bias alone, the two generations appear the same.

The Bland-Altman analysis tells a different story (Figure 1). The two generations differed drastically in consistency. For the Series 9, all six readings fell above the oximeter, the standard deviation of the differences was only 0.77 BPM, and the 95% limits of agreement spanned just 3 BPM (+0.17 to +3.17). For Series 3, the differences are scattered in both directions. Two of the six readings fell below the oximeter as the standard deviation was 2.80 BPM, and the limits of agreement spanned nearly 11 BPM (-3.93 to +7.03), almost four times wider than the Series 9. The single largest individual variation in the study, +5.4 BPM, occurred in the Series 3 group. The per-participant values are given in Table 1.

Overall, the newer hardware didn't center on the oximeter more accurately than the older hardware. Instead, it clustered around the same small offset more closely. In this data, the improvement is more in precision rather than in average accuracy.

Because the oximeter itself is an estimate rather than a source of accuracy, these differences are best understood relative to its own measurement uncertainty instead of deviations from a true value. Taking the reference devices' stated tolerance of roughly ±2 BPM in this heart-rate range, five of the six Series 9 differences fell at or within that range, and the sixth exceeded it only slightly (+2.4 BPM). The watch's small positive offset is within the range that the reference instruments' own error could account for. However, the Series 3 behaved differently. Four of its six differences exceeded the ±2 BPM tolerance, including the study's

largest disagreement of +5.4 BPM and a reading 2.5 BPM below the oximeter, so for the older watch, the disagreement was frequently larger than the reference's own uncertainty can explain.

Group	Participant	Oximeter (BPM)	Apple Watch (BPM)	Difference (Watch – Oximeter)
Series 9	1	63.0	64.6	+1.6
Series 9	2	72.8	74.8	+2.0
Series 9	3	71.0	72.8	+1.8
Series 9	4	75.4	77.8	+2.4
Series 9	5	74.8	76.8	+2.0
Series 9	6	77.2	77.4	+0.2
Series 3	1	86.4	89.0	+2.6
Series 3	2	83.6	85.0	+1.4
Series 3	3	77.6	83.0	+5.4
Series 3	4	96.0	99.0	+3.0
Series 3	5	86.0	83.5	−2.5
Series 3	6	77.4	76.8	−0.6

Figure 1. Bland-Altman plots of agreement between each Apple Watch generation and the finger pulse oximeter at rest. Solid line, mean bias; dashed lines, 95% limits of agreement. The Series 9 shows tight, uniformly positive differences; the Series 3 shows wide, bidirectional differences.

Discussion

The main result is that, at rest, both Apple Watch generations agreed with the finger pulse oximeter to a degree most users would consider acceptable, but they did so in very different ways. The Series 9s' average overestimate of 1.7 BPM aligns almost exactly with the resting mean absolute error of 1.8 BPM that Bent and colleagues measured against a clinical ECG, which suggests that the watch's small and consistent positive offset against an optical reference is the same as its offset against the electrical gold standard (Bent et al.).The watch reading slightly high is reasonable given that the wrist and fingertip PPG assess different vascular densities. The more notable finding is how stable the offset was for the newer device.

The difference in precision is where the comparison between generations becomes interesting. Although the two generations share the same average bias, the Series 3’s limits of agreement are nearly four times wider, so the watches are not interchangeable. A clinician or

athlete interpreting a single Series 3 reading value could be off by five or six beats in either direction, while the same reading from a Series 9 would almost always land within three beats and on the higher side. This is the same thing with the other literature's emphasis that wrist PPG reliability depends heavily on signal quality, which is affected by sensor design, skin perfusion, and pigmentation, which are all factors a six-year hardware gap could reasonably affect (Bent et al.). Most notably, the sample spanned a wide range of skin tones (Monk 3 to 8 on the Monk Skin Tone scale), and because an optical sensor must detect a pulsatile signal through the skin whose pigmentation influences light absorption due to melanin, this variation is a reasonable contributor to the scatter observed. It is worth noting what this study does not show. Because the comparison device was an optical instrument rather than an ECG, none of these results establish "accuracy" in an absolute sense. They establish agreement between two consumer-grade optical devices under ideal conditions. The Series 9's average offset was small enough to fall within the oximeter's stated tolerance, which is exactly why it cannot be read as a measure of the watch's error. The difference is not larger than what the reference device alone could produce. Across other literature, it is given that the harder test for wrist PPG is motion, and that agreement degrades once a user begins to move (Alfonso et al.). It also warns that performance can fall in clinical populations such as patients with atrial fibrillation (Seshadri et al.). Resting Agreement in healthy people is the easiest case, and even there, the older device was inconsistent.

For everyday resting use, tracking a baseline heart rate over time and noticing a trend, both generations are serviceable, with the newer one clearly preferable for anyone who cares about the reliability of an individual reading. For anything that would influence a clinical decision, neither optical device should be substituted for a direct electrical measurement.

Limitations

There are several limitations regarding these conclusions. First and most important, the comparison used a finger pulse oximeter rather than an ECG, so the study measures agreement between two optical estimates, not accuracy against a true reference. Second, the sample was small (six participants per device) and drawn from a single classroom, which limits the statistical power. Third, the two watch generations were measured on different individuals who also differed by sex (the Series 9 group was mostly male and the Series 3 group was mostly female), and resting heart rate differs by sex. The groups also were not matched based on skin tone, which is a factor that is known to affect optical heart rate sensing through differences in light absorption. Because the demographic survey was anonymous, the distribution of skin tones across the two watch groups is unknown, which adds another uncontrolled variable to the sex imbalance. The sample was also predominantly Asian, which limits how far the findings generalize. Fourth, all measurements were taken at rest, so the results say nothing about movement. Finally, hand placement and band position were approximated. Future studies should pair the watch against the ECG, use the same participants across devices, balance and individually record sex, age, and skin tone, and measure light and moderate activity.

Conclusion

At rest, both an Apple Watch Series 9 and an Apple Watch Series 3 both agreed with a finger pulse oximeter to within a few beats per minute on average, with each generation reading slightly high. The two generations differed in reliability, not in average offset. The Series 9's readings were tightly and consistently grouped, while the Series 3's varied widely and in both directions. Within the limits of a small, single-session, rest-only comparison against an optical reference, the data is consistent and shows improved measurement consistency in newer Apple Watch hardware. No optical wrist device, old or new, should be treated as a substitute for an electrocardiogram when an accurate heart rate truly matters.

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Comparing the Psychological Effects of Two Distinct Dance Forms: Ballet and Contemporary By Lucia Neill

Abstract

This study examines the differences in psychological effects between two distinct dance styles: ballet and contemporary. While prior research has established that dance broadly improves psychological well-being, few studies differentiate between styles. Using a mixed-method approach, this study collected both quantitative and qualitative data from experienced adolescent dancers before and after participation in each style. Results indicate that both styles improve psychological well-being, but with distinct effects: ballet is associated with control, challenge, and accomplishment, while contemporary is associated with emotional expression, connection, and flow-state experiences. Findings suggest that differentiating dance styles can improve targeted psychological interventions.

Introduction

Many studies have established the positive effects of participatory dance engagement on psychological health across broad populations. For example, dance is proven to be helpful for treating mental and somatic issues in adolescent girls through increasing self-trust (Duberg et al.). Participatory dance engagement has also been linked to decreased self-judgement and increased trust in older populations, and has been identified as a mechanism to mitigate depression effects or reduce depression levels (Cohen & Aisenburg-Shafran). For depression interventions, dance in combination with psychological interventions and psychoactive drugs is proven to be more effective for positive coping than drugs or therapy alone, demonstrating dance's effectiveness as a targeted intervention that can address complex needs (Mo et al.).

While these studies establish the positive psychological effects of participatory dance engagement, they overwhelmingly use "dance" as a general umbrella term and do not acknowledge that dance has distinct styles that may create different effects. My research project aims to answer the question, what are the differences in positive psychological effects between two distinct dance forms: ballet and contemporary? The Oxford English Dictionary defines ballet as: "An artistic dance form performed to music using precise and highly formalized set steps and gestures" (Oxford University Press), while contemporary dance is defined as an expressive genre that combines movement from multiple styles including jazz, ballet, modern, and lyrical (Ballet Arizona & MasterClass).

This study's purpose is twofold: 1. to gather quantitative data that can be used to determine if a particular dance style produces any significantly distinct psychological effects and 2. to gather qualitative data to capture a more holistic picture of a participant's psychological response to two distinct dance styles. I used a mixed-method survey that was given to dancers directly before and after taking class in an assigned style on the same day, one week apart. On occasion one, group Red took ballet only; group Orange took contemporary only; and group Yellow took both ballet and contemporary. On occasion two, group Red took contemporary only;

group Orange took ballet only; and group Yellow continued to take both ballet and contemporary. I hypothesized that ballet would make participants more focused, aware, and in control, while contemporary would make participants feel more emotionally attuned, expressive, and connected to an inner "flow-state:" a state where one is so involved with what they are doing that they forget about almost everything but the activity itself (Csikszentmihalyi et al.). Understanding how different types of dance affect the brain can contribute new data to the field of dance psychology, and ultimately produce more effective and tailored methods for dance interventions to be used to promote psychological and cognitive well-being.

Literature Review

Origins of Dance Psychology

Peter Lovatt, an acclaimed dance psychology researcher, defines the field of dance psychology as the scientific, psychological study of dancers and dance (Lovatt). Dance psychology has both philosophical and biological bases that dance psychology studies rest upon.

The origins of dance psychology as a field of study can be traced back to Maurice Merleau-Ponty, a 20th century French phenomenological philosopher who argued the importance of the physical body in human perception of the world. Specifically, Merleau-Ponty believed we are embodied creatures that experience the world through our "lived body," which he defined as our conscious self that is omnipresent in all activities and mental processes (Duberg et al.). Merleau-Ponty proposed that the physical body is at the very center of our lived experience (Li) and paved the foundation for the embodiment theory. The embodiment theory is a framework that sees the human mind and body as inextricably linked. It opposes the traditional Western philosophy that views them as separate entities (Meridian University). The mind is seen as rooted in the body and therefore impacted by the person's experiences. A causal relationship between kinetic action and psychological effects can be derived from this theory (Schwendener et al.). Betty Block and Judy Lee Kissell in "The Dance: Essence of Embodiment" apply the embodiment theory to dance. They argue that "few human experiences express so vividly and so totally the meaning of an embodied being-in-the-world as does dance" (Block & Kissell). When further discussing the interplay between movement and our embodied brain, Block and Kissell reveal that dance fosters kinesthetic awareness that can translate into increased awareness of mental state.

Neurobiology of Dance Experience

Philosophy establishes a foundation for correlation between participatory dance engagement and positive psychological effects, but there is also physical evidence that dance satisfies reward pathways in the brain (Foster Vander Elst et al.). The biological premise of dance's ability to impact the brain is the foundation for the growing field of dance neuroscience, which works in tandem with dance psychology, and can be defined as the exploration of how dance engagement impacts the brain. In a Harvard Medical School publication, it was explained

that “Scientists gave little thought to the neurological effects of dance until relatively recently, when researchers began to investigate the complex mental coordination that dance requires” (Edwards, para. 2). Specifically, dance engages what is called a “pleasure double play:” while the movement stimulates reward centers in the brain, music activates sensory motor circuits (Edwards).

Observed Effects of Dance Engagement

A recurring theme in dance psychology literature is that participatory dance engagement leads to improved psychological well-being. When comparing college students engaging in sports classes versus dance classes, it was found that those engaged in dance felt “significantly more creative, happy, secure, strong, confident, relaxed, coordinated, exhilarated, motivated, healthy and competent” (Gurley et al., 63). In a study observing dance and self-esteem, it was concluded that adults participating in dance displayed positive changes in mental self-awareness, physical self-awareness, and self-development; while adolescents participating in dance were observed to have increases in self-trust, body related self-expression, and positive body perceptions (Schwender et al.). There is also biological evidence for dance as a mechanism for stress reduction and increased stress regulation skills (Klaperski-van der Wal et al.). Klaperski-van der Wal and colleagues examined the neurobiological relationship between music, social contact, and movement which correlated to the presence of oxytocin, β-endorphin modulation, and dopamine.

Dance Interventions

Dance is growing increasingly prominent as an intervention for psychological disorders and neurological disease. This pattern can be seen across multiple populations. Dance has been proven to reduce depression symptoms in African adolescent girls (Tao et al.). Dance interventions in combination with psychoactive drugs were proven to be the most effective depression intervention for depression patients in mainland China (Mo et al.), while college students participating in dance classes experienced more improvement in depression and anxiety symptoms than their counterparts in academic or sports classes (Gurley et al.). A study focused on older women participating in a dance program designed for elderly populations reported decreased depression levels in experienced dancers, and reductions in self-judgement across all experience levels (Cohen & Aisenberg-Shafran). The researchers also noted that the observed reduction in self-judgement serves as a predictor for decreased depression levels. Lastly, dance interventions have also been proven to decrease neurological disease. Specifically, dance relieved symptoms for patients with Parkinson’s Disease, a disease in which dopamine producing cells in the brain are lost. Dopamine is crucial to the brain’s system for controlling movement and coordination. Those who have Parkinson’s commonly experience slowed movement, stiffness, balance problems, and coordination problems. Through engaging in dance (in the form of rhythmic auditory stimulation) patients can improve gait and upper extremity functions

(Edwards). These improvements demonstrate dance's ability to positively alter the biology of our brain.

Gap

The gap that the present study addresses is the lack of research on the positive psychological effects of distinct dance styles. When studied in a research context, "dance" is commonly used as an umbrella term to describe coordinated physical movement performed in synchronization with music. However, dance as an art form is an intricate and specialized field with many genres. Using dance as an umbrella term fails to acknowledge the distinct choreography, participation patterns, social and cultural contexts, and music associated with different styles of dance. While many sources have proven dance to have positive psychological effects for participants, like Tao et al. and Gurley et al. , these studies fail to acknowledge the type of dance studied. Some sources have acknowledged the use of a distinct dance style: like Mo et al. only using Chinese dance in their study, and Delattre et al. using social dance. However, these studies only report on the effects of the distinct style they are studying, rather than comparing the effects of styles like I intend to do.

One study that is particularly relevant to my gap is an Eastern European study entitled "Effect of dancing on subjective experiences and psychological state of dancers." This study aimed to measure the psychological effects of two selected dance styles: street dance and modern scenic dance. The results indicated an increase in positive psychological components and decrease in negative components, both in street dance and modern scenic dance. However, the method and analysis did not align with the purpose of measuring the effects of the distinct dance styles selected. The researcher did not compare survey results of the separate styles and instead purely analyzed dance's impacts on psychological state. Because of this, there was no relevant data reported on the differences between the two dance styles. My research aims to fill this gap by comparing two dance styles and producing data that can support the hypothesis that distinct dance styles produce different psychological effects. Researchers commonly synthesize all dance styles when studying dance, but there is potential for further knowledge to be gained by separating dance styles in research. This project both addresses that gap and contributes to the existing body of dance psychology research by exploring differences in the psychological effects of two distinct dance forms: ballet and contemporary.

Method

Participants

My research population was experienced dancers: dancers placed in level V or IV/V (V is the highest level at this location), at X dance studio. Dancers were experienced in both contemporary and ballet. I originally had 20 participants in my study. 10 agreed to participate in the surveys, and the other 10 agreed to be in group Yellow: the group that listed words and phrases to describe changes in their psychological state after classes. All participants were age

15-18, and identified as female. However, one participant dropped out, making my final sample size 19, and I ended up having 9 participants in group Yellow.

Study Design

To get a comprehensive picture of the psychological effects created by dance, I used a mixed method made up of a quantitative and qualitative survey. This approach helped me answer my research question by giving me both qualitative data detailing dancers' subjective experiences with their assigned dance style, and quantitative data that I used to compare their psychological state before and after participating in each style.

"Engagement in the arts is inherently a combination of subjective and objective experiences" (Stutesman et al., 5). Because of this, the survey method I used was best suited for my research. It allowed me to try to define an objective basis that my results can rest upon while also gathering qualitative perspectives, making room for each dancer's unique experiences. Dance engages the brain in complex ways (Edwards) and purely quantifying what dance is doing to the brain would not paint a holistic picture of how dance impacts a person. However, using naturalistic observation, interviews, and other methods that do not involve a quantitative aspect would make it extremely hard to prove any significant effects, communicate results to a non-dancer population, and garner respect in the greater field of psychology. Overall, experiences with art are not fundamentally quantitative or qualitative, and choosing only one of these methods limits the psychological study of the arts (Stutesman et al.).

Measures

The first part of my method is the quantitative section of my survey. My survey was created to evaluate participants' psychological state: defined as temporary emotional condition and cognitive processes. The survey was made up of 20 statements about emotion, cognition, creativity, self-awareness and behavior. Subjects indicated their agreement using the Likert scale, with 1 being strongly disagree and 5 being strongly agree. I employed a 5-point Likert scale rather than a 7-point scale, because the 5-point scale is associated with reduced participant frustration and improved response quality and rate (Babakus & Mangold). I chose to use a quantitative survey to generate concrete data that could be used to determine if dancers' experience in ballet or contemporary created a statistically significant difference in their psychological state. My survey questions are informed by surveys from the University of Pennsylvania Positive Psychology Center, as well as from lived experience as a contemporary and ballet dancer. Since I am the same demographic as my research population, I wrote down multiple adjectives and adverbs to describe my psychological state after dancing in contemporary and ballet. Using my lived experience helped me create surveys tailored specifically for dancers and the effects of dance, rather than using only general psychology measurements.

The second part of my method is the qualitative section of my survey. In both the pre-class and post-class survey, subjects were invited to describe their current mood more in depth, and to describe any outside factors influencing their psychological state. These questions

were used both to give me more insight into the dancer's experience that day and in their assigned class, and to determine if I should eliminate a participant based on whether they had an outside experience that was heavily skewing their responses. Along with this, in the post-class survey I asked respondents to list some adjectives and adverbs to describe their psychological state after dancing, and asked respondents to describe how their experience dancing shifted their psychological state. Having participants describe what aspects of the class may have shifted their mood helps me identify style-specific elements that caused a shift in psychological state. Participants listing words and phrases to describe their psychological state helps me identify themes that my questions in the quantitative section of my survey may have missed.

Procedure

Half of the participants were divided into two groups: Orange and Red (Figure 1). Surveys were distributed to dancers in groups Orange and Red directly before and after taking a class in an assigned style. The first week, group Orange completed a survey before and after ballet class, with no participation in contemporary class. The second week, the Orange group completed the survey before and after taking a contemporary class, with no participation in ballet. The Red group followed the opposite schedule. The first week, they completed the survey before and after contemporary class, with no participation in ballet class. The second week, they completed the survey before and after ballet class, with no participation in contemporary class. The rotating schedule helped me eliminate other variables that could impact results, for example: personal style preference, having a bad day, exhaustion.

The remaining participants were assigned to group Yellow. This group took both contemporary and ballet classes both times, and completed only question 8 of the qualitative survey, which involved recording words and phrases describing changes in their psychological state that they attributed to each dance style. They then repeated this process one week later to assess consistency in their responses. The commitment was more extensive for participants in group Orange and Red because it involved more surveying and missing other dance classes, so I also created group Yellow to generate more data as I was unsure if I would be able to get enough participants without it. Along with this, I created group Yellow to have a group that could internally compare their experiences in the styles.

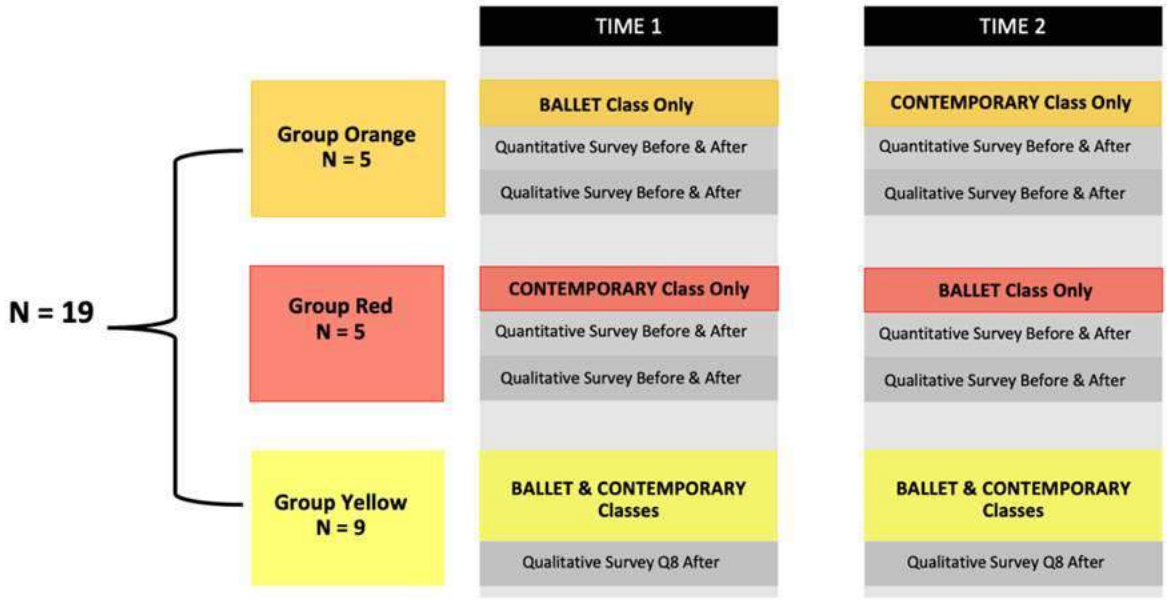


Figure 1. Participants organized into groups.

A related study by Gurley et al., compares psychological effects of dance versus sports using a similar strategy of splitting subjects into groups made up of each class being compared. The quantitative part of my survey mirrors this study, as Gurley et al. also had subjects evaluate their agreement with statements using a Likert scale. Another study that informed my method was Narikbayeva et al. This study examined dance's impact on creativity and social skills using surveys, observation, and guided group discussions. I used Narikbayeva and colleagues' qualitative survey questions as a model for both my quantitative and qualitative questions.

Ethical Practices

I followed ethical research practices when conducting this study. This study was approved by the Institutional Review Board at the educational institution I attend. All participants signed an informed consent form prior to the start of the study. This form described the purpose of the study, subject involvement, possible risks, possible benefits, confidentiality, data storage procedures, and contact information. By signing this form, participants agreed to have their data used for the study but also knew that their confidentiality would be maintained as all subjects were referred to using a letter. To avoid psychological or physical harm, participants were told to stop dancing if they felt pain, and that they did not have to answer any survey questions that they did not feel comfortable answering. Participants were also aware that they could drop out of the study at any time and have their data destroyed if they wished.

Results

Quantitative Survey Results

The 10 participants in group Orange and Red took the pre-class survey before their class and the post-class survey after completing class both weeks. The results of the survey were stored on an excel spreadsheet on a password protected device. The participants' agreement with the statements were made into quantitative data by assigning a numerical value from 1-5 . Strongly disagree was assigned the value 1 and strongly agree was assigned the value 5. From there, I was able to calculate the shift in agreement with the statement for each participant, I did this by using the equation below:

Pre-class survey agreement value – post-class survey agreement value = mood shift

The mood shifts were organized into two groups based on the style the participants took. I then used a paired t-test on each statement for each group. A paired t-test is used to determine if the shift in mean between two related measurements is statistically significant. Statistical significance is determined by comparing the difference between paired observations to assess if it significantly deviates from zero relative to the data's variability. This formula is commonly used to compare pre-test and post-test results and helped me determine if the shift in agreement with each statement was statistically significant for the different styles. If this p-value produced by the paired t-test was less than 0.05, it was considered statistically significant. For my quantitative data, I defined a style being associated with an effect if it created a statistically significant shift in means for the statement.

For the statement "I feel in control of my emotions," the participants taking ballet had a statistically significant improvement in agreement ($p= 0.04$) from pre-class to post-class, while participants taking contemporary did not ($p=0.23$) (Figure 6). For the statements "I like to do things that are frightening or challenging ($p= 0.002$)," "I am able to recognize and understand others' emotions ($p= 0.03$)" (Figure 3) and "It seems I am 'running on automatic,' without much awareness of what I am doing ($p= 0.04$)," participants taking contemporary had a statistically significant change in means from pre-test to post-test scores, while participants taking ballet did not. Both groups had a statistically significant shift in means from pre-test to post-test for the statements "I feel energized (contemporary $p= 0.01$, ballet $p= 0.03$)," "My mind feels clear (contemporary $p=0.03$, ballet $p=0.01$)" (Figure 5), "I feel focused (contemporary $p=0.02$, ballet $p=0.02$)," "I feel inspired to do or create something (contemporary $p=0.03$, ballet $p=0.007$)" (Figure 2), and "I am in a flow-state (contemporary $p= 0.007$, ballet $p= 0.05$)"(Figure 4). For the statements "My mind feels clear" and "I feel focused," the shifts in means from pre-test to post-test were equivalent for both styles. However, for the statements "I feel energized," "I feel inspired to do or create something," "I understand my current emotions," and "I am in a flow-state," participants who took contemporary had a greater shift in mean from pre-test to post-test. A major pattern across all the quantitative results was that ballet participants rarely put strongly agree with any of elements in the post-class survey, while this was common for contemporary participants.



Figure 2. Comparison for the statement: "I feel inspired to do or create something."

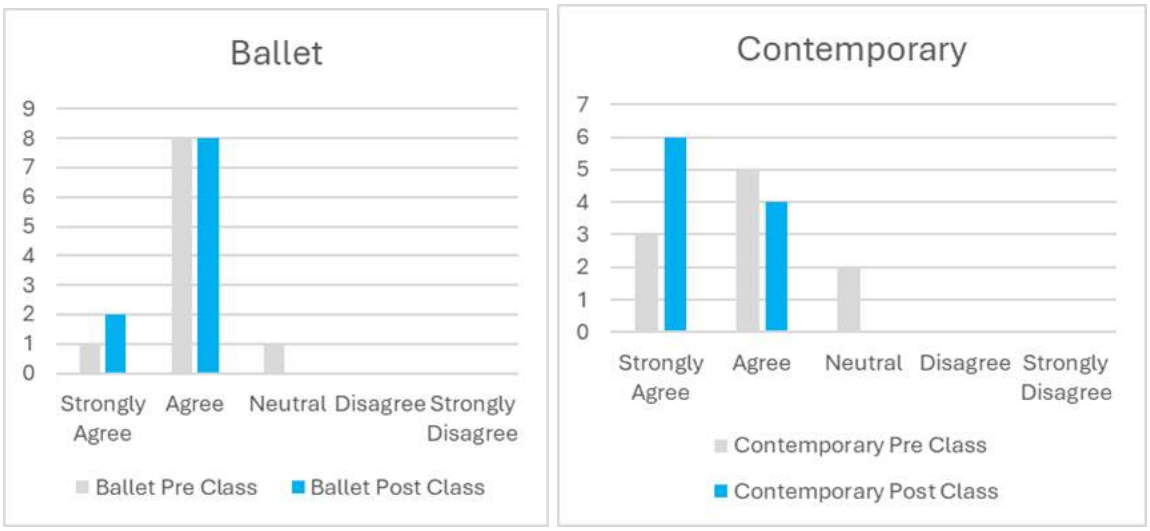


Figure 3. Comparison for the statement: "I am able to recognize and understand others' emotions."

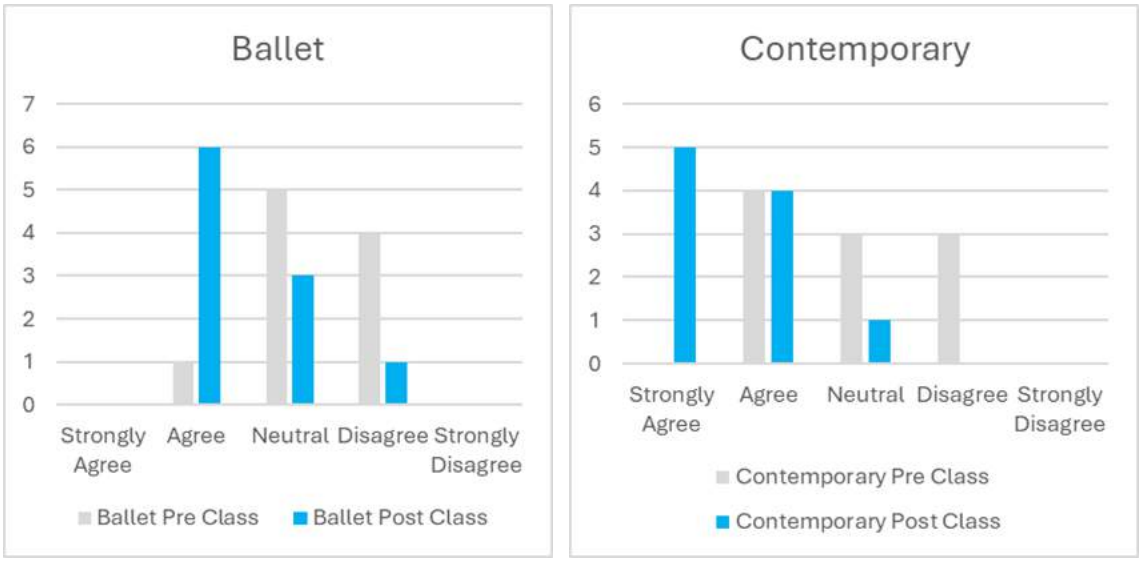


Figure 4. Comparison for the statement: “I am in a flow-state.”

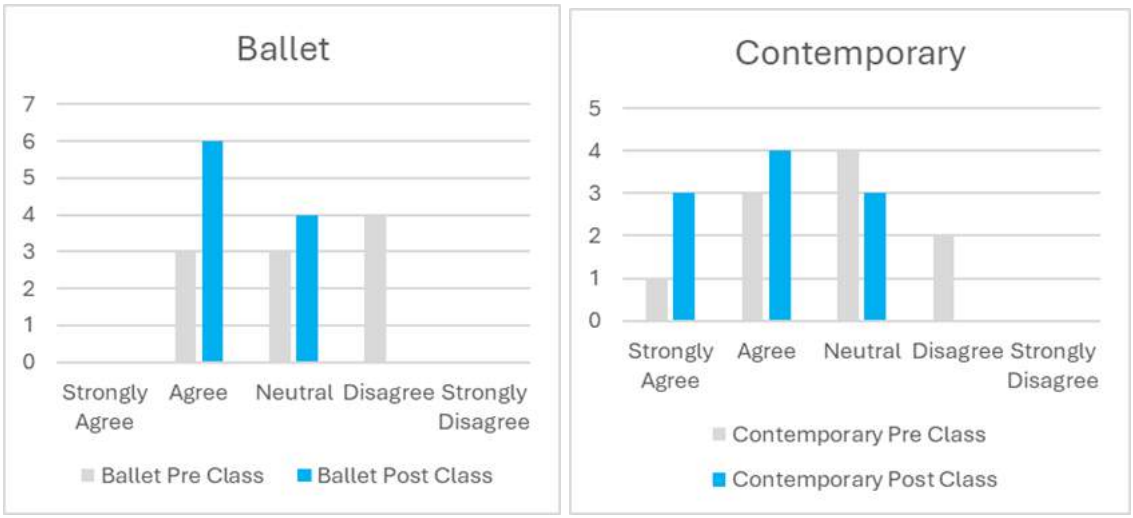


Figure 5. Comparison for the statement:”My mind feels clear.”

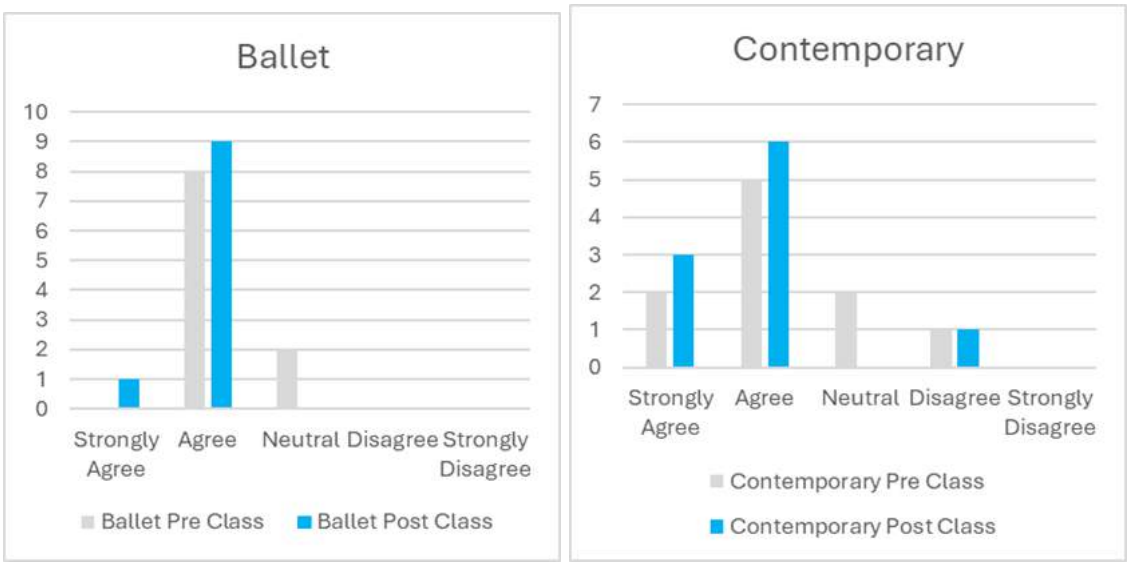


Figure 6. Comparison for the statement: " I feel in control of my emotions."

Coding of Open-Ended Responses

To analyze the qualitative results, I measured the abundance of themes within survey responses. Quantifying emotional themes helps determine which themes characterize a style and provides a more objective way to compare dancers' experiences in each style. For all of the qualitative responses, I coded units of meaning to themes that emerged in the responses (Figures 7&8). During coding, I counted each mention of a theme in a specific response, as this helped me discern which themes were most significant. I looked at the context surrounding the unit of meaning to determine which theme I thought it correlated to, rather than just looking for keywords. I defined a theme as a recurring response that was stated five or more times. I had a peer researcher look over my work to try to eliminate researcher bias.

Question 8 asked participants to attribute words to how they felt dancing the distinct styles (Figures 9&10). In responses to this question, both groups had more than 13 mentions of increased well-being and more than 6 mentions of empowerment/confidence. However, a key difference between the styles was the mention of challenge: ballet participants had 12 mentions of challenge while contemporary participants only had 7. Another difference was that the themes of self-expression, release, mind-body integration, and peace only arose in contemporary participants' responses, while the themes of elegance, control, and focus only emerged in ballet participants' responses.

For the qualitative survey questions that both groups Orange and Red filled out, ballet had more mentions of increased feelings of accomplishment, while contemporary had more mentions of increased well-being and feeling more energized. However, question 6 asked respondents why they thought the changes occurred in that style. In response to this question, increased well-being was considered a theme for those who took ballet, but not those who took contemporary. Also in response to question 6, the theme of community came up 14 times in contemporary participants' answers, but was not a theme in ballet responses. Along with this,

negative self-perception (both due to personal error and outside factors) was counted as a cause for mood shift 7 times in ballet participants' responses, yet contemporary respondents did not mention negative self-perception enough for it to be considered a theme. A final notable difference was the theme of artistic appreciation, which came up as a cause for mood shifts in contemporary respondents, but not ballet respondents.

Theme (what shifted/ current mood)	Quantity
Increased exhaustion	4
Increased feelings of accomplishment	3
Well-being	14
Freedom	1
Mind cleared (not running on automatic)	2
Energized	10
Negative emotion	5
Self-expression	2
Peace	4
Focused	3
Artistic inspiration/ appreciation	1

Theme (why)	Quantity
Artistic appreciation/ inspiration	7
Increased feelings of accomplishment	4
Well-being	2
Physical movement	4
Community	14
Negative self-perception (personal error)	1
Negative self-perception (outside factors)	1
Focus	2
Challenge	1
Anxiety	1

Figure 7. Quantity of themes for contemporary participants responses to question 5,6,7.

Theme (what shifted/ current mood)	Quantity
Increased exhaustion	6
Increased feelings of accomplishment	5
Well-being	10
Increased confidence	1
Mind cleared (not running on automatic)	3
Energized	6
Negative emotion	3
Freedom	1
Mind-body integration	1
Peace	2
Curiosity	1
Artistic appreciation	1

Theme (why)	Quantity
Artistic appreciation	2
Increased feelings of accomplishment	4
Well-being	5
Physical movement	2
Community	4
Negative self-perception (personal error)	3
Negative self-perception (outside factors)	4

Figure 8. Quantity of themes for ballet participants responses to question 5,6, and 7.



Figure 9. Question 8-word cloud for contemporary participants



Figure 10. Word cloud for ballet participants responses to question 8.

Discussion

Previous dance psychology research has attributed increased calm, positive body perception, trust, self-expression, excitement, creativity, confidence, relaxation, motivation, intelligence, energy, and self-esteem to dance participants (Gurley et al. & Schwender et al. & Klaperski-van der Wal et al). My study affirmed many of these effects, and illuminated that though some of these effects are shared between ballet and contemporary, others are more prevalent in a specific style.

Effects of Ballet

From synthesizing written responses and statistically significant differences in agreement with my Likert questions, I can conclude that ballet can be attributed to feeling happy,

challenged, accomplished, and in control. Ballet participants had a statistically significant improvement in agreement with the statement "I feel in control of my emotions" in the quantitative survey, while in the qualitative surveys the themes of feeling challenged – and also having a sense of accomplishment in meeting the challenge – were the most prevalent (with most people viewing challenge as a positive). For example, one subject stated that they were "thankful for such a fun and challenging class," while another subject stated, "achieving success in combinations feeds my self-confidence." Ballet is an academic technique that has a lot of physical demand (Guest & Kant). In comparison to contemporary, ballet has a more rigid technique that forces the dancer to follow stricter guidelines to perform the movement correctly. Because of this, it is logical to connect the rigor of the technique to feelings of challenge, but my research illuminates that this challenge also creates positive feelings of accomplishment. The only theme that arose in ballet participants' answers to why they thought ballet evoked these effects was an increase in feelings of well-being. This presents the idea that although ballet is associated with challenge, tackling this challenge creates feelings of well-being and accomplishment.

Effects of Contemporary

On the other hand, contemporary can be attributed to greater emotional understanding, self-expression, mind-body integration, peace, inspiration, and feelings of flow-state. Contemporary is more concentrated on expression of mental landscape through physical movement than ballet. One participant stated, "did a short combo that required personal improv and artistry which allowed me to be in a meditative state and look within" - demonstrating how this style of the movement required more inward reflection that led participants to feel like they expressed their emotions and thereby reached a state of mental clarity and well-being. Respondents attributed these effects most commonly to community and artistic appreciation. This furthers the idea that the nature of contemporary dance fosters a type of vulnerable expression that promotes community and bonding. One participant exemplified this idea stating, "We also got to watch our friends which made me so happy seeing them dance and express themselves." Overall, contemporary's more creative, free-from, emotional nature presents the opportunity for self-expression and connection that benefits participants' psychological health.

However, another trend came up that I did not expect. There is a clear pattern of contemporary producing more overall extreme shifts in psychological state. This is evidenced by larger differences in means and far more contemporary participants selecting that they "strongly agreed" with statements in their post-class survey (Figures 2,3,4,5, and 6). My qualitative data also supports this trend, as the theme of increased well-being was more prevalent in contemporary dancers' responses. This may indicate that overall, contemporary has a stronger positive effect on psychological state than ballet. I hypothesized that ballet and contemporary would both create positive psychological effects, yet these specific effects would overlap and deviate between the styles. I did not hypothesize that one style would overall have stronger effect than another. I theorize that this disparity between contemporary and ballet has grounds in the

embodiment theory. The embodiment theory proposes that knowledge is generated and psychological state is impacted by physical experience (Schwendener et al.). This is far more applicable to contemporary dance, where the movement is more rooted in sensation, exploration, and feeling than ballet is. Furthermore, contemporary ballet lacks the rigid "right or wrong" standard that ballet has, which could explain the reduced "negative self-perception" experienced by contemporary dance participants (7 counts in ballet, 2 counts in contemporary). Overall, this illuminates how contemporary has the potential to promote stronger positive psychological effects than ballet.

Limitations

My small sample size with limited diversity and geographic scope may reduce the extent to which my results are generalizable. It is possible that with more participants, more items may have had a statistically significant change. Along with this, all of my participants came from dance studio X in Washington and were experienced female dancers between 15-18 years old, although I did have a large ethnicity range in my responses. Studio environment may play a role in experiences with dance. However, there is no previous research suggesting that dance creates different psychological effects in different locations, so I believe this research can be generalized to a larger geographic area. Lastly, the length of the classes in each style was different, which could have impacted the subject's experiences. The ballet class was two hours, while the contemporary class was one hour. However, the length used for each class is typical to the style, so changing it would make the class uncharacteristic to the style.

Another limitation I encountered is the subjective nature of trying to quantify psychological state. I tried to counter this by employing both quantitative and qualitative methods to get a holistic picture of subjects' psychological state. However, it is possible I missed other variables impacting participants' psychological state; though I did use a question in my qualitative survey to offer participants a place to tell me about anything that may have impacted their experience at dance. Further, having multiple groups take both styles also helped give me a range of participants who could offset an outlier.

Conclusion

Future Research

Studying the psychological effects of distinct dance styles is an unexplored area of dance psychology. There are countless other dance forms that could be studied, for example hip-hop, jazz, and ethnic dance styles such as flamenco, African, or Irish dance. Along with this, my research model could be applied to more diverse demographics to create more generalizable results; for example: beginners and non-dancers, elderly populations, adult dancers, and other locations. Furthermore, my quantitative survey evidenced that it is possible for one style to overall have a greater effect on psychological state. Because my study did not fully focus on this,

there is potential for future research on whether contemporary is more effective at creating positive psychological effects for participants than other styles.

Further Implications

My research illuminates how using specific dance styles in dance interventions for mental health can help target specific aspects of psychological state. This research could be applied to dance therapy and expanded within the emerging fields of neuroaesthetics and neuroarts. Dance therapy is, "The psychotherapeutic use of dance, movement, body awareness, and embodied communication to foster healing and well-being for all individuals, families, and communities" (American Dance Therapy Association, para. 1). Neuroarts is "an interdisciplinary field, rooted in the science of neuroaesthetics and ways of knowing, which explores how the arts and aesthetic experiences change the brain, body, and behavior and how this knowledge can be applied to advance health and well-being across society" (NeuroArts Blueprint Initiative, para. 2). Within these fields that specifically leverage artistic participation for positive psychological impacts, my research can provide valuable tools for refining and tailoring the use of dance to achieve specific desired outcomes. For example, if a clinician is treating a patient who has a lack of self-efficacy, my research suggests ballet's focus on challenges that evokes feelings of accomplishment would be more effective for this patient. On the other hand, if a patient is struggling with emotional repression, using contemporary dance may be a more successful approach to help them become more emotionally attuned and feel expressed.

Final Thoughts

The research question, "What are the differences in positive psychological effects between two distinct dance forms: ballet and contemporary?" can be answered using my quantitative and qualitative data gathered. By analyzing the disparities between the styles through shifts in agreement in the quantitative survey, and the differences in number of theme occurrences in the qualitative survey, the research question is answered with data that reveals that some psychological effects are shared between the styles, while other effects are more prevalent in a specific style. My hypothesis that "ballet will make participants more focused, aware, and in control; while contemporary will make participants feel more emotionally attuned, expressive, and connected to an inner 'flow-state,'" was partially correct. While ballet can be attributed to feelings of control, it is more accurate to associate feelings of challenge, accomplishment, and self-efficacy with ballet. My hypothesis that contemporary overall helps participants feel expressed and emotionally attuned was reflected in the data. However, I did not foresee contemporary creating an overall larger effect than ballet. These findings are important contributions to understanding dance's effect on the brain and effectively leveraging dance for psychological interventions.

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The Cognitive Impact of Childhood Lead Exposure: A Global Meta-Analysis of Effect Sizes

By Ella Spitzer

Abstract

Lead is a heavy metal neurotoxin that disrupts neurological development by interfering with synapse formation, neurotransmitter signaling, and neuronal growth in children. Although numerous epidemiological studies report an inverse association between blood lead levels (BLLs)(μg/dL) and cognitive measures, like IQ, MDI, and PPVT, the magnitude of this effect across populations is unclear and under-explored. This meta-analysis explores the relationship between elevated blood lead levels and cognitive capacity in children worldwide using an effect size parameter, Cohen's d, and comparing d values over time

In our meta-analysis, 13 eligible studies examining the relationship between BLL and standardized cognitive outcomes in children were identified. Both regression-based and group comparison designs were included. For regression studies, effect sizes were derived from correlation coefficients (r) and converted to Cohen's d. For group-comparison studies, Cohen's d was calculated using the pooled standard deviation and the difference in means. Across studies conducted in the United States, Mexico, Nigeria, Poland, Australia, China, and pooled international cohorts, elevated BLLs were consistently associated with lower cognitive performance. Cohen's d effect sizes ranged from small ($d \approx -0.169$) to very large ($d \approx -3.822$), with most studies demonstrating small-to-moderate negative effects ($d \approx -0.20$ to -0.45).

This meta-analysis demonstrates that elevated blood lead levels are associated with measurable and statistically significant reductions in cognitive capacity across diverse populations have remained consistent across studies spanning nearly 3 decades. Although individual effect sizes are typically small to moderate, their widespread occurrence may have substantial impacts. Even modest reductions in cognitive performance at the individual level may shift the distribution of cognitive ability across entire populations, increasing educational support needs, reducing lifetime productivity, and generating substantial economic cost. These findings reinforce the absence of a safe exposure threshold and highlight the need for continued public health efforts to reduce childhood lead exposure.

Introduction

Environmental neurotoxins are materials in the water, air, food, and soil that negatively affect the human nervous system. Numerous environmental neurotoxins, including mercury, pesticides, and heavy metals like lead, have been linked to impaired neurological development. Among these, lead has been studied most extensively because of its historical prevalence, persistence in the environment, and well-established effects on the developing brain (Gonzalez-Villalva et al.). During childhood, the brain undergoes rapid development, during which synapse formation, neuronal migration, and myelination occur (Desye et al.). These processes are essential for learning, memory, attention, and higher cognitive functioning. Because the developing nervous system is highly sensitive to chemical disruption, exposure to neurotoxins, like lead, during early developmental stages can interfere with neurotransmitter

signaling and neural connectivity (Desye et al.). When this disruption occurs at an early age, it can lead to a wide scope of neurological and developmental issues, resulting in long-term deficits in cognition, behavior, and academic performance (Surkan et al.).

Lead is one of the most extensively studied environmental neurotoxins and has been recognized as a major public health concern due to its widespread historical use and well-documented effects on neurological development (Grosse et al.). As lead-containing products deteriorate and release particles into the environment, humans may be exposed through old paint, industrial emissions, and contaminated water pipes, which can cause harm to our nervous system (Grosse et al.). Prior research shows that exposure to high levels of lead can cause developmental delays, behavioral problems, and cognitive impairment (Needleman et al.).

Because cognitive development influences educational achievement, behavioral regulation, and long-term socioeconomic outcomes, factors that impair neurological function during childhood represent a major public health concern (Grosse et al.). Early landmark studies, including Needleman et al. (1979), were among the first to demonstrate that even low levels of lead exposure were associated with reduced cognitive performance in children. These findings contributed significantly to major public health interventions, including the removal of lead from gasoline and stricter regulation of lead-based paint (Mushak; Needleman et al.).

Beginning in the 1970s, many countries implemented major policies to reduce lead exposure following growing evidence of its adverse health effects. The United States began phasing out leaded gasoline in the 1970s and restricted lead-based paint for residential use in 1978 (M. Chen et al.). Similar measures were subsequently adopted in numerous countries, culminating in the global elimination of leaded gasoline for road vehicles, which was officially achieved in 2021 through international efforts led by governments and organizations such as the United Nations Environment Programme (UNEP) (M. Chen et al.).

Although many countries have made substantial regulatory progress through the phase-out of leaded gasoline and stricter controls on lead-containing products, lead exposure remains a persistent environmental health concern in numerous regions due to aging infrastructure, industrial contamination, and old housing material (Grosse et al.; Wan et al.). Many recent studies have shown an association between elevated blood lead levels and decreased cognitive capacity. However, the magnitude of this effect across populations remains unclear (Dike et al.; Jusko et al.; Nwobi et al.; Wan et al.). Understanding the size of this impact is critical, as population-level reductions in cognitive performance may contribute to increased educational support needs, reduced workforce productivity, and broader economic and public health concerns (Grosse et al.). In a 2023 Lancet Planetary Health analysis, Larsen and Sánchez-Triana estimated that lead exposure resulted in the loss of approximately 765 million IQ points among children under 5 globally, contributing to a total economic burden of roughly US$6 trillion, or 6.9% of global GDP, in 2019 (Larsen and Sánchez-Triana). Effect sizes, such as Cohen's d, allow for direct comparison across studies and provide a clearer measure of the overall impact of lead exposure.

The goal of this study is to answer two questions: to what extent do elevated blood lead levels reduce cognitive performance in children across global populations, and how has it changed over the past few decades? In this study, we will calculate and compare the effect sizes parameter Cohen's d across international studies to quantify the magnitude of cognitive impact from environmental lead exposure in children and compare d values across time. Based on previous research demonstrating an inverse relationship between blood lead levels and cognitive outcomes, it was hypothesized that elevated blood lead levels would be associated with negative Cohen's d effect sizes across studies, indicating reduced cognitive performance in exposed children. It was further hypothesized that this negative relationship would remain consistent across countries and study periods despite differences in population characteristics and cognitive assessments.

Methods

After a systematic search of PubMed, 1,695 papers were identified that examined the effects of the neurotoxin lead (Pb) on cognition. Studies were screened and selected based on inclusion and exclusion criteria, including population, study design, availability of paper, and inclusion of statistical data required to calculate Cohen's d, as shown in Figure 1. Finally, 13 papers were selected that met the criteria. Location was not an exclusion criterion for the search; however, the final papers chosen included a variety of places, United States, Nigeria, Australia, China, Mexico, Poland, and an international cohort, to ensure a broader world meta-analysis. Within the selected pool of studies, several used multivariable linear regression models to examine the association between blood lead level (BLL) and standardized cognitive outcomes (IQ, PPVT, MDI). These studies reported β coefficients, which represent the change in cognitive score per microgram per deciliter (μg/dL) increase in BLL, adjusted for covariates such as socioeconomic status, maternal education, and other environmental factors.

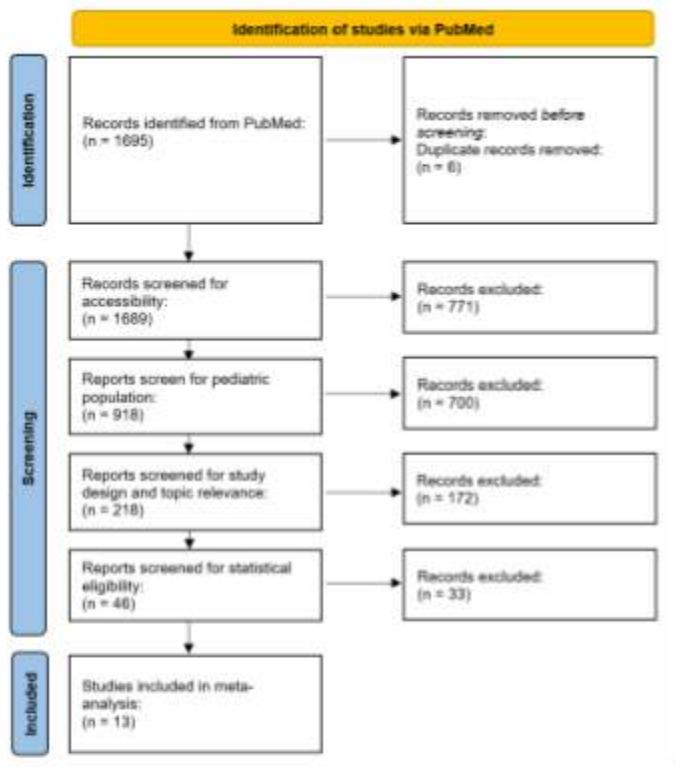


Figure 1: PRISMA Flowchart for Study Selection

This flow chart summarizes the study selection process used in the meta-analysis. A total of 1,695 studies were identified through PubMed and screened according to predefined inclusion and exclusion criteria, resulting in 13 studies eligible for analysis.

For these studies, Bellinger et al. (1992), Canfield et al. (2003), A. Chen et al. (2005), Kordas et al. (2006), Lanphear et al. (2005), Surkan et al. (2007), Tong et al. (1996), Wan et al. (2020), effect sizes were calculated from β coefficients to correlation coefficients (r) by using $\frac{\beta}{SE} = t$ to calculate t, $df = n - 2$ to calculate df, then $r = \frac{t}{\sqrt{t^2+df}}$ to calculate the correlation coefficient. This was then translated to Cohen's d using the formula $d = \frac{2r}{\sqrt{1-r^2}}$. For studies in which the standard error was not directly reported, A. Chen et al. (2005) and Kordas et al. (2006), SE was calculated from the 95% confidence interval using $SE = \frac{upper-lower}{2\ x\ 1.96}$. This method standardized regression-based observational data into a common effect-size metric. For Kordas et al. (2006), Lanphear et al. (2005), Surkan et al. (2007), when calculating degrees of freedom, we had to adjust for the number of predictors, known as k. The formula $df = n - k - 2$ was used to calculate degrees of freedom for these studies (Borenstein et al.). The other included studies, Jedrychowski et al. (2009), Jusko et al. (2008), Kordas et al. (2004), Nwobi et al. (2019), compared cognitive outcomes between exposure groups (higher vs lower BLL). These studies provided group means, standard deviations, and sample sizes. For the

comparison designs, the formula $SD = \sqrt{\frac{(n_1-1)SD_1^2+(n_2-1)SD_2^2}{n_1+n_2-2}}$ was used to calculate pooled SD, and $d = \frac{\bar{x}_1-\bar{x}_2}{SD_{pooled}}$ was used to calculate Cohen's d. For Jusko et al. (2008), the SD used to calculate Cohen's d was taken from table 1, which reported the SD for Full-Scale IQ for all children with complete data, making it the pooled SD (Borenstein et al.).

Calculating the Cohen's d value for each of the 13 studies standardizes mean differences between exposure groups, allowing comparison across studies using different cognitive assessments and initial information. Although cognitive outcomes varied across studies (IQ, PPVT, MDI), all measures were standardized developmental assessments with comparable scaling. The Mental Development Index (MDI) has been described as statistically analogous to IQ, and the PPVT is a norm-referenced standardized cognitive test. Therefore, no score conversion was required prior to calculating effect sizes (A. Chen et al.).

For each eligible study, numerical data required to calculate standardized effect sizes were systematically extracted, including sample size (n), regression coefficients (β), standard errors (SE), 95% confidence intervals, group means, standard deviations, and number of predictors included in multivariable models. When standard errors were not directly reported, they were derived from reported 95% confidence intervals using established statistical conversion methods (Borenstein et al.). All extracted values were entered into a structured spreadsheet, where effect size calculations were performed consistently across studies. To ensure straightforward comparability, all effect sizes were converted to Cohen's d, providing a standardized metric independent of the original cognitive scale units. Cognitive outcomes included IQ, PPVT, and MDI scores. Because these are standardized developmental assessments with comparable scaling, no additional score normalization was required (A. Chen et al.). All calculations were conducted using formula-based statistical procedures within spreadsheet software to maintain reproducibility and consistency. No weighting by study size was applied in this phase, as the primary objective was to quantify and compare the magnitude of effect across diverse populations rather than produce a pooled aggregate estimate.

Using Regression to Correlation Effect Size

Paper	Year	Location	n	β	95% CI	SE	df (k*)	t	r	Cohen's d
Wan	2020	Southern China	333	-0.12		0.03	331	-4	-0.215	**-0.44**
Dike IC	2020	Ishiagu and Akaeze, Nigeria							-0.886	**-3.822**
Surkan	2007	Massachusetts, USA	408	-6.04		2.39	397 (9)	-2.527	-0.126	**-0.254**
Kordas (2006)	2006	Mexico	532	-0.71	-1.43 to .02	0.37	518 (12)	-1.92	-0.084	**-0.169**
Lanphear	2005	Pooled International Cohort	1333	-2.7		0.53	1319 (12)	-5.094	-0.139	**-0.281**
Chen	2005	Boston, Massachusetts, US	644	-5.4	-7.8 to -2.9	1.25	642	-4.32	-0.168	**-0.341**
Canfield	2003	Rochester, New York, USA	172	-0.46		0.15	170	-3.067	-0.229	**-0.471**
Tong	1996	Port Pirie, Australia	375	-4.3		2.1	373	-2.048	-0.105	**-0.211**
Bellinger	1992	Boston, Massachusetts, US	148	-1.53		0.56	146	-2.732	-0.221	**-0.453**

Using Group 1 and 2 Comparison

Paper	Year	Location	Mean 1	Mean 2	n 1	n 2	SD 1	SD 2	Pooled SD	Cohen's d
Nwobi	2019	Ibadan, Nigeria	91.5	85.9	140	169	14	11.4	12.74	**-0.44**
Jedrychowski	2009	Krakow, Poland	103.58	101.48	83	80	11.4	13.1	12.264	**-0.171**
Jusko	2008	Rochester, New York, USA	91.1	85.9	79	62			14.4	**-0.3611**
Kordas (2004)	2004	Mexico	106.3	95.3	291	51	14.6	15	14.66	**-0.75**

Figure 2: Statistical Information and Cohen's d Values

This table summarizes the statistical data extracted and calculated from each study and the resulting Cohen's d effect sizes. Negative effect sizes indicate an association between higher blood lead levels and lower cognitive performance.

Results

As expected, across all 13 included studies, elevated BLLs were consistently associated with decreased cognitive performance in children. Of the 13 studies, eight used regression-based analyses and four used exposure group comparisons. Effect sizes were standardized to Cohen's d to allow direct cross-study comparison. When analyzing Cohen's d, values around .2 indicates a small effect size, .5 a medium effect size, and .8 a large effect size (Borenstein et al.). For regression-based studies, standardized effect sizes ranged from small, d = -.169, to medium, -.471. The majority of regression-derived effects fell between d = -.20 and -.45, indicating consistent small to moderate reductions in cognitive scores per increase in blood lead concentration (μg/dL). In group-comparison studies, effect sizes were similarly negative, indicating lower mean cognitive scores in higher-exposure groups than in lower-exposure groups. Most group-derived effect sizes ranged from approximately d = -.17 to -.44. One extreme value, d = -3.822, was identified in the study by Dike et al. (2020), where a very strong reported correlation was directly provided. This extreme value was treated as an outlier relative to the broader literature and interpreted cautiously, as it may reflect unique population conditions, reduced variance within the sample, or unusually high environmental exposure levels. In studies with lower variance or more concentrated exposure ranges, effect sizes may appear artificially amplified, exaggerating the magnitude of observed relationships (Borenstein et al.).

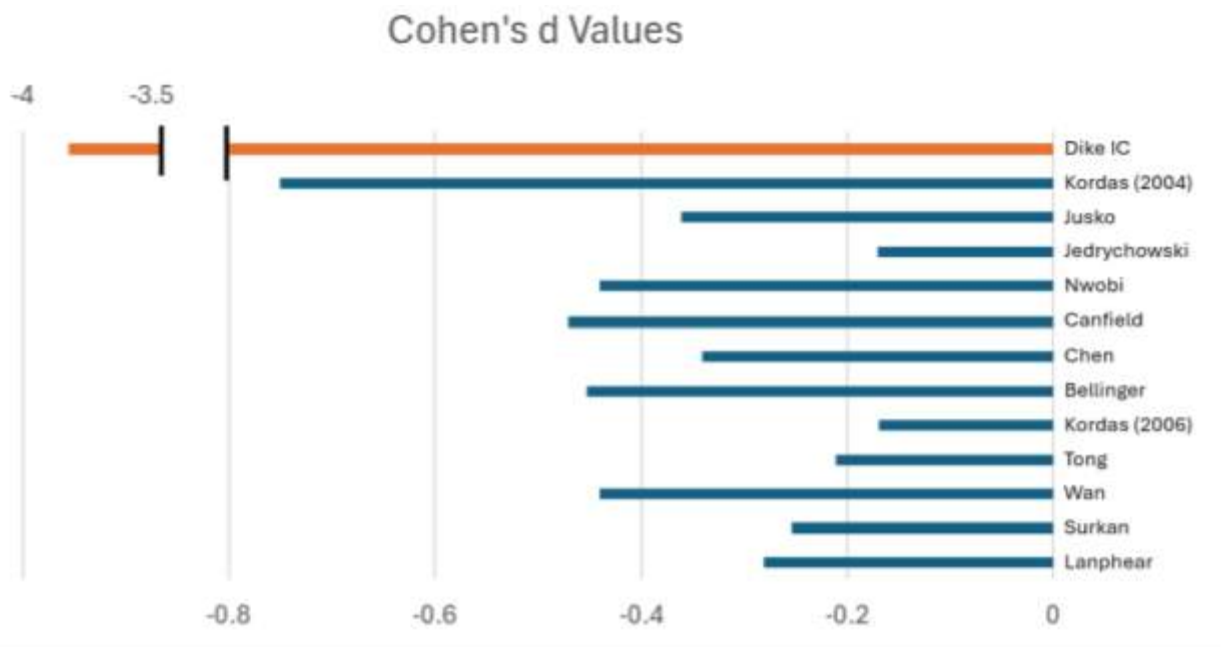


Figure 3 – Truncated Graph of Resulting Effect Sizes

This graph displays the Cohen's d values calculated for each included study. Most effect sizes fall within the small-to-moderate range of -0.2 to -0.45 and consistently indicate reduced cognitive performance associated with higher blood lead levels.

To examine whether the magnitude of lead's cognitive effects has changed over time, Cohen's d values were compared across studies published between 1992 and 2020. Despite substantial reductions in population-level lead exposure following regulatory interventions such as the phase-out of leaded gasoline and restrictions on lead-based paint, effect sizes remained relatively stable across decades. The average value for the studies conducted in the 90s is d = -0.332. For the studies conducted in the 2000s, the average d value is d = -0.34976. For the studies conducted in the past 10 years, not including the outlier value to avoid skewing the average, the average d value is d = -0.44. Although the average effect size appears slightly larger in more recent studies, the difference between the decades are small. This suggests that the neurocognitive effects of lead exposure have remained broadly consistent over time despite major regulatory changes.

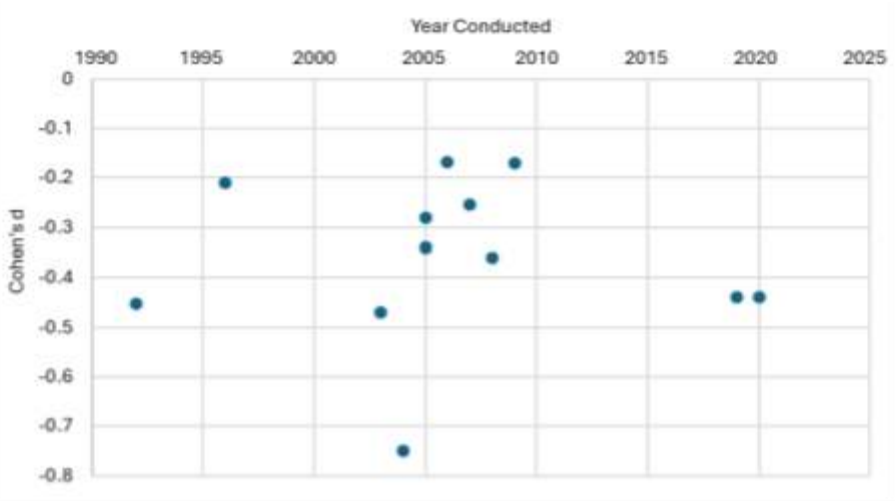


Figure 4 - Scatterplot of Cohen's d by Year (Excluding the Outlier)

This scatterplot shows the relationship between the year the study was conducted and the Cohen's d value. No clear temporal trend was observed which suggests that the magnitude of lead-associated cognitive impairment has remained relatively unchanged across decades.

Overall, the direction of effect was consistent across all included studies: higher BLLs were associated with decreased cognitive performance. While effect sizes were generally small to moderate, their consistency across multiple countries suggests a persistent and widespread impact of lead exposure on cognitive performance. These results demonstrate that even though many believe that childhood lead exposure has decreased due to major regulations on lead products, cognitive impairment due to lead exposure in children has remained remarkably stable over the past 3 decades. The consistency shown across countries, study designs, and time periods represents a new perspective on childhood lead exposure.

Discussion

This meta-analysis sought to quantify the magnitude of cognitive impairment associated with elevated blood lead levels in children across diverse global populations by converting regression coefficients and group mean differences into a standardized effect size metric, Cohen's d, and comparing those values across the studies, spanning around 30 years. This study provides a direct comparison of the strengths of association across multiple study designs, time periods, and geographic contexts. The results demonstrate a consistent, negative relationship between blood lead exposure and cognitive performance. Despite differences in population and cognitive measures, effect sizes showed surprising stability over time, indicating that the neurocognitive impact of lead exposure has remained consistent throughout decades.

An additional finding of this study was the relative consistency of effect sizes across publication decades. Although substantial regulatory interventions have dramatically reduced average blood lead levels since the 1970s, the magnitude of the association between lead exposure and cognitive impairment remained remarkably consistent across studies published

from 1992 to 2020 (Gonzalez-Villalva et al.). The average Cohen's d values ranged from approximately -0.33 in studies from the 1990s and -0.35 in the 2000s to -0.44 in studies from the past decade, indicating only modest variation over time. This pattern suggests that while public health policies have put strict regulations on lead products, children are still being exposed to and affected by lead.

The present findings are consistent with early foundational research, such as Needleman et al. (1979), which played a pivotal role in shaping environmental policy and reducing widespread lead exposure (Mushak; Needleman et al.). Although average blood lead levels have declined substantially since the removal of leaded gasoline and restrictions on lead based paint, exposure remains common in many regions due to aging infrastructure, industrial emissions, informal recycling activities, and legacy environmental contamination (Desye et al.).

Even small standardized reductions in cognitive performance at the individual level translate into substantial population-level consequences. A shift of just 1 to 5 IQ points across large populations can significantly alter the distribution of cognitive ability, increasing the number of individuals requiring additional educational support while reducing the proportion of individuals in higher performance ranges. The consistency of findings across countries, including both high-income and middle-income regions, indicates that the neurotoxic effects of lead are biologically universal rather than culturally or socially specific. While socioeconomic and environmental confounders were statistically controlled in these studies, the association between blood lead level and cognitive decline remains significant. These findings reinforce the well-established understanding that lead acts as a neurodevelopmental toxin, particularly harmful during a critical period of synaptic formation and brain maturation during childhood (Desye et al.). However, unlike previous reviews, this study quantified and directly compared Cohen's d values, highlighting the stability of these effect sizes over time.

Limitations

Several limitations must be acknowledged. First, due to ethical constraints, true experimental manipulation of blood lead levels is not feasible. Therefore, all included studies used observational or quasi-experimental designs, incorporating statistical controls such as socioeconomic status and maternal education to reduce confounding variables and strengthen causal inference. Second, some regression-based studies required the derivation of standard errors from confidence intervals, introducing a potential minor estimation variability. Third, although cognitive measures vary across studies, they are standardized development assessments with comparable scaling. Nonetheless, minor measurement heterogeneity may contribute to variance and to the magnitude of effect sizes. Fourth, this meta-analysis did not weigh by study size in the Cohen's d calculations, because the main goal of this study was to quantify and compare the magnitude of effect across different studies rather than calculate a pooled aggregate estimate. Weighting by study size would cause the studies with smaller participant numbers to have a much smaller relative importance. An additional limitation involves the comparison of effect sizes across decades. Although average Cohen's d values were calculated for studies

published in different time periods, the number of studies available within each decade was relatively small and unevenly distributed. Furthermore, the decade-based comparisons were descriptive and did not involve formal statistical trend testing because the studies included in my analysis did not track their participants over time. As a result, conclusions regarding the stability of effect sizes over time should be interpreted cautiously and viewed as preliminary observations rather than definitive evidence of temporal trends. Finally, an extreme outlier in the effect size suggests potential differences in the environment in which the sample was collected. The large Cohen's d in the study by Dike et al. (2020) may suggest that some populations are more exposed to lead in their environment than others, due to specific locations or socioeconomic status.

Conclusion

This meta-analysis found that the cognitive effects of childhood lead exposure are not only consistently negative, but also the magnitude of that impairment has remained surprisingly stable across three decades of research, despite major reductions in environmental lead exposure. Excluding one extreme outlier, most effect sizes are clustered within a narrow small-to-moderate range (d = -0.20 to -0.45), suggesting that lead produces a predictable and measurable reduction in cognitive performance across diverse populations. Although these individual effects may appear modest, their cumulative impact across millions of children can translate into substantial educational, economic, and public health consequences.

The absence of a safe exposure threshold, combined with consistent cross-national findings, reinforces the urgent need for continued environmental remediation efforts and preventive public health strategies. Lead exposure is not only an environmental contamination issue, but a measurable threat to human intellectual development.

Future Research

Future research should expand upon these findings by conducting further longitudinal-dose response analysis to better characterize the relationship between varying levels of blood lead levels exposure and cognitive decline over time, particularly at exposure levels below current regulatory thresholds. Additional investigation into low-level lead exposure is critical to determine whether even minimal concentrations continue to produce measurable neurodevelopmental effects. Incorporating neuroimaging and neurobiological markers could further clarify the structural and functional brain changes associated with elevated blood lead levels. Future studies should also evaluate the effectiveness of policy-driven interventions, such as lead pipe replacement and soil remediation programs, to determine whether reductions in environmental exposure correspond to measurable cognitive improvements at the broader population level.

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Assessing the Aerodynamic Effects Various Fin Profiles Have on the Performance and Trajectory of Model Rockets By Carsten Pribadi and Kyle Kennedy

Abstract

Model rocket fins are essential components during a model rocket's flight. Without them, flight stability and apogee are both compromised. However, there are many fin shapes, profiles, and structures that one can incorporate into their model rocket design, with each distinct fin set design affecting the rocket's aerodynamics. There are many different opinions on what fin shape performs the best and what fin shape performs the worst, along with why certain fin shapes behave in their respective ways. We decided to put these ideas to the test; to discover what effects each fin profile has on its parent rocket, we ran multiple experiments in the form of launching several rockets, each with a different set of fins. In this research paper, twelve different fin shapes and profiles are tested, analyzed, and compared for their various flight performances. Following the experiment, the effects of fin shapes on a model rocket are studied and analyzed in more detail, and the reasons for these changes are thoroughly investigated. The fin shapes we tested include trapezoidal symmetrical, trapezoidal delta, trapezoidal swept, and elliptical. The fin cross-sections we tested include square, rounded, and airfoil. Through this paper, we seek to learn more about not just why each fin set affects a rocket in a certain way, but also about aerodynamics and the behavior of airflow in general.

Introduction

During a rocket launch, one of the most important aspects of its flight is the rocket's stability. A rocket is stable if it can counter the dynamic forces it is subject to, exerted by the rocket motor's thrust, weight, and atmospheric effects, including drag and wind. An unstable rocket would be extremely chaotic, unpredictable, and hazardous.

According to Van Milligan, in an Apogee Rockets newsletter, a rocket's stability is determined by the location of the rocket's center of gravity (CG) and the location of the rocket's center of pressure (CP). "The definition of Center-of-Pressure is the point on the rocket where all the aerodynamic forces balance," Van Milligan says (2). Van Milligan also says that you can use a 2-dimensional cutout of a rocket to find the CP – this can be found at the point at which there is an equal amount of surface area both forward and aft. The rocket's CG is defined as the point at which there is an equal amount of mass both forward and aft; thus, you can determine a rocket's CG by finding the point at which you can balance the rocket on your finger or the edge of a ruler (Van Milligan).

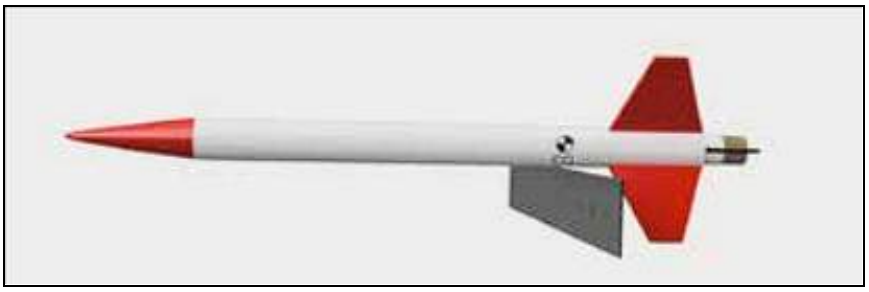


Figure 1: A visualization of balancing a model rocket on the edge of a ruler, revealing its CG. [4]

Van Milligan also says that a rocket is more stable the further back the CP is from the CG; however, a rocket is less stable if the CP is too close to the CG, and a rocket is completely unstable and unpredictable if the CP is ahead of the CG. This is because airflow that is not parallel to the rocket's trajectory will result in torque that rotates the rocket about its CG; however, since the CP is further aft than the CG, once the rotation aligns the rocket to the airflow, the torque is effectively eliminated and the rocket stays parallel to the airflow. A diagram to illustrate this idea is seen below:

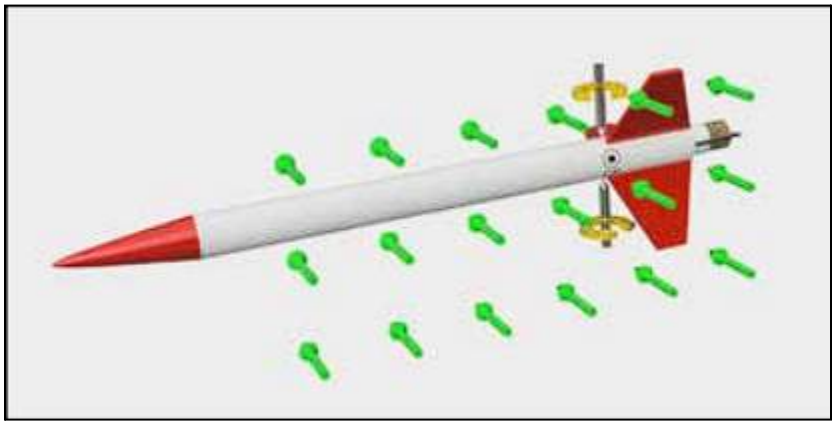


Figure 2: A diagram illustrating how an aft CP helps eliminate angular momentum derived from gusts of wind. [4]

Thus, when one designs and constructs a rocket, it is essential to make sure our CP is at least one body tube diameter behind the CG (this is a common rule of thumb in model rocketry) (Van Milligan).

Since the rocket's CP is directly dependent on the rocket's surface area distribution, it would make sense to think that one could make the rocket more stable by adding surface area to the back of the rocket. This is the exact principle behind rocket fins – adding surface area to the back of the rocket to pull the CP back and, in turn, increase rocket stability.

There are many shapes, sizes, and materials from which you can make rocket fins. One property of fins, particularly trapezoidal fins, is called the sweep angle. Wood defines sweep angle as "...the angle at which the wing is translated backwards (or occasionally forwards) relative to the root chord of the wing." (par. 2)

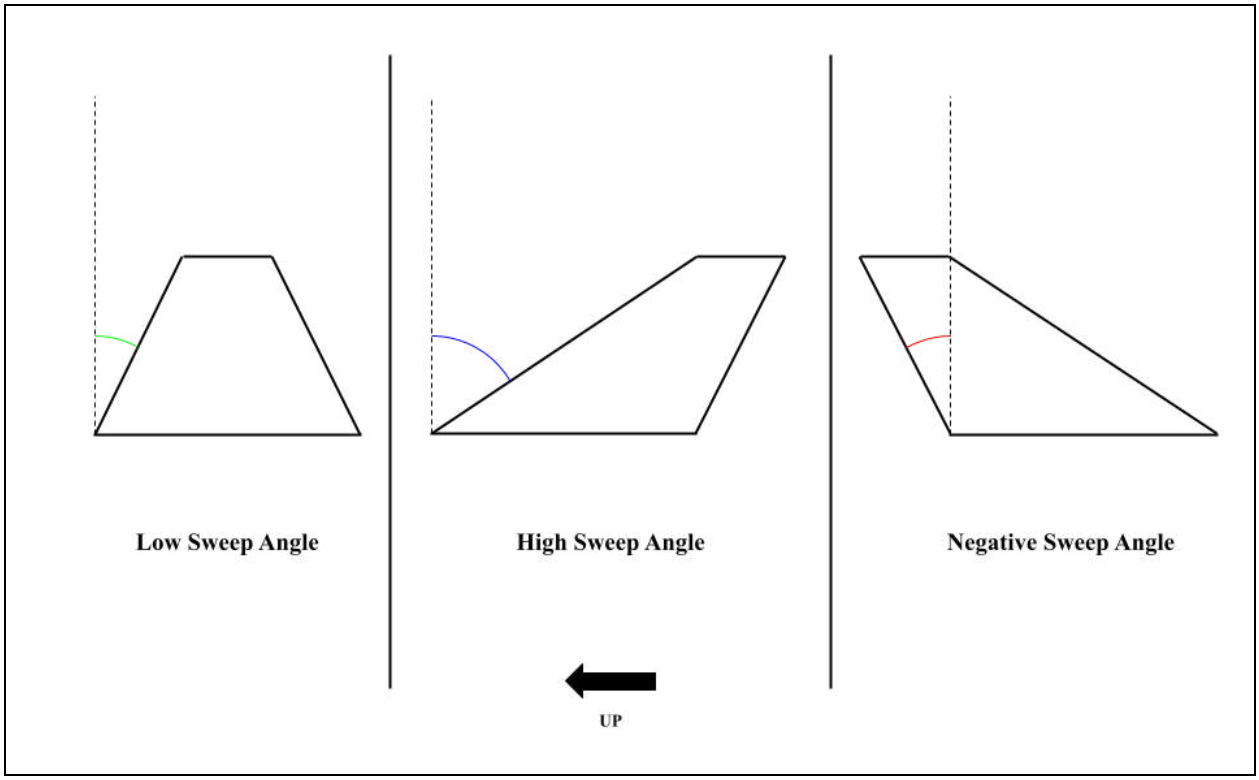


Figure 3: Three fin designs with varying sweep angles. The low sweep angle design could be called “symmetrical”, since it is symmetrical along the vertical axis, and the high sweep angle design could be called “swept”. Created by author.

As we can see in Figure 3, some fins have a high sweep angle, some have low sweep angles, and some even have negative sweep angles – meaning that their tip chord is forward instead of aft. Since fins do not just affect CP, but also have mass, the shapes and sizes of rocket fins will heavily influence the behavior of the rocket.

But how exactly does fin shape and structure influence the trajectory and apogee of a rocket? How exactly does a more swept-back fin affect the rocket’s drag? How does the cross-section of a fin (square, rounded, airfoil) impact the rocket’s apogee? These are the questions this research project aims to answer – and to answer them, we conducted multiple experiments to further research and analyze fin aerodynamics.

Our Hypothesis and Other Relevant Work

This experiment has 2 criteria: fin shape and fin cross-section. There are 4 distinct fin shapes: trapezoidal symmetrical, trapezoidal delta, swept trapezoidal, and elliptical.

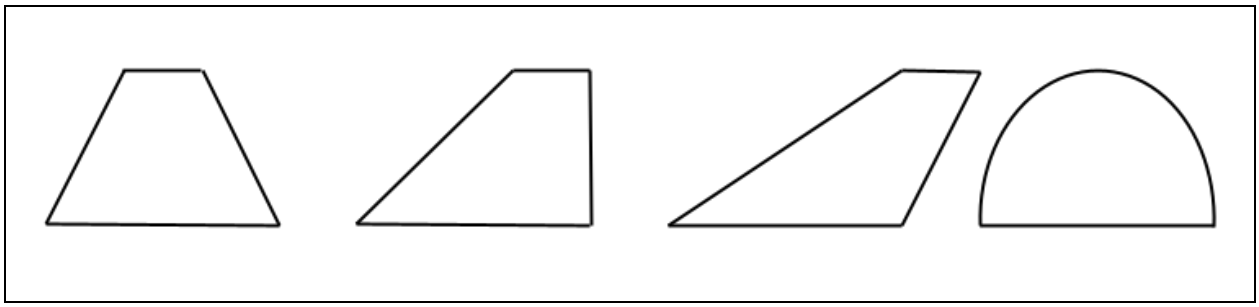


Figure 4: A visualization of each of the four fin shapes. From left to right: trapezoidal symmetrical, trapezoidal delta, trapezoidal swept, and elliptical. Created by author.

	Trapezoidal Symm:	Trapezoidal Delta:	Trapezoidal Swept:	Elliptical:
Root Chord (in)	3	3	3	3
Tip Chord (in)	1	1	1	N/A
Sweep Angle (°)	26.6	45	56.3	N/A
Height (in)	2	2	2	2
Maximum Thickness (in)	0.125"	0.125"	0.125"	0.125"
PLA Infill (%)	50	50	50	50

Figure 5: The specifications of each of the four fin shapes. All fins' root chord, height, maximum thickness, and PLA infill are the same. Created by author.

Additionally, there are 3 distinct fin profiles: square, rounded, and airfoiled.

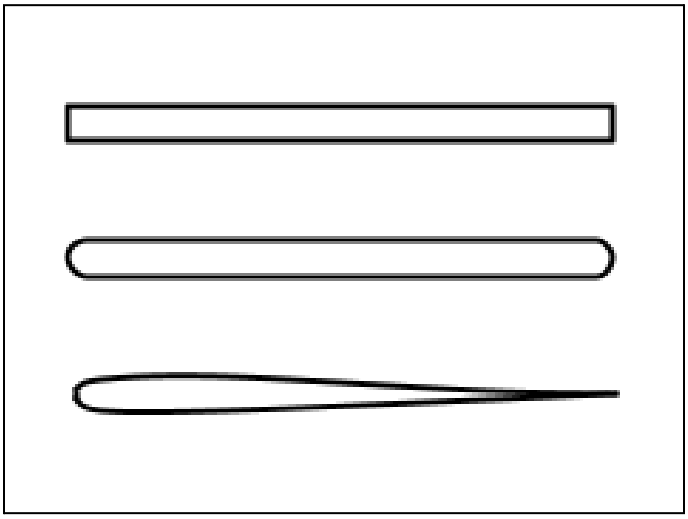


Figure 6: A bird's-eye-view visualization of each of the three fin cross-sections. From top to bottom: square cross-section, rounded cross-section, and airfoil cross-section. Created by author.

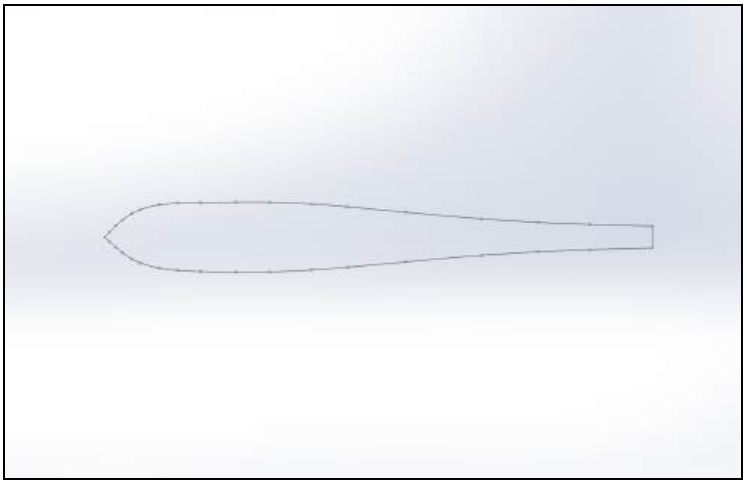


Figure 7: A bird's-eye-view visualization of the splines used in SOLIDWORKS for Makers to make the airfoil cross-section fins. Created by author.

All of our fins were 3D-printed and were composed of PLA material. PLA, also known as polylactic acid, is a common 3D-printing filament and is the easiest fin material to use for our project. During the printing of our fins, we considered switching to PETG, a more heatproof solution better suited for the high temperatures experienced in model rocketry. However, PLA ended up being the best choice due to its ease to use. We are 3D-printing our fins to save the cost of purchasing countless sets of fins. It should be noted that 3D-printed fins, especially when being used on mid or high-power rockets, are heavily advised against due to their fragility in comparison to stronger materials such as plywood or fiberglass. We are only allowing 3D-printed fins to be used for this research project since our rockets are classified as low-power.

Now that our research scope is fully established, we can proceed with analyzing the findings of others.

There are 2 main claims regarding the impact of fin shape on flight trajectory and apogee. The first claim is backed up by Tim Van Milligan et al. and a few other sources published as science fair papers by Batscha and Dhyaram from the California Science & Engineering Fair. This claim states that trapezoidal symmetrical fins result in the highest drag and the lowest apogee, while elliptical fins result in the lowest drag and the highest apogee (Milligan; Batscha; Dhyaram). This first main claim appears to be the most popular among most rocket flyers and hobbyists.

The second main claim is similar, stating that trapezoidal symmetrical fins result in the lowest apogee, while trapezoidal fins with a high sweep angle result in the highest apogee. Notice the difference – while the first claim states that elliptical fins reach the highest altitudes, the second claim states that swept-back trapezoidal fins reach the highest altitudes. Unlike the first claim, this second main claim is mainly supported by computer simulations such as OpenRocket and RockSim.

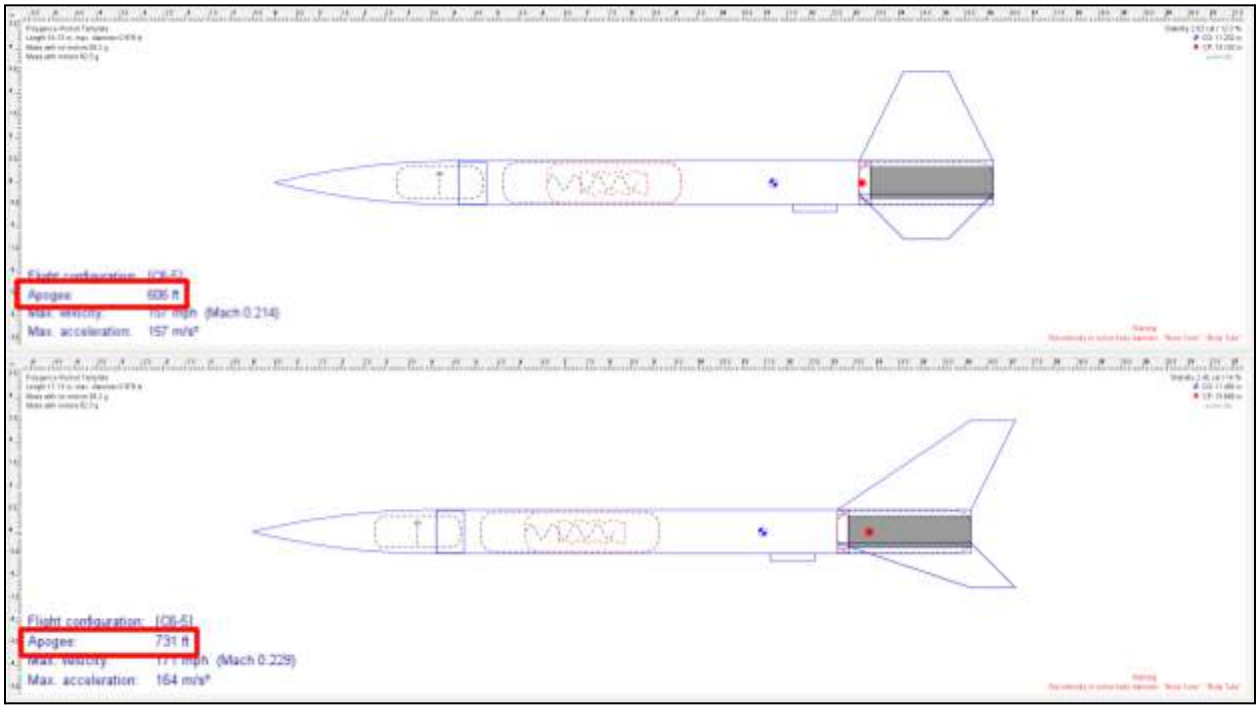


Figure 8: A visualization of the second claim; during testing in OpenRocket 24.12, trapezoidal swept fins perform the best at 731 feet, and trapezoidal symmetrical fins perform the worst at 606 feet. Created by author.

To conclude, here are two quick descriptions of each main claim:

- Claim 1: Trapezoidal symmetrical fins result in the lowest apogees, while elliptical fins result in the highest apogees
- Claim 2: Trapezoidal symmetrical fins result in the lowest apogees, while trapezoidal swept fins result in the highest apogees

Van Milligan backs up the first claim by stating that elliptical fins produce the least "induced drag." As a fin generates lift, the pressure difference between the top and bottom of the fin causes air to spiral at the tip chord, creating vortices. This concept of spiraling air gaining angular momentum as it attempts to equalize the air pressure difference is not unique – the same phenomenon occurs at a much larger scale in tornadoes and is a very familiar and common occurrence in the aviation field. In fact, according to Boldmethod, this is the exact reason that most modern airliners have wingtips; these shapes on the ends of both wings help disrupt airflow and mitigate induced drag. Van Milligan argues, "The reason the elliptical fin has the lowest induced drag is that the shape of the fin orients more of the lift force closer to the body tube of the rocket because the fin is longer near the body tube. That means there is less of a lift force created near the tip of the fin because the fin is shorter in that section of the fin." (Milligan 4)

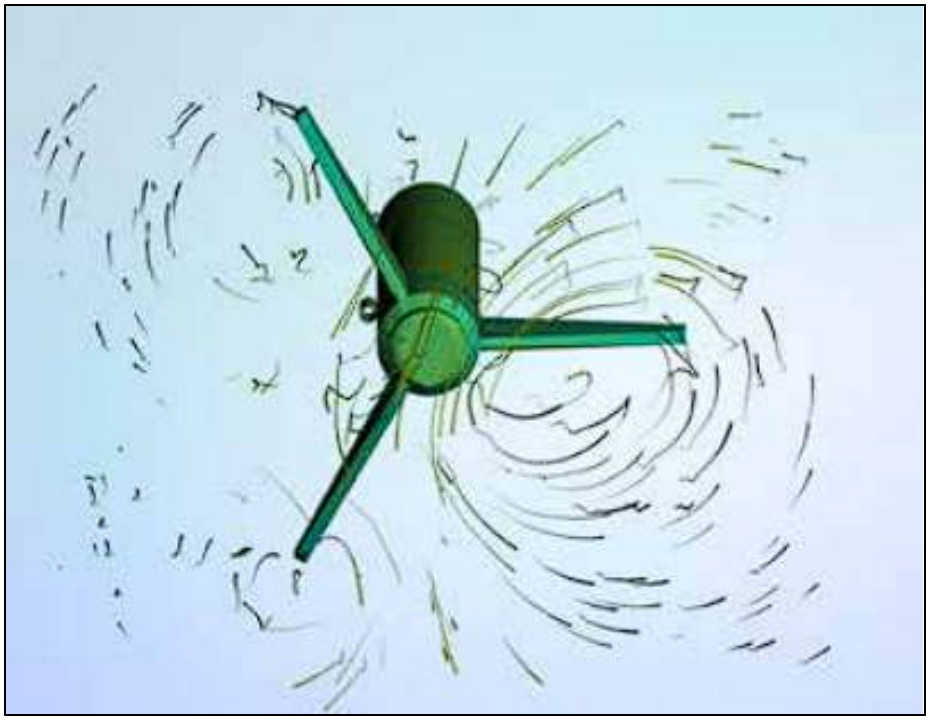


Figure 9: A computer simulation displaying how vortices are created at model rocket fin tips. [5]

After analyzing others' relevant work, our fully developed hypothesis is that swept-back, trapezoidal fins result in the highest altitude, and trapezoidal, symmetrical fins result in the lowest altitude. We also think elliptical fins result in the second-lowest altitude, and trapezoidal delta fins result in the second-highest altitude.

Swept-back fins produce the best results because swept-back fins pull the CP back towards the aft more than the other fin shapes, which, as mentioned before, make the rocket more stable. Additionally, the streamlined shape of swept-back fins produces less drag than the other 3 fin shapes. We also believe that elliptical fins produce better results than trapezoidal symmetrical fins despite their somewhat similar proportions and surface area because of their curved edge, which is more aerodynamic than the sharp turns seen in trapezoidal symmetrical fins' geometry.

Among the 3 cross-sections (square, rounded, airfoil), square cross-section fins would reach the lowest altitude, airfoiled fins would reach the highest altitude due to their streamlined design, and rounded fins would be somewhere in the middle, since they are more streamlined than square fins but less ideal than airfoiled fins.

This concludes our hypothesis, allowing us to proceed with laying out the plan for our experiment.

Test Apparatus

This experiment tested 4 fin shapes and 3 fin cross-sections. Our 4 fin shapes include trapezoidal symmetrical, trapezoidal delta, swept trapezoidal, and elliptical. Our 3 fin

cross-sections include square, rounded, and airfoil. When we insert these 2 criteria into a matrix, we get 12 different combinations of fin sets.

Building and flying 12 individual rockets for each fin set would be impractical. This is why we created a way to quickly and efficiently swap out and reuse fins, allowing us to only construct 3 primary rockets instead of 12 and one extra rocket as a spare in case one rocket gets lost. What we have created is called a fin rail: it allows fins to be removed and reattached without glue or any other adhesive. It's also easy and practical to create, being made of PLA and 3D-printing in under 2 hours. 3 of them are attached to a model rocket (since there are 3 fins to attach), and the fins slide in and out through the rail, creating an efficient way to avoid the impracticality of constructing several rockets.

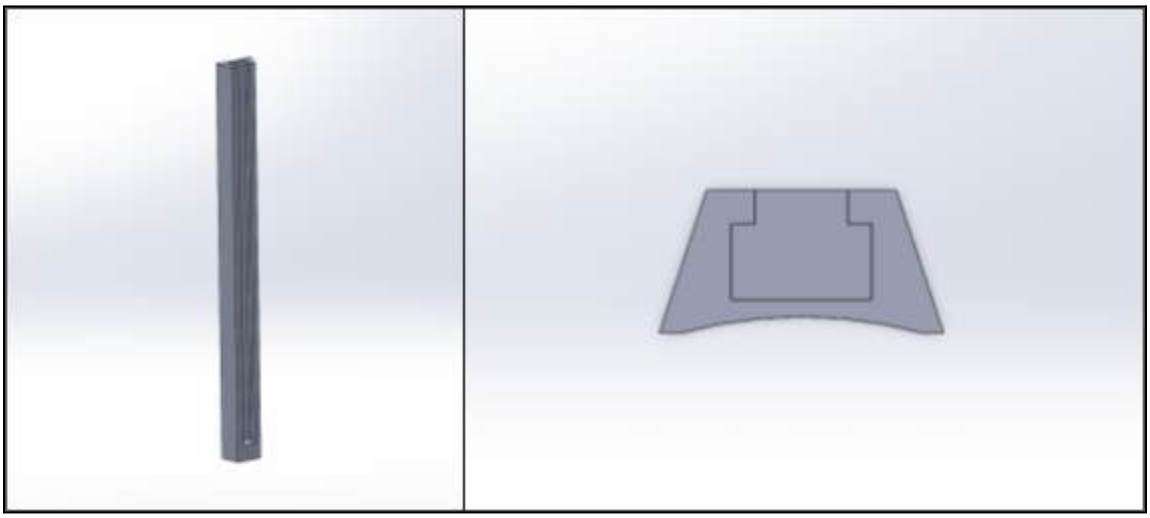


Figure 10: Two views of our fin rail inside of SOLIDWORKS for Makers. One view is from the side, and another view is from the top down. Created by author.

All 3 rockets were identical to each other – they were constructed with a 12" BT-50 body tube, a PNC-24C nosecone, and an 18-24mm motor adapter, just to name the major components. All rockets flew on an Estes C6-5 motor, and the data was recorded using a JollyLogic AltimeterTwo kept in the nosecone of each rocket.

Experiment

Each fin set has a unique name, composed of one uppercase letter and one lowercase letter. The uppercase letter defined the fin shape, while the lowercase letter defined the fin cross-section. We created a matrix to display this idea.

	S(ymmetrical)	**D**(elta)	(s)**W**(ept)	**E**(lliptical)
s(quare)	Ss	Ds	Ws	Es
r(ounded)	Sr	Dr	Wr	Er
a(irfoil)	Sa	Da	Wa	Ea

Figure 11: Our matrix for displaying each fin set's unique name. Uppercase letters S, D, W, and E define fin shape, while lowercase letters s, r, and a define fin cross-section. Created by author.

We have also created a simple spreadsheet to stay organized during the launch day and keep track of which launches have already been executed and which ones are next.

	A	B
1	Ss	Ds
2	Ws	Es
3	Sr	Dr
4	Wr	Er
5	Sa	Da
6	Wa	Ea

Figure 12: Our organizational spreadsheet for the launch day. The A column is for one rocket, and the B column is for the other. Created by author.

With all the plans set in place and the organizational spreadsheets made, it is time to prepare for the launch and execute the experiment.





Figure 13 (left): One of our rockets flying into the sky after ignition. Created by author.
Figure 14 (right): One of our rockets begins to lift off from the launchpad. Created by author.



Figure 15: One of our rockets approximately 20 feet above the ground just as it lifts off. Created by author.





Figure 16 (left): One of our rockets' contrails can be seen against the blue sky. Created by author.
Figure 17 (right): One of our rockets reaches the apogee of its flight. Created by author.

Following the experiment, we obtained the following results.

	Trapezoidal Symm.	Trapezoidal Delta	Trapezoidal Swept	Elliptical	AVG
Square	527	553	559	543	545.5
Rounded	545	548	588	529	552.5
Airfoiled	692	687	694	682	688.75
AVG	588	596	613.67	584.67	
	RED = low performance				
	YELLOW = mediocre performance				
	GREEN = best performance				

Figure 18: The results from the experiment. Conditional formatting was used; cells colored red performed relatively low, while cells colored green performed relatively high. All data is interpreted in imperial feet. Created by author.

At this point, we were set to analyze our results and discover why certain phenomena may have occurred. This helped us better understand how fins affect a rocket's trajectory.

Analyzing Our Findings

Our hypothesis was correct in predicting which fin sets would yield the highest altitudes – the trapezoidal swept shape obtained the highest apogee in all 3 rows, and the airfoil cross-section obtained the highest apogee for all 4 fin shapes by far. Our reasoning for this is the same as our argument for our hypothesis: the more swept back a set of fins is, the further back the CP is, thus stability is increased, and the more aerodynamic the rocket is. Additionally, an airfoil cross-section flows through moving air much more easily and produces less drag than square cross-sections or rounded cross-sections, which is why airfoil cross-section fin sets obtained the highest altitudes.

Despite these correct predictions, our hypothesis was not entirely accurate. For example, We predicted that trapezoidal symmetrical fins would be the worst-performing fin shape out of the four. However, elliptical fins actually performed worse than trapezoidal symmetrical fins by just a couple of feet, defying our expectations.

	Trapezoidal Symm.
Square	527
Rounded	545
Airfoiled	692
AVG	588

Figure 19: This table compares the data of the trapezoidal symmetrical fin shape and the elliptical fin shape. Elliptical fins, as seen in the bottom row, perform ever so slightly worse than the trapezoidal symmetrical fins. Conditional formatting was used; cells colored red performed relatively low, while cells colored green performed relatively high. All data is interpreted in imperial feet. Created by author.

Additionally, we initially believed that trapezoidal delta fins would fall somewhere in between trapezoidal symmetrical and trapezoidal swept fins. And while this is true, trapezoidal delta fins surprisingly perform more similarly to trapezoidal symmetrical fins than trapezoidal swept fins, showing how trapezoidal swept fins are the best-performing fin shape by a wide margin.

	Trapezoidal Symm.	Trapezoidal Delta	Trapezoidal Swept
Square	527	553	559
Rounded	545	548	588
Airfoiled	692	687	694
AVG	588	596	613.67

Figure 20: This table compares the data of the trapezoidal symmetrical fin shape, the trapezoidal delta fin shape, and the trapezoidal swept fin shape. As seen by the averages at the bottom, trapezoidal swept fins surpass the other two fin shapes in performance by far. Conditional formatting was used; cells colored red performed relatively low, while cells colored green performed relatively high. All data is interpreted in imperial feet. Created by author.

One aspect of the received data that was surprising was the unusual lack of variation among the airfoil cross-section fin sets. The other cross-sections show large variations between fin shapes, with differences sometimes up to 70 feet between profiles. Additionally, apogees among fin shapes follow a distinct pattern in the square cross-section row and the rounded cross-section row: trapezoidal symmetrical or elliptical is always last, trapezoidal delta is always somewhere in the middle, and trapezoidal swept is always first. However, in the airfoil cross-section row, fin shapes do not seem to matter.

Square	527	553	559	543
Rounded	545	548	588	529
Airfoiled	692	687	694	682

Figure 21: This table compares the data of the three fin cross-section types. As seen in the bottom row, airfoil cross-section fins do not vary much in performance compared to the other fin cross-sections. Created by author.

The pattern breaks, and all four fin profiles with airfoil cross-sections perform relatively equally, with a difference of only 12 feet between the lowest-performing and the highest-performing.

Why would an airfoil cross-section fin set subdue the effects of fin shape and surface area? Our leading theory to this strange occurrence explains that due to the low speed of the rockets (the fastest one reaching just under 170 miles per hour), the amount of induced drag that each fin shape creates is negligible (since drag increases with the square of velocity).

To summarize our findings, while our hypothesis was proven correct in some areas, such as which fins would obtain the highest apogee, we were also proven incorrect in many areas, such as which fins would obtain the lowest apogee. Additionally, we were incredibly puzzled at

the fact that all of the airfoil cross-section fins perform relatively equally, regardless of their surface area or profile.

Conclusions and Takeaways

To close, we dived into how different fin shapes, profiles, and cross-sections can impact a rocket's trajectory in this research project. We researched others' claims and thoughts on the subject, and then gave our own thoughts. We carried out an experiment that tested out various fin shapes and cross-sections, and our results seemed to communicate that our hypothesis was correct, with the exception of elliptical fins performing less than initially thought.

Through our analysis, we discovered how airfoil cross-section fins produced the best results out of the three given fin cross-sections. We theorize that this occurs because of the more streamlined shape of the airfoil cross-section – while all three cross-section types reach a maximum thickness of 0.125", meaning that they all have to displace the same amount of air, the forward airfoil cross-section stops less air molecules and does a better job in cutting through the air when compared to other cross-sections, which produces less drag. Additionally, the aft airfoil cross-section lets the separated air reconnect at the end of the fin easier. This explanation is similar to the reason why the swept trapezoidal fin shape produced the best results out of the four given fin shapes – its swept design collides with air molecules less violently than similar designs with lower sweep angles.

Something surprising about our test results was the lack of performance variation in airfoil cross-section fins. This also went against our initial hypothesis, and it was much more confusing to decipher an explanation for it than for the other findings that were contrary to our hypothesis. While we eventually concluded that while trapezoidal swept fins are generally the right choice, at low speeds and with an airfoil cross-section, it really does not matter what shape is chosen.

Among all of the claims we could find from others, none of them could accurately predict how airfoil cross-section fins would truly behave. We find this to be exceptionally fascinating, and we continue to find it strange how no one has ever come to these conclusions before. If anything, we believe this research project goes to show how valuable real-world experiments are compared to simply running simulations and making educated guesses, and how there are so many factors, both natural and artificial, that can contribute to drastically differing results in not just the study of aerodynamics or model rocketry but science as a whole.

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CRISPR-Cas9 in Alzheimer's Disease: Current Progress and Future Perspectives
By Kazuhiro Takagi

Abstract

One of the most common types of dementia is Alzheimer's disease (AD), and every day, millions of people worldwide experience a slow disappearance into cognitive impairment. To compound this issue, despite decades of extensive research, there is no known cure for this condition. However, a revolutionary gene-editing technology may offer new hope. CRISPR-Cas9 is a revolutionary gene-editing technology that was first introduced in 2012. Its significance lies in its high efficiency and precision, which is significantly better than those of past gene editing tools. Not only that, but it is also very easy to produce and use, as the technology employs enzymes derived from bacteria that scientists can cultivate and use to target specific DNA sequences using only RNA. These enzymes are also relatively easy to produce. Many aspects of what leads to AD are being uncovered, and two main proteins are believed to cause AD: amyloid-beta and tau. Amyloid beta is a fragment of the Amyloid Precursor Protein (APP), and it is normally produced in healthy patients. However, a patient with AD has unusual levels of this protein because of a mutation that alters its structure, or because it is cleaved in an unusual way, allowing it to self-aggregate and form plaques. On the other hand, tau proteins, which are essential for the stability of neuronal cells, especially their microtubules, do not function properly in patients with AD, and the neurons cannot maintain their structure. This is usually caused by hyperphosphorylation of the proteins, which can be led by mutations in the DNA that affect tau. There have been significant efforts made to make AD curable, as evidenced by numerous successful experiments conducted in vitro and in vivo models. For example, CRISPR-Cas9 successfully altered tau expression by editing specific genes associated with this protein. For instance, CRISPR-Cas9 successfully altered tau expression by editing specific genes related to the protein in animal models. Another is a successful effort to reduce the production of amyloid-beta plaques in stem cell models derived from patients with Alzheimer's. However, CRISPR-Cas9 is not perfect, and therefore there are many obstacles to overcome. It sometimes makes mistakes or accidentally cuts the wrong DNA sequence. These mistakes might result in negative changes in the brain. Not only that, but it is also challenging to deliver the medicine to the brain in the first place, as the brain is protected by a powerful barrier called the blood-brain barrier, which prevents unwanted molecules from entering. Furthermore, the challenge lies not only in the technical requirements for these treatments but also in addressing the complex ethical implications they raise. Overall, although there are lots of hurdles to make Alzheimer's disease curable, with CRISPR Cas9, it is no longer a distant dream or figment of science fiction but is becoming a scientific possibility.

Introduction

AD is a progressive neurodegenerative disorder that typically affects adults over 50 years of age (DeTure & Dickson). It is the most common type of dementia, and once diagnosed, one

can only slow down the progression of the disease, and no known cure or method can completely stop this neurodegenerative condition (Lane et al.). Presently, it is the sixth leading cause of death in the USA, and families who are related to anyone suffering from AD experience their elderly relatives starting to forget things, sometimes important memories, as they recede from reality. Not only that, it is very financially difficult for families to support their relatives who are suffering from AD. The reason, despite decades of research, that there is no known cure is that AD is highly interconnected with aging and, therefore, DNA. DNA is a core component of the cell, serving as the blueprint that determines how proteins behave and function within the cell. There are two abnormal proteins believed to be among the leading causes of AD: tau and amyloid-beta. They are both normal, everyday proteins in the body, and tau protein, especially, is an essential part of the neuron cell. However, once a mutation occurs in the neuron cell, it becomes an abnormal shape, which leads it to have completely different properties, and become toxic to the brain (Perl). Artificially correcting these genes might be a possible solution to this problem. To undo the mutations in the neuron cell, scientists must be able to edit these changes on command. This is where genome editing technology comes in. Gene editing has been studied for decades, and numerous techniques have been developed. To name a few, there are Zinc Finger Nucleases, Transcription Activator-like Effector Nucleases, and meganucleases, and the newer Rectron Library Recombineering platform. These all have different mechanisms, and some were good in specific criteria, while others were not so great. For example, meganucleases are highly efficient but require longer recognition sequences (Danilo et al.). On the other hand, Zinc Finger Nucleases are highly specific but can be challenging to design and implement (Durai). However, a new genome-editing tool, CRISPR-Cas9, is a significant breakthrough that makes gene editing a viable medical treatment, and it has been tested in clinical trials in patients as a therapy. CRISPR-Cas9 is much more efficient, accurate, and easy to use than past models. It uses an enzyme from a bacterium and a single-stranded RNA to guide the enzyme to its target site (Jiang & Doudna). Using these precise CRISPR-Cas9 techniques to correct the mutation that causes the creation of abnormal proteins, which eventually leads to AD, might be a realistic solution to cure AD. This research paper's goal is to explore how CRISPR-Cas9 can modulate amyloid and tau pathways to treat or understand AD.

Overview of Alzheimer's disease

Over a century ago, Alois Alzheimer first discovered and described a neurodegenerative disease that would later be named after him. His original observation noted the presence of amyloid plaques and neurofibrillary tangles, which remain topics of discussion today (Alzheimer et al.). Alzheimer's disease is now described as a condition that is characterized by initial memory impairment and cognitive decline that can ultimately influence behavior, language, spatial skills, and movement, and it is the most common type of dementia. Over many years, researchers have learned that one of the leading causes of Alzheimer's disease is the misprocessing of a large membrane protein, which is commonly known as APP (Kumar et al.). When APP is cleaved by enzymes named β-secretase and γ-secretase, it produces small peptides,

such as Aβ40 and Aβ42 (Goedert). These proteins, which weigh approximately four kDa, tend to misfold into beta-sheet structures. When misfolded, they become sticky and clump together, eventually accumulating outside neurons as amyloid plaques (Sipe & Cohen). The plaques are detectable by their binding to particular dyes and their characteristic of birefringence under polarized light (Sipe & Cohen). The accumulation of plaques is considered a critical early trigger in AD, and these plaques disrupt synaptic communication between neurons, creating a toxic environment that can ultimately lead to cell death (Han et al.). Densely packed amyloid plaques that damage neurons are often referred to as neuritic plaques. Radiating from the center of the plaques are strands of Aβ fibrils that extend into the surrounding tissue, where clusters of damaged neuronal processes and activated glial cells are found (Dickson). The surrounding areas often exhibit dystrophic neurites, some of which may contain distinctive tau filaments, supporting the idea that Aβ buildup contributes directly to neuronal loss and cognitive decline (Perl). Moreover, the plaques are not all the same; they show different pathological features, for example, changes in neurofilament organization and accumulation of faulty mitochondria and lysosomal bodies. Experimental studies have demonstrated that the introduction of Aβ fibrils externally can lead to rapid cell death and compromise cell membranes (Han et al., 2017). Overall, once amyloid-beta plaques form, they activate various kinases that disrupt the normal phosphorylation patterns of the tau protein, further promoting its aggregation into neurofibrillary tangles (Azargoonjahromi). Neurofibrillary tangles are part of the tau pathology, which is also believed to be one of the leading causes of Alzheimer's disease. Tau is essential for normal brain function, as it helps build and maintain the internal framework of nerve and glial cells. It achieves this by promoting the assembly and maintenance of microtubules, key components of the cell's cytoskeleton (Donison et al.). Microtubules serve as highways that transport molecules and nutrients to the neuron, and they also regulate cell division and intracellular transport. Within tau, there is a specific section (the microtubule binding domain) that is responsible for anchoring the protein to microtubules. This domain is vital for both constructing and reinforcing the network of microtubules (El Mammeri et al.). In the case of AD, abnormal levels of phosphate groups are added to the tau protein, which is a process known as hyperphosphorylation (Brion et al.). This may be caused by mutations in the MAPT gene, which codes for the tau protein, or mutations in proteins associated with tau pathology. In a healthy condition, tau maintains a paperclip shape that is essential for its role in binding and stabilizing microtubules (Jeganathan et al.). However, when hyperphosphorylation occurs, tau loses its proper structure, and the microtubule-binding domain does not function properly. Not only does it compromise its normal function, but it also promotes further self-phosphorylation and aggregation. As a result, hyperphosphorylated tau molecules begin to assemble into toxic, soluble clusters. Over time, these clusters evolve into insoluble filamentous structures, such as paired helical or straight filaments, which eventually coalesce into the NFTs characteristic of advanced tauopathies (Lasagna-Reeves et al.). Historically, the pattern in which tau lesions emerged was thought to be simply due to specific brain regions being more vulnerable to damage. However, new evidence suggests that rather than regional susceptibility alone, tau pathology actually spreads in a

prion-like manner, moving through interconnected brain areas and seeding further abnormalities (Mudher et al.).

Overview of CRISPR-Cas9

CRISPR-Cas9 was first discovered as a natural defense mechanism in bacteria. It was initially identified as an unusual repeated DNA segment in E. coli back in 1987. However, it was not until the early 2000s that scientists discovered these sequences were part of an adaptive immune system that allowed bacteria to recognize and counteract viral invaders (Tyumentseva et al.). The first CRISPRs were detected 30 years ago by Y. Ishino in Escherichia coli while analyzing the gene responsible for the isozyme conversion of alkaline phosphatase (Ishino et al.). At the time, it was almost impossible to predict the biological function of the unusual repeated sequences due to insufficient DNA sequence data, especially for mobile genetic elements. The realization that these once-mysterious DNA repeats were integral to bacterial defense opened a whole new avenue of research, paving the way for turning the system into a highly accurate tool for genome editing. Once researchers had identified the core components of the CRISPR system – Cas9, crRNA, and tracrRNA – they discovered that combining the crRNA and tracrRNA into a single guide RNA could effectively direct Cas9 to a specific target sequence(Jinek et al.). This breakthrough meant that the enzyme could be programmed to cut virtually any DNA target, transforming an ancient microbial immune mechanism into a versatile tool for genome editing. Furthermore, scientists later adapted the system for use in mammalian cells, for example, in 2013, human HEK293 FT cells were modified by introducing SpCas9 alongside a guide RNA aimed at either EMX1 or PAVALB gene loci, thereby inducing precise double-strand breaks that were subsequently repaired via non-homologous end joining or homology-directed repair (Cong et al.). This adaptation of the newly discovered enzyme not only unlocks a powerful method for precise genetic modifications but also paves the way for numerous innovations in biotechnology and medicine. In the process of using Cas9, before it cuts the DNA, it first searches the genetic material for a short sequence, 5'-NGG, which serves as a protospacer-adjacent motif. Only when this PAM is identified can it guide the RNA to hybridize with the matching DNA sequence, a step that then activates Cas9 to break the double-stranded DNA (Mojica et al.). This careful step-by-step mechanism highlights how this CRISPR system ensures specificity by coupling the initial PAM search with subsequent guide RNA-DNA pairing, which ensures accurate DNA cleavage. After CRISPR induces a double-stranded DNA break, the cell attempts to repair the damage using one of two major pathways. The first NHEJ quickly reconnects the DNA ends without a template, but its imprecision often produces small insertions or deletions that disrupt the gene, commonly leading to knockout (Scully & Xie). The second method, HDR, relies on a homologous template to precisely repair the break, enabling the insertion or replacement of DNA sequences; however, it is inefficient and typically limited to specific stages of the cell cycle (Cong et al.). To deliver these templates and new genes, CRISPR-Cas9 and viral vectors, such as AAV and lentivirus, are commonly used. AAV vectors work by binding to cell surface receptors, allowing them to enter the cell. Once inside, they travel to the nucleus, where the genetic

material is released (Asmamaw Mengstie). Unlike lentiviruses, AAV does not integrate into the host genome but remains as an episome, enabling gene expression without altering the Host's DNA (Gliwa et al.). Lentiviral vectors, on the other hand, utilize reverse transcription to convert their RNA into DNA, which is then integrated into the host genome, ensuring long-term gene expression (Mao et al.). This ability makes lentivirus particularly useful for applications requiring stable genetic modifications. AAV vectors are known for their broad tissue tropism and low immunogenicity, which makes them suitable for therapeutic applications. However, their limited packaging capacity restricts the size of genetic material they can carry (Gliwa et al.). On the other hand, Lentiviral vectors have a larger genetic payload capacity but also pose a risk of insertional mutagenesis, which can disrupt essential genes (Mao et al.). Another way to deliver genetic material and CRISPR is by Non viral delivery using lipid nanoparticles which harnesses the natural attraction between negatively charged genetic materials, such as guide RNAs and CRISPR and positively charged ionizable lipids. By adjusting the pH during preparation, the lipids become charged enough to bind the CRISPR ribonucleoproteins, forming a stable, protective particle. Once the nanoparticle is internalized by the cell, the acidic environment inside the endosomes prompts the release of the CRISPR cargo into the cytosol, allowing it to reach the nucleus. Very similarly, electroporation uses controlled electrical pulses to mom

Applications for CRISPR-Cas9 in AD

CRISPR-Cas9 technology has revolutionized AD research, offering gene-editing accuracy never before achieved and enabling researchers to investigate and potentially repair disease pathology. Applications of CRISPR-Cas9 in AD vary from in vitro and in vivo models, which provide information on the disease, mechanisms, and therapeutic strategies in different ways (Lu et al.). In vitro CRISPR-Cas9 experiments have enabled researchers to edit key genes associated with AD under controlled cell culture conditions. One of the primary targets is the APP gene, which encodes the APP protein. APP mutations can lead to excess production of amyloid beta; therefore, by editing this gene, researchers expect to reduce amyloid beta accumulation and thereby combat its neurotoxicity. It was demonstrated that once CRISPR-Cas9 has knocked out or edited APP to its original state, it can efficiently decrease amyloid-beta levels, offering a promising avenue for therapeutic interventions (György et al.). Another significant target is the MAPT gene, which encodes for tau protein. Neurofibrillary tangles caused by hyperphosphorylation of tau proteins are caused by a mutation in the MAPT gene. Modulation by CRISPR-Cas9 of MAPT aims to block tau hyperphosphorylation and consequent tangle formation, ultimately leading to neuronal dysfunction (Tan et al.). It has been shown that gene editing can alter tau expression, and the progression of the disease may be asserted (De Plano et al.). Furthermore, patient-derived iPSC-derived AD neurons are also valuable model systems for probing disease mechanisms. Patient-derived cell-derived neurons allow researchers to investigate genetic mutations and test therapeutic interventions in a specific patient without actually doing so. CRISPR-Cas9 was utilized to repair mutations in iPSC-delivered neurons, providing insights into disease pathology and therapeutic strategy(Paquet et al.). Beyond cell

culture models, or in vivo models, CRISPR-Cas9 was employed in transgenic mouse models carrying human APP and PSEN mutations that model the AD pathology. These models enable the study of disease progression and the determination of gene-editing interventions within an organism (Serneels et al.). By performing CRISPR-Cas9-mediated correction, scientists can test the impact of genetic mutations on AD phenotypes using these models. One of the most intriguing applications is CRISPR-mediated correction of the PSEN1 gene and APPswe mutations. They are common AD mutations and the underlying cause of early-onset disease. Studies have shown that CRISPR-Cas9 can correct these familial mutations with accuracy in mouse models, thereby reducing the amyloid beta burden and improving neuronal activity (Rahimi et al.). Another key approach in AD research is tau-targeting using CRISPR-Cas9. By editing tau-related genes with precision, scientists hope to prevent tangle formation, ultimately halting neurodegeneration. Experiments have demonstrated that CRISPR-Cas9 is effective in reducing tau clumping and plaques, resulting in improved cognitive function in animal models (De Plano et al.). To determine the effectiveness of these treatments, scientists conduct cognitive and behavioral testing after editing. The testing consists of assessment of memory, learning, and cognitive function, providing insights into the therapeutic potential of gene-editing strategies. Research has shown notable cognitive improvement in capacity after gene correction from CRISPR-Cas9, highlighting the therapeutic promise of this technology in AD (Barman et al.). Despite these promising outcomes of CRISPR-Cas9 in AD research, various challenges remain to be addressed. Perhaps the most daunting challenge is the delivery efficacy, as precise gene editing in the brain requires advanced delivery systems. Researchers are exploring new methods of transport, such as viral vectors and nanoparticles, to enhance CRISPR-Cas9 delivery to neuronal cells. (Lu et al.). Off-target effects are the second challenge, which can lead to undesired genetic changes. Researchers are refining the specificity of CRISPR-Cas9 to minimize these risks and enable the safe therapeutic use of this technology. Advancements in prime editing and base editing are also being investigated to enhance specificity and prevent off-target mutations (Rahimi et al.). The ethical considerations also play a crucial role in the use of CRISPR-Cas9. Although gene editing has enormous potential, its use in human patients needs to be considered and assessed for long-term effects and ethical issues. Regulatory settings and clinical trials will be paramount in determining the feasibility of CRISPR-based therapies for AD (De Plano et al.). CRISPR-Cas9 technology has revolutionized the study of AD by enabling accurate gene editing to establish disease mechanisms and develop possible treatments. In vitro use with the cell culture system allows APP and MAPT gene-targeted modifications, whereas in vivo animal models provide data on genetic correction and cognitive improvements as well as its effect as a whole. Despite delivery efficiency limitations, off-target activities, and ethical issues, CRISPR-Cas9 is a promising contender in the path to effective AD treatments. Additional advancements in gene editing technology can pave the way for precision medicine approaches to combat this crippling neurodegenerative illness.

Therapeutic potential and challenges

CRISPR-Cas9 technology is a groundbreaking genetic study tool with hopeful potential for the treatment of neurodegenerative diseases such as Alzheimer's. Using CRISPR, researchers are investigating how to edit genes implicated in AD pathology, including the APP and presenilin genes PSEN1 and PSEN2, which are involved in amyloid-beta plaque deposition. There have been promising ~~preclinical results, with reductions in amyloid-beta and~~ neuroinflammation upon CRISPR-based gene editing (Jinek et al.). CRISPR has also been helpful in designing accurate AD models, thereby enhancing the ability to understand disease onset and identify new therapeutic targets (Khan et al.). Although these developments are promising, utilizing CRISPR in the medical field and its application as a treatment for patients presents a significant challenge due to concerns regarding efficacy and safety. One significant limitation is the potential for off-target effects, which can lead to undesirable genetic modifications. CRISPR does not have perfect accuracy, while the human genome is rather complex, and it is challenging to edit and correct a specific section with absolute precision. Even a small, undesirable mutation can cause unintended consequences, which can exacerbate neurological diseases rather than cure them (Zhang et al.). Delivery is also a huge hurdle. The blood-brain barrier, or BBB, is a barrier that hinders the successful delivery of CRISPR reagents into the brain and to neurons. Current delivery methods, such as viral vectors and nanoparticles, have shown promise but also pose risks of immune responses, toxicity, and limited cargo capacity (Lentz et al.; Zorkina et al.). The long-term impacts of CRISPR-based therapies remain unknown, and long-term clinical trials will be necessary to assess their safety, efficacy, and the duration of gene modification. The ethics of using CRISPR for AD therapy are high. One of the fundamental concerns is the potential for germline editing, where the genetic changes can be passed down through generations. Although somatic gene editing—specifically, modifying non-reproductive cells—is more likely to be accepted, the threat of unintended germline modification raises significant ethical concerns (Kohn et al.). The other serious consideration is access. Future gene therapies could be expensive and could possibly cause healthcare inequities in that only the wealthy patients will be able to have access (Delhove et al.). Policymaking and regulatory concerns over CRISPR use also exist, with dual national guidelines in place. Having explicit ethical guidelines and ensuring equal access to future therapies will be essential to the wise development and implementation of CRISPR-based AD therapies. CRISPR-mediated therapies have immense potential in that they enable selective genetic modifications to delay or possibly stop disease progression. However, looming challenges include off-targeting, delivery hurdles, and ethical considerations. Although early results from preclinical studies are promising, further studies are needed to enhance CRISPR technology, refine its safety, and establish ethical guidelines for its clinical applications. While there are lots of hurdles to overcome, CRISPR may be an effective therapy for AD, giving hope for AD patients and their families affected by this debilitating neurodegenerative disorder.

Conclusion

CRISPR-Cas9 has quickly revolutionized gene editing and opened new possibilities once thought highly unrealistic. This new technology brings hope to find a potential treatment for AD that has long been considered incurable. CRISPR-Cas9 allows scientists to make changes in genes as they wish, with minimal costs. It expanded the frontiers of AD and other neurodegenerative research, enabling scientists to gain a deeper understanding of its relationship with DNA, such as by mutating in vivo models to simulate AD, and by creating and testing in vitro models derived from real AD patients. Along with other scientific achievements, such as iPSC, recent studies have shown that CRISPR intervention can reduce beta-amyloid production by correcting mutations in APP, and decrease brain inflammation while enhancing neuroprotective effects (Miskalis et al.). Researchers are also using CRISPR to recreate AD models, enabling them to better understand disease progression and identify potential therapeutic targets (Serneels et al.). With the revolutionary invention of CRISPR, a deeper understanding of AD is becoming more attainable, paving the way for groundbreaking treatments that could potentially halt or reverse neurodegeneration. Some examples of possible treatments include targeting the APOE-e4 gene, which is responsible for cleaving APP to form amyloid-beta proteins, and correcting mutations so that cleavage proceeds as intended, thereby reducing the accumulation of abnormal amyloid-beta proteins (Teter et al.). Another possibility is boosting neuroprotective factors. For example, modifying the APP processing can promote neuroprotective effects while also reducing toxic beta-amyloid proteins. This strategy could slow disease progression and enhance brain resilience (Chen et al.). The list could go on forever, and the possibilities are endless. However, there are ethical and political considerations that require discussion, and scientists must overcome many obstacles, such as the BBB, for AD treatment to become a reality. However, if these obstacles can be resolved, CRISPR could possibly revolutionize Alzheimer's treatment and potentially eliminate the title as an incurable disease. For the tens of millions of people watching loved ones slowly disappear into cognitive decline, this technology offers hope, potentially saving millions of people worldwide and providing a conscious and colorful life.

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Platform-based Solutions for Reducing the Cost of Alzheimer's Care in Canada: Identifying System Inefficiencies and Designing a Scalable Digital Marketplace

By Georgia Baricevac

ABSTRACT

Alzheimer's disease and related dementias impose an estimated $40.1 billion annual economic burden on Canada, a figure projected to grow by over 275% in the next three decades. This paper examines three major structural drivers of that cost: informal caregiver labour, fragmented long-term care delivery, and avoidable hospitalization, and argues that a significant proportion of these costs arises not from the disease itself but from systemic inefficiencies in how care is matched, verified, and coordinated. Drawing on a review of published government and academic sources alongside primary survey data collected from eight respondents across age groups and care roles, this paper proposes a digital platform model that connects families directly with verified caregivers, eliminates costly intermediary agencies, and increases price transparency. The proposed platform, working title CareConnect, is modelled on marketplace dynamics similar to those in adjacent sectors and is designed to reduce direct care costs by an estimated 20–40% per household while improving caregiver utilization and reducing search delays. Limitations, including trust barriers, technology adoption among older populations, and regulatory compliance, are discussed in full.

Keywords

Alzheimer's disease, dementia care, caregiver shortage, platform economy, digital health marketplace, elder care costs, Canada

INTRODUCTION

Alzheimer's disease is not merely a health crisis. It is an economic and social one. In Canada, over 600,000 individuals currently live with dementia, and that number is expected to nearly double by 2030 as the population ages [1]. The financial consequences of this trajectory are severe: the Alzheimer Society of Canada estimates the total economic burden at $40.1 billion annually as of 2020, with projections indicating growth exceeding 275% over the next 30 years [2]. These figures capture direct medical and institutional costs, but they obscure a deeper truth: the majority of care — approximately 75% — is provided informally, by unpaid family members and friends who bear enormous personal, professional, and financial costs largely invisible to policymakers [2].

The economic burden of Alzheimer's and dementia in Canada is concentrated across three domains: direct health system costs (hospitalization, medication, professional care), direct non-health costs (home modifications, specialized equipment), and indirect costs (lost productivity for both paid and unpaid caregivers). According to the Canadian Network for the Economics of Alzheimer's Disease and Related Dementias (CANCEA), the total cost reached $40.1 billion in 2020 and is expected to surpass $150 billion annually within 30 years [3]. Private

in-home support ranges from approximately $2,500 to $7,000 per month, depending on the intensity of care required, while private memory care facilities regularly exceed $6,000 per month [4]. Many families find themselves in coverage gaps, requiring care but not qualifying for the full extent of publicly funded support [5].

The single largest driver of cost is the unpaid labour of family members, friends, and community volunteers. The Alzheimer Society of Canada estimates that over 472 million hours of informal care were provided in 2020 alone, representing an estimated $21.8 billion in lost productivity [2]. Roughly 22% of caregivers leave the paid workforce entirely. Approximately 8 million Canadians provide unpaid care of some kind, contributing an estimated 5.7 billion hours of labour annually [6]. The 2021 Canadian Community Health Survey found that of households reporting receipt of home care, nearly half reported needing formal care worker support but not receiving it [7]. Research published in Home Health Care Management & Practice further identifies the gendered dimension of this burden, noting that women disproportionately absorb both paid and unpaid caregiving responsibilities [8].

A second major cost driver is the fragmentation of long-term and home care delivery. Private memory care facilities are the most expensive single care setting, driven by high staff-to-resident ratios, specialized security infrastructure, and the complexity of dementia-specific programming, with monthly fees in urban centres approaching $10,000 [4]. The fragmentation of service delivery (where families must navigate multiple agencies, government portals, and waitlists independently) imposes significant coordination overhead that drives up cost without improving care quality.

A third cost driver is avoidable hospitalization. Dementia patients have significantly higher rates of emergency department visits and longer average hospital stays than age-matched patients without dementia. Approximately half of all Alternate Level of Care (ALC) days in Canada, days when hospital patients occupy acute beds while awaiting long-term care placement, are attributable to dementia [9]. These ALC days impose enormous costs on the acute care system while providing suboptimal care to patients who would be better served in community settings.

Canada is also facing a structural workforce crisis in elder care. There is an estimated 25% shortage of paid Personal Support Workers (PSWs), with data suggesting that 80% of those currently employed are considering leaving the profession due to low wages, high stress, and inadequate benefits [10]. The Canadian Centre for Caregiving Excellence has characterized the situation as a "caregiving crisis," noting that 72% of caregivers report burnout and 500,000 have exited the paid workforce due to caregiving responsibilities [11].

Beyond these cost drivers, five structural inefficiencies compound the problem. First, staffing agencies charge families a rate significantly higher than the wage paid to workers, with markups reaching 30–50% above caregiver wages, a coordination cost that is, in principle, reducible through direct matching [10]. Second, available caregivers exist but are not discoverable through current systems, resulting in extended periods during which families pay premium rates for whoever is immediately available. Third, the market for elder care in Canada

is characterized by opacity: families rarely know the cost of care before contacting providers, and comparison across options is difficult. Fourth, current placement processes frequently prioritize availability over fit, and poor matches lead to turnover that disrupts care continuity and drives adverse health outcomes. Fifth, significant administrative effort is duplicated across care providers, government bodies, and family coordinators, adding cost without adding clinical value.

The standard policy responses to this crisis, expanding long-term care capacity, hiring more personal support workers, and increasing government subsidies, are necessary but insufficient on their own. They address supply without addressing the inefficiencies that inflate cost at every stage of care delivery. This paper proposes that a platform-based model, a digital marketplace for verified elder care, represents a scalable, low-capital mechanism for reducing these inefficiencies. The corresponding author is the founder of Pages for Memories, a community fundraiser supporting the Alzheimer Society of BC and Yukon, and this paper reflects both academic inquiry and a personal commitment to developing practical, business-oriented solutions to Canada's caregiving crisis.

MATERIALS AND METHODS

To supplement the secondary literature review with primary data, a structured survey was designed and distributed to community members with direct or indirect experience of Alzheimer's care. The survey consisted of twelve questions covering four domains: personal experience with Alzheimer's disease, perceived caregiving challenges, cost perceptions, and openness to platform-based solutions.

Participants were recruited through convenience sampling and distributed to parents, teachers, and community contacts of the corresponding author in Vancouver, BC. No personally identifying information was collected. Respondents were not compensated for participation. The survey was administered digitally, and responses were recorded anonymously.

This study did not involve clinical intervention, medical records, or vulnerable populations in a clinical sense. Participation was entirely voluntary, and responses were collected in aggregate. All data reported in this paper reflect anonymous group-level findings, and no individual can be identified from the results presented.

Eight completed responses were received and included in the analysis. Responses were analyzed descriptively, with findings reported as frequencies and proportions across response categories. No inferential statistics were applied, given the small sample size. The findings are presented as directional and exploratory rather than statistically representative, and this limitation is acknowledged explicitly in the Discussion section.

RESULTS

Respondent Profile

Respondents represented four age groups: Under 18, 18–29, 30–44, and 45–60. Approximately half reported having been directly or indirectly affected by Alzheimer's disease. Caregiving roles among respondents included family members supporting a loved one's care, one respondent with 20 years of professional care experience, and several respondents with no direct caregiving involvement.

Finding 1: Finding Qualified Caregivers Is the Most Commonly Cited Challenge

"Finding qualified caregivers" was the most frequently cited challenge, appearing in responses from five of eight participants (62.5%). This was followed by the cost of care, emotional stress, and time commitment. The prevalence of caregiver-finding difficulty is consistent with the secondary literature's description of a fragmented, low-transparency market.

Finding 2: Access to Reliable Care Is Widely Perceived as Difficult

When asked how difficult it is to find reliable Alzheimer's care, six respondents (75%) selected "Very difficult" and two (25%) selected "Somewhat difficult." No respondents rated access as easy or neutral, suggesting that access difficulty is a cross-cutting experience across age groups and care roles.

Finding 3: In-Home Caregivers and Long-Term Care Facilities Are Perceived as the Most Expensive Components

When asked what they believed to be the most expensive aspect of Alzheimer's care, the plurality selected in-home caregivers (three respondents, 37.5%), followed by long-term care facilities (two respondents, 25%), medical treatments (two respondents, 25%), and specialized services (one respondent, 12.5%). This distribution is consistent with the secondary literature's identification of direct care labour as the dominant cost category.

Finding 4: Care Costs Are Widely Perceived as Unaffordable

Four of eight respondents (50%) described Alzheimer's care as "Very unaffordable," two (25%) selected "Somewhat unaffordable," and two (25%) selected "Neutral." No respondents described care as affordable.

Finding 5: Caregiver Shortage and High Service Fees Are Perceived as Root Causes of High Costs

When asked what causes high costs in Alzheimer's care, the most commonly cited factors were shortage of caregivers (six respondents, 75%), high service fees (five respondents, 62.5%), lack of government support (five respondents, 62.5%), and administrative inefficiencies (one respondent, 12.5%).

Finding 6: Trust in an Online Platform Is Conditional

When asked whether they would trust an online platform to help find and manage Alzheimer's care, three respondents (37.5%) said "Yes" and five (62.5%) said "Maybe." No respondents said "No." All eight respondents (100%) indicated that verified caregiver credentials and reviews or ratings were the features most important to building that trust.

Finding 7: Support for a Cost-Reducing Platform Is Unanimous

When asked whether a platform that reduces costs and improves access would be valuable, all eight respondents (100%) answered "Yes."

Qualitative Observations

One respondent noted the value of examining care systems developed in other countries, reflecting awareness that Canada's approach to elder care may benefit from international comparison. Another respondent specifically cited government funding as a priority solution, reflecting the tension between private-market and publicly funded approaches.

DISCUSSION

Proposed Solution: CareConnect

The survey findings, taken together with the secondary literature, support the proposition that a digital marketplace for Alzheimer's caregiving represents a credible mechanism for reducing costs while improving access. The proposed platform, CareConnect, connects families seeking Alzheimer's and dementia care with verified, independently operating caregivers, addressing the five structural inefficiencies identified in the Introduction through a centralized, transparent, technology-mediated coordination system.

The core proposition is that by disintermediating the staffing agency and enabling direct family-to-caregiver connection with platform-enforced verification standards, CareConnect can reduce the cost of care for families while increasing net compensation for caregivers. The platform captures a portion of this value as revenue through a commission-based model.

CareConnect's core features are designed to directly address each identified inefficiency. To address agency markup, the platform retains a commission of approximately 10–15% per booking, substantially lower than the 30–50% markup charged by traditional staffing agencies, redistributing value to both families and caregivers. To address search friction, families specify their care needs, location, schedule, and preferences, and an algorithm surfaces ranked caregiver recommendations filterable by language, gender, experience level, and availability. To address price opacity, all caregiver rates are listed publicly before contact is made. To address caregiver-client mismatch, caregiver profiles display verified training history and dementia-specific specializations, enabling fit-based rather than availability-based matching. To address administrative duplication, the platform provides integrated scheduling, shift logging, in-platform messaging, and shared care plan documentation.

A secondary revenue stream consists of an optional premium subscription for families requiring enhanced services, including priority matching, care coordination support, and access to a dedicated platform concierge. For caregivers, registration is free, and they benefit from greater visibility, reduced administrative burden, and higher take-home pay than they would receive through most agency arrangements.

CareConnect differentiates from existing general elder care platforms on three dimensions. First, it is designed specifically for dementia and Alzheimer's care, with caregiver profiles and matching algorithms reflecting dementia-specific competencies rather than general elder care. Second, it invests in credential verification as a competitive moat, a design choice directly supported by the survey finding that all eight respondents identified verified credentials as the single most important trust feature. Third, it is designed to operate within the specific regulatory environment of Canadian provinces, including alignment with health authority guidelines, the Personal Information Protection and Electronic Documents Act (PIPEDA), and provincial caregiver certification standards.

Impact Assessment

The primary impact mechanism is direct cost reduction for families. By replacing agency markup (30–50%) with a platform commission (10–15%), families could achieve savings of 15–35% on direct care costs. For a family spending $4,000 per month on in-home care, this represents $600–$1,400 in monthly savings, or $7,200–$16,800 annually. A secondary impact is improved caregiver income and retention: because caregivers receive a higher share of the effective rate, CareConnect directly addresses the low-compensation driver of workforce shortage identified in the literature [10][11]. A tertiary impact is potential reduction in preventable hospitalization through improved caregiver-client matching and reduced gaps in care coverage, consistent with evidence that care continuity is associated with better health outcomes in dementia care [9]. Finally, by reducing the administrative and logistical burden on family caregivers, the platform may modestly contribute to reducing the burnout documented in the literature [6][11].

The addressable market is substantial. Over 600,000 Canadians currently live with Alzheimer's or a related dementia [1]. At a conservative 10% platform penetration among families coordinating home care, and an average of $2,000 per month in facilitated bookings at a 12.5% commission, the platform would generate meaningful annual revenue. Illustrative projections suggest approximately $1.1 million gross revenue in a BC pilot (500 families), scaling to approximately $11.3 million across BC and Ontario by Year 3 (5,000 families), and potentially exceeding $35 million nationally by Year 5 (15,000 families plus premium subscriptions). These figures are illustrative and not based on detailed financial modelling; they demonstrate the revenue logic rather than constituting a financial forecast.

Limitations

Several limitations of this study must be acknowledged. First, the primary survey data is based on eight respondents, which is insufficient for statistical generalization. The findings are directional and consistent with the secondary literature, but a subsequent study with 50 to 100 respondents stratified by province, age, and caregiving role would substantially strengthen the empirical foundation. Second, the elder care context presents specific trust challenges: five of eight survey respondents said "Maybe" rather than "Yes" to trusting an online platform, and their trust was explicitly conditional on robust verification. Building and sustaining that trust requires investment in verification infrastructure, clear liability frameworks, and responsive dispute resolution that the current proposal does not fully specify. Technology adoption among older adults and their primary caregivers is a related challenge requiring accessibility-first platform design. Third, elder care in Canada is regulated at the provincial level, and requirements for caregiver certification, privacy compliance, and care coordination vary significantly across jurisdictions, adding complexity and cost to geographic expansion. Fourth, a platform connecting families with independent caregivers carries the risk of off-platform arrangements once an initial match is made, requiring platform design incentives to maintain engagement. Fifth, when caregivers operate as independent contractors, questions of liability in the event of an incident are more complex than in an agency model, requiring partnership with insurance providers and careful design of terms of service.

CONCLUSION

Alzheimer's care in Canada is in crisis, not primarily because of the disease itself, but because of the structural inefficiencies of the system in which care is delivered. Agency markups inflate costs without improving outcomes. Fragmented information systems prolong search and delay placement. Poor matching generates turnover that disrupts continuity. Administrative duplication consumes resources that could otherwise support care delivery. These are not inevitable features of a complex problem; they are addressable inefficiencies that a well-designed platform could materially reduce.

This paper has argued that a digital marketplace for verified Alzheimer's care (designed to connect families directly with independent caregivers, with price transparency and social accountability built in) represents a credible and scalable mechanism for reducing both the cost and the access barriers associated with dementia care in Canada. The proposed model is grounded in a review of peer-reviewed literature and government health data, supported by directional primary survey findings, and designed with an honest account of its limitations.

The most significant finding from the primary research is perhaps the simplest: all eight respondents said they would support a platform that reduces costs and improves access. The demand exists. The inefficiencies exist. The technology to address them exists. What is required is the institutional will, regulatory clarity, and entrepreneurial investment to bring them together. Pages for Memories represents one expression of that commitment. This paper represents another: an argument, grounded in evidence, that business-oriented thinking can be brought to bear on one of Canada's most pressing human challenges.

CONFLICT OF INTEREST STATEMENT

The author declares no financial conflicts of interest. The author is the founder of Pages for Memories, a non-profit community fundraiser supporting the Alzheimer Society of BC and Yukon. CareConnect is a proposed concept developed for academic purposes and is not a currently operating commercial entity.

ETHICS STATEMENT

This study involved a voluntary, anonymous survey distributed to community members. No clinical intervention, medical records, or identifiable personal data were collected. Participation was entirely voluntary, and responses were analyzed in aggregate only.

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Understanding and Addressing Healthcare Inequities in the United States
By Erin Williams

Abstract

Health inequity in the United States is largely driven by persistent disparities that arise from a complex combination of social and systemic factors. Minority communities are often impacted the most because discrimination creates barriers to their participation in medical research and access to proper treatment. This contributes to worse health outcomes, especially for women and people of color. Despite the government's attempt to reduce inequity, many people still lack access to adequate healthcare. Universal healthcare has been widely proposed as a viable solution to addressing these inequities, since it could help reduce the financial barriers that prevent people from obtaining health insurance and healthcare. All in all, universal healthcare is essential to confronting systemic health inequities across the United States.

Introduction

Health inequity in the United States is influenced by a variety of factors, including gender, race, socioeconomic status and environment. Health research has advanced rapidly, and many life-changing medications and treatments have been developed, often through groundbreaking clinical trials. But unfortunately, many are often excluded from these trials, including women, minorities and other disadvantaged groups. These disparities often lead to poorer health outcomes and increased rates of illness. Different government administrations have attempted to develop and execute plans to reduce health inequity and increase access, with varying degrees of success. Many have proposed universal healthcare as a solution, especially given that other wealthy and developed countries that have adopted it rank higher in terms of equitable healthcare quality and access. In short, fair and equal access to healthcare in the U.S. is long overdue and needs to be prioritized.

New York State Assemblymember Chris Burdick says, “The concept of health inequities stems from pretty compelling evidence that the government is not doing enough. They are not doing enough in terms of providing equity in the delivery of services, and health services, especially maternal health, prenatal health and more. The ones that are getting hurt by this are the people of color because the government is not doing a good job of addressing these health disparities.” Health disparities are very common in minority groups and typically stem from factors that individuals can’t control. Disparities in health happen when individuals and communities encounter increased rates of health issues such as obesity, breast cancer, and heart disease (Robyn 1). Dr. Joseph Bettancourt, the president of commonwealth fund said at a media briefing: “We’ve long known that racial and ethnic disparities in health and healthcare have existed in our country. Quite simply and on average our Commonwealth Fund 2024 State Health Disparities report shows that disparities exist in every state in our nation. Even in states that have strong overall health systems, racial and ethnic health disparities can be dramatic” (Gunn 4).

Gender Inequity

Women in the United States often have more difficulty affording and accessing healthcare than women in many other countries. For instance, women in the United States face the greatest rate of avoidable deaths, with 270 out of every 100,000 deaths being preventable with the correct timing of quality treatment (Gunja 4). Additionally, women in the United States and Canada were among the fewest to report having a primary doctor or a consistent place for care, while almost all women in the U.K. and Netherlands reported having one (Gunja 13).

Women are often less likely to participate in biomedical research as well, since most of this research pertains to men. For that reason, it is often harder to diagnose women for diseases particular to their sex and symptoms (McKinsey 4). Women can have varied reactions to the same treatment provided to men, and often that treatment is ineffective given the differences between male and female physiology. Not only should research include more women, who make up half of our society, but some research should focus exclusively on women. Right now, only 11 percent of U.S. national funding goes towards women's health research (McKinsey 23). Maternal Morbidity in minority communities. Lack of research can delay diagnoses for women and lead to ineffective treatments. For example, new mothers don't always receive proper treatment because there is little data on maternal health. In fact, 800 women die from avoidable causes regarding pregnancy and childbirth each year across the globe (McKinsey 11).

Minority communities in the United States have higher maternal morbidity rates compared to other wealthy countries. In a study, the WHO reported that the U.S. is one of seven countries to report they had a significant increase in maternal mortalities since 2000; the other countries are Venezuela, Cyprus, Greece, Mauritius, Belize, Dominican Republic, and U.S. Commonwealth of Puerto Rico (Eugene 1). Even though technology has advanced in the medical field along with plentiful resources, U.S. maternal outcomes are worsening over time. In contrast, other countries have more affordable and stronger maternal health care systems throughout pregnancy and postpartum compared to the U.S. and prioritize consistent quality care. For example, the maternal mortality ratio in 2018 was 3 per 100,000 or fewer in in the Netherlands, Norway, and New Zealand, compared to 17 per every 100,000 in the United States (Tikkanen 3).

The quality of the U.S. maternal care system worsened further during the COVID-19 pandemic. U.S. pregnancy related deaths increased dramatically, going from 660 to doubling in 2019-2021 (Eugene 2). One reason that minorities suffered in particular during the pandemic was the lack of access to hospital care. People didn't want to go near healthcare facilities during this time, and many could no longer afford healthcare after losing their jobs. This was especially common in rural areas with higher Black populations, where there were fewer resources and health services available (Eugene 20). Even when services were available, U.S. hospitals and providers were overwhelmed with patients and often understaffed. Furthermore, minority communities often had less access to vaccines during COVID (Eugene 18). This resulted in increased mortality rates. Post pandemic-related mortality rates among Hispanic women, for example, increased by 125% during this time (Eugene 4).

Overall, forgoing pregnancy care and checkups, especially during times of crisis like a pandemic, can lead to severe and deadly complications that could easily be treated by equal access to healthcare.

One way to do this would be to expand coverage provided by Medicaid. Reducing rates of maternal morbidity and focusing on postpartum care is just as important as the delivery of the baby. Greater Medicaid coverage for women postpartum is an example of a beneficial policy that provides women with quality healthcare access and coverage (Eugene 11). Expanding coverage can help decrease the risk of diseases such as cardiomyopathy and others that are large contributors to maternal morbidity. Medicaid plays a large role in women's health as it helps many low-income women pay for care. For example, in 2023, Medicaid paid for 41% of U.S. births and supplied 75% of services for family planning (KFF 6). Since many women in underserved groups can't afford to continue care postpartum, expanding Medicaid coverage will help ensure that everyone receives this life-saving care.

Racial Inequity

Minority groups are marginalized within the healthcare system due to structural racism which results in discriminatory policies and worsening health outcomes. Shaped by a history of racism and coupled with geographic struggles across the world, racial and ethnic populations in the United States are subject to inequities in the healthcare system. These disparities stem from various factors such as poverty, crime, and discrimination and ultimately result in poorer health outcomes.

Racial And Ethnic Disparities in Medical Advancements. Minority groups and people of color are especially underrepresented in clinical trials and often have difficulty accessing new medications and treatments. An analysis in 2020 of 32,000 individuals who were part of new drug trials found that only 6% were Black, 6% were Asian, 19% were Hispanic and 35% were 65 or older (McCarthy 2). It is often difficult for some people of color to be included in clinical trials because of lack of insurance, issues with transportation, difficult work schedules and hospitals with fewer resources are likely to not have available clinical trials (Ndugga 2). From 2000 to 2020, over half of U.S. clinical trials didn't report data on participants' race or ethnicity (Ndugga 4). Barriers to clinical trials, especially for minority communities, can hinder the creation of medicine that is geared towards everyone and includes research from every group receiving it. Because minority populations are underrepresented in clinical trials, the drugs developed from these trials are not designed or approved for them (Ndugga 6). "Conversely, white people were overrepresented in clinical trials, with a median enrollment of 80% and 10% of trials reported 100% white enrollees" (Ndugga 5), with a range of 20% to 0% of minority groups being represented.

Different ethnic populations have varying genetic traits and reactions, and often times, a certain population may be more susceptible to a certain disease. An analysis of drug approvals of the FDA during 2014-2021 showed that Black people were not included in as many trials as they should have been, and this is reflected in their reaction to certain diseases (Ndugga 6). Creating a

drug that is only tested on white people can often have negative side effects or unexpected reactions that were never researched before developing the drug.

Minorities also face multiple barriers to accessing newly developed medications and technology because they are very expensive. Sickle cell disease is an example of a condition that affects more Black and Hispanic people than other groups, and the development of gene therapy could be lifesaving. Unfortunately, it is very expensive -- more than 2 million dollars (Ndugga 7). More than 90% of people with sickle cell disease are non-Hispanic Black, or African American, and around 100,000 people are diagnosed with it (CDC 1). A sickle cell patient, Nesha, told the Sick Cell blog reporters that, 'We've got to fight with medical staff and basically prove that we're in pain in order to get what they know we need'" (Sickcells 3).

Minority populations also struggle to get lifesaving medication for diabetes. They have increased rates of diabetes complications, such as chronic kidney disease, hypoglycemia, and cardiovascular disease, which could be prevented with new diabetes medications (Hopkins 1). But these medications are expensive and inaccessible, and Black patients were 20% less likely to begin these new medications while American Indian and Alaskan Native patients were 50% less likely to start the new medications (Hopkins 2).

Research proves that clinical algorithms and tools could possibly have racial bias because the data on which they are trained may be biased and excludes some of the population (Ndugga 7). Many healthcare providers use these tools to prescribe prescriptions and find a treatment plan for their patients. This can lead to discrimination and neglect of minority patients by following the systems of bias and discriminatory recommendations. Payton, the co-founder of the Institute for Data, Research and Innovation Science (IDRIS) at Rutgers University conducted a study on AI algorithms used in healthcare and discovered representation is lacking in medical research among AI developers and Black and Brown patients are underrepresented. The algorithms can make wrong assumptions about patients and leave out critical details because they are not created using diverse patient data or perspectives (Stetler 1). Payton says, "Algorithmic bias can also fail to account for disparities in healthcare outcomes, such as an overall mortality rate that is nearly 30 percent higher for non-Hispanic Black patients versus non-Hispanic white patients, a figure that can also be attributed to higher rates of certain illnesses" (Stetler 2).

Pediatric Health Disparities. The health of children of color has significantly declined in the past 16 years due to unequal treatment, delayed care and misdiagnosis. A researcher at Northwestern University and a pediatrician at Lurie Children's Hospital of Chicago, Nia-Heard Garris, explained that almost every minority group experiences disparities in healthcare. (Godoy 2). The largest disparities were discovered in pain management, as children of color are not as likely to receive painkillers for various severe issues compared to white children (Godoy 5). In 2024, research shown at the American Academy of Pediatrics proved that Black children were 27% less likely to receive an opioid prescription compared to white patients who were 10% more likely to be given opioids (Shah 2). Because of the lower likelihood of children of color to receive pain medication, the illness can worsen rapidly leading to poorer health outcomes overall.

Additionally, children of color also wait longer in the emergency room (Godoy 4). National emergency department research found that Black pediatric patients waited 27% longer for emergency care compared to white patients (Johnson 8). Waiting longer for emergency care in life-or-death situations can increase risk of complications and death.

Racial inequities are most prominent in specialty medical services as children of color have a reduced likelihood to receive diagnostic imaging and have a higher risk of experiencing complications during and after surgical procedures (Godoy 3). Delayed imaging can result in misdiagnosis and incorrect treatment, so underlying health issues may be dismissed. A large study conducted in 2021 with over 13 million pediatric ER visits discovered that Black children are around 18% less likely to receive diagnostic imaging compared to white children (Marin 1). In conclusion, disparities in child healthcare are prominent within our healthcare system and consistently contribute to poorer health outcomes in crucial times for care, particularly for children of color.

In short, our healthcare system needs to address the barriers that prevent too many Americans, especially minority groups, from receiving life-saving care and treatment.
Racist Policies Impacting Health. Yet before seeking to address these barriers, it is important to understand the systemic barriers that create them in the first place. They include Redlining, a mortgage practice used by banks to discriminate against people of color by refusing to give them mortgages in certain areas (Lathan 1). By refusing to give people of color mortgages, it ensures they will be in segregated and isolated communities that are often congested and highly polluted. Redlined communities statistically suffer more health problems than those in wealthier communities.

It began when the Homeowner's Loan Corporation was created by the federal government to help homeowners who were in default on mortgages avoid foreclosure during The Great Depression (Lathan 1). They created maps to look at the neighborhood risk focused on property values and racial arrangement (Lathan 1). These maps put people of color in poorer communities with no investment access and fewer resources while white people were able to access mortgages, own land and start and continue families through generations in a safe and wealthy area. Communities with minority populations were outlined in red and labeled as risky, which prevented residents from getting mortgages and therefore owning their own land (Lathan 2). It has been illegal since 1968, but redlining has had long-lasting effects on minority communities and still occurs unlawfully today. In general, people living in redlined areas are disproportionately affected by air pollution, increased reproductive health disorders, and decreased access to urban amenities (Lathan 1). Additionally, these areas have little green space with fewer trees and parks, and more asphalt resulting in pollutants in the air and worsening environmental conditions (Lathan 3). Because redlined areas were and continue to be mainly ignored by developers and facility improvement was scarce, people living in the historically redlined communities also have increased rates of cardiovascular disease, asthma, and maternal morbidity (Lathan 5).

Redlining has a direct correlation with poorer health outcomes. According to a study published in 2023 by JAMA Network Open, “Among veterans living with cardiovascular disease, those who lived in historically redlined neighborhoods (rated "D") had a 13% higher risk of dying from any cause and a 14% higher risk of experiencing a major adverse cardiovascular event compared to those who lived in historically white, wealthy areas” (Castillo 1). People living in formerly redlined neighborhoods have higher risks of illnesses such as preterm birth, cancer, tuberculosis and maternal depression (Garber 2). Nancy Krieger, a professor of social epidemiology at the Harvard T.H. Chan School of Public Health discovered a connection with redlining in New York between redlining and preterm births and also in Massachusetts with late-stage cancer diagnoses (Godoy 11). Redlining is an underestimated and less talked about crisis that continues to harm public health.

Insurance and Universal Healthcare

Given the steep cost of healthcare and lack of insurance, millions of Americans opt to forgo coverage, appointments and treatments. Yet this often leads to serious health complications. Unless the government acts decisively to address this matter, more Americans will continue to suffer the consequences. In 2024, for example, thirty-six percent of adults admitted to not going to healthcare appointments because it was too expensive, leading them to miss crucial treatment for harmful medical conditions (Sparks 2).

Marginalized groups are even more likely to skip care, and women are more likely than men to skip care. In 2024, 38% of women were reported to have skipped appointments compared to 32% of men (Sparks 8). In April of 2025, the West Health Gallup Healthcare Affordability Index reported that Black Americans had a 46% higher rate of reporting they couldn’t afford healthcare and Hispanic Americans had a 52% rate (West Health 1). More specifically, a 2025 report done in Connecticut found that 77% of Black and 78% of Hispanic adults reported going without care compared to 52% of white people who responded (Healthcare Value Hub 9). These statistics highlight the disparities between different minority and marginalized groups compared to white individuals. This leads to worse conditions for these groups and increased disease rates due to lack of treatment and care.

Ultimately, insurance dictates whether people can afford appointments. Seventy-five percent of uninsured adults reported that they skipped or postponed needed care because they couldn’t afford it (Sparks 2). But even with insurance, costs are so high that 75% of insured adults reported they skipped appointments because they still couldn’t afford it (Sparks 8). Americans who have insurance still pay large amounts of money out of pocket due to high deductibles and high-cost bills, coupled with expensive copays. Income plays a large factor in affording insurance and being able to pay for appointments as well. It’s reported that 64% of people earning less than $24,000 had difficulties with affordability. Low-income families often face a choice of forgoing appointments and care or putting food on the table and providing for their family.

The U.S healthcare system is ranked lower than a multitude of other high-income countries in multiple factors such as availability, life expectancy, and cost. In a report issued in 2024 by the Commonwealth Fund, America had the lowest life expectancy and the highest rates of avoidable deaths compared to Australia, Canada, France, Germany, the Netherlands, New Zealand, and the U.K. (Gamble 1). Dr. Tracy R. Nichols, professor and chair of the department of Community & Global Health at Lehigh University, spoke about the comparison with other countries: "Our health outcomes compared to some low and middle-income countries may be better. But we are one of, if not, the richest nation, and when we compare other countries' health outcomes, we are near or at the bottom. We have some cutting-edge technology, but it's not addressing the country as a whole. So, it's only addressing certain people or certain populations." There is not enough primary care available in America and there are 26 million Americans without insurance making it much more difficult to receive care compared to the Netherlands, U.K. and Germany (Gamble 2). For example, In the Netherlands every single person has a primary care doctor (Harrah 1). This may be a more beneficial approach than the United States because more people will be able to afford care and know exactly how much they will owe.

European healthcare systems are vastly different from the U.S. Most importantly, the great majority of European countries offer universal healthcare to all citizens. In the U.S., with its private market-based healthcare system, millions remain uninsured, even with the Affordable Care Act (Nashbio 1). The ACA was created in 2010 with the goal of giving more Americans access to health insurance, while decreasing costs. This has involved offering all Americans more affordable insurance options and expanding Medicaid. The ACA now provides health insurance to more than 25 million Americans (Blumenthal 1). And under the law, insurers must issue policies to everyone and cannot turn anyone away because of their health status (Rapfogel 2). The ACA is among the government's first attempts to try and reduce health disparities, and while it did help cover some individual's healthcare costs, the deductibles were still very high. When President Barack Obama implemented the ACA, it was a positive change for some people, but it worked with private insurance companies and many working-class families still could not obtain full coverage, so they still had to pay a lot of out-of-pocket costs (Vries 3). Although the ACA has helped improve healthcare for many, it still prioritizes private companies and profit over inclusivity for everyone. Although it is a step in the right direction, we need universal healthcare for everyone.

Unfortunately, in President Trump's first term he sought to undermine the ACA. And by attempting to unsuccessfully revoke the ACA, it in turn steered us away from achieving health equity. Many Americans depend on the ACA to receive life-saving treatments and cover the enormous out of pocket costs associated with healthcare. With the price of basic necessities like healthcare rapidly increasing, it is impossible for many low-income families to keep up with medical costs. Because the U.S. ranks low in affordability and availability of health insurance, many people do not have a primary care provider and cannot receive treatment after hours (Gamble 2).

The United States could benefit from adopting a European style healthcare system to ensure we are properly allocating the money we invest into healthcare. Trying universal coverage and potentially lowering costs of care would promote better population health overall. The United States spent 17.2 percent of its GDP on healthcare in 2024, which was 5 percentage points more than the majority of European countries (Schmitt 1). This means that the U.S. is spending more on healthcare compared to European countries. Despite this, we still do not have universal coverage, and our healthcare ratings internationally are low.

One reason for this is the U.S. funding and organization of our healthcare system. In the U.S., healthcare is paid for by private insurance, employers, households and some public programs. In comparison, in Europe, funding for healthcare comes from mandatory social insurance or tax-based funding (Meyer 3). For example, the U.K. uses a single payer system in which the government is the only entity paying for healthcare services (Brittanica 3). In comparison, in 2026, The U.S. spent $14,775 per person in healthcare, while the U.K. spent $6,747 and has consistently ranked higher on health system performance (Telesford 2). In fact, researchers have estimated that $438 billion could be saved annually if we adopted universal healthcare (Brittanica 17). Researchers at the Yale School of Public Health also concluded that "a single-payer, universal health-care system is likely to lead to a 13 percent savings in national health-care expenditure" (Brittanica 18). It's clear that the U.S. could save a tremendous amount of money by investing in universal healthcare, which would also be more effective. This was especially evident during the COVID-19 pandemic.

A study done in June of 2022 discovered that the U.S. could have saved approximately $105.6 billion in COVID-19 hospitalization costs if it used a single payer healthcare system (Galvani 1). An additional finding showed that if the U.S. in 2020 had had a single-payer universal health care system, almost 212,000 American lives would have been saved that year (Blair 1). Overall, a universal healthcare system can not only reduce unnecessary spending but also save thousands of lives.

History of Health Insurance in the U.S. Attempts to institute universal healthcare have endured throughout history. Unlike European nations that swiftly adopted government systems of social insurance early on, the U.S. was divided and therefore took longer to create a social health insurance system. In Europe, social insurance programs, such as compulsory sickness insurance, were made by conservative governments to protect their income and lessen support for the socialist movements by strengthening their loyalty to the state (Palmer 1). The government had a clear and effective plan that appealed to citizens. In comparison, the U.S. took much longer to make progress towards universal healthcare because people feared the government would have too much control. For example, during the Progressive Era in the United States, people didn't support universal health insurance, making it difficult for proposals or bills to pass from healthcare reformers. Even though President Theodore Roosevelt was in support of health insurance, the majority of reform efforts didn't involve the government, and the conservative leaders that came after delayed the advancement of social welfare (Palmer 2).

By 1915, the American Association of Labor Legislation created a model health insurance bill that focused on employed low-income individuals, offering medical care and sick pay where costs were shared by workers, employers and the government (Palmer 3). Although the American Medical Association (AMA) first supported the proposal, it was ultimately withdrawn due to political and social disagreements. Essentially, the American Federation of Labor was against it as they believed it would expand government control and weaken labor unions. The AMA also convinced Americans that a national health insurance system would be similar to socialism, which many people were against at the time (Aslan 1). In the 1920's, healthcare costs were skyrocketing and significantly impacting low-income families, which led to the conclusion that more people should be able to access medical care. Voluntary health insurance was introduced, but this idea was faced with a lot of opposition from medical professionals (Palmer 7).

Efforts continued during President Franklin D. Roosevelt's New Deal period which brought national health insurance proposals, which were blocked continuously through the exclusion from the 1935 Social Security Act and then put off due to unemployment issues and war (Palmer 8). Because so many people were afraid of giving the government more power, expansion of health insurance was very limited, and a universal system was completely out of the picture.

Even though many New Deal insurance proposals failed, government involvement in healthcare was always part of the discussion, and soon elderly coverage of medical costs came back into political debates. For example, the debate over the King-Anderson Bill, which had the goal of extending social security to cover medical needs of people 65+, eventually led to the creation of Medicare in 1965, even though it was strongly opposed by many politicians (Brittanica 10). In the early 1970s, after Medicare was created, President Nixon and Senator Ted Kennedy proposed different reform plans for healthcare, which were both aimed at universal healthcare, but neither proposal, National Health Strategy nor The Health Security Act passed (Brittanica 11). Another major attempt for government involvement in healthcare was introduced in the early 1990s. President Clinton proposed the Health Security Act in an attempt to achieve universal healthcare coverage through required insurance and employer mandates, but it was strongly opposed and alternate single-payer systems proposals were created but failed to pass congress (Brittanica12).

Two decades later, President Obama further advanced health equity efforts by passing the Affordable Care Act. Obama took a different approach to the bills and proposals from the past. Instead of trying to make unrealistic, quick sweeping changes to the entire healthcare system, Obamacare (the Affordable Care Act) offered an easier transition and helped millions of people get healthcare. Obamacare was signed into law in 2010, with the goal of expanding health insurance in the U.S. and insuring around 27 million uninsured Americans (Brittanica 13). It expanded access to millions of Americans, but we still didn't have a universal healthcare system. And many people continued to lack access to basic healthcare and struggled to pay their medical bills.

Therefore, debates and proposals continued about whether we should have universal healthcare. Senator Bernie Sanders and Physicians for a National Health Program pushed for a federally run single-payer system that would provide coverage for all Americans (Brittanica 14). Many people in the Democratic Party have recently tried to spark support for the Sanders single-payer system. NY State Assemblymember Chris Burdick is a co-sponsor of the NY Health Act which would provide for a single payer system. He says, "Critics say that would bankrupt us. My feeling is we're getting killed by costs as it is. And we have to do something to help the individuals that are getting bankrupted by the cost of healthcare." The idea of a single-payer system initially weakened in the 2020 primaries but is now prominent because of new candidates who are extremely concerned about the rising costs of healthcare. The issue with the proposals was that the candidates who supported a single-payer plan couldn't explain how it would be funded (Brownstein 2). This has been a common issue that's prevailed throughout history as skepticism arises from citizens who are worried that the universal healthcare proposals are completely unachievable. However, it has been proven through financial research now that a 10-year bill for a single payer plan would cost less than it would in 2020 (Brownstein 2).

The Debate Continues. A current democratic senate candidate in the running for Michigan, Adbul El-Sayed, is in support of universal healthcare where the single-payer debate is most prominent. His two opponents Stevens and McMorrow don't support Medicare for all and instead support a public option which would let Americans buy into Medicare to compete with private insurance companies (Brownstein 6). El- Sayed states in his campaign, "Michiganders deserve an economy that works for them, guaranteed healthcare, clean air and water and affordable housing" highlighting his core values in his mission to provide healthcare to all people within the state.

President Biden's administration supported Obama's actions to reduce health inequity by introducing new policies. They started the Special Enrollment Period (SEP) in February 2021, during the COVID pandemic, which let individuals enroll in marketplace ACA coverage, which is a marketplace that offers insurance plans to people, because of the Covid-19 pandemic, and 2.5 million people enrolled over the 6 months (Waldrop 1). They expanded this in September by making an all-year SEP that applies to anyone with incomes at or lower than 150% of the federal poverty level (Waldrop 2). A large amount of the population lost their healthcare coverage during the pandemic and had difficulty finding resources to get it back. The SEP helped them get this coverage back and improved their safety. Due to the increase of funding of $10 million in 2020 to almost $100 million in both 2022 and 2023, healthcare navigators were able to help consumers by improving their understanding of their coverage options and enrollment (Waldrop 2). Many people who don't have access to various resources are unsure of what options they have for coverage. So, they have no option but to pay for assistance themselves. Helping customers with this through government funding encourages people to use resources like Medicaid and educates them on their options. The Biden Administration also enforced regulations which protected consumers from being deceived by short term health plans that don't include benefits like pregnancy care or protections for pre-existing conditions (Waldrop 3). Medicaid enrollees were

entitled to an entire year covered postpartum, as states took a state plan amendment for a Medicaid coverage extension (Waldrop 3). New mothers are especially vulnerable and giving them an entire year promotes good mental and physical health for both the mother and the child. Overall, The Biden Administration fixed the "family glitch" which made coverage for healthcare less expensive for more than five million people. They did this by including individual and family plans in ACA affordability rules (Waldrop 4).

Today, the current Trump Administration continues to push back health equity progress by reducing key programs like Medicaid and the ACA that increase health equity and funding towards them. This leaves millions of Americans with thousands of dollars of debt or without health insurance resulting in worsening health conditions. For example, Reshonda, a 50-year-old small business owner, relies on the ACA, and it saved her life when she was tested and diagnosed with breast cancer: "I can't go without, but I can't afford to pay the premiums at basically $600 per month." (Cross 1). Citizens across the U.S. like Reshonda, are in danger of losing lifesaving healthcare if President Trump continues to decrease crucial funding and programs.

The One Big Beautiful Bill (OBBB) was signed by President Trump. This bill is harmful to health equity because it removes a large amount of funding allocated for Medicaid while increasing the debt ceiling by $5 trillion yearly and cuts 15% of Medicaid spending (Macneil 1), which is vital for low-income families across America. Premiums are going to double for ACA enrollees due to the bill's choice to not renew the subsidies, which lowers the costs of the monthly premiums in the ACA marketplace (Macneil 3). The ACA is supposed to be an affordable and convenient option for people but increasing the premiums will send millions of people into deep medical debt. Reducing Medicaid has grave consequences as research has proven that decreasing access to Medicaid increases early mortality rates and negatively affects overall health (Macneil 2). Millions of Americans' health will suffer from these cuts. The Congressional Budget Office estimates the OBBB would lead 11.8 million Americans to lose their health insurance, but this is just a general estimate, so the impact of the bill could have a larger or smaller effect on health insurance (Macneil 2): "But regardless of the precise effect, it is undoubtedly the largest, most regressive cut to federal health benefits that has ever been enacted in the U.S." (Macneil 3).

President Trump also signed executive orders to remove DEIA programs throughout the federal government which cut many jobs in the minority health and chronic disease prevention office while suggesting a $900 million cut of funding to the Indian Health Services (Ndugga 10). Targeting Indian Health Services will leave Indian communities across the U.S. vulnerable. Many Indian populations are already struggling to maintain good health and afford basic necessities. So, removing such a large amount of funding will pose a serious threat. Two thousand five hundred employees were removed from the Indian Health Services which gives healthcare to 2.5 million American Indians and Alaska Natives (Wild 1). The IHS has already been dealing with a thirty percent vacancy rate for medical staff (Wild 1). There aren't enough doctors and nurses there to help provide care for Native Americans, worsening access for a

minority that is already often isolated. The National Council of Urban Indian Health (NCUIH) reported that fifty percent of Urban Indian Organizations could have to stop their services after six months without funding (National Council 2). NCUIH CEO Francy's Crevier, expresses her concerns for the Native Communities wellbeing: "The proposed budget cuts are a direct threat to the health and well-being of American Indian and Alaska Native communities. We call on Secretary Kennedy to honor his commitment to prioritizing Indian Country and appeal these proposed reductions. Lives are at stake and this could have catastrophic consequences." This is an urgent issue as Native American lives are on the line. The lack of funding and understaffing is likely to cause a national public health crisis in which Native Americans who are already marginalized are put in danger.

Maternal health services have also suffered due to the Trump Administration's cuts to the CDC Division of Maternal and Infant Health Services, including the removal of the Pregnancy Risk Assessment Monitoring System, which has been used to monitor and collect data on maternal health disparities (Ndugga 11). With no data collection for maternal health disparities, we won't know how many pregnant women need assistance financially or medically. The U.S. government has the power to improve health equity with resources and plenty of funding, but we still have been unable to prioritize Americans' health responsibly and equitably.

Solutions for Reducing Health Inequity

Increasing health equity could be possible by improving and educating people on the ACA and other forms of coverage, creating legislation that prioritizes health equity and teaching healthcare staff about discrimination and bias.

There have been programs created by the National Institutes of Health (NIH) and Food and Drug Administration (FDA) designed to increase minority group participation in clinical trials. For example, pharmaceutical companies will now have greater difficulty getting FDA approval if clinical trial data doesn't include a variety of minority populations (McCarthy 4). With the same goal in mind, the NIH tells researchers to create designated recruiting targets to have a diverse population in their trials (McCarthy 4). Additionally, NIH guidelines requiring minority participation were put in place so that women and unrepresented groups are included in clinical trials (Ndugga 3).

The FDA encouraged Pfizer and Moderna to include people of color in their vaccine trials (Ndugga 4). Originally in Moderna's trial for the Covid-19 vaccine only 7% of participants were Black, when the public showed alarm, the trial was slowed down to recruit and encourage more Black people to participate (McCarthy 3).

Working with community clinics has been proven by researchers to increase diversity in clinical trials because they have relationships with patients (Ndugga 4). Educating and focusing on community-based initiatives can help encourage more people to get involved in trials. Community-based initiatives have proven helpful in reducing health inequity. Dr. Tracy R. Nichols, professor and chair of the department of Community & Global Health at Lehigh University, describes how these initiatives can help communities: "We wanted to design

interventions with people that address barriers at the individual level, at the interpersonal level, at the organizational and social policy level and include the people who are directly impacted."

Providing coverage for expensive treatments and medications is one way to reduce disparities in access (Ndugga 9). Increasing coverage for expensive medications can help individuals receive lifesaving treatment that they wouldn't be able to otherwise receive because it's brand new and extremely expensive.

Conclusion

Health inequity continues to be one of the most troubling issues plaguing the United States today. Millions of Americans face difficulties accessing quality, affordable and consistent healthcare due to a multitude of factors, such as unfair insurance policies and discrimination which create barriers to care. These barriers lead to consistent unequal health outcomes. Even though the government has taken some actions to target and create insurance policies that would expand healthcare access, more needs to be done. Americans are still spiraling into deep debt just to afford basic checkups so they can maintain their health and live a healthy lifestyle. My research shows that minority populations and women are particularly disadvantaged when it comes to accessing quality treatment and new medications, which ultimately results in higher rates of illnesses and complications. Universal healthcare has been proposed as a solution that is predicted to reduce U.S. government spending and expand coverage to every American. This would promote improved health outcomes for everyone. Now more than ever, reducing health inequity is a critical issue that we need to address.

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Artificial Intelligence: Revolutionizing Portfolio Management By Nikhil Pasya

Abstract

Artificial Intelligence, commonly known as AI, is transforming the management of investment portfolios. AI models have moved beyond the limitations of traditional, bias-prone methods and advanced to a much more systematic approach. This paper examines the projected impact of AI across each operational phase of portfolio management, ranging from execution to feedback. It analyzes how AI models utilize methodologies such as Gradient Boosting and Long Short-Term Memory (LSTM) networks to optimize signal generation and asset forecasting by processing large-scale datasets at unparalleled speeds. Moreover, the paper delves into how methods such as Natural Language Processing (NLP) and Sentiment Analysis facilitate the production of large-scale data and the identification of market trends. However, despite these computational advantages, adoption rates are constrained due to a deficit in transparency. To mitigate this "black box" dilemma, Explainable AI (XAI) has emerged as a critical framework. Through the lens of an XAI package called SHAP, the paper explores the transparency that XAI brings and shows how it will explain its decisions in an extremely detailed manner. Ultimately, the future of portfolio management will not involve the complete replacement of human expertise with AI, but rather a collaborative model that integrates AI's computational capabilities with human oversight to create more resilient, profitable, and accessible portfolios.

The AI Revolution in Portfolio Management

Artificial Intelligence (AI) is fundamentally reshaping the management of investment portfolios by transitioning from traditional methods to more data-driven strategies. This set of technologies, including advanced algorithms, machine learning, and natural language tools, enables financial services organizations to better understand markets and customers, analyze and learn from digital journeys, thereby replicating cognitive functions at scale (IBM). The rapid evolution of AI models and technologies is changing investor expectations and reshaping portfolio management as a whole. This paper examines the transformative impact that AI has on the three core stages of portfolio management: planning, execution, and feedback. It will also explore the applications that are key for AI usage, such as signal generation and high-dimensional forecasting. Lastly, it will also focus on the critical challenges that are hindering the involvement of AI in portfolio management, as well as the "black box" problem and the innovative solution known as XAI (Explainable AI).

The field of portfolio management has been historically shaped by foundational methods, such as Modern Portfolio Theory (MPT) and the Capital Asset Pricing Model (CAPM) (Ma et al.). Over time, many scholars and practitioners realized that these classical approaches were outdated and have since critiqued them for their limitations in navigating complex, globalized markets. Those critiques stemmed from two main issues: human bias and systemic risk (Ma et al.). First, research in behavioral finance has shown how human biases (overconfidence, fear of loss, following the crowd) could cause deviation from rational analysis,

an issue traditional models fail to account for ("The Role of Behavioral Finance"). Second, the markets were ill-equipped to handle systemic risk, in which the failure of one sector causes a cascading collapse of the financial system. In response to these new obstacles, a new wave of research has explored a modern solution: Artificial Intelligence. With the introduction of AI, those previous issues were now accounted for, as AI offered methodological and technological processes to address these financial obstacles, making its influence especially prominent in the core stages of portfolio management: planning, execution, and feedback (Bartram et al.; Sutiene et al.).

The current literature agrees that artificial intelligence is transforming portfolio management by improving forecasting accuracy, risk assessment, and decision-making beyond the abilities of traditional models. Bartram et al. argue that AI can process significant quantities of data and identify complex patterns and correlations that conventional methods often miss. In a similar fashion, Ma et al. demonstrate that machine learning and deep learning models can improve portfolio optimization and return prediction by recognizing nonlinear relationships in markets. Bahoo et al.'s comprehensive review further supports this consensus by explaining how AI has outperformed traditional financial approaches, using methods such as Random Forests, Gradient Boosting Trees, clustering, and network analysis. To further expand on these findings, Darwish et al. show that Natural Language Processing and sentiment analysis enable AI systems to incorporate online information from areas including newspapers and social media to effectively adapt to variable market conditions. Collectively, these studies suggest that AI has become a valuable asset in improving the efficiency of the planning, execution, and evaluation stages of portfolio management.

Although these studies agree on AI's effectiveness, researchers have also identified issues related to the adoption of these models in portfolio management. Černevičienė and Kabašinskas find that many advanced AI systems fall under the "black box" category, meaning they provide an output without clearly explaining the reasoning behind their decision. This lack of transparency leads to a reduced sense of trust for investors and creates concern regarding accountability. Lundberg addresses this issue through the development of a tool known as SHAP (SHapely Additive explanations), a framework that utilizes game-theoretic principles to quantify the levels of contribution that certain factors have in the decision-making process. Furthermore, research done by Sutiene et al. emphasizes that explainability in predictions is a huge factor for the integration of AI into financial decision-making, while IBM's report highlights the need for transparency and risk assessment as essential for a successful implementation. Together, these sources indicate that the future of AI in portfolio management is not purely based on performance but also on explainability and trustworthiness to facilitate a more seamless process.

While the existing literature provides extensive discussion on explainability frameworks, portfolio optimization techniques, and AI forecasting models, most studies examine these topics individually or focus on theoretical applications. This paper contributes to the literature by connecting these principles to the entire portfolio management process, connecting planning, execution, feedback, and transparency into a single framework. Furthermore, it showcases

real-world examples in firms such as Goldman Sachs and JPMorgan to demonstrate the effects of AI's implementation in the industry. By combining academic research on NLP, machine learning, and Explainable AI with recent evidence of industry adoption, this paper offers a comprehensive perspective of AI-driven portfolio management restructuring, as well as the utile value of frameworks such as SHAP in overcoming the current barriers of acceptance.

Core AI Applications in Investing

Artificial Intelligence has been crucial for the execution process. Specifically, it utilizes a process signal generation, a trigger that indicates an opportunity to sell, buy, or hold an asset. This is primarily due to AI's ability to process and scan vast amounts of information at an unparalleled speed, far exceeding the proficiency of any traditional methods (Google Cloud). AI-driven algorithms, for instance, can analyze massive datasets, including historical market data, news sentiment, and real-time price movements, to execute trades at speeds and scales beyond human capability (Ma et al.; IBM). This rapid analysis has led to improvements in asset return and risk estimates, primarily due to the new involvement of AI models and their computational capabilities. For example, a recent study from the University of Chicago found that a GPT-4-powered model, using Chain-of-Thought reasoning, achieved an earnings prediction accuracy of 60.35%, significantly outperforming human analysts who had an accuracy of only 52.71% (Burton). Additionally, AI's superior ability to generate returns has been demonstrated by a Stanford study that showed an AI analyst outperformed 93% of human mutual fund managers over a 30-year period, generating an average of 600% more alpha per quarter (Stanford Report). Machine Learning (ML) techniques such as Gradient Boosting Trees, models that sequentially correct previous errors for better prediction, and Random Forest, which uses multiple decision trees for robust forecasting, both excel at picking out high-performing assets, even when scanning complex databases (Ma et al.; Bahoo et al.) (See Figures 1 and 2).

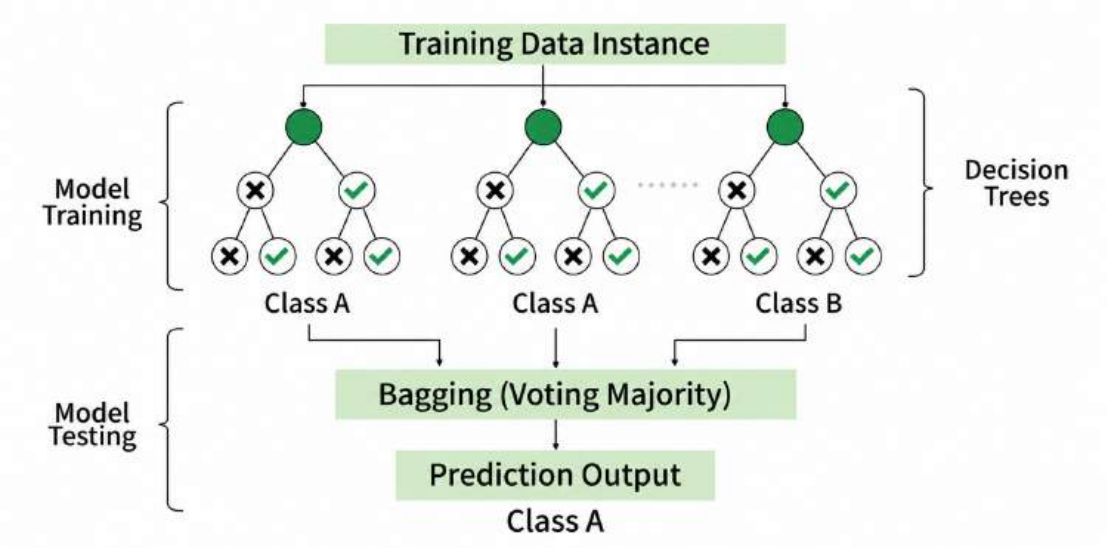


Fig. 1. "Random Forest Classifier", Random forest classification algorithm, 2026.

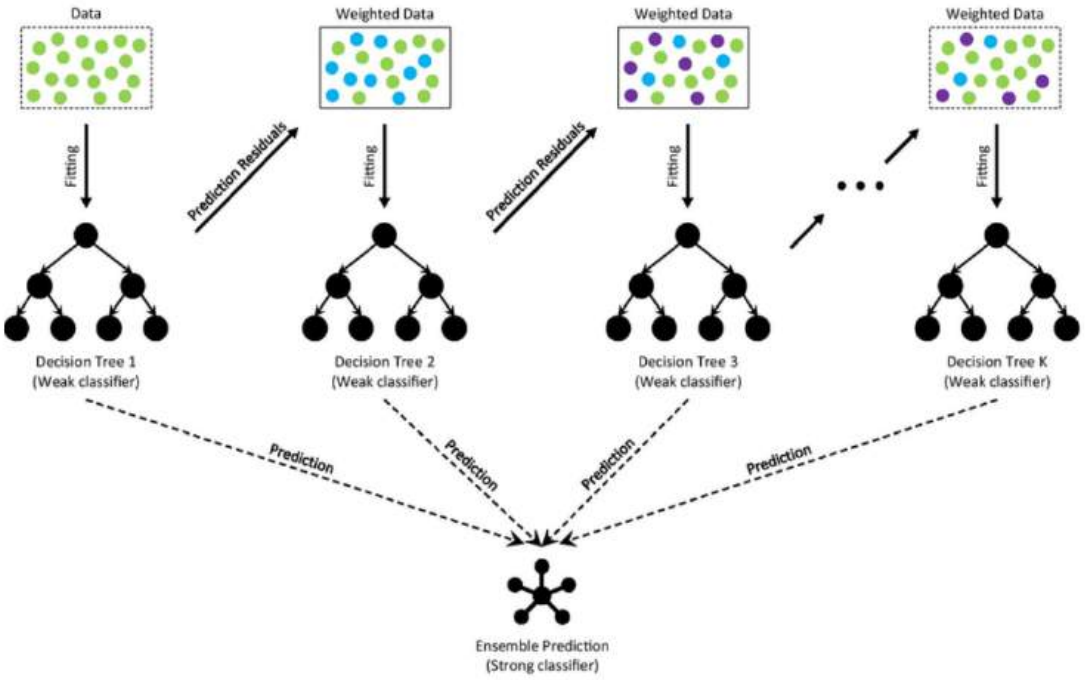


Fig. 2. Haowen Deng, et al., Gradient boosting tree classification algorithm, 2021.

Moreover, the capabilities of AI extend into high-dimensional forecasting, meaning it uses a large amount of past data and influencing factors to forecast an asset's profitability. One particular deep learning model known as LSTM (Long Short-Term Memory) is used to detect patterns over long data sequences. This model is superior to previous methods due to its proficiency in anticipating complex financial trends (Bartram et al.).

Aside from its predictive capabilities, AI can enhance one's market understanding through a process called correlation, which involves analyzing how two financial assets change in relation to each other (See Figure 3). It also uses other methods, such as clustering, which involves grouping similar assets (See Figure 4), and network analysis, which, unlike correlation, focuses on a much broader aspect of connections instead of pairwise relationships. AI's ability to process large datasets at speeds previously regarded as unfathomable to humans, combined with its ability to discern complex, non-linear patterns, gives it a distinct advantage in performing these methods of analysis. Consequently, the algorithmic models can uncover critical market patterns that human analysts frequently overlook. In essence, these techniques give AI an edge in revealing underlying market structures and identifying hidden relationships among assets (Bahoo et al.).

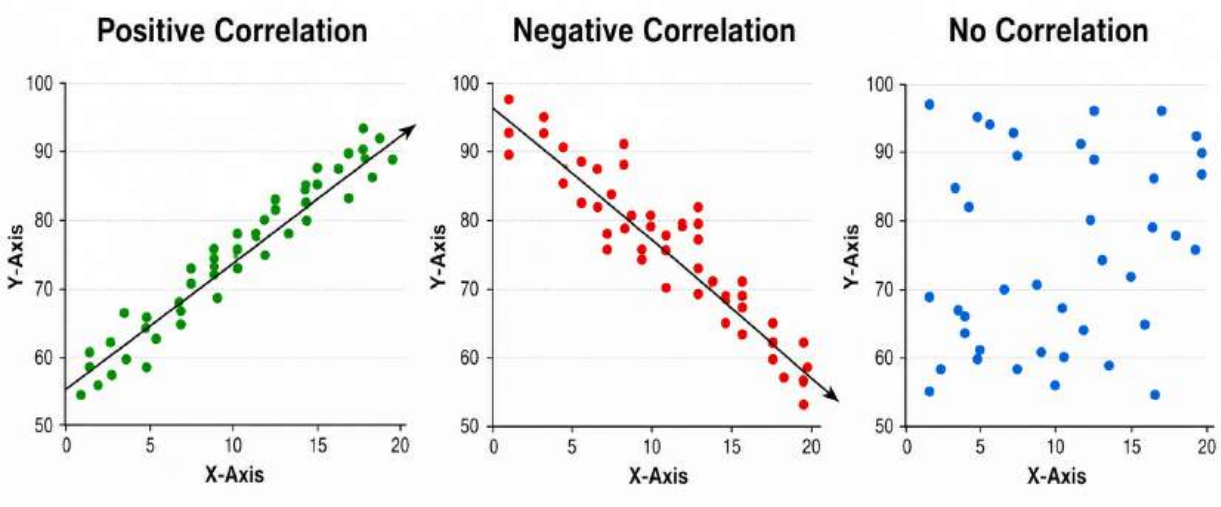


Fig. 3. Comparison of trends through correlation

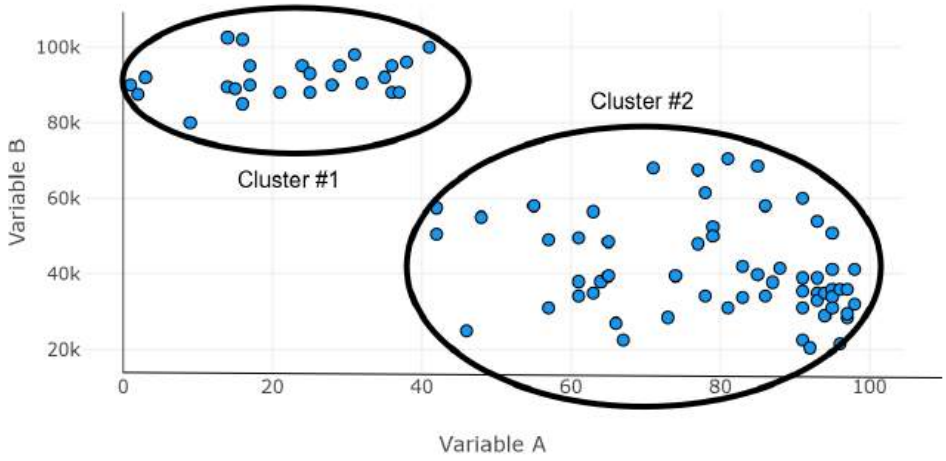


Fig. 4. Illustration of clustering method

Additionally, AI will continue to enhance traditional datasets by using Natural Language Processing (NLP), a computer's ability to understand, interpret, and generate human language, and Sentiment Analysis, which identifies any emotional tones (positive, negative, neutral) present in texts (Darwish et al.). With the integration of these modernized methods, AI will be able to extract crucial market sentiment using platforms such as social media, significantly improving its predictive abilities through quality, real-time insights, potentially leading to more adaptive and profitable portfolio adjustments based on shifts in public perception (Darwish et al.). AI will also assist in the selection of assets by incorporating approaches categorized as Multi-Criteria Decision Making (MCDM), essentially utilizing multiple factors or goals rather than focusing on a single piece of information. These advancements will lead to portfolio choices based on a wide range of technical and fundamental indicators (Bahoo et al.).

Portfolio Optimization Through AI

Lastly, in the feedback stage, AI will greatly improve portfolio evaluation through advanced appraisal techniques such as Equal Weight Portfolios (EWP), where each asset will be given the same percentage of the investor's capital, and Inverse Volatility Portfolios (IVP), which assign less of the original capital to volatile assets and more to the more stable ones (Sutiene et al.). By leveraging its unparalleled processing speed for large quantities of data, AI can continuously adjust capital distribution, according to both IVP and EWP, in real time. This efficiency allows the AI models to notably improve their portfolio management abilities, relative to outdated, manual allocation methods. By optimizing trade timing, evaluating performance, and reducing evident biases in decision-making, they achieve distinct superiority in this particular financial sector (Bahoo et al.).

Prospectively, the integration of AI into portfolio management is projected to increase significantly. Specifically, AI is expected to refine its predictive capabilities, resulting in more accurate forecasts of asset returns and risks, ultimately leading to superior portfolio performance compared to conventional approaches (Bartram et al.). This trajectory is already evident in prominent institutional firms, including JPMorgan, where AI-driven predictive analytics have enhanced risk modeling and forecasting accuracy, in turn strengthening the portfolio decision-making process across various asset classes (Sparkco AI). AI's improvement in the financial sector will also result in the automation of simple asset management and greater operational efficiency, thereby liberating human capital for more strategic, high-level roles. For instance, Goldman Sachs' firm-wide use of its GS AI Assistant enabled thousands of employees to automate repetitive tasks, such as portfolio analysis, document summarization, and data evaluation (Yahoo Finance). This increased efficiency also contributes to reduced operational costs (Google Cloud).

In addition, AI's superior computational velocity enables its risk management to be based on real-time information, including the detection of emerging market anomalies, and for continuous market monitoring (IBM). One example of this is JPMorgan's AI systems, which are already integrated into its risk management infrastructure and monitor markets in real time to identify potential anomalies before they escalate (Sparkco AI). A subsequent iteration in market development is the ability for AI to create highly personalized portfolios, tailoring the assets to granular data on individual investors' risk tolerance and preferences (Google Cloud). Crucially, the application with the most transformative value is dynamic rebalancing, where portfolios are swiftly adapted to any market fluctuations, rather than adhering to rigid, predetermined prompts and schedules. This, in turn, results in more optimized performance while also accounting for the level of risk the user is willing to take (Bahoo et al.).

Emerging Technologies and Human Collaboration

The next level of advancement in AI portfolio management will be propelled by technologies like Deep Learning (DL), Reinforcement Learning (RL), and Deep Reinforcement Learning (DRL). These paradigms will lead to more self-sufficient and adaptive portfolio

systems. DL models, as they consist of multi-layered neural networks, a type of machine learning application that is inspired by how the human brain functions, will continue to excel at mapping out vast amounts of complex financial data and use that information to more accurately predict the return on assets. RL uses simulated trial-and-error scenarios, enabling the AI agents to learn sequential, dynamic, and optimal portfolio decisions. When brought together, a form of technology known as DRL is created, combining the feature extraction of DL and RL's decision-making, allowing it to grasp the subtle effects that various financial factors have. For those reasons, DRL is perfectly suited to continuous adjustments to an investment portfolio (Bahoo et al.).

The emergence of new methodologies and tools is set to transform financial analysis. Graph Neural Networks (GNNs), a new kind of AI, will be able to analyze how different financial elements are connected, how they affect each other, and how those relationships alter over time. At the same time, improvements in Natural Language Processing (NLP) will lead to a better understanding of human language, enabling AI to more quickly and accurately process what investors are saying on the news and social media (Darwish et al.). These changes will help AI improve at filtering out market noise and focusing on the important financial data. Furthermore, new hybrid methods that combine AI and human expertise are being developed, which is already shifting the very definition of a financial occupation. These models will not center on AI replacing people, but will instead create a new division of labor where humans will use their critical judgment to interpret, validate, and oversee the outputs of AI, rather than performing manual data processing and computation (Darwish et al.; West). This new reality rewards professionals who are fluent in both finance and the language of these models, with new roles such as model risk officers and conversational system trainers emerging. Thanks to the widespread availability of programming languages such as Python, individuals from all backgrounds will have access to powerful AI tools, which will lead to efficient portfolio construction and better returns globally (Bahoo et al.).

Transparency to Adoption Challenges

The progression of AI in the financial sector is significantly influenced by Robo-Advisors (RAs), which facilitate automated portfolio management. A recent survey revealed that consumers were mostly open to using RAs, with about 63% of Americans considering them (Finio and Downie). Receptiveness was highest among Millennials and higher-income earners. However, despite so many people being open to them, only around 1% employ robo-advisors (Finio and Downie). This gap exists despite the fact that 80% of those with human advisors would transition to utilizing robo-advisors if they were aware of their cost-effectiveness, as AI-powered automation can lead to reduced operational costs and free human employees for higher-value activities (Finio and Downie). This reluctance is largely due to a lack of understanding and trust, most evidently when consumers exhibit apprehension regarding the "black box" nature of AI. Unlike a human advisor who can thoroughly explain their justification behind a recommendation, these models often provide directives without clarifying their

underlying reasoning, which erodes user confidence and makes it difficult to assess the risk involved. This challenge is being directly addressed by a new type of AI known as XAI (eXplainable AI), which is designed to rebuild trust by showing users each step of the decision-making process.

Transparency Solution: Explainable AI

Explainable AI (XAI) refers to a type of AI model that can generate interpretable outputs, leading to its decisions being more transparent and understandable to humans (Černevičienė and Kabašinskas). This is critical in high-consequence domains such as healthcare, criminal justice, and finance because it is essential for users to verify the underlying algorithmic pathway for AI to reach a conclusion. Many modern AI chatbot models, including ChatGPT, Google Gemini, and Microsoft Copilot, are classified under the umbrella of "black box" AI, meaning their internal decision-making processes are not easily understandable (Černevičienė and Kabašinskas). With the introduction of XAI, researchers and practitioners aim to elucidate the methods of AI models, providing explanations to increase trust, usability, and accountability (Černevičienė and Kabašinskas).

Moreover, XAI functions are classified into two main categories: global and local explanations (Černevičienė and Kabašinskas) (See Figure 5). Global explanations describe the overall behavior of a model using the entire dataset, often through visual aids such as input importance bar plots. Local explanations, on the other hand, are more tailored toward individual predictions, showing how specific imputed values can alter a particular decision.

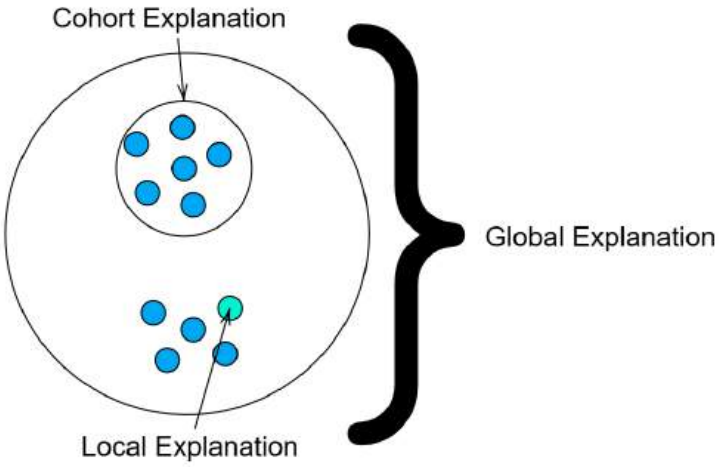


Fig. 5. Comparison of Cohort, Local, and Global Explanations

Two of the most common applications for explaining AI models include LIME and SHAP. LIME functions by building a simple model to explain each prediction individually, assessing how the prediction changes when the input is slightly altered. Similarly, SHAP utilizes ideas from game theory to determine the level of importance each factor had in its ultimate decision (Černevičienė and Kabašinskas; Lundberg).

SHAP's Presence in XAI

SHAP (SHapley Additive explanations) is a popular XAI method for interpreting model predictions by using a concept from cooperative game theory (Lundberg). SHAP treats each input feature as a contributor to the final prediction and assigns each one a specific importance value. This method's reliability is based on three key properties: local accuracy, consistency, and missingness. Local accuracy ensures that the sum of each feature's assigned importance value exactly equals the model's final prediction. Consistency guarantees that if a feature's contribution to a decision increases, its SHAP value will also increase. While it may seem that SHAP is altering the values based on the previous definition, it is only used to explain the model's prediction, not to alter the underlying coefficients or parameters. Lastly, missingness ensures that any feature with no impact on the prediction is assigned a SHAP value of zero. These three properties allow SHAP to serve as a reliable interpretation tool across many different types of machine learning models (Lundberg).

To explain how SHAP works, think of the prediction having a starting value of 0 at a baseline, which is then modified by adding the contribution of each input (Lundberg). SHAP, essentially, evaluates all possible combinations of the inputs and analyzes how each input changes the prediction when modified. For example, if the amount of annual income was an input for an AI portfolio manager, then it would change the value of it to see how much the prediction would differ from the original.

While these calculations are computationally expensive, algorithms designed with better efficiency have already been developed. A few examples include Kernel SHAP, Tree SHAP, and Deep SHAP. Kernel SHAP is very versatile as it is model-agnostic, usable for most types of models, and Tree SHAP is used for making tree models. Lastly, Deep SHAP is used for neural networks. Put differently, SHAP has many ways to visualize the way it arrived at its prediction. For instance, it can create simple graphs that break down a single prediction, such as a waterfall chart that shows the individual contribution that each factor had to the final result. It can also create charts that give a broader view, such as a beeswarm plot, which shows how the impact of a single factor can vary across multiple predictions, much like a common scatter plot. These visuals aid analysts and investors in being easily able to see why the AI made a decision, whether it is for a single asset or the portfolio as a whole (Lundberg).

Visualization of SHAP Usage

A SHAP waterfall plot is one of the mainstream plots used to explain predictions made by a standard AI model (See Figure 6). Regarding portfolio management, this plot would be used to explain the predicted profitability of a single asset, such as a stock. The process begins at the bottom of the graph with the baseline prediction value E[f(x)], which, in terms of portfolio management, would relate to the expected profitability of the stock. From this average, each bar shows how a specific financial factor contributes to the final prediction, either making it appear more or less profitable.

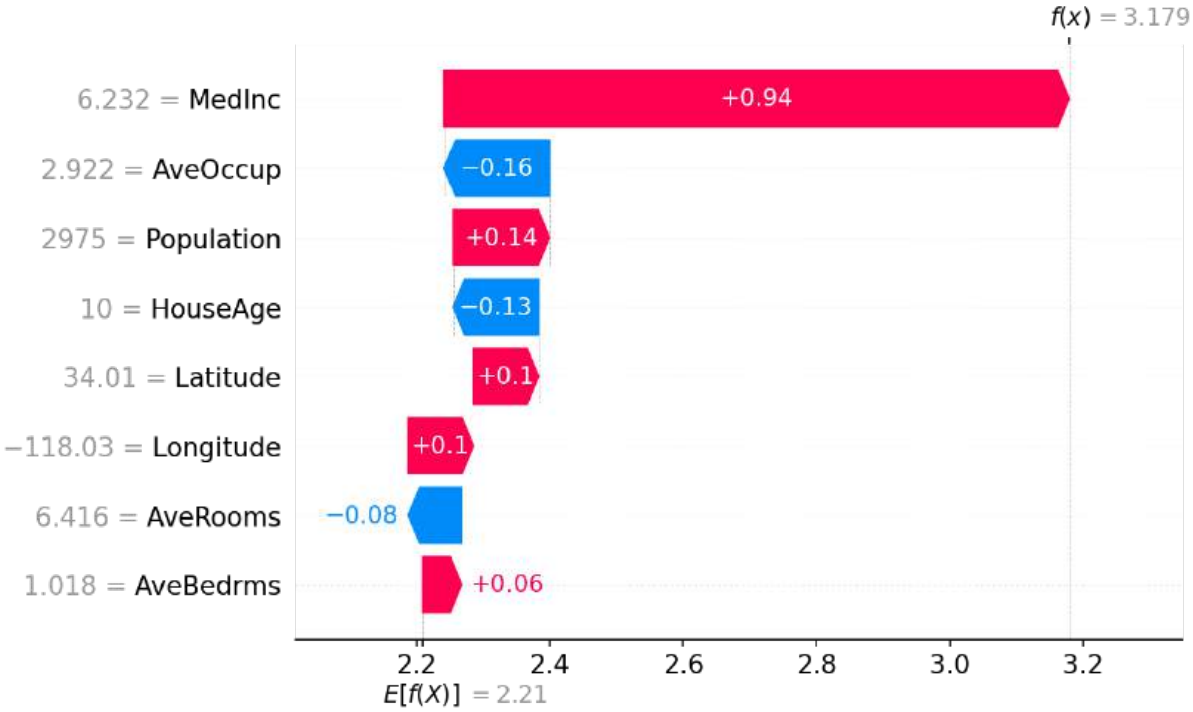


Fig. 6. Scott Lundberg, Example of a SHAP waterfall plot, 2018.

The red bars indicate a positive contribution, meaning that the AI believes that a particular stock would have a promising value in that area, indicating an estimated higher profit margin. On the other hand, the blue bars represent a negative contribution, which implies that the stock would suffer from that particular statistic, such as if it had a high debt-to-equity ratio. By going over the "waterfall" of contributions, all of the positive and negative values add up to the final predicted value: f(x). Essentially, if the final value is positive, then it is likely to be profitable, depending on how high the value is. However, if the value is negative, then it is not likely to be profitable, relative to how large the negative value is. This value provides the portfolio manager with a complete breakdown of the reasoning behind the said prediction, allowing them to easily understand and verify the AI's logic.

This detailed breakdown of a model's reasoning is why the integration of eXplainable AI is a critical step in building a sense of trust between human analysts and their AI counterparts. Without this level of transparency, a sense of skepticism would still linger, regardless of the accuracy of the AI model. This would limit the adoption of AI in modern portfolio management, regulating its role to that of support rather than collaboration. With the introduction of XAI comes the next frontier for portfolio management, where human characteristics, such as judgment, creativity, and ethical oversight, are complemented wth the immense processing power and data-driven insights of AI. In essence, the successful integration of XAI is not just about providing a method of understanding a model's logic, but rather enabling a seamless partnership that harnesses the strengths of both humans and artificial intelligence.

The Path Forward

Ultimately, the evolution of AI in portfolio management represents a fundamental shift from traditional, inefficient methods to a more adaptive and systematic approach. As shown through this paper, the future of portfolio management will not only be determined by one technological innovation but by a fusion of several, all working coherently with one another. The continued advancement of predictive models like DRL and GNNs will provide superior forecasting and market understanding, while the parallel development of XAI will address the critical need for trust and transparency in automated decisions. The combination of both predictive power and explainability will be key to maximizing the transformative impact that AI will have on the financial sector. The next stage of portfolio management will be collaborative, where human expertise is supported by AI's unparalleled analytical capabilities. This new allocation of labor will redefine financial roles, leading to a more efficient and resilient financial ecosystem for investors worldwide, as AI adoption in portfolio management continues to expand across financial institutions.

Glossary

Tools and Libraries

SHAP (SHapley Additive exPlanations)	interprets model predictions and visualizes feature contributions
Scikit-learn	for model training and evaluation (linear regression, boosted trees, logistic regression)
Transformers (Hugging Face)	explainability analysis on NLP models
Matplotlib / Seaborn	visualization of SHAP values and model insights
Pandas / NumPy	data manipulation and preprocessing

Models and Techniques

Linear Regression	baseline model for feature importance and SHAP interpretability
Boosted Trees (XGBoost / LightGBM)	for comparing local vs. global feature explanations
Logistic Regression	binary classification explainability comparisons
Transformer-based NLP Model	tests SHAP performance on deep language models

Conceptual Framework

Explainable AI (XAI)	guides interpretability, transparency, and accountability
Shapley Value Theory	mathematical foundation for fair feature attribution in SHAP
Global vs. Local Interpretability	categorizes explanation levels in the study

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Historical and Cultural Factors Influencing Youth Sports Participation and Professional League Development in South Korea By Minjae Choi

Abstract

This paper investigates how historical, social, and cultural factors impact the youth sports participation rates and professional league development in South Korea. The aftermath of the Korean War forced the government to prioritize economic development and rebuilding; thus, national sports development was slow and sporadic. Furthermore, Korea's all-or-nothing approach to education, disappearing physical education classes, and societal pressure continue to prevent young people from pursuing a professional sports career. In searching for a solution to these problems, the final section of the paper analyzes key strategies implemented by Major League Soccer (MLS) to attract and support young talent. These include integrated academic and athletic programs, career development, and post-career support. While the histories and cultures of the United States and Korea are different, many of these strategies can address the Korean issues. Thus, if Korea's national soccer league, K-League, implements safety nets that could balance education and sports for the young people in the way MLS has, it would reduce the perceived risk of professional athletic paths and improve the development of K-League.

Introduction

One prevailing argument in sports development literature is that the growth of professional sports leagues encourage greater participation among young people, creating a positive cycle in which increased interest in sports not only strengthens the league but also creates job opportunities for youth. While there is evidence for this effect, it is perhaps a mistake to think of it as a one-way street, as the reverse is equally important: a steady influx of young athletes is necessary for the long-term success of a professional league. This is particularly relevant for nationally popular leagues whose survival relies heavily on domestic talent development.

However, in South Korea, where the national soccer league (K-League) does depend on domestic talent, historical and cultural factors may discourage young people from pursuing professional athletic careers. Due to the highly competitive education system and a cultural "all-or-nothing" mindset, students feel pressured to make career-defining decisions at an early age. This increases the perceived risks associated with a professional sports career. Consequently, young people may hesitate to take athletic pathways despite the popularity of professional leagues. Therefore, the purpose of this paper is to examine how South Korea's culture and historical background influences youth participation in professional sports. By comparing the South Korean context with Western counterparts such as Major League Soccer (MLS), this study seeks to identify barriers to youth athletic participation and propose recommendations for fostering sustainable domestic sports development in South Korea.

History of Sports Development in Korea

According to Riordan, uncovering patterns in national sports development requires an examination of both social and physical environmental factors including but not limited to culture, geographic and population size, history, economic status, and politics (Riordan). These all influence how the population interacts with sports and physical activity. Scheerder added to this discourse when he argued that sports participation and the popularity of particular sports vary among nations due to differences in sport policy systems, policy-making processes, and historical and social contexts (Scheerder). It is important to note that not all of these factors influence sport participation equally. For South Korea, it can be argued that the history of the nation might be the dominant factor, as South Korea's poor economy after the Korean War led to limited and sporadic government involvement in the development of national sports (Hyung-Joong and Eunah). During this crucial post-war recovery period, the Korean government prioritized economic stabilization, peacebuilding, and reconstruction efforts, leaving no resources for sports development. While this is understandable, as sports are seen as primarily recreational, it nevertheless sets the tone for government involvement in sports.

This can be seen in how slow the development of a comprehensive sport policy system was in South Korea; it took nearly 30 years. Seon-Jong writes that it was not until 1989, notably the year after the 1988 Seoul Olympics, that South Korea recognized the extent of its low sport participation rates. At an international conference, the Sport for All Korean Association (SAKA) reported that only approximately 20% of the Korean population participated in sport and physical activity, a rate significantly lower than those of many other countries (Kim). These findings highlighted the need for greater government attention to sport participation and contributed to the development of policies that would increase public engagement in sport.

While it took several more years for the Korean government to take action, the government did try to increase participation by hosting international sport events such as the Winter Universiade in 1997, the Asian Games in 1998, and the 2002 World Cup (Hyung-Joong and Eunah). Hosting such large-scale sport events can be an effective strategy because elite sports boost international prestige of the nation as well as create a 'feel-good-factor' among the population, possibly motivating the domestic audience to become more active in sports (Grix). Furthermore, large-scale elite sports events also help the national economy because direct economical contributions can be made through sport (Publications Office of the European Union). That is, the increased tourism, the sale of broadcasting rights, merchandise, and other commercial activities associated with major sporting events can all bring financial benefits for the host country.

In theory, this hosting large-scale sports events was a particularly attractive method for Korea, as it could support economic development, which was the government's priority at the time, while simultaneously encouraging greater participation in sport among the population. However, the results were not as impressive as expected because the effectiveness of this strategy depends on the success of the host nation. While the 1997 Winter Universiad and the 1998 Asian Games may have generated economic benefits for the country, South Korea did not achieve particularly notable sporting success in either event. As a result, these competitions did

not inspire substantial increases in Korean youth participation or motivate large numbers of young people to pursue professional sporting careers. Even in subsequent events in which Korea performed well, such as the 2002 World Cup when the Korean team made it to the semi-finals, the success still failed to attract younger people into soccer. Taken together, these occasions suggest that hosting international sporting events may not be sufficient to increase sports participation rates even if accompanied by visible athletic achievements. In Korea, there seem to be other barriers that prevent youth from participating in sports.

Cultural and Social Factors Influencing Sports Participation

As Riordan and Scheerder mentioned, social and cultural factors also play an important part in the participation rate of youth in sports or physical activity. First, because elementary and middle schools are considered compulsory education in Korea, it is worth examining how the education system impacts youth participation in sports. Physical Education (PE) is one of the subjects that must be provided to students throughout elementary, middle, and high school in Korea. Its purpose is to help students develop athletic skills and teamwork as well as teach them about the rules of different sports, which can motivate them to participate more in sport and physical activity even outside of school (Jung and Kim). However, over time, PE sessions became less and less of a priority. Even though the Ministry of Education set the number of required PE sessions per week, many Korean schools still replaced the PE sessions with academic classes or individual preparation time for the other subjects (Seung). This is because of the increasingly competitive school system in Korea; schools are trying to send more students into the top-rated universities because it will bolster the school's reputation and increase their ranking. Because PE is not required for university entrance exams, and will not increase prestige, PE classes are often the first to be cut.

With Korea's lack of natural resources, prioritizing education was seen as a means to rebuild the country as quickly as possible after the Korean War. However, one could argue that this strategy has formed a society in which students are forced to focus on academics to the detriment of other interests. In fact, Sun-Geun Oh explains that there is immense social pressure on teenagers to target top rated universities, leading students to consider sport and physical activity participation as a waste of time (Sun-Geun). In other words, the way Korean society emphasizes top rated universities has created an 'all-or-nothing' approach. Students are forced to invest all their time into education or sports, and sports is almost always on the losing side. To make matters worse, a career in professional sports is seen as higher risk due to the lackluster state of the national leagues. Even after Korea's success in the 2002 World Cup, the K-League failed to increase the popularity of soccer amongst the youth, which means the league has fewer resources to develop domestic talent. Because it seems harder to secure a successful future professional sports career than a traditional one, it is understandable that young Koreans would hesitate to pursue sports.

Lessons from MLS

Thus far, this study has explained how Korea's history, society, and culture have contributed to low sports participation rates. However, this bleak background does not necessarily determine the future trajectory of national sports. By examining successful leagues such as the Major League Soccer (MLS), it is possible to identify strategies that can be adapted to the Korean context in order to encourage greater sports participation among young people.

First, MLS provides a youth development platform where they can balance elite training with rigorous academic standards (Elite). Many MLS academies, such as YSC Academy of Philadelphia Union or Zions Bank Academy, have adapted built in private schools and educational systems for trainees. This allows young players to adjust their academics and training without falling behind, providing alternative pathways just in case professional paths do not work out for them. This is the opposite of Korea's all-or-nothing approach, and would make professional pathways in Korea less risky for students.

Second, MLS capitalizes on the role of college soccer in the U.S. If aspiring young soccer players do not secure a professional contract by the age of 18, they can still apply for college scholarships using their soccer skills, ensuring their training does not go to waste (MLSsoccer.com). Furthermore, there are many pathways to the professional league from university teams. This provides yet another opportunity for youth to pursue their dreams of a professional sports career. If the K-League also partnered with universities to build sports programs, it could create more pathways for students to enter sports at lower risk.

Finally, MLS post-career support is attractive for potential players as well. Whenever the player's career ends, the MLS Player Association (MLSPA) offers an extensive network to provide former players with careers in internships, coaching, and other professional opportunities that would allow them to continue participating in the field they love (MLS). Because the MLS itself is larger than the K-League, more opportunities are available leading to more attraction among young people. As such, it would take a substantial amount of time and investment for the K-League to offer something similar to Korean players, but developing post-career opportunities alongside other aspects of the program mentioned above would mean comprehensive support for potential players.

Conclusion

In conclusion, historical, cultural, and social factors in Korea have played a crucial role in professional sports development in Korea, especially the national soccer league K-League. The uncertainty among the paths and "all-or-nothing" cultural mindset creates a high-risk environment that demotivates young people from pursuing professional sports. In the U.S., MLS has solved related issues by providing more comprehensive player training, support, and post-career opportunities. It is clear that for the K-League to thrive, government efforts need to go beyond hosting elite large-scale sports events. Implementing structural safety nets where young people can easily switch to different career paths would reduce the perceived risk of taking professional paths in sports and lead to success for national sports leagues in the future.

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Code-Switching and Heritage Language Loss Among Second-Generation South Asian Immigrants By Meera Kalluraya

Abstract

This study examines how the frequency of code-switching between home and school environments relates to heritage language loss among second-generation South Asian immigrants in the United States. Using a mixed-methods design, data was collected through a 22-question online survey given to 13 second-generation South Asian immigrants between the ages of 11 and 25, followed by semi-structured interviews with three participants. Quantitative analysis of Likert scale responses revealed consistent patterns of heritage language loss, with the majority of respondents reporting reduced heritage language use, lower confidence in speaking the heritage language, and increased reliance on English over time. Thematic analysis of interview transcripts identified three major themes: code-switching as a symptom of language loss, the perceived influence of English-dominant schooling on language loss, and the retention of receptive ability alongside declining productive fluency. The findings suggest that code-switching frequency and heritage language loss may be part of a self-reinforcing cycle shaped by English-dominant schooling and no formal heritage language education. Given the underrepresentation of this population in existing literature, this study contributes exploratory evidence toward understanding code-switching among second-generation South Asian immigrants.

Introduction

For second-generation South Asian immigrants in the United States, language is the bridge between generations, connecting children to their parents, grandparents, and the cultures they came from. Many children of immigrants grow up navigating two linguistic worlds at the same time as they are born into households where a heritage language is spoken but they are educated in an English-dominant school system. Over time, the balance between those cultures changes as the heritage language begins to fade.

South Asian heritage languages, such as Tamil, Hindi, Marathi, Kannada, and Telugu, are deeply tied to family relationships, cultural traditions, and intergenerational identity. Losing fluency in these languages can mean losing access to conversations with grandparents and cultural practices.

One behavior that is seen in this process is code-switching: the practice of alternating between a heritage language and English depending on the social context. Code-switching is common in bilingual households and has been studied in depth in linguistics. However, less attention has been paid to how the frequency of code-switching specifically relates to heritage language loss in second-generation South Asian immigrant children and whether switching more often is associated with losing the heritage language faster.

This study examines how code-switching frequency across home and school environments relates to heritage language loss among second-generation South Asian immigrants in the United States by using a mixed-methods approach combining a 22-question online survey

and follow-up interviews with three participants. The findings have implications not only for understanding bilingual development in immigrant communities but for how families, schools, and communities think about heritage language preservation.

Literature Review

Defining Code-Switching

Code-switching refers to the practice of alternating between two or more languages within a conversation or across social contexts (Myers-Scotton 47). For the purposes of this study, I examined code switching in terms of language use and home versus school behavioral differences.

Code-Switching in Bilingual Development

Code-switching is prevalent in immigrant households where children navigate between home and school environments. In research on bilingual children, code-switching is a result of language exposure, context, and social expectations. Smolak et al. found that younger bilingual children tend to switch more between utterances than within them, and that as children age, switching patterns shift toward within-utterance switching, suggesting that code-switching behavior evolves alongside language development (502). Schachinger Tenes et al. further found that lower proficiency in one language predicts higher switching into the dominant language, meaning that as children's heritage language weakens, they are likely to switch into English more frequently (945). Research in the context of Pakistani immigrant families shows that this kind of code-switching can help children participate in multiple cultural environments, maintain family connections, and communicate across generations, though Fatima and Nadeem note that these dynamics are shaped by specific cultural and institutional pressures that may differ across South Asian diaspora communities (Fatima and Nadeem 2025). In language-development research, code-switching is generally linked to bilingualism rather than confusion about identity. Kaushanskaya and Crespo, studying Spanish-English bilingual children specifically, found that code-switching exposure was associated with improved language performance among children with stronger verbal working memory, though they caution that this relationship does not hold uniformly across all bilingual populations (708). Williams et al. found that negative emotional arousal triggers spontaneous switching, particularly back toward the heritage language, which speakers describe as feeling more natural and intimate during emotionally charged moments — a finding with particular relevance to immigrant family contexts where the heritage language carries deep emotional weight (833). In school-based contexts, Wu et al. found that English dominance and parental attitudes toward code-switching were among the strongest predictors of how often children switched between languages, suggesting that switching behavior is shaped not just by individual proficiency but by the broader social and family environment (2937).

Code-Switching, Social Pressure, and Identity

At the same time, code-switching can cause pressure as children who change their speech, behavior, or identity based on the setting may experience feelings of not fully belonging in either culture. Studies of immigrant identity find that while code-switching can be a strategy for acceptance, it can also lead to emotional distress if children feel they must suppress parts of their heritage to fit in (Fatima and Nadeem 2025). While Fatima and Nadeem emphasize code-switching as a tool for maintaining cultural connections and navigating multiple social environments, Kapantzoglou et al. suggest that frequent switching among younger children may also lead to declining heritage language proficiency rather than bilingual competence (1607). Sun et al. found that children in heritage language classrooms tend to mirror their teachers' code-switching patterns, suggesting that the instructional environment plays a meaningful role in how children relate to their heritage language — and that the absence of such instruction may accelerate its decline (312).

Code-Switching and Heritage Language Loss in South Asian Contexts

For children of South Asian immigrants specifically, maintaining the heritage language is often tied to family relationships, cultural traditions, and personal identity (Fatima and Nadeem 2025). South Asian immigrant households often carry strong intergenerational expectations around language preservation, where speaking the heritage language is seen as a marker of cultural loyalty and connection to older generations (Fatima and Nadeem 2025). This pressure can be complicated by the linguistic diversity within the South Asian community as families speaking Hindi, Tamil, Kannada, Telugu, Marathi, or other languages navigate different degrees of community support and institutional recognition for their heritage language in the United States. Kapantzoglou et al. found that when younger children code-switch, it may reflect reduced fluency in the heritage language or increasing adjustment to English-dominant settings rather than bilingual competence (1607). Studies also show that switching between English and South Asian languages like Hindi can support both communication and identity, making code-switching a useful lens for understanding bilingual development in immigrant children (Sahni 2025). At the same time, research on Pakistani immigrant families suggests that institutional prioritization of English in schools further weakens heritage language maintenance even in families that actively try to preserve it, though the extent to which this applies to South Asian immigrant communities in the United States remains understudied (Fatima and Nadeem 2025).

Although prior research has examined code-switching among bilingual children broadly, relatively little research has explored how language and behavior-based code-switching relates to heritage language loss among second-generation South Asian immigrants specifically. This study seeks to address that gap by examining how code-switching frequency across home and school environments relates to heritage language loss in this population.

Methodology

Research Design

This study used a mixed-methods design that combined quantitative survey data with qualitative open-ended responses and follow-up interviews to see how code-switching relates to heritage language loss in second-generation South Asian immigrants in the United States. The survey used Likert scale questions and open-ended responses so that the data reflected measurable patterns and personal experiences. Based on the survey responses, a few were selected for follow up interviews to gain a more detailed insight into the trends identified in the survey data.

Participants

The study included 13 survey respondents and 3 follow-up interview participants. All participants were second-generation South Asian immigrants, meaning they were born in the United States with at least one parent who immigrated from South Asia. Participants were recruited through personal networks, social media, and community connections within South Asian immigrant communities. Respondents ranged from age 11 to 25. Although the upper end of this range is older than what is typically considered childhood, older participants were included because heritage language loss is a continuous process that extends into young adulthood, and their accounts of language shift during childhood and adolescence provide valuable insight into the long-term trajectory of code-switching and language loss. One participant was 11 years old; this participant was included because their responses reflected active, ongoing heritage language experiences rather than retrospective accounts, providing a valuable perspective on code-switching and language use at an earlier stage of development. Most participants grew up in California or Illinois. All participants had at least one South Asian heritage language. Very few participants had any formal education in their heritage language. Three participants were selected for follow-up interviews based on the depth of their survey responses. All participation was anonymous. For minor participants, parental consent was obtained prior to participation, and minor participants provided their own assent. Because the study included only 13 survey respondents, findings should be interpreted as exploratory rather than representative of all second-generation South Asian immigrants in the United States.

Data Collection

The data was collected through a 22 question online survey made up of 19 closed-ended questions and 3 open-ended questions. The closed-ended questions used a mix of Likert scales and multiple choice questions, while the open-ended questions allowed participants to describe their experiences in their own words. Follow up interviews were set up based on the depth of the survey responses. The interviews followed a general set of questions but allowed room for conversation. The goal was to expand on the patterns identified in the survey and gather stronger evidence. The survey used three sections to analyze three different aspects:

Section 1: Demographics

Section 2: Language Use, Code-Switching, and Identity
Section 3: Follow-Up Interviews

Three participants were selected for recorded semi-structured interviews based on the depth of their survey responses. The interviews followed a general set of questions centered on how code-switching frequency across home and school settings related to heritage language loss over time, but allowed room for open conversation.

Data Analysis

Survey responses were analyzed using two approaches based on the type of data collected. For the Likert scale questions, general trends were analyzed across participants using descriptive statistics, including frequencies and percentages for each response category, such as how many participants agreed that their heritage language has become harder to speak over time or that they felt more comfortable speaking English instead of their heritage language. For the open-ended survey responses and follow-up interviews, thematic analysis was used. Responses were read through to identify recurring ideas which were grouped into broader themes such as code-switching as a symptom of language loss, English-dominant schooling associated with that loss, and the gap between comprehension and speaking ability. Quotes from both the survey and interviews were selected to illustrate each theme in the findings section.

Results/Findings

The findings are organized into two parts: trends identified based on the 13 survey responses and themes seen in the three follow-up interviews.

Survey Findings

The survey data revealed a pattern of heritage language decline across participants. 9 out of 13 respondents reported speaking their heritage language often or always when they were younger, but 11 out of 13 reported speaking it sometimes, rarely, or never as they have gotten older. 10 out of 13 respondents agreed or strongly agreed that they use their heritage language less now than when they were younger. 10 out of 13 agreed or strongly agreed that their heritage language has become harder to speak over time.

When asked about code-switching behaviors, 10 out of 13 respondents reported often or always mixing English words into their heritage language when speaking it, and 9 out of 13 reported often or always having trouble finding the right word in their heritage language. 11 out of 13 respondents agreed or strongly agreed that they feel less confident speaking their heritage language than English, and 9 out of 13 agreed or strongly agreed that they feel more comfortable speaking English than their heritage language in public. 9 out of 13 agreed or strongly agreed that their parents speak the heritage language to them more than they speak it back, and 7 out of 13 agreed or strongly agreed that they can understand their heritage language but struggle to respond, suggesting that even though participants retained their ability to understand their

heritage language, their speaking ability declined. 7 out of 13 agreed or strongly agreed that they use different words, tone, or behavior at home than at school, reflecting the behavioral dimension of code-switching across environments. Very few participants had formal heritage language education, which could explain why there was a widespread decline in fluency across the respondents.

Finding	Number	Percentage
Use heritage language less now than when younger	10/13	76.9%
Heritage language harder to speak over time	10/13	76.9%
Less confident in heritage language than English	11/13	84.6%
Mix English into heritage language often/always	10/13	76.9%
Trouble finding the right word often/always	9/13	69.2%
More comfortable in English than heritage language in public	9/13	69.2%
Parents speak heritage language more than they speak it back	9/13	69.2%
Understand but struggle to respond	7/13	53.8%
Use different words/tone/behavior at home vs school	7/13	53.8%

Interview Findings

Three major themes came out of the interviews: code-switching as a symptom of language loss, the perceived influence of English-dominant schooling on language loss, and the erosion of active speaking ability while comprehension ability is retained.

Theme 1: Code-switching as a symptom of language loss

All three interview participants described switching to English while speaking their heritage language as not a deliberate choice, but rather, as a result of not knowing or not feeling confident to say their word in their heritage language. One participant explained that she switches to English specifically for non-conversational words because she only knows words in her heritage language she used regularly growing up and never had received formal schooling in her language: "If you asked me to say 'serendipity' in Marathi, I would scratch my head and tell you I don't know." Another participant described how even though she knows a word in Kannada, she defaults to English in fear of saying it wrong: "I might know the word in Kannada, but because I don't feel confident in me speaking it, because I'm so used to speaking English, I'm too scared to say the wrong word, so I just say it in English instead." Another participant described reverting to English because it is what comes naturally and how she knows how to express herself comfortably: "I usually revert back to English because that's what comes naturally to me and what I feel like I can express myself more comfortably in." This reflects what Kaushanskaya and Crespo found in their study of Spanish-English bilingual children: as

one language becomes dominant, it may displace the other, suggesting that as fluency in English increases, heritage language use may decrease (714).

Theme 2: Perceived Influence of English-Dominant Schooling on Language Loss

All three participants directly connected spending full days speaking English at school to the decline of speaking their heritage language. One participant described how learning English vocabulary, especially in advanced classes, pushed her knowledge of Marathi out: "Speaking only English in school and learning more extensive vocab, especially in AP classes, only reinforces the language spot in my brain for English and just further pushes out the less-used Marathi, Hindi, and Kannada." One participant stated that she stopped speaking her heritage language at home because she wanted to speak English the way her peers did at school: "I wanted to speak English, and I knew English as a kid, but I stopped speaking [my heritage language] at home too because I wanted to speak that English instead." This suggests that social pressure in school environments may be associated with higher code-switching frequency and reduced heritage language use, consistent with Fatima and Nadeem's finding in the context of Pakistani immigrant families that institutional prioritization of English weakens heritage language maintenance even in families that actively try to preserve it. Another participant described how first to second grade was a turning point when English became dominant at school and at home: "Everybody in my house was just speaking English because it was most convenient, so we kind of just forgot it because English was everywhere." She also added that reading in English throughout her childhood deepened her fluency in English and decreased her fluency in Telugu.

Theme 3: Comprehension retained, speaking ability lost

Across all three interviews, participants explained that they were able to understand their heritage language when spoken to them but struggled to respond in it. One participant described a conversation with her grandparents where they speak to her in Marathi and she responds in English: "They always speak to me in that language, but I no longer can respond properly in Marathi. So now it's typically just them speaking in Marathi and me responding in English." One participant described how her conversations with her grandparents in her native language have become limited to short phrases just to get the point across rather than full conversations: "I don't really have conversations with my grandparents. It's only when necessary — little words, little phrases just to get my point across." This pattern was also seen in the survey data where 7 out of 13 respondents agreed or strongly agreed that they understand their heritage language but struggle to respond, suggesting this is a widespread experience and aligning with what Kapantzoglou et al. identify as the divergence between receptive and productive language ability in heritage language contexts (1612).

Discussion

This study examined how the frequency of code-switching between home and school environments relates to heritage language loss among second-generation South Asian immigrants in the United States. The findings from both the survey and the follow-up interviews suggest a relationship between increased code-switching and decline in heritage language ability.

The most consistent pattern across the data was that as the participants spent more time in English dominated school environments, their use and confidence in speaking their heritage language declined. This aligns with existing research in the literature suggesting that code-switching may signal language imbalance when younger children do it (Kapantzoglou et al. 1607). This means that immersion in the English dominant school setting does not just reduce heritage language use in school, it may also be associated with reduced use at home, eventually suggesting a replacement of the heritage language even in spaces where it was once default. One interview participant described how she actively chose to stop speaking her heritage language because she wanted to speak English the way her peers did at school.

The interview data also complicated the direction of the relationship between code-switching and language loss. Rather than code-switching simply causing language loss, the findings suggest that as participants lost vocabulary and confidence in their heritage language they code-switched more frequently out of necessity. As they code-switched more, they had fewer opportunities to practice the heritage language, which was associated with further language loss. This is a pattern consistent with what Kapantzoglou et al. describe as the relationship between reduced proficiency and increased switching frequency in bilingual children (1608). This cycle is captured by one of the interview participants' description of knowing a word in Kannada but defaulting to English anyway out of fear of saying it wrong.

The finding that comprehension is retained while speaking ability declines is also important. Across both the survey and the interviews, participants consistently described being able to understand their heritage language when spoken to them but struggled to respond in it. This suggests that passive exposure to heritage language at home, through parents speaking it, may not be sufficient to maintain fluency when the dominant language outside the home is English. This has implications for how heritage language maintenance is understood in immigrant households, suggesting that hearing the language is not the same as using it.

Finally, the almost complete absence of formal heritage language education across participants plays a key role in the results of the survey and interview. Research suggests that formal instruction supports vocabulary, literacy, and grammatical confidence in a language (Fatima and Nadeem 2025). The data suggests that without that foundation, participants may have been limited to conversational vocabulary learned at home, which became insufficient as English expanded into more areas of their lives. These findings suggest that families and community organizations seeking to maintain heritage languages may benefit from providing structured opportunities for literacy and formal language learning in addition to everyday conversation at home. Such opportunities could include heritage language schools, community classes offered through cultural or religious organizations, tutoring programs, and deliberate family language policies that set aside consistent time for heritage language use at home.

These findings should be interpreted with caution given several limitations. The sample size of 13 survey respondents and 3 interview participants is small, meaning the patterns identified here may not reflect the experiences of all second-generation South Asian immigrants in the United States. The sample was also concentrated in California and Illinois, which may not capture the range of experiences across other regions. Additionally, all language ability data was self-reported, meaning findings reflect participants' perceptions of their fluency rather than objectively measured language ability. Finally, with only 3 interview participants, the qualitative themes identified here are suggestive rather than conclusive.

This study's methods are also limited by the wide developmental age gap among participants, who ranged from 11 to 25 years old. This age range introduces potential confounding variables related to life stage and cognitive language environment. The linguistic pressures faced by a university student differ vastly from the school-based peer pressures experienced by an 11-year-old. Future iterations of this research would benefit from grouping data into distinct cohorts — such as adolescents (11 to 17) and young adults (18 to 25) — to isolate how shifting social environments affect the trajectory of heritage language maintenance over time.

Conclusion

This study suggests that code-switching frequency and heritage language loss among second-generation South Asian immigrants may be part of the same self-reinforcing cycle shaped by English-dominant schooling. While existing research has portrayed code-switching as a neutral part of life in a bilingual household, the experiences presented in this study suggest that for second-generation immigrants, frequent switching may be associated with deeper language loss.

The primary contribution of this study is the integration of quantitative survey trends with qualitative interview data to gain an understanding of how this cycle may operate for individuals. Participants experienced language loss as shrinking conversations with grandparents, growing discomfort when asked to speak their heritage language, and an incremental inability to speak a language that was once part of their daily life.

This study is limited by its small sample size, small geographic concentration, and reliance on self-reported data which mean findings reflect perception instead of measured fluency. Future research should survey larger and more diverse samples, track language shifts over time, and examine whether interventions such as heritage language schools or deliberate family language policies can slow the cycle identified here.

Given that language loss within immigrant communities carries consequences not just for communication but for intergenerational relationships and cultural loss, understanding this cycle is an important question. For second-generation South Asian immigrants specifically, the loss of a heritage language is rarely just the loss of words; it is the loss of a way of connecting to family, culture, and identity that cannot always be recovered once it is gone.

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Tracing the "New" Groups in U.S. Homelessness History By Eric Wang

Introduction

Mainstream modern homeless research draws a line between what is dubbed the "old" homeless and the "new" homeless, with the "new" homeless having a marked change in demographics. Beginning in the 1980s, scholars such as Peter Rossi defined this "new" homeless group as a more diverse category, expanded to include women and African Americans, a stark contrast to the single, old, white men comprising "old" homelessness (Rossi 34). Public discourse similarly identifies the 1980s as the start of a large spike in homelessness, but it also considers the Great Depression as the watershed moment and root of social problems. In this paper, I will show that these so-called "new" groups of the homeless: women, African Americans, and children, have been a fixture of American homelessness ever since colonial times, as opposed to being modern additions.

Colonial homelessness largely consisted of drifters, individuals who, due to repeated armed conflicts and indentured servitude, roamed from town to town. As social benefits depended on one's standing and communal approval, those who were deemed unworthy would be kicked out of town and denied help. Among those whose lives were particularly precarious were widows and children. Unmarried women without local family ties would have an even harder time obtaining acceptance into a town, being also prohibited from owning property. While African American slaves were, to some extent, considered part of local communities, to become a runaway slave would void that status. The disproportional representation of African Americans among the homeless can also be seen from the start, as shown by almshouse population data from the early 1800s.

Through the Civil War, Reconstruction, and the industrial era, African American homelessness would expand. While the Civil War led to the emancipation of enslaved peoples, it also caused widespread homelessness too large for the Union army to tackle. Similarly, Reconstruction's failure allowed the entrenchment of racial structural problems and a retention of the old status quo. After its end, African American homelessness expanded into tenant farmers stuck in near-slavery status, migrants still in destitution, cowboys, and tramps.

Simultaneously, the Northern cities of the industrial era were brimming with thousands of street children. While some were orphans, most of these children were the result of a whirlwind of problems: severe economic depressions, an influx of immigrants and resulting lack of housing, and a landscape of changing job opportunities. Due to poverty and/or density, families were forced to push their children out into the streets to make money. These children would be later categorized into deserving and undeserving by charitable groups, with only the deserving ones given help, a practice reminiscent of colonial towns choosing whether to accept someone into their fold.

Throughout this time, women continued to be disadvantaged and overlooked. With no societal safety net to catch them, a family break-up, eviction, or unemployment could send a woman into homelessness. As opposed to men, however, homeless women tended to remain in one city, explaining the apparent lack of women among the tramps of the industrial era. They

would also try to conceal their status, wishing not to be mistaken as prostitutes. Still, to live, they either worked long hours for low wages or resorted to prostitution. While mothers' pension programs were created, they too separated the assumed worthy from the unworthy, and only the worthy women would receive outside relief.

Through a careful look into the history of homelessness, this paper will show that these "new" groups of homelessness in the United States are not so new, with roots reaching back to colonial times and stretching through history.

The Colonial Era and Early Homelessness

The first documented cases of homelessness in the land that would become the United States of America date to the 1640s, when "vagrant persons" were classified as "social outcasts" that Boston peace officers should apprehend (Kusmer 13).

The largest source of homelessness during this period was likely war, as wars between the colonists and Native Americans caused homelessness on both sides. In his book *Down and Out and On the Road*, Kenneth Kusmer states that King Phillip's War in 1675-1676 caused the first upsurge of homelessness in New England by forcing settlers off their farms and property (Kusmer 13). Continued wars between the colonists, the natives, and the French would ravage the frontier, driving many families into homelessness. The French and Indian War (1756-1763) and other American Indian wars had similar effects, causing more homelessness, with Native Americans being driven out of their ancestral lands (Kusmer 13). The 1830 Indian Removal Act would further evict thousands of Native Americans from their homes ("U.S. Statutes at Large 459-460).

In addition to wars, in the seventeenth and eighteenth centuries, scores of people, male and female, seeking a new life in the New World became indentured servants. Although they were offered free passage over the Atlantic Ocean, upon arrival in America, they would have to work for several years without pay to offset the cost of their trips. According to their agreements, once their indentures were up, they would receive a piece of land of their own. However, land was not infinite, and Kusmer states that by the early 18th century, most indentured servants were unable to obtain their own land (Kusmer 15). With no land of their own, these unlucky migrants would often become homeless and drift from town to town.

The situation was exacerbated by the Elizabethan poor laws that were in effect in New England, which decreed that individual towns would be responsible for the care of their own poor populations (Kusmer 20). In handling the matter, towns drew a sharp distinction between what they considered "settled" people and newcomers. Under the poor laws, "settled" individuals were the only ones entitled to help from the rest of the town. According to Leanne Serbulo, local governments would assist residents who sheltered the local homeless or provided them with food in exchange for work (Serbulo 6). As evidence, a November 1753 town meeting for Chelmsford, Massachusetts, includes mention of payment given to Mr. W. Parker for caring for Joanna Cory, an orphaned and homeless girl (Olasky). No such responsibility existed for those who were not considered legitimate members of towns.

Transient homeless people found themselves stuck in limbo. While they could apply to join a town, those the town deemed unworthy, such as paupers, widows, children, the disabled, and the elderly, would often be "warned" out. As noted by Peter Rossi, this resulted in dozens of individuals being constantly shunned from town to town, forced to wander in a homeless daze due to being denied settlement rights (Kusmer 17).

Unmarried women had a particularly difficult time obtaining settlement rights, as being unmarried clashed with the colonial perception of women as wives and mothers. Stephanie Golden says that these women would be seen as undeserving and not "real" women (Golden 114). Their limited ability to earn money and hold property only worsened their chances. The result, according to Golden, was that a third to a half of the paupers in some towns were female (Golden 113). We'll circle back to this gendered phenomenon later in the paper.

Although surviving under the atrocious conditions of enslavement, Africans and African Americans were considered community members regarding their living conditions. The same, however, could not be argued for runaway slaves who were indeed considered homeless (Johnson 584). According to Mary Louise Booth's *History of the City of New York*, poorhouses inside the city, which were mainly maintained by the work of the white homeless, also housed black slaves (Booth 347). But apart from runaway slaves, free blacks also made up a significant portion of the homeless, and according to Kenneth Kusmer, newly freed blacks were disproportionately represented among the homeless in America by the 1820s. Looking at the city of Philadelphia, from 1823 to 1826, though blacks only made up 10% of the city's population, they accounted for 40-50% of the people imprisoned for vagrancy and for 20% of the almshouse population (Kusmer 24). Though it is important to note that vagrancy was often used for racial profiling in the post-Civil War South, the above data describes a city in the pre-Civil War North, and was used by African American intellectual W. E. B. Du Bois. In his social study on African Americans in Philadelphia, W. E. B. Du Bois found that in 1837, Philadelphia's almshouse housed 235 African American paupers, or 14% of the total almshouse population. By comparison, Philadelphia's black population at the time was 7.4%. Of those 235, 129 of them, or 55%, were women. In addition, these women were overall younger than the men. Du Bois further reports that in 1847 there were 196 African American paupers in Philadelphia's almshouse (Du Bois 270).

Colonial homelessness consisted of men, women, families, and the elderly, forced to wander due to their inability to access, either because they lost it or because it was denied to them, settlement rights, alongside runaway slaves, free African Americans, and displaced Native Americans: a demographic that will repeat throughout history.

The Civil War, Reconstruction, and African American Homelessness

The American Civil War, pitting the northern Union against the southern Confederacy and lasting from 1861 to 1865, resulted in the emancipation of millions of enslaved Americans. But it also created structural racial problems that led to much African American homelessness.

During the fighting, which was mostly in the South, it was common for enslaved individuals to rush toward advancing Union troops seeking help. While the Union generals were welcoming, the sheer number of enslaved groups made it impossible for the Union forces to help them all (Johnson 586). Crowding into former army camps and southern cities and villages, these vulnerable populations had no option but to become homeless. Roberta Johnson states that even those who were lucky enough to receive paid work from the Union army most often spent their wages on feeding their families, waiting months for the materials that would allow them to build a shelter (Johnson 586). According to Linda Slaughter, there were 20,000 such formerly enslaved blacks in Washington, DC, 100,000 in Virginia, 50,000 in North Carolina, and thousands more across the South (Slaughter 91). It is estimated that there were at least a million homeless African Americans spread across the South, with some scholars estimating numbers as high as four million (Johnson 587).

The Civil War was followed by a failed Reconstruction, a period that lasted from 1865 to 1877, in which the federal government reintegrated the southern states that had seceded while also trying to address the status and rights of millions of emancipated African Americans. To help the newly freed population, President Lincoln ordered that in the sales of land previously owned by slave owners, parcels of it had to be set aside for African Americans (Johnson 587). But, as argued by Roberta Johnson, a lack of resources kept the policy from being effective. In the March 1863 sales, African Americans only bought 6 out of the 47 available land parcels, a meager 13%, and in another sale in South Carolina in 1864, African Americans were basically unable to conduct business (Johnson 603). Andrew Johnson's efforts against Reconstruction edicts, such as his executive orders helping restore the South's economy to former rebels and undermining the Freedmen's Bureau, which helped restore the status quo and weakened efforts to help African Americans, further contributed to increased African American homelessness (Johnson 587). With nowhere to go, freed populations often had to return to working the land, but were forced to do so under contractual agreements that offered no improvement to their living conditions. With no guarantee of shelter, these new tenant farmers started their free life in a state of homelessness (Johnson 587).

With Reconstruction formally ending with the Compromise of 1877, the scenario got significantly worse for African Americans, who could now be charged with several minor crimes, including vagrancy, and be presented with a choice to either pay off their debt by laboring for a planter or be sent to a chain gang (Cohen 244-245). Kenneth Kusmer provides several examples: in 1882 Louisiana, an African American was convicted of vagrancy and sentenced to be sold off as a laborer for a year, and in 1889 Missouri, four African Americans were similarly convicted of vagrancy and sold off as laborers for six months (Kusmer 68-69). In Alabama, convicted vagrants would often be leased to coal mines (Kusmer 69).

Although the Civil War and Reconstruction periods were central in the fight to emancipate America's enslaved peoples, they ultimately failed to bring about widespread reform and led to most of the newly freed slaves falling back into destitution and/or homelessness, as can be seen throughout the rest of the 19th century.

Urban Street Children

By the late 1800s, with people beginning to pour into cities, it wasn't long before homelessness sharply rose in them. In this urban context, one group stands out in particular: the children.

In the mid to late 19th century, street children were found everywhere in cities, with estimates reaching 5,000 to 30,000 in New York City alone (Gilfoyle 855). According to Timothy Gilfoyle, these children lacked adult supervision and formal education, and usually took jobs like selling newspapers and picking up rags, though that often overlapped with pickpocketing (Gilfoyle 859). They lived, slept, and ate on the streets and alleys, with no formal home of their own.

A variety of reasons led children to the streets. Some were orphans, some ran away or were the children of drunkards, preferring the streets to their troubled homes. Most, however, were driven into this condition by a combination of factors: severe economic depressions, lack of affordable housing due to immigrant influx, and a landscape of changing job opportunities (Rivlin and Manzo 26). Before the massive transatlantic immigration waves, children could often become apprentices or domestic servants when their families needed money; the arrival of cheap new immigrant adult workers, however, made child labor much less desirable (Rivlin and Manzo 27). The Civil War and economic depressions from 1873-1878, 1884-1887, and 1893-1898 also pushed many families into homelessness (Rivlin and Manzo 26). Low wages, high unemployment rates, and rising prices meant that the family's breadwinner getting sick could mean destitution. In a bid for survival, older children would be pushed out of the house due to overall poverty and density, forced to work on the streets to make money for the family (Rivlin and Manzo 26). It was also common for widows and unmarried women to abandon their children if they were unable to or couldn't afford to care for them (Kusmer 25).

To the public gaze, street children were seen with a mixture of sympathy, as being the poor victims of bad parents, and scorn, for being immoral and corrupt (Rivlin and Manzo 27). They were somewhat admired for their entrepreneurism but also feared, believed to pose a threat to public health and domestic family life (Gilfoyle 853-855). While adults would offer them pity and charity to appease their own moral guilt, the overall stance on homeless children was the same as that for homeless adults of the era: that their homelessness was the undeniable result of their own character flaws or lack of morals (Rivlin and Manzo 29). According to a newspaper article published by the New York Times in 1881, local charities divided street children, and in fact, all homeless people, into two groups: one small group being the industrious and improvident who were deserving of help, and the other comprised "criminal poor whose vices made them so" ("The Evils of Pauperism" 3). People were still convinced that a change in character could eliminate poverty and homelessness, and school was seen as a remedy. The Children's Aid Society, founded in 1853, would provide training for "honest work" for the street children (Nelson 62). This partitioning of the deserving and undeserving feels similar to how colonial towns decided whether to accept someone into their town or not.

Eventually, many street children would be sent west, where child labor was still in demand (Nelson 66).

Women During the Industrial Era

Classic research on the tramps of this era focuses on describing them as male, white, mobile, seasonal workers. But against this image, women continue to appear as consistent characters in narratives of homelessness.

Let's rewind to the Civil War, the beginning of the industrial era. According to Kenneth Kusmer, police station lodgers recorded the percentage of homeless women during the Civil War as exceeding 40% (Kusmer 111). Furthermore, immigrants, and especially the Irish, were overrepresented in the nationwide homeless female population, with immigrants accounting for 63% of homeless women and the Irish comprising half of that group (Kusmer 107). Leanna Serbulo states that homeless women who migrated to the cities in search of work would often live in cheap lodging houses or on the streets (Serbulo 8). Women would also tend to remain in one city, instead of tramping across the country like men (Serbulo 8). It is quite likely, however, that these numbers were even higher, as homeless women would go to great lengths to conceal their status (Serbulo 8-9). During this time, a woman being out alone would likely be taken for a prostitute, so maintaining propriety and hiding one's living condition would be important to safeguard reputation (Golden 116). While many homeless women did turn to prostitution, many more did not. The causes of female homelessness at that time included the break-up of families, alcoholism, eviction, poverty, unemployment, and the lack of a societal safety net (Golden 119; Serbulo 4).

Leanna Serbulo divides the homeless women of this time into three groups: the single, adrift, working women; the prostitutes; and the unmarried, widowed, and divorced women (Serbulo 14). For the working women, low wages resulted in widespread poverty. The Consumers' League of Oregon's 1912 survey of working women found that their wages were "miserably inadequate to meet the cost of living" (O'Hara and Consumers' League of Oregon Social Survey Committee 6). Factory workers not only suffered from these low wages but also had to endure long hours and frequent layoffs (Serbulo 35). Fruit canneries were seen as the worst, due to the employment of children and extremely long hours, reaching up to 16 hours at the height of the season (O'Hara and Consumers' League of Oregon Social Survey Committee 33).

The alternative to working long hours for low wages was prostitution. An 1858 study on prostitution in New York, based on 2000 questionnaires, reported that over a quarter of the women who answered had become prostitutes due to destitution (Golden 119). For others, working was too "difficult a life," with few material comforts and bad conditions (Serbulo 64). Around 75% of the women heard in the study had been employed but still chose prostitution, likely since prostitutes could earn much more than regular jobs (Golden 119). Unlike adrift, working women, prostitutes were more visible to the public, resulting in them being seen as the female version of the male tramp, and often prosecuted under the same vagrancy laws (Serbulo

65-66). Anti-vice campaigns did little to help, as the women's reasons and their fate afterward were often overlooked (Serbulo 86).

Between widowed mothers and unmarried mothers, widows were seen as much more deserving of aid (Serbulo 16). Mother's pension programs were created to specifically support widowed mothers. These programs, while an early social welfare program, would separate the widows into two groups, the "worthy" and the "unworthy" (Serbulo 16-17). Widows deemed "worthy" would receive outdoor relief meant to encourage them to stay home with their children, with Oregon's mothers' pension giving $10 a month for mothers of one child and an additional $7.50 a month per additional child (Serbulo 98). On the other hand, women deemed "unworthy" were restricted to only indoor relief from those programs (Serbulo 16). Both groups, however, needed to support their children while working.

Female homelessness during the industrial era consisted of many groups, with single women, widows, and unmarried women with children working for low wages to try to support themselves and their families, while other women resorted to prostitution to escape their own cycles of poverty.

African American Homelessness until the Great Depression

Following Reconstruction's failure, African American homelessness diversified. According to Roberta Johnson, thousands of African Americans left during and after the Civil War to become cowboys in the West (Johnson 587-588). A map made by Philip Durham shows that their drives would start in Texas but reach New Mexico, Oklahoma, Kansas, Colorado, Nebraska, Wyoming, South Dakota, and Montana (Durham 117).

Many African Americans also migrated north. In these northern cities, after legal solutions failed, vagrants would be lodged in almshouses. Arrests made by vagrant detectives in Philadelphia from 1887 to 1896 included an average of 9.44% African Americans, with the highest rate being 12.9% in 1892 (Du Bois 271). Records from the Blockley Almshouse from 1891 to 1896 indicate that an average of 9.14% of paupers admitted to the almshouse were African American during this period (Du Bois 272). Kenneth Kusmer states that most of these African American homeless had been formerly enslaved, choosing to migrate north after emancipation (Kusmer 107). Furthermore, while African American adults sixteen or older accounted for an average of 9% of all adults, African American children under sixteen accounted for an average of 12.3% of all children, over 3% more than that of the adults (Du Bois 272). These statistics, provided by W. E. B. Du Bois, indicates a significant number of African American homeless in Philadelphia.

Yet others would join the tramps. Tramps, most prominent in the period between the Civil War and World War I, would roam the roads searching for work and adventure, largely due to a high demand for mobile labor (Johnson 589). Despite it being harder to find lodging and solicit assistance, there was a sizable number of African American tramps (Johnson 590). Paul T. Ringenbach states that New York City would sometimes be called the "Black Hole of Calcutta" due to the city attracting a large number of African American homeless (Ringenbach 10).

In conclusion, African American homelessness after Reconstruction diversified, with some becoming cowboys, some going north, and others tramping.

Conclusion

In contrast to popular discourse, which often claims that the Great Depression is the root of social problems, and mainstream homelessness research, which claims that the new homeless of the 1980s contained "new" groups of homeless people, historical analysis shows that women, children, and African Americans have been part of the history of homelessness in America since colonial times. Although the circumstances changed, the people affected remained the same.

Colonial towns singled out women and children as unnecessary, refusing them entry into the town's community and support system. They were then subject to a flurry of disadvantages and problems during the industrial era, while being separated into the worthy and unworthy, determining who received aid. African Americans were disproportionately represented among the homeless even in the early 1800s, and though the Civil War emancipated them, Reconstruction failed to establish systematic change, sending many of them back into destitution.

By the time the Great Depression came and caused large increases in homelessness across the board, women, children, and African Americans already had sizeable amounts of homelessness.

Between the Great Depression and the 1980s, several policy changes further exacerbated the issue, contributing to the resurgence of homelessness into public view in the 1980s. One such change was urban renewal. The Housing Act of 1949 authorized several urban renewal programs meant to create "a decent home and a suitable living environment for every American family," but these programs, on average, destroyed more housing than they created, and 90% of the low-income housing units that were destroyed never got replaced (Lipsitz). The creation of a federal mortgage program that financed suburban housing also helped entrench segregation and poverty, as these suburban houses were only available to whites (Sciences et al.). The Housing Act of 1954 would further urban renewal programs, clearing out more low-income housing (Sciences et al.). These programs especially impacted African Americans and other minorities, causing an increase in the amount of homelessness within these groups' recent history.

The 1980s then witnessed many cuts to social programs and welfare under Ronald Reagan, who personally tainted the public's perception of welfare benefits and their recipients. Reagan's 1986 State of the Union speech described welfare as a "spider's web of dependency" (Reagan). Budgets under Reagan saw widespread cuts to welfare programs. For example, in 1982, the income limit for food stamps for families of four was lowered, making one million people lose their benefits (Abramovitz and Hopkins). Furthermore, these cuts disproportionately affected the poor, female, and other minorities. It was projected that two-thirds of the savings in 1983 would be from cuts toward families with incomes under $20,000 a year (Abramovitz and Hopkins 569). Access to day care, abortion, and family planning was also reduced (Abramovitz and Hopkins 572). Programs that were spared from the first round of budget cuts also had mostly white recipients (Abramovitz and Hopkins 572). The cuts under Reaganomics disproportionally

affected women and minorities, leading to an increase in homelessness among those very same groups we have previously discussed.

Throughout the history of the United States, homelessness has been a consistent issue. The “new” groups of homelessness have been present since colonial times; they were only more harshly impacted by recent policies than the “old” groups of homelessness. Though the circumstances, location, and condition of the homeless changed, the people did not.

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The Disconnection Between Historical Awareness and Action in Contemporary China: A Hangzhou Study of the Value-Action Gap and the Need for Experiential History Education

BY Yuanming Song



Abstract

In this paper, I argue that contemporary China has a history problem that is not well described by simple indifference. The paradox is sharper than that. Publicly, history and traditional culture receive strong verbal respect. In practice, however, historical learning is often deferred, instrumentalized, or outsourced to institutions. Drawing on my original Hangzhou survey, I show that people repeatedly affirm the importance of local history and heritage preservation, yet their knowledge is usually shallow and their everyday use of historical thinking is limited. The study therefore frames the issue as a value-action gap: people can sincerely endorse a value while still failing to organize their behavior around it. Research on present bias, social signaling, behavioral barriers, cultural learning, and experiential education helps explain why long-term goods often lose to short-term incentives, even when people know better. In the Chinese case, the problem is intensified by educational sorting, labor-market pressure, and a public culture in which it is respectable to praise history but materially safer to prioritize fields seen as more practical.

This revised version adds one further claim: historical wisdom is not absorbed simply by hearing that history matters. Human beings are cultural learners. We learn through prestige, imitation, reputation, repeated practice, and lived experience, not only through abstract statements. Harvard University's Human Nature course is useful here because it does not treat biological and cultural explanations as enemies; instead, it asks how evolved human psychology makes culture, learning, norms, cooperation, and belief possible. That framework suggests that history education in China should be redesigned so that students do not only memorize dynasties and dates. They should handle local evidence, speak with elders, visit historical places, create cultural products, compare historical cases to present dilemmas, and reflect on how the past changes their own choices. In Hangzhou, this could be piloted through places such as Wahaha High School, the student-run Tomorrowland history shop, West Lake-related museums, the Grand Canal cultural system, the China National Silk Museum, the China Tea Museum, the Zhejiang Intangible Cultural Heritage Museum, community centers, and local culture and tourism organizations. My conclusion is that China does not suffer from a total absence of historical respect. It suffers from a failure to convert respect into durable habits of learning, judgment, and use.

Main Conclusions and What This Research Adds

1. The central finding is a value-action gap, not simple historical ignorance.	Hangzhou respondents strongly praised history and heritage, but their self-reported depth of knowledge and daily use of historical lessons were much weaker.
2. Hangzhou is a strong test case, not a random example.	Because Hangzhou is unusually rich in heritage - West Lake, the Grand Canal, Southern Song history, tea, silk, poetry, legends, and craft traditions - weak practical engagement there suggests a wider national problem.
3. The paper adds a behavioral and human-nature explanation.	History is not failing only because students lack information. It is failing because abstract respect does not automatically overcome present bias, exam pressure, social signaling, and the evolved human tendency to learn through practice, prestige, imitation, and group norms.
4. The paper proposes a practical reform direction.	History education should move from ceremonial reverence and exam memorization toward experiential historical wisdom: place-based learning, oral history, role-play, community projects, cultural-product design, and structured reflection on present-day choices.
5. Biology matters, but it cannot replace history.	An understanding of human nature can help teachers design better history lessons because memory, emotion, imitation, status, cooperation, and belonging shape learning. But this is complex: biology explains learning tendencies, while history supplies moral, cultural, and contextual judgment.

Introduction

China is one of the world's oldest continuous civilizations, and modern Chinese public culture invokes that fact constantly. School slogans, museums, national media, tourism campaigns, local festivals, and everyday patriotic language all stress civilizational depth. On paper, then, China should be a society with an unusually strong historical consciousness. Yet the practical picture looks much less secure. People often speak as if history matters, but far fewer build their studies, decisions, conversations, or community lives around real historical engagement. This is the contradiction that pushed me to write this paper.

The contradiction appears clearly in both public polling and my own fieldwork. A Phoenix survey on traditional culture found overwhelming stated support for cultural learning and preservation, but it also suggested that many respondents felt the current excitement around tradition was more superficial than fully lived (PhoenixNet). My Hangzhou survey showed something similar on a local scale. Most respondents said learning local history mattered. Most said preserving heritage mattered. But when questions shifted from principle to knowledge, behavior, and daily use, the pattern weakened fast. Historical awareness was present, but often in a light and noncommittal form.

I do not think the best explanation is simply that people are hypocritical, shallow, or lazy. That answer is too easy, and also too moralizing. The problem, I think, is better understood through the idea of a value-action gap. In environmental studies, researchers have long noticed that people can affirm environmental values while still failing to conserve energy, reduce waste,

or change consumption patterns (Kollmuss and Agyeman 240; Bamberg and Moser 15). The same logic can apply to history. The short-term costs of engaging history can feel immediate and concrete: less exam utility, weaker labor-market signaling, more time, more effort, and less obvious reward. The benefits of history, by contrast, are usually slower, more collective, and harder to quantify.

This matters especially in China. Harvard Extension School's course Power and Civilization: China emphasizes that modern China still bears the imprint of historical experience, philosophy, religion, and political thought (Harvard Extension School). If that is true, then historical disengagement is not a minor educational problem. It means people are living inside historical structures that they are becoming less able to read. A society can celebrate its civilization while growing less fluent in the actual uses of history.

This paper therefore argues three things. First, the history problem in China is best understood as a value-action gap rather than as simple ignorance. Second, that gap is produced by identifiable mechanisms: present bias, social signaling, educational sorting, and the outsourcing of historical responsibility to museums, schools, and the state. Third, the consequences are real. They include weaker public judgment, thinner cultural continuity, and reduced capacity to recognize analogies between present crises and past ones. I use Hangzhou as my main case because it is historically rich enough that, if the gap is visible there, it is difficult to dismiss it as a local anomaly.

The paper also asks a forward-looking question: what would it mean to teach history not merely as information, but as lived wisdom? That question requires a more interdisciplinary answer than history classes usually give. Historical wisdom is about comparison, moral judgment, social memory, and human behavior. To teach it well, teachers need some understanding of how human beings actually learn. That is why the later sections bring in Harvard University's Human Nature course. The course's core value for this paper is not that it gives a simple biological formula for culture. It is almost the opposite. It shows that biology and culture interact: human beings are shaped by evolved capacities for learning, but what they learn depends on institutions, prestige, imitation, norms, rituals, and social experience. That makes history education both more difficult and more promising. It is difficult because merely telling students a lesson may not change how they act. It is promising because schools can design experiences that make historical wisdom socially visible, emotionally memorable, and practically useful.

A Framework for the Gap: Why Values Do Not Automatically Become Behavior

The idea of a value-action gap comes from a very basic observation: people often do not do what they say they care about. Environmental researchers have documented this problem for years. Individuals report concern about sustainability, but the concern does not consistently translate into lower consumption, greener purchases, or conservation behavior (Kollmuss and Agyeman 240-41). A newer experimental literature shows that behavioral barriers remain strong

even when people know the 'right' answer and express pro-environmental intentions (Hoffmann, Kanitsar, and Seifert). In other words, stated values are real, but they are not self-executing.

I find this literature useful for history because it moves the discussion away from accusation and toward mechanism. Once I started thinking in these terms, the Chinese case looked much clearer. History in China is not broadly hated. It is broadly displaced. A value can be honored rhetorically and still lose every practical competition that matters.

One reason is present bias. Human beings systematically discount long-term benefits when they compete with short-term incentives or short-term friction. In the environmental literature, this helps explain why people who care about climate issues still do not always take costly action now for a future collective good (Gifford 291-92). In the history case, the structure is similar. The benefits of historical learning are long-range: deeper judgment, stronger identity, better policy imagination, richer cultural continuity. The costs are immediate: more reading, less exam efficiency, less obvious job payoff, and sometimes the feeling that one is spending effort on something noble but nonurgent. That sounds like a small distinction, but it really is not. Societies are built out of repeated choices of this kind.

A second mechanism is social signaling. Values are rarely just private beliefs. They are also social performances. People often echo what their community says is good, respectable, or civilized. But they also watch what their community actually rewards. Harvard's Human Nature syllabus treats reputation, social norms, prestige, and conformism as central problems in human behavior and cultural learning (Harvard University, Human Nature Syllabus). That matters here because contemporary Chinese history education exists in a mixed signaling environment. It is polite and cultured to say that history matters. Yet the strongest educational and economic rewards often flow toward STEM fields, credential competition, and visibly marketable skills. Under those conditions, public praise of history can coexist very comfortably with private avoidance of it.

A third mechanism is mismatch. Human cognition did not evolve for the abstract scale, long time horizon, and institutional complexity of modern life. Even if one handles that idea cautiously, it helps explain why indirect or delayed goods are often underweighted. Historical learning usually does not solve a same-day crisis. It builds context slowly. It changes interpretation before it changes outcome. That kind of benefit is easy to neglect in a high-pressure social environment. China's urban educational culture intensifies this effect. When students and families face sharp sorting pressures, subjects with diffuse long-term benefits get pushed aside by subjects that seem to produce immediate admissions or employment returns.

This is why I do not find 'people are just lazy' to be an adequate answer. The literature on inaction and behavior repeatedly shows that behavior is shaped by habit, cost, feedback, and environmental design, not simply by moral seriousness or willpower (Griskevicius, Cantu, and Van Vugt 115; Schultz 1080). If history in China is repeatedly deferred, I should ask not only what people believe, but also what the institutional environment rewards, how quickly benefits are visible, and what kinds of historical actions are made easy or difficult.

Why Historical Awareness Matters in China

Once the value-action framework is in place, the next question is simple: why should weak historical action matter so much? My answer is that in China history is not only heritage. It is the infrastructure for judgment. When historical learning becomes shallow, people do not just lose facts. They lose comparison, proportion, and a sense of how present dilemmas sit inside longer trajectories.

One way to see this is through economic analogy. Commentators have repeatedly drawn comparisons between China's real-estate crisis and Japan's post-bubble stagnation, warning that the resemblance is serious enough to deserve public attention (Yi). I do not claim that the two cases are identical. They are not. But historical comparison does not require perfect sameness. It requires the ability to see structure, warning signs, and repeated psychological patterns. If housing appreciation comes to feel natural, if debt-fueled optimism becomes culturally normal, and if few people treat foreign historical cases as usable lessons rather than distant trivia, then the public becomes easier to surprise by outcomes that were not really unprecedented at all.

A second reason historical awareness matters is cultural continuity. UNESCO's materials on intangible cultural heritage make an important point: heritage survives not because it is stored somewhere, but because it remains relevant enough to be transmitted, recreated, and lived by communities across generations (UNESCO, 'Convention'; UNESCO, 'Safeguarding without Freezing'; UNESCO, 'Transmission'). That distinction is crucial for China. A tradition can be symbolically celebrated and still become practically fragile. It can exist in museums, videos, and official discourse while losing everyday bearers. If young people admire heritage mostly as aesthetic content but not as practice, then continuity becomes thinner than it looks.

A third reason is political and civilizational. The China-centered historical materials I studied kept returning to a recurring tension: how can power be made effective without becoming blind, and how can moral legitimacy be preserved without collapsing into administrative weakness? Chinese history is full of arguments about governance, order, credibility, statecraft, and moral restraint. That is one reason the neglect of history is such a serious irony. The historical archive is not just decorative. It is one of the places where Chinese civilization repeatedly thought through the problem of power itself.

This is where the paper becomes less conventional. I am not arguing only that history is nice, enriching, or identity-affirming. I am arguing that history is practical in a deeper sense. When I worked through cases from Chinese statecraft, I kept coming back to the same realization: historical study is one of the only ways to hold together questions that modern life keeps splitting apart. Strength and goodness. Efficiency and legitimacy. Preservation and change. Cultural pride and critical judgment. If public engagement with history becomes mostly ceremonial, those questions become easier to flatten.

One example is the Qin reforms associated with Shang Yang. Those reforms helped turn Qin into a far more powerful and centralized state, but they also exposed the costs of reducing politics to administrative force, discipline, and narrow utility (Major; Harvard Extension School). Later Chinese statecraft repeatedly wrestled with that same problem in different forms: how can

a state be strong without becoming morally coarse, and how can order remain effective without treating people as instruments? This kind of history is not decorative knowledge. It gives language for recurrent problems that are still with us.

Methodology

To study this issue empirically, I conducted an original survey in Hangzhou in late 2024. I chose Hangzhou because it is one of the most historically saturated cities in China: a former Southern Song capital, home to West Lake, tied to major literary traditions, and strongly identified with silk, tea, canals, and urban heritage. West Lake has inspired poets, scholars, and artists since the ninth century, and the Grand Canal connects Beijing to Zhejiang through a waterway system that UNESCO describes as a major communication route for imperial China (UNESCO, 'West Lake'; UNESCO, 'Grand Canal'). If historical engagement appears weak even in Hangzhou, that tells me something important about the larger national pattern.

The survey collected 305 responses from current residents, former residents, and tourists, though the sample was primarily local. It was administered through SoJump and asked respondents about four broad areas: knowledge of Hangzhou history and cultural heritage, perceptions of other people's knowledge, attitudes toward the value of history and preservation, and the role history plays in daily life and practical decisions. I also included questions about role models, consumer choices, and possible interventions that might increase historical interest. The sample included a wide age range, with about one third under eighteen and the rest spread across adult age groups.

This method has clear limits. The survey was online, self-reported, and not nationally representative. It cannot tell me everything about China as a whole. But that is not what I need it to do. What I need is a well-defined local case through which I can observe how historical respect and historical action come apart. For that purpose, Hangzhou is not a weak site. It is a strong one.

The study is also exploratory. It should not be read as a final national diagnosis or as proof that Hangzhou residents are unusually uninterested in history. In fact, the opposite may be true: Hangzhou's visible heritage may make its residents more historically aware than residents of many other cities. That is precisely why the gap matters. If the gap appears even where history is visible, beautiful, and marketable, then the issue is unlikely to be solved by simply saying that China needs more museums or more heritage slogans. The harder problem is how to turn visibility into use.

Findings: Respect Is High, Action Is Weak

My strongest finding is not that people disregard history. It is that they affirm it very strongly while engaging it only lightly. This pattern repeats across categories.

On attitudes, the numbers were overwhelmingly positive. About 89.5% of respondents said it is important to learn and master Hangzhou's history, and 85.3% said protecting Hangzhou's cultural heritage is 'very important.' When asked whether heritage protection matters,

virtually no one said it was unimportant. At the level of declared values, then, the picture looks excellent.

But knowledge questions immediately complicated that picture. In most categories, respondents described themselves as having only 'some' knowledge rather than deep familiarity. Only 14.4% said they were very familiar with the history of Hangzhou's landmarks. Only 15.4% said the same about traditional cultural practices such as tea culture or silk weaving. Poetry and cuisine scored somewhat higher, but still not at a level suggesting broad expertise. The only area with a large 'very familiar' group was folklore and legend, especially stories like the Legend of the White Snake. That tells me something important. What travels best is not always what is most historically deep; often it is what is already narratively vivid in popular culture.

This depth problem appeared again when respondents evaluated other people. Most felt that the average Hangzhou resident had some knowledge, but not much more than that. Detailed literacy was not imagined as socially widespread. In other words, respondents not only possessed middling knowledge themselves; they also sensed that middling knowledge was normal.

The behavioral questions made the gap even clearer. Only 24% said they often refer to historical examples or lessons when making decisions. Almost half said they do so only sometimes, and 28.5% said they rarely or never use history in that way. I find this one of the most important results in the whole survey. It moves the issue from admiration to use. History is respected, but not regularly consulted.

The role-model question showed the same pattern. Only 31.8% said their main idols tended to be historical figures. About half selected the softer answer of 'sometimes,' which suggests mixed attention, and 18% said historical figures were not their main models at all. This result does not mean that contemporary idols are wrong. It means that history is no longer the default archive of aspiration for many people, especially younger ones. Historical figures remain available, but not central.

Language use pointed in a similar direction. About a third of respondents said they often use historical idioms or allusions in daily speech, while nearly half said they do so only occasionally. That still suggests some continuity, but it is a thin continuity. The old habit of carrying history into ordinary expression appears weaker than the civilizational rhetoric around history would lead one to expect.

The consumer questions were interesting because they pointed toward an opportunity. More than a third said they were very inclined to choose products with historical or cultural significance, and more than half said they were somewhat inclined to do so. In other words, historical consumption looks stronger than historical study. People are willing to engage history aesthetically, commercially, and symbolically, even when they do not engage it analytically. This is not enough by itself, but it is not trivial. It suggests that entry points exist.

The open-ended responses reinforced that view. Many respondents proposed interactive exhibitions, school visits, history-themed media, games, creative products, and community events. They wanted history to be made engaging, visible, and social. This matters because it

shows that the problem is not simple hostility. Many people do want more contact with history. They just do not want that contact to arrive in the old rote, exam-heavy, one-way form.

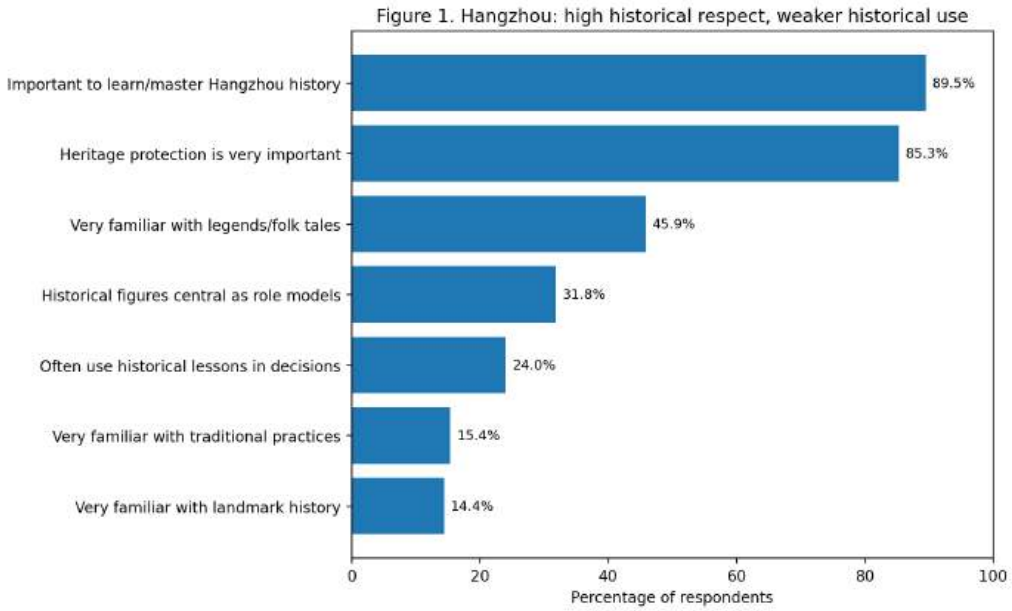


Figure 1. The survey shows strong stated respect for history but weaker depth and daily use. Percentages are from the author's Hangzhou survey (N = 305).

Discussion: China's History Problem as a Value-Action Gap

Taken together, these findings suggest that China's issue is not a collapse of declared respect. It is a failure of translation. Historical value is present, but it does not consistently become historical behavior. That is why the value-action framework fits so well.

Present bias helps explain why history is repeatedly deferred. The benefits of historical study are long-run, cumulative, and often indirect. The costs are immediate. In a system where students and families are already under pressure, it is rational in a narrow sense to protect the subjects and activities that offer faster and clearer returns. History loses not because it has no value, but because its value is temporally structured in a weaker way.

Social signaling also matters. In China, it is socially safe, and often expected, to praise tradition and civilization. But the same society sends very different signals through educational prestige, parental anxiety, and labor-market rankings. A widely circulated report on graduate outcomes, for example, noted that among 2015 bachelor's degree disciplines, history had the lowest six-month employment rate at 86.4%, compared with stronger outcomes in fields such as management ('大学生就业基本稳定'). I do not treat that number as destiny. Still, numbers like that shape parental reasoning, school culture, and student self-protection. When public respect and material reward point in different directions, behavior tends to follow reward.

That is why I think it is misleading to interpret the gap morally. People are not simply betraying their values. They are navigating a system that makes historical action comparatively expensive. The same logic appears in the literature on environmental behavior. Huge collective

goods often fail to generate enough action unless institutions lower the cost of participation, make feedback visible, and reshape norms. History works similarly. If the only form of serious historical engagement is dense textbook learning with uncertain practical reward, then most people will drift toward lighter and more immediately gratifying forms of contact.

There is another issue too: institutional outsourcing. My survey found that respondents strongly supported heritage protection and overwhelmingly believed Hangzhou's cultural heritage was already being adequately protected. That sounds positive, but it also reveals a subtle problem. When people believe the government, museums, schools, and formal heritage systems are already handling the work of preservation, they may feel less personal obligation to build historical habits themselves. The burden shifts upward. Heritage becomes something managed for the public rather than something actively practiced by it.

This is exactly where the China-centered historical material deepens the analysis. In the political traditions I studied, history is not passive memory. It is a working archive of statecraft, ethics, and comparison. Chinese political actors repeatedly read earlier dynasties in order to diagnose current problems. They did not always read them well, of course, but they assumed that history was usable. That tradition helps reveal what is lost in the contemporary gap. A society may still display its past, but if it no longer uses history as a tool of interpretation, then history becomes visually prominent and intellectually thin.

The evidence from cultural products supports this interpretation. The recent success of Black Myth: Wukong is useful not because a video game solves the history problem by itself, but because it demonstrates that interest can be activated when the form changes. Commentators have noted that the game's success pushed many players toward broader curiosity about Journey to the West and Chinese cultural tradition, showing how entertainment can open the door to deeper engagement ('Black Myth'; Zhang). This does not mean every answer is gamification. It means the barrier is not a lack of capacity. Often it is a lack of design.

Human Nature, Culture, and Why Experiential History Matters

The most important addition to this paper is a human-nature explanation of why history education often fails even when students can repeat historical facts. Harvard University's Human Nature course begins from an interdisciplinary premise: human behavior is best understood by combining social science, psychology, biology, and cultural analysis rather than treating biological and cultural explanations as opposites (Harvard University, Human Nature Syllabus). That premise matters for history education. History is a cultural subject, but the learners who encounter it are biological and social beings. They remember, imitate, fear embarrassment, seek belonging, respond to prestige, and care about reputation. A history lesson that ignores those facts is teaching an imagined student, not a real one.

The syllabus's organizing questions are especially relevant. It asks how evolutionary theory can help explain human motivation, learning, psychology, and culture; how humans decide what to learn, how to learn it, and from whom to learn it; how culture and genetic evolution interact; and how cooperation, norms, beliefs, and rituals shape social life (Harvard

University, Human Nature Syllabus). These are not side issues. They describe the exact processes by which history either becomes meaningful or stays dead on the page.

One of the course's most useful ideas for this paper is cultural learning. Human beings do not learn mainly by independently testing every truth from zero. We learn from parents, teachers, peers, famous people, admired groups, institutions, stories, and repeated social cues. Henrich argues that human success depends heavily on the ability to accumulate cultural knowledge across generations, often through imitation and trust in more knowledgeable or prestigious models (Henrich). Richerson and Boyd make a similar point: culture is not a decorative layer placed on top of biology; it is part of how humans adapt and transmit useful behavior (Richerson and Boyd). If this is right, then history education cannot rely only on information delivery. It must shape the social environment in which students decide whether history is worth copying, discussing, and using.

Prestige and conformism are especially important. The Human Nature syllabus includes prestige, deference, and conformism as central topics in the evolution of culture. In a classroom, this means students are constantly observing what counts as impressive. If the impressive student is the one who memorizes fastest for the test, then students will learn that history is a memory competition. If the impressive student is the one who can connect Song Dynasty urban life to modern Hangzhou housing, tourism, consumption, and public space, then history becomes a form of interpretation. The formal curriculum may be the same, but the lived culture of the classroom is different.

This also explains why experience matters. People often understand a principle more deeply when they have some contact with the situation the principle describes. That does not mean students need to personally experience famine, war, dynastic collapse, or social trauma. That would be absurd and unethical. It means that students need structured, safe, partial experiences that let historical problems become emotionally and socially legible. They can interview elders about reform-era life. They can map how a canal shaped trade and migration. They can handle a tea or silk craft and see the labor behind the symbol. They can role-play policy choices under uncertainty. They can design a cultural product and then discover that a beautiful image becomes shallow unless it is supported by context. In these activities, history stops being a statement and becomes a problem students have to inhabit.

This is consistent with experiential education theory. Dewey argued that education should connect learning to experience rather than treating knowledge as material poured into passive students (Dewey). Kolb later described learning as a cycle of concrete experience, reflection, conceptualization, and experimentation (Kolb). The human-nature framework gives a deeper reason for why that cycle matters. Students are not only rational information processors. They are social learners whose memory and motivation are strengthened by action, emotion, imitation, feedback, and public meaning. A student who walks along the Grand Canal, interviews a local worker, studies imperial logistics, and then compares canal governance to modern infrastructure may remember the lesson differently from a student who only copied a textbook line about the Sui dynasty.

This does not make biology a replacement for history. It makes biology a tool for teaching history more honestly. Human nature helps explain why students may ignore lessons that remain abstract, why they imitate prestigious peers, why group norms shape curiosity, and why present bias makes long-term historical wisdom feel less urgent. But history supplies the content that biology cannot provide: the particularity of Hangzhou, the moral ambiguity of statecraft, the tragedy and achievement of past societies, and the difference between a useful analogy and a lazy comparison. The complexity is exactly the point. To teach historical wisdom well, educators need both: the biological and psychological understanding of how humans learn, and the historical understanding of what is worth learning.

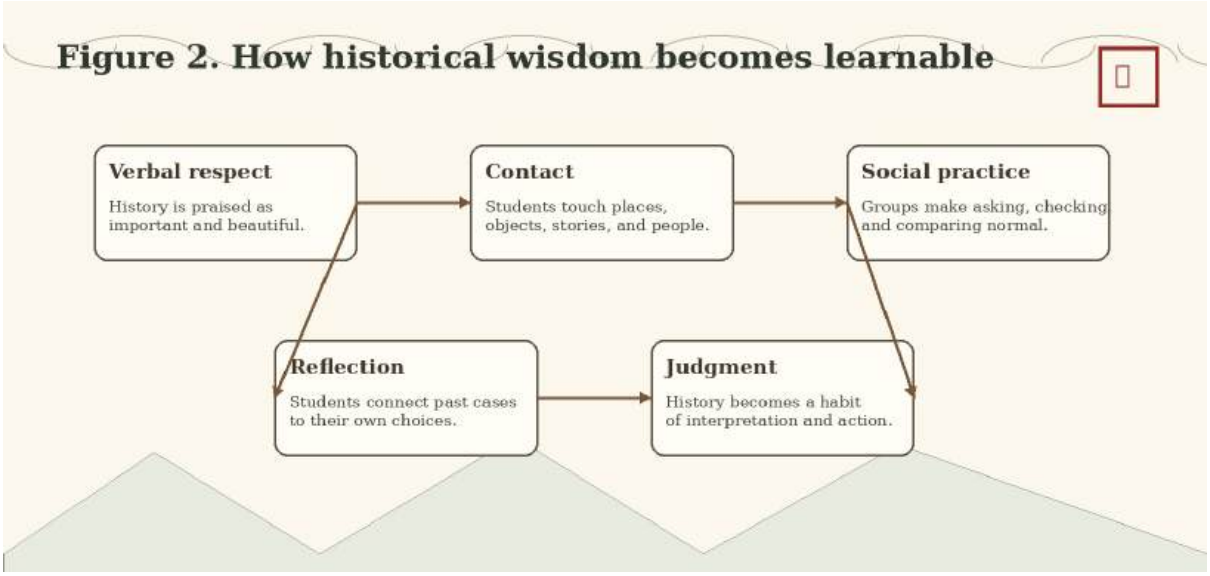


Figure 2. The proposed model turns verbal respect into repeated social practice, experiential contact, reflection, and usable historical judgment.

Toward an Experiential History Curriculum for Hangzhou and China

If the diagnosis is correct, then China's history education problem cannot be solved by simply adding more pages to textbooks or more slogans about cultural confidence. A more serious overhaul of history education should be considered. At minimum, schools should introduce new lessons that combine historical cases with student experience. The goal would not be to make history easier in a shallow way. It would be to make history more usable.

The first reform should be historical analogy labs. Instead of asking students only to memorize what happened, teachers could ask them to compare historical situations to present problems while also identifying the limits of the comparison. For example, a unit on Japan's asset bubble and China's property adjustment could teach students how optimism, credit, status, and policy incentives interact. A unit on Qin state-building could ask how administrative efficiency can produce strength while also creating moral and social costs. A unit on Hangzhou's Southern Song economy could ask how commerce, urban life, taste, and technology reshape daily behavior. Students would not be asked to force one lesson onto the present. They would be

trained to ask: what is similar, what is different, what is dangerous about the analogy, and what does the past allow us to see that the present hides?

The second reform should be place-based historical learning. Hangzhou is unusually well suited for this. West Lake is not only a scenic attraction; UNESCO describes it as a cultural landscape shaped by temples, pagodas, gardens, causeways, and artistic imagination over centuries (UNESCO, 'West Lake'). The Grand Canal is not only a waterway; it is a vast communication and transport system connecting imperial regions (UNESCO, 'Grand Canal'). A student can learn these facts in a classroom, but the facts become more powerful when the student stands at the site, maps the route, studies why the place mattered, and then asks what kinds of labor, administration, ecology, and memory were required to make it last.

The third reform should be oral-history and community-history work. Students could interview grandparents, local elders, craftspeople, museum workers, tea farmers, canal guides, or neighborhood residents. They could ask not only 'what happened,' but 'what changed in how people lived, worked, feared, hoped, and made decisions?' This matters because history is not only dynastic chronology. It is also the felt experience of ordinary people living through change. If students do not hear such voices, history remains too clean. It becomes a sequence of outcomes rather than a field of human decisions.

The fourth reform should be cultural-product learning. My own project points toward this through the student-run history shop Tomorrowland. A product with a historical design can be superficial, but it can also become a learning device. Students could design a tote bag, sticker, poster, short video, or museum-card set connected to Hangzhou history. Each product would require a brief evidence note, a QR code linking to reliable sources, and a reflection on what can be lost when history becomes only aesthetic. This turns the existing consumer interest found in my survey into a bridge toward deeper interpretation.

The fifth reform should be social-norm design inside history classes. If human beings learn through prestige, imitation, and belonging, then history classes should make careful historical reasoning socially attractive. Groups could assign rotating roles: evidence checker, analogy maker, skeptic, storyteller, and present-day connector. Students would learn that a strong historical thinker is not the person who sounds certain first, but the person who can test a comparison, revise an opinion, and respect evidence. This would turn history into a practiced norm rather than a private hobby.

The sixth reform should be a small biology-of-history module. This sounds strange at first, but it may be necessary. Students should learn why human memory is selective, why social pressure shapes belief, why stories are more memorable than lists, why prestige affects imitation, why present bias makes long-term wisdom difficult, and why rituals and repeated practices help transmit culture. This would not turn history into biology. It would help students understand why historical lessons are so easy to praise and so hard to live. In other words, it would teach the value-action gap from the inside.

Local Implementation: Hangzhou, Schools, and Cultural Organizations

Hangzhou is not only the research site in this paper. It is also the obvious place to test the proposed reform. The city has a rare combination of historical depth, museums, tourism infrastructure, intangible heritage institutions, schools, and youth culture. That makes it possible to build an experiential history program without inventing everything from nothing.

The first possible pilot site is Wahaha High School, my own school. This would be the most realistic starting point because a student-led model already exists through Tomorrowland, the history shop and cultural-product project. A pilot could begin with one semester-long elective or club program. Students would choose one Hangzhou historical theme, research it, create a cultural product or exhibition, test it with classmates or visitors, collect feedback, and then write a reflection connecting the historical content to one present-day issue. The point would not be sales. The point would be to convert aesthetic interest into evidence-based curiosity and then into judgment.

A second pilot could involve other Hangzhou schools or international departments. Many schools want project-based learning, community engagement, and distinctive student research, but they often lack locally grounded content. Hangzhou history could supply that content. A school could run a 'West Lake as Cultural Landscape' project, a 'Grand Canal and Urban Logistics' project, a 'Silk and Labor' project, or a 'Tea, Taste, and Social Identity' project. Each would combine history, fieldwork, biology of learning, communication, and reflective writing.

A third pilot could involve museums and heritage institutions. The China National Silk Museum, China Tea Museum, West Lake Museum, Grand Canal-related museums, Southern Song Dynasty Official Kiln Museum, and Zhejiang Intangible Cultural Heritage Museum all connect directly to the themes in this paper. UNESCO's Courier has described the Zhejiang Intangible Cultural Heritage Museum as a place where visitors can actively participate in cultural traditions, which is exactly the kind of experiential contact this paper argues for (UNESCO Courier). Students could work with such institutions to design youth-friendly learning trails, interview scripts, short videos, artifact cards, or guided reflection sheets.

A fourth pilot could involve local cultural and tourism organizations. Hangzhou's culture and tourism ecosystem already promotes local heritage; the challenge is to deepen the public's relationship with it. Organizations connected to the Hangzhou Municipal Bureau of Culture, Radio, TV and Tourism, district cultural offices, community centers, libraries, and youth volunteer groups could use the model for heritage weeks, walking tours, intergenerational oral-history events, or short-video campaigns. The important principle is that activities should not stop at admiration. Every activity should ask participants to explain, compare, reflect, and apply.

A fifth pilot could involve digital creators and cultural enterprises. The survey suggests that people are open to historical consumption, and the popularity of historical games, dramas, short videos, and Hanfu culture shows that entry points already exist. The problem is that these forms can remain shallow if they are not connected to evidence. Hangzhou could support creator programs where students or young creators make short historical content with museum

fact-checking, local archives, and educator guidance. In that model, digital media becomes not a distraction from history, but a path into it.

The table below summarizes how different institutions could use the proposed model. These are not claimed partnerships. They are plausible implementation sites that follow logically from the research findings.



Figure 3. A local pilot could connect schools, student projects, museums, heritage institutions, community spaces, and cultural organizations.

Possible Hangzhou Pilot Uses

Institution or Place	How the Model Could Be Used
Wahaha High School / Tomorrowland	Student-led history shop, QR-linked product research, oral-history interviews, and reflection essays.
Other Hangzhou schools	Project-based local history units connecting classroom topics to field visits and student experiences.
Museums and heritage sites	Youth learning trails, artifact cards, student docents, guided reflection sheets, and short videos.
Community centers and libraries	Elder interviews, neighborhood history nights, preservation workshops, and local story archives.
Culture/tourism and ICH organizations	Heritage weeks, fact-checked creator programs, youth volunteer projects, and public-facing history campaigns.

Why Biology Matters for Historical Wisdom - and Why This Is Complex

The claim that biology matters for teaching history may sound risky, so it needs to be handled carefully. The point is not that biology determines what students should believe. It does not. The point is that every history lesson is received by human beings with certain learning tendencies. Students are not empty containers. They are social, emotional, status-sensitive, memory-limited, group-oriented learners. A teacher who ignores this may think a lesson has been taught when it has only been delivered.

This matters because historical wisdom is different from historical information. Information can be tested by asking whether a student remembers a date, name, or definition. Wisdom is harder. It involves judgment under uncertainty, the ability to compare cases without flattening them, sensitivity to human motives, and a willingness to see that the present is not always as new as it feels. These are partly cognitive skills, partly moral habits, and partly social practices. That is why they cannot be produced by memorization alone.

Biology also explains why some historical lessons are emotionally difficult. Human beings may prefer flattering stories about their group. They may avoid shame. They may imitate confident peers. They may reduce complex past events into heroes and villains because simple narratives are easier to remember. They may discount long-term lessons because present rewards feel stronger. These tendencies are not moral failures by themselves. They are predictable human tendencies. A better curriculum would design around them instead of pretending they do not exist.

At the same time, using biology badly would make the paper weaker. It would be wrong to say that Chinese students ignore history because of some fixed biological trait. The human-nature argument is universal, not ethnic. All humans are vulnerable to present bias, prestige imitation, conformity, narrative simplification, and social signaling. The Chinese case is distinctive because those tendencies operate inside particular institutions: high-stakes exams, parental anxiety, labor-market pressure, official heritage promotion, school schedules, museum systems, and digital culture. Biology supplies the general learning architecture. Chinese history and society supply the specific environment.

This is why the proposed reform is complex. It is not enough for historians to say, 'students need more facts.' It is not enough for psychologists to say, 'students need better motivation.' It is not enough for policymakers to say, 'culture must be promoted.' The problem sits between levels. Historical wisdom requires content, experience, social design, institutional incentives, and reflective practice. If any one of those is missing, the value-action gap can reappear. Students may know the facts but not use them. They may enjoy the activity but not understand the evidence. They may admire culture but outsource preservation to museums. They may produce a beautiful product but fail to ask what it means.

A stronger history education system would therefore be interdisciplinary by design. It would teach students history, but also how humans learn from history. It would teach local pride, but also comparison and critique. It would use games, products, museums, and media, but would always move beyond aesthetics toward explanation. It would respect China's historical depth, but

would not reduce that depth to slogans. In the best version, history would become what it should be: a training ground for judgment.

Conclusion

I began this paper with a paradox: how can a society that speaks so often about five thousand years of civilization remain so uneven in its actual historical engagement? My answer is that the paradox is real, but not mysterious. China's problem is not that people openly reject history. It is that history repeatedly loses when it has to compete with stronger short-term incentives, stronger institutional signals, and weaker everyday habits of use.

My Hangzhou survey makes that visible. Respondents respected history. They supported preservation. They were willing to praise cultural learning. Yet their knowledge was usually moderate, their daily use of historical lessons was limited, and their strongest forms of engagement often ran through aesthetics and consumption rather than sustained study. That pattern is exactly what a value-action gap looks like.

The human-nature framework deepens this conclusion. People do not become historically wise simply by being told that history matters. They need contact, repetition, models, prestige, feedback, group norms, and reflection. They need to experience historical thinking in safe but real ways: visiting places, interviewing people, making things, comparing cases, defending interpretations, and revising their assumptions. This is not a soft add-on to history education. It may be the missing mechanism that turns respect into action.

That is why I do not think the most useful question is 'Do Chinese people value history?' Clearly many do. The better question is: under what conditions can that value become durable action? Once I ask that, the answer changes. The issue is no longer only cultural attitudes. It becomes a problem of incentives, pedagogy, feedback, design, and public norms.

This is why the stakes are larger than nostalgia. If modern China still bears the imprint of its historical experience, then weak historical engagement means living inside structures one cannot fully read. That is an intellectual risk, a civic risk, and also a cultural risk. A society does not lose its past all at once. It loses it when reverence remains verbal, while practice gets thinner year by year. I think that is what this paper is really about.

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Correlational Analysis of Social Media Content Type, Political Behavior, and the News-Finds-Me (NFM) Perception By Anushka Patni

Abstract

With the growth of misinformation and public distrust in news institutions, active news consumption and democratically supportive political behaviors become critical. Current research suggests the prevalence of the potentially injurious News-Finds-Me (NFM) perception, where individuals rely on news to find them incidentally through social media streams to stay informed. The future of America's politics is increasingly shaped by youth engagement in digital environments, and online social media forums pose significant implications for what that future looks like. This study aims to assess how exposure to and engagement with specific types of social media content (friends/family, entertainment, educational, news/current events, political, and sponsored) drives political behavior and the presence of the NFM perception amongst Floridian students aged 16-20 years old. The results show that social media content regarding politics and news/current events have the most significant positive relationships to political behavior, which interestingly has a negative relationship to passive news consumption behaviors. Directions for future research lie in assessing causal relationships between these variables and creating interventions to strengthen democratically supportive behavior.

Literature Review

Social Media and Misinformation

The advent of social media has given unique ground for misinformation to thrive as a symptom of its very purpose: making it easy to share information. In the aftermath of COVID-19, this unfortunate feature of social media has become increasingly prevalent, with 73% of U.S. adults reporting they had seen inaccurate news about the 2024 Presidential Election at least somewhat often (Shearer et al.). The influx of fake news has complicated existing interventions to misinformation, manipulating existing vulnerabilities within social media platforms (Lazer et al. 1094). Wu et al. expounds on these vulnerabilities, particularly how social media's user-based structure enables anonymous users and automated accounts to disseminate fake news easily, quickly, and without accountability (133). A study exemplifying Wu et al.'s analysis was conducted by Sahar Barbibi-Bartov et al. where they found that 5.2% of registered voters were responsible for 80% of the fake news shared on Twitter (now X) during the 2020 Presidential Election (979). Taken together, these studies suggest that the spread of misinformation is not simply a result of individual user behavior, but is amplified by structural features of social media platforms that prioritize rapid and widespread content dissemination.

These risks have garnered governmental attention, with members of the United States Congress recognizing how the spread of fake news poses significant threats to truth-based democratic institutions (Cho and Zhu). Unfortunately, research to date suggests that political polarization can exacerbate the propagation of fake news. Del Vicario et al. discuss how selective exposure to content creates homogenous audiences, which catalyze the diffusion of fake news in

tandem with polarization (554). Osmunden et al. extend this argument in their study about the psychology behind sharing political news, where they found that "fake news sharing—as well as sharing of real news—reflects partisan goals" (1012). These studies suggest that affective, or partisan-based polarization, poses a particular risk to democratic institutions than strictly ideological polarization. According to a study by Boxell et al., America has seen the most rapid increase in affective polarization over the course of the last four decades when compared to the 11 other countries in their analysis (2). These findings suggest that misinformation has greater risks for America's democratic environment, as compared to the political spheres of other nations. As social media becomes increasingly infested with fake news, the likelihood of it being shared by polarized Americans is thus higher (Dufour et al. 2). This catalyzes spillover effects that undermine democracy, such as mass disengagement with news and public distrust in news institutions (Adams et al. 1441). Recognizing the extent of the spread of misinformation, it is necessary to acknowledge when the American public grows increasingly prone to its detrimental impact.

Social Media and News Exposure

A growing body of research shows that social media has developed a unique phenomenon—incidental news exposure (INE). Defined first by David Tewksbury, incidental news exposure occurs when "people encounter current affairs information when they had not been actively seeking it", almost exclusively in the absence of a motivation to be informed (534). Feezell adapted INE to reflect political exposure explicitly, defining incidental political exposure (IPE) as "exposure to political information that results as a second-order effect of first-order entertainment seeking (483)." INE and IPE are two distinct phenomena, as news and political information are not always the same. While both often relate to civic affairs and current events, treating the two as a homogenous pair, as most studies to date have done, has subsequently created the potential for misconceptions to grow. Thus, this study makes the distinction to see if observed correlations are upheld.

Tewksbury framed INE when the internet was still relatively new, and evidence of the idea has multiplied since the rise of social media. In fact, the surplus of content social media offers has been dubbed "news overload", going so far as to drive news-avoidant behaviors (Tian 2). Scheffauer et al. found that high political discussion is directly correlated with high INE amongst Americans, demonstrating how social media feeds adapt to explicit interests (643). Even if individuals are indifferent to news consumption, political interest may be enough to heighten INE. Feezell studied how exposure to political content on social media related to perceived importance of political issues, and found that the amount of INE proportionally impacts perceived importance, particularly among individuals with lower political interest who express avoidant behaviors (491). Shahin et al. solidify these findings, as they found that INE and IPE lead to political participation in online environments (158). While these studies collectively demonstrate that incidental exposure can influence political engagement, they don't delve into content engagement, particularly among youth populations, the next growing voting

body. Thus, further research must investigate how the relationship between INE and IPE manifests amongst youth and emerging voters.

The News-Finds-Me Perception

To understand the relationship between user engagement behaviors and INE/IPE, researchers may take one of three paths: conduct a correlational analysis, assess causality, or create a theoretical framework for the engagement perceptions. In 2017, Homero Gil de Zúñiga took the third path and characterized a novel phenomenon with his peers: the News Finds Me (NFM) perception, or the "the extent to which individuals believe they can indirectly stay informed about public-affairs–despite not actively following news–through Internet use, information received from peers and online social networks" (107). By 2021, the theory had been refined to include four key factors: reliance on peers, the belief of being well-informed, a lack of active news seeking behavior, and an overreliance on social media algorithms to facilitate INE (Gil de Zuñiga and Cheng 4-6). Individuals demonstrating each factor would agree with the respective statements (see table 1).

Items	Dimension	Item wordings
1	Peers Reliance	I rely on my friends to tell me what's important when news happens.
2		I rely on information from my friends based on what they like or follow through social media.
3	Well-informed	I do not worry about keeping up with news because I know news will find me.
4		I can be well-informed even when I don't actively follow the news.
5	Non-seeking	I do not have to actively seek news because when important public affairs break, they will get to me in social media.
6		I'm up-to-date and informed about public affairs news, even when I do not actively seek news myself.
7	Algorithmic Reliance	I rely on social media algorithms to tell me what's important when news happens.
8		I rely on social media algorithms to provide me with important news and public affairs.

Table 1: Question wording for NFM, adopted from Gil de Zúñiga and Cheng (2021).

Experts have demonstrated considerable acceptance regarding the NFM framework, and current research has suggested that this perception is detrimental to democratic institutions. In a case study concerning adults in South Korea, researchers Park and Kaye found that INE and the NFM construct have a proportional relationship, but that NFM is directly associated with a decrease in news consumption (175). Segado-Boj et al. found that NFM-affected users tend to

demonstrate less pessimism towards news sources, suggesting greater susceptibility to misinformation. These compounded findings present significant concerns for the stability of traditional news outlets. Crilley and Gillespie discuss how social media and misinformation have posed the single biggest challenge facing modern journalism, and mass disengagement with news would further reinforce these damages (173). The NFM perception also poses a significant threat to democracy, directly undermining people's perceived importance of active political knowledge-building (Lee and Xenos 22). Gil de Zúñiga and Diehl find that NFM is actually inversely related to political interest and participation over time, threatening democracy (1267). Existing literature has indicated that the NFM perception has a negative impact on politically oriented behavior, and its implications for America's democratic state is apparent. To further understand how this construct undermines American institutions, its prevalence must be assessed in accordance with the youth population.

Furthermore, although existing research consistently identifies the NFM perception as negatively associated with political knowledge and participation, these findings often treat the construct as uniform. Despite the division of the NFM construct into components, the current conversation regarding news-consumption behaviors has not yet investigated how individual aspects of the perception affect politically oriented behavior. This raises an unresolved question in the literature: whether specific dimensions of NFM, rather than the construct as a whole, impede on forms of political engagement.

Youth Political Engagement

When assessing political behavior amongst youth, recent data reports underwhelming political engagement. The electoral participation amongst young people dropped notably in 2024, from over 50% in the 2020 presidential contest to 42% in 2024 (Medina et al.). At large, the youth population demonstrates less interest than the average American population has in politics. Polls conducted by the AP-NORC Center for Public Affairs reveal this discrepancy. Youth voters are 11 percentage points (%pt) less likely than the average to find voting substantially important, and 12%pt less likely to follow politics closely, showing significant apathy to political issues ("Younger Adults"). Underage American teenagers display similar opinions, as they are 4%pt less likely than youth voters to follow politics, but 5%pt more likely than youth voters to value voting, suggesting that young adults find voting less important as they grow older ("Many Teens Want"). By 2028, these young generations—Millennials and Generation Z—will constitute more than half of the electorate (Winograd et al.). It is necessary to understand what impacts the political behavior of American youth, many of whom will gain the franchise by the next presidential election.

With the dawn of the internet, and especially social media, political engagement has evolved amongst youth. Bakker and Vreese distinguish between online and offline political behavior, which may be further characterized as passive and active (457). Online participation primarily includes engagement with social media content and online discussion forums, while active participation centers around voting and advocacy work. Kahne and Bowyer take this

investigation further, as they assess how general online activity, broken into the dichotomy of friendship-driven (FD) and interest-driven (ID) engagement, may encourage political activity amongst youth (472). Engagement here is seen as a measure of interaction with social media content, seen in behaviors such as liking, commenting, sharing, or reposting. Kahne and Bowyer's research is based around the idea of political socialization, the mechanism by which individuals develop political beliefs, and found that FD activity strengthened engagement in online political discussions, whereas ID activity promoted engagement in offline political activities (489). Mihailidis and Thenevin interpret online, social media-based engagement and offline engagement as equivalent in the digital age, both uniquely beneficial to democracy (1613). Their analysis encourages experts like Bakker and Vreese to recognize the increasing value of social media civic engagement, and notably makes the argument that citizens ought to build social media competency to cultivate "agents of social change" and empower participatory democracy in America (Mihailidis and Thenevin 1619).

Gap in Literature

While Kahne and Bowyer's research initiated the study of how engagement with non-political content may correlate to political behavior, more research must be done to further characterize and compare content-engagement and exposure to examine whether current social media behavior in American youth does, in fact, facilitate participatory democracy. This analysis can be extended to Gil de Zuñiga's NFM construct as well, further driving understanding as to what specifically drives news consumption behaviors. Furthermore, research to date has not focused on the emerging voting body, and case studies have not been centered on Florida's population. Thus, this research paper will conduct a correlational study around this inquiry to determine whether the type of social media content Floridian students aged 16-20 are exposed to/engage with has a relationship to A) political behavior and B) the NFM perception. This study contributes to existing literature by disaggregating content exposure and engagement into specific categories (friends/family, entertainment, educational, news/current events, political, and sponsored) and examining how these distinctions interact with individual components of the NFM perception, rather than treating both constructs as uniform. This analysis was based around 5 hypotheses:

> *H1: High exposure to/engagement with friends/family, educational, news/current events, and political social media content will be positively correlated to political behavior.*
> *H2: High exposure to/engagement with friends/family, educational, news/current events, and political social media content will be positively correlated to the NFM perception, specifically the peer-reliance, well-informed, and non-seeking components.*
> *H3: High feed diversity will be positively correlated to political behavior and the NFM perception.*
> *H4: Higher overall engagement with social media content will be positively correlated to political behavior.*

H5: Higher overall social media consumption will be positively correlated to the NFM perception, specifically the algorithmic reliance component.

Methodology

This study utilized a quantitative, cross-sectional design to investigate the correlation between content exposure/engagement via social media and both (1) political behavior and (2) perception of news consumption. This design was ideal, as it can gather significant, standardized data across a wide range of participants while complying with the given time constraints. The survey asked participants to report their social media engagement, social media content exposure, political behavior, and news perceptions according to the Likert Scale. While this study does rely on self-reported measures, risking recall or social desirability bias, the use of multiple-item constructs and anonymous response collection strengthens reliability and reduces distortion. Additionally, Guess et al. validated the correlation between behavior and self-reports, suggesting that these measures may be an accurate indicator of realized behavior and perception (254). The survey asked participants how strongly they agreed or disagreed with given statements, streamlining the process to standardize the self-reported data for statistical analysis.

Survey Design

This survey was designed via Google Forms and included 5 sections: (1) Consent Form, (2) Demographics, (3) Content Exposure/Engagement, (4) NFM Perception, and (5) Political Behavior.

1. **Consent Form**

This section asked respondents to consent to participation in this study via a multiple-choice selection—"I consent" or "I don't consent". If the participant was a minor, then a parent/guardian would also have to give their consent through a similar mechanism. Both these selections were required, with an option for "N/A" if the participant was an adult. All responses where appropriate consent was not given were not analyzed to ensure participants' wishes were respected, and this data was collected ethically.

2. **Demographics**

This survey asked for key demographics, such as age, grade, Florida region, and gender. This data collection was primarily done to see what the sample's common demographics were. This portion of the survey also asked about general social media behaviors, including time spent on social media, apps most commonly used, and whether the individual is likely to post online. Such data can inform future findings to see if there is a correlation between general social media behaviors and political/news consumption behaviors.

3. **Content Exposure/Engagement**

This survey assessed the level of content exposure/engagement by first asking users to rate how often they see the identified types of content, how likely they are to engage with said content, and how variable their feed was. This rating was done according to the Likert scale, allowing for a standardized and reliable method to assess content exposure/engagement. This differentiation and interaction-focused questionnaire was informed first by Tewksbury and Weaver, who originally identified INE, and next by Kahne and Bowyer, who investigated how exposure to and engagement with nonpolitical content—separated into friendship-driven and interest-driven categories—affected political behavior (536; 472). This section aims to expand past these categories and hone in on more specific kinds of content to investigate whether type of content itself has any relation to news consumption and political perceptions and/or behaviors.

4. **NFM Perception**

This fourth section asked participants to rate a series of statements, according to the Likert scale, based on relatability, followed by a question asking them to rate how likely they are to use specified news sources. The statements were formed using the questionnaire that Gil de Zuñiga, the founder of the NFM construct, had created as a model (Gil de Zuñiga and Cheng 4). Understanding how response-styles and biases may skew the accuracy of self-reported data, multiple statements highlighted similar themes, aiming to control for participant variance (Van Vaerenbergh and Thomas). This section directly assesses whether the participant displays signs of the NFM construct, while simultaneously cross-referencing that information with where the respondent receives news from.

5. **Political Behavior**

The first question under this section asks participants to take an external survey—the Pew Research Center's Typology Quiz (Pew Research Center). Acknowledging that the quiz is not perfect as a relation of real-alignment, this is still critical to indicate how far left or right the participant is on the political spectrum. This data is not used as a direct factor, but instead is compounded as a further indicator of how knowledgeable the respondent is on politics. The second question asks whether the respondent is, or is planning to be, registered to vote, while the last section asks participants to rate a series of statements, according to the Likert scale, based on relatability. These statements assess what the respondent's perceived political behavior is, and place a specific emphasis on online political behavior based on conclusions by Bakker and Vreese, who suggest social-media-based political behavior ought to be considered as real, measurable political participation (457).

Participants and Sampling

The sampling group for this survey consisted of Florida residents aged 16-20, as they will be the youngest group of voters in the next Presidential Election and come from a variety of socioeconomic backgrounds (US Census Bureau). This age group is critical to understanding the behavior of the youth voters has become increasingly necessary to reflect what the next

generation of politics and news consumption will look like in the age of social media (Medina et al.). Sampling from a relatively large population also helps control for location and income as variables, more effectively isolating social media use as the primary factor. All information was collected anonymously, reflecting ethical considerations and protecting participant privacy. Data collection occurred without incentives and was entirely voluntary to further ensure data was not skewed by bias.

After receiving approval from the Institutional Review Board (IRB) to ensure ethical standards were fully met, the process of data collection began. To disseminate the survey, the survey link was sent out to educators across Florida's public schools and posted on social media. The contact information of high school teachers who worked in the English Language Arts, Social Studies, and Critical Thinking departments was obtained from their respective county-level school page, which included a comprehensive faculty directory. At the college and university level, professors were contacted via the email addresses listed on their department's faculty page, with a focus on those in the Political Science, Journalism, Communications, and Dual Enrollment divisions. As a failsafe for an expected low response rate, the survey was also sent out to various organized groups, including the Equality in Forensics Florida Chapter, the Rhizome Florida Chapter, and the Florida Youth Action Fund. Although the sampling method was non-random, efforts were made to recruit participants across multiple institutions and organizations to introduce response variability. As such, the findings are best interpreted as identifying patterns of association rather than broadly generalizable conclusions.

Data Analysis

Over the 75-day period where the survey link was open (from December 9, 2025 to February 22, 2026), a total of 110 responses were collected. Of these responses, 95 responses could be used in data analysis, with responses exempted because their age inputs did not fit the survey group's ideal range of 16-20 years. No other reasons to exclude respondents' data entry were found.

In the survey, participants self-reported their exposure to/engagement with content types, demonstrated qualities of the NFM perception, and reported information pertaining to their political behavior and alignment. This data was consolidated into 16 independent variables concerning online behavior and 6 dependent variables concerning the NFM perception and political behavior (see table 2). This was done by first assigning ranked numerical values to each question answer based on the Likert scale and given numerics, then calculating the mean of all answers relevant to each respective variable. This consolidated qualitative data into quantitative, ordinal data and variables that could be statistically analyzed.

#	**Independent Variables**	**Dependent Variables**
1	Exposure to Content Posted by Friends/Family	NFM
2	Exposure to Entertainment Content	NFM: Peers

3	Exposure to Educational Content	NFM: Well-informed
4	Exposure to News/Current Events	NFM: Non-seeking
5	Exposure to Political Content	NFM: Algorithmic Reliance
6	Exposure to Sponsored Content	Political Behavior
7	Similarity to Friends'/Family's Feeds	
8	Overall Feed Diversity	
9	Hours Spent Online	
10	Overall Online Engagement	
11	Engagement With Content Posted by Friends/Family	
12	Engagement With Entertainment Content	
13	Engagement With Educational Content	
14	Engagement With News/Current Events	
15	Engagement With Political Content	
16	Engagement With Sponsored Content	

Table 2: Considered variables—16 independent variables and 6 dependent variables.

This cross-sectional study was built upon observation and self-report, and thus is characteristic of a correlational analysis, restricting its capability to generalize causal relationships. Acknowledging this limitation, the focus of statistical analysis was to assess correlational relationships, which was done by calculating the respective Spearman's rank correlation coefficient with Google Sheets. Spearman's rank correlation is specific to ordinal data, and like Pearson's coefficient, ranges between -1 and +1, with a value of greater magnitude reflecting correlational strength (Wisniewski and Brannan).

These coefficients were compared, and the strength of each relationship was found according to the respective r values (see fig. 1). Only one statistically significant very strong correlation was found; a notable amount of moderate and strong correlations were observed; and numerous weak correlations were discovered. All very weak correlations were statistically insignificant.

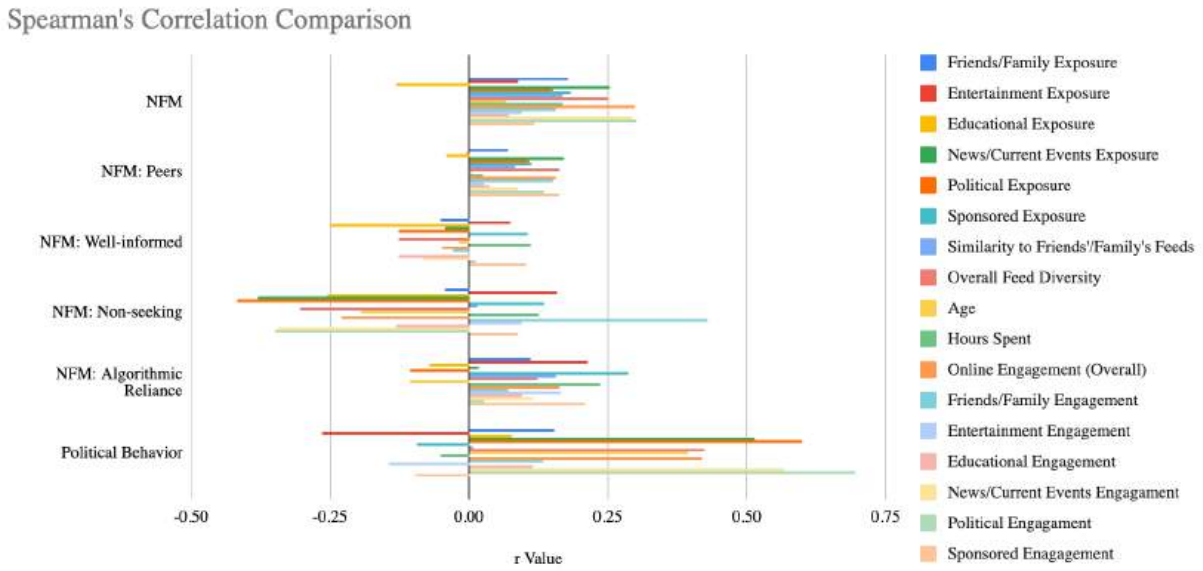


Fig. 1: Comparing Spearman's correlation coefficient for independent/dependent variables.

Results

On average, the survey group demonstrated levels of political behavior and the NFM perception consistent with other participant samples, suggesting that Floridian youth are equally as susceptible to the NFM perception and equally as inclined to participate in democratically valuable behavior as those surveyed by other researchers. Between components of the NFM perception, respondents were on average less likely to report signs of the non-seeking and algorithmic reliance behaviors, and slightly more likely to report the belief that they are well-informed. Concerning dependent variables, this population was significantly more likely to be exposed to entertainment content than all other forms of content, but had relatively moderate feed diversity. The survey group also had lower than supposed levels of engagement with social media content, with the highest reported tendency to interact with content posted by friends/family and very low likelihood of interacting with sponsored content or ads.

The strongest demonstrated correlation was the positive relationship between engagement with political content and political behavior ($r = 0.70$, $p < 0.0001$). Political behavior also demonstrated a strong correlation to engagement with news/current events content ($r = 0.57$, $p < 0.00001$) and a moderate correlation to overall engagement with social media content ($r = 0.42$, $p < 0.0001$) (see fig. 2). Along with engagement, political behavior also demonstrated a strong correlation to exposure to both political content ($r = 0.60$, $p < 0.00001$) and news/current events content ($r = 0.51$, $p < 0.00001$), as well as a weak negative correlation to exposure to entertainment content ($r = -0.26$, $p < 0.05$) (see fig. 3). Political behavior also had moderate positive correlations to feed diversity ($r = 0.40$, $p < 0.0001$) (see fig. 4).

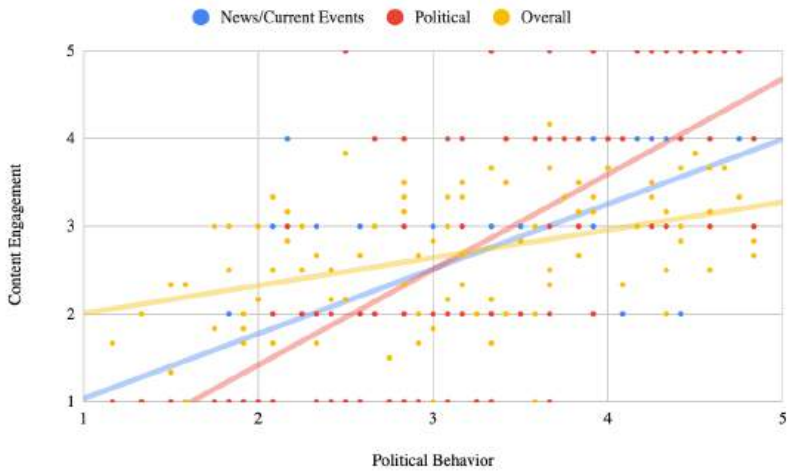


Fig. 2: Significant relationships between social media content engagement and political behavior.

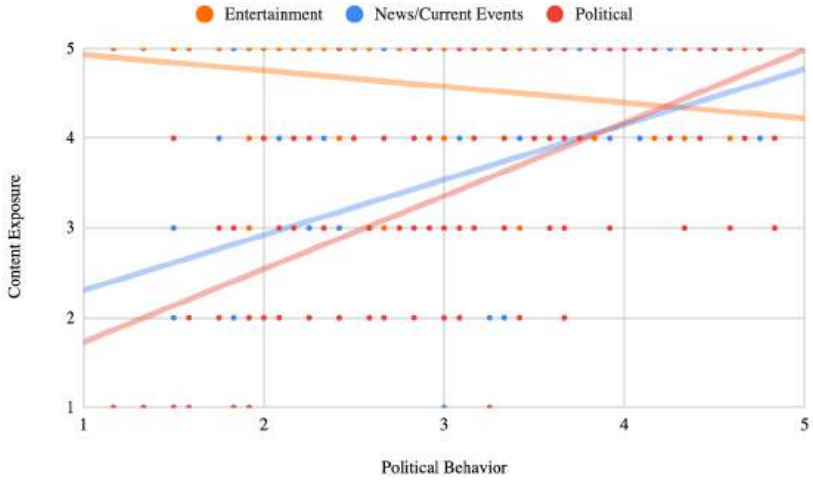


Fig. 3: Significant relationships between social media content exposure and political behavior.

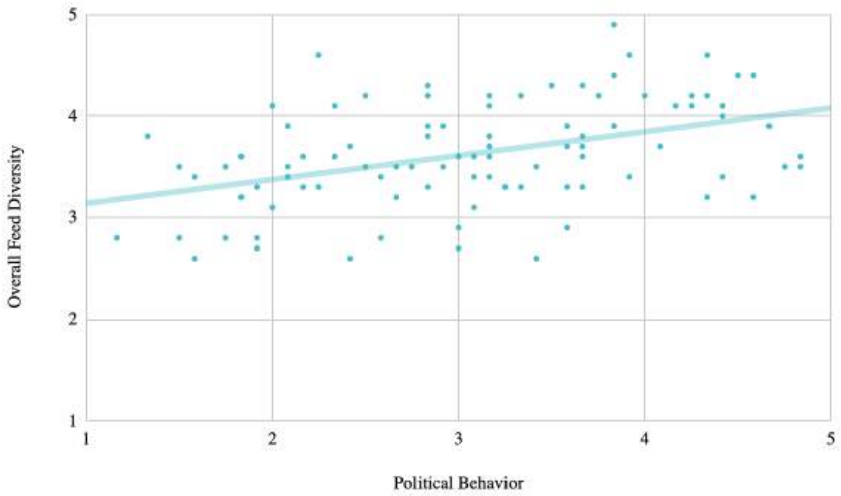


Fig. 4: Relationship between overall feed diversity and political behavior.

The non-seeking component of the NFM perception had inverse correlations to many variables political behavior was correlated positively to, with moderate negative correlations to engagement with news/current events ($r = -0.35$, $p < 0.001$) and political content ($r = -0.35$, $p < 0.001$), news/current events ($r = -0.38$, $p < 0.001$) and political content exposure ($r = -0.42$, $p < 0.0001$), and overall feed diversity ($r = -0.31$, $p < 0.01$) (see fig. 5; see fig. 6; see fig. 7). This component also had a weak negative correlation to overall engagement with content ($r = -0.26$, $p < 0.05$) and exposure to educational content ($r = -0.23$, $p < 0.05$).

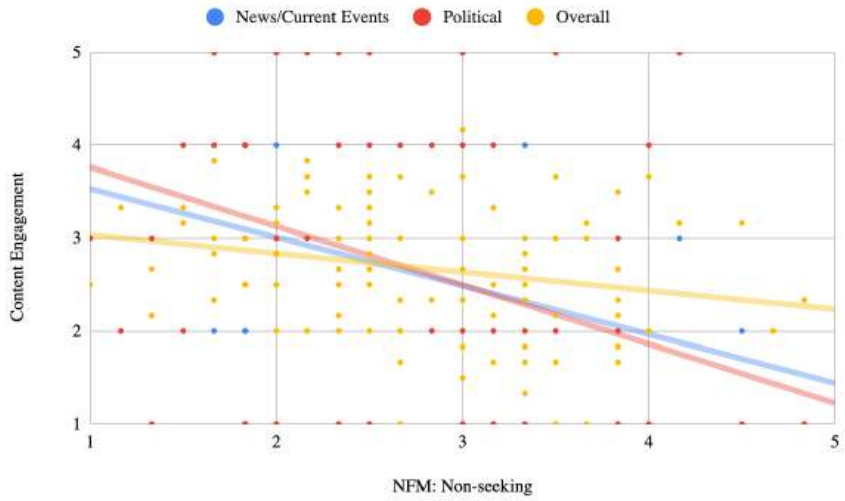


Fig. 5: Significant relationships between social media content engagement and the non-seeking component of the NFM perception.

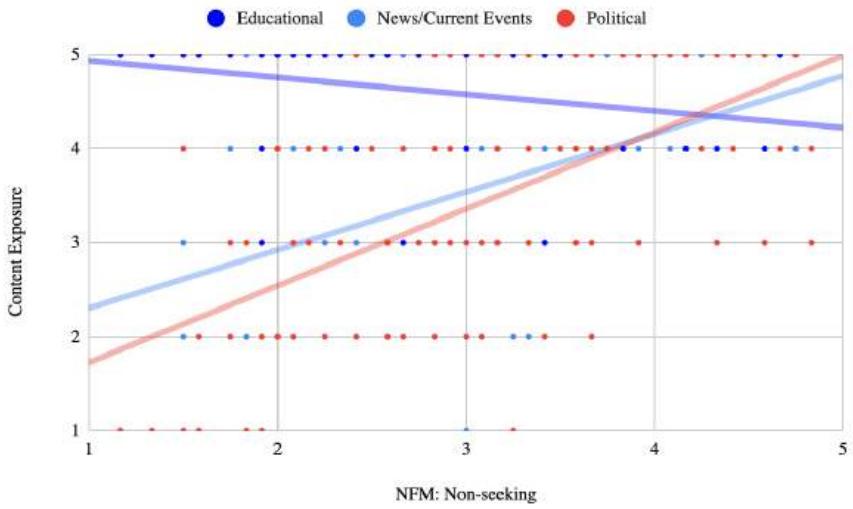


Fig. 6: Significant relationships between social media content exposure and the non-seeking component of the NFM perception.

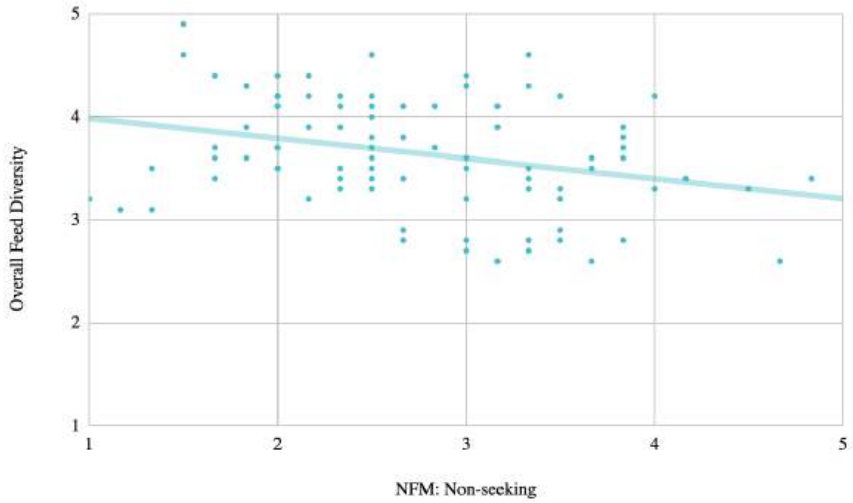


Fig. 7: Relationship between overall feed diversity and the non-seeking component of the NFM perception.

The last moderate relationships were found with the NFM perception as a whole, which demonstrated positive correlations to overall online engagement ($r = 0.30$, $p < 0.01$), engagement with political content ($r = 0.30$, $p < 0.01$), and engagement with news/current events content ($r = 0.30$, $p < 0.01$) (see fig. 8). The overall NFM perception also had weak correlations to exposure to news/current event content ($r = 0.25$, $p < 0.05$) and overall feed diversity ($r = 0.25$, $p < 0.05$) (see fig. 9, see fig. 10).

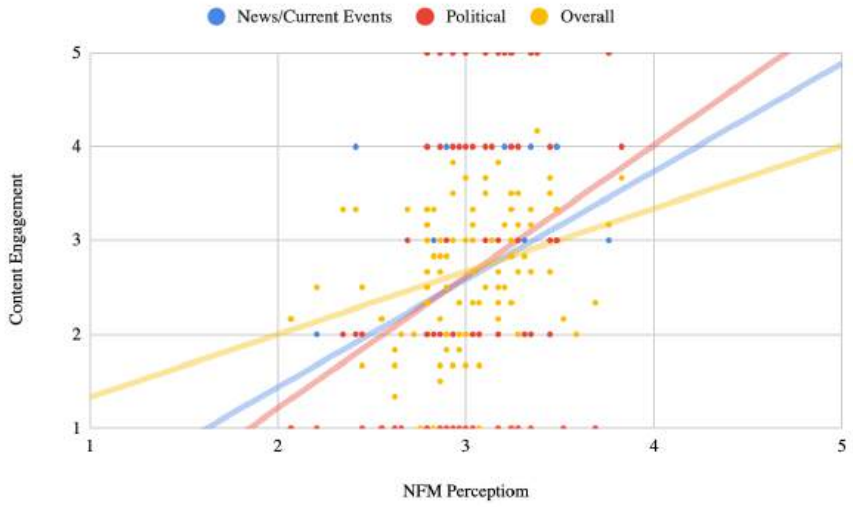


Fig. 8: Significant relationships between social media content engagement and the NFM perception.

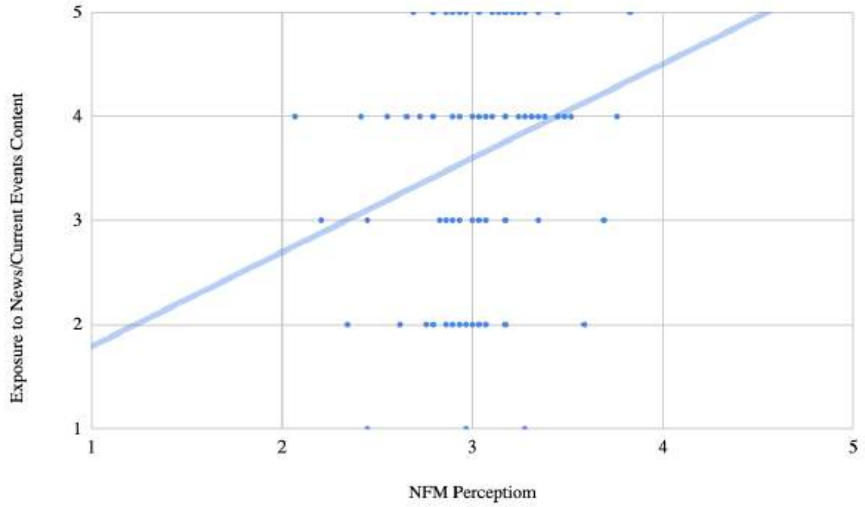


Fig. 9: Relationships between exposure to news/current events content and the NFM perception.

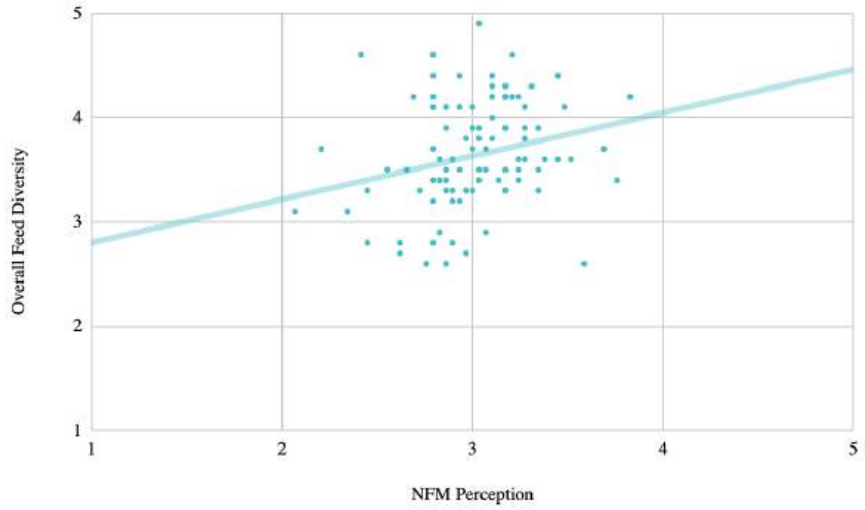


Fig. 10: Relationship between overall feed diversity and the NFM perception.

Further weak relationships were found for other components of the NFM perception. For example, the algorithmic reliance component demonstrated weak positive correlations to exposure to entertainment ($r = 0.21$, $p < 0.05$) and sponsored content ($r = 0.29$, $p < 0.01$), hours spent on social media ($r = 0.24$, $p < 0.05$), and engagement with sponsored content ($r = 0.21$, $p < 0.05$) (see fig. 11, see fig. 12, see fig. 13). The well-informed component also demonstrated a weak negative relationship to exposure to educational content ($r = -0.25$, $p < 0.05$), but the peers reliance component demonstrated no significant relationships (see fig. 14).

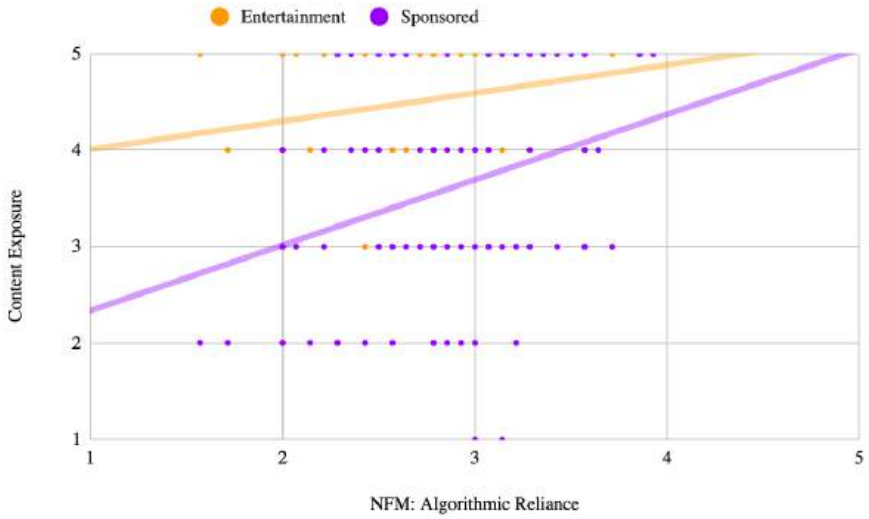


Fig 11: Significant relationships between content exposure and the algorithmic reliance component of the NFM perception.

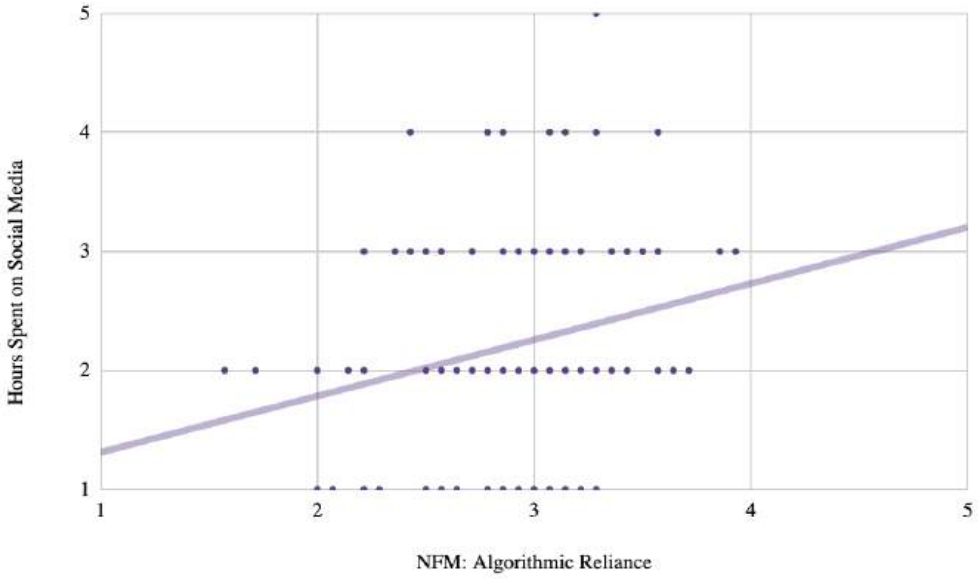


Fig 12: Relationship between hours spent on social media and the algorithmic reliance component of the NFM perception.

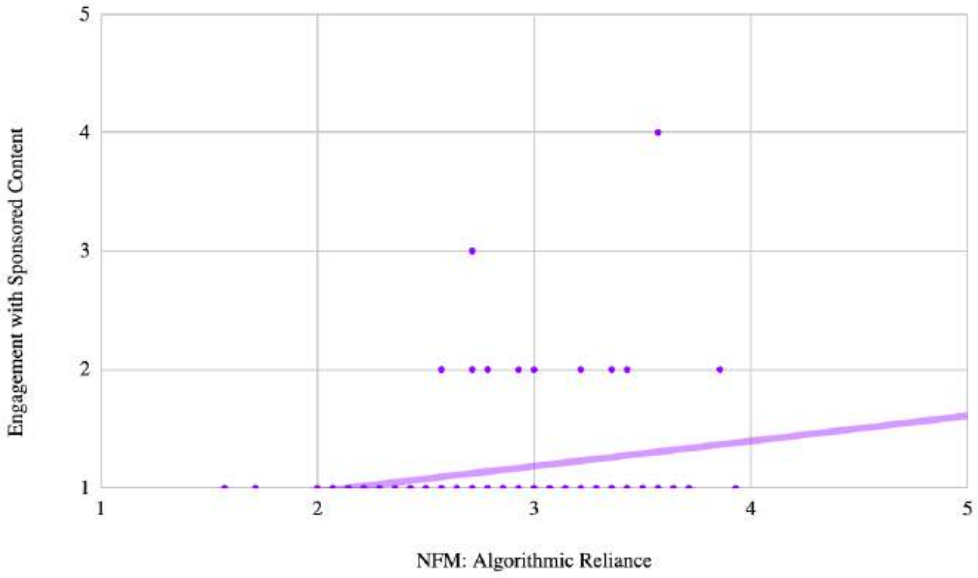


Fig 13: Relationship between engagement with sponsored content and the algorithmic reliance component of the NFM perception.

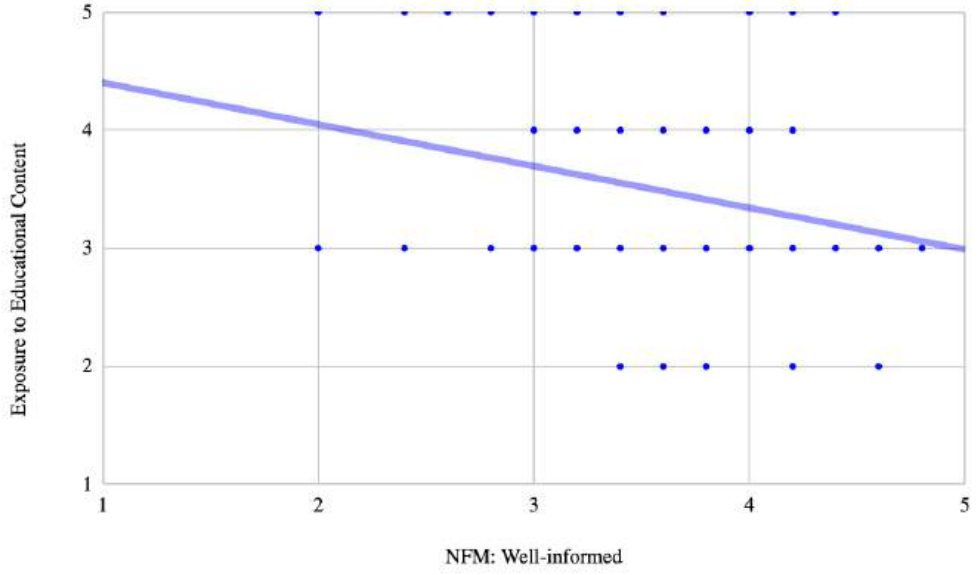


Fig 14: Relationship between exposure to educational content and the well-informed component of the NFM perception.

Between these independent variables, further notable relationships were demonstrated. Specifically, political behavior displayed a moderate negative correlation to the non-seeking component of the NFM perception ($r = -0.45$, $p < 0.0001$) and a weak positive correlation to the NFM perception as a whole ($r = 0.28$, $p < 0.01$) (see fig. 15).

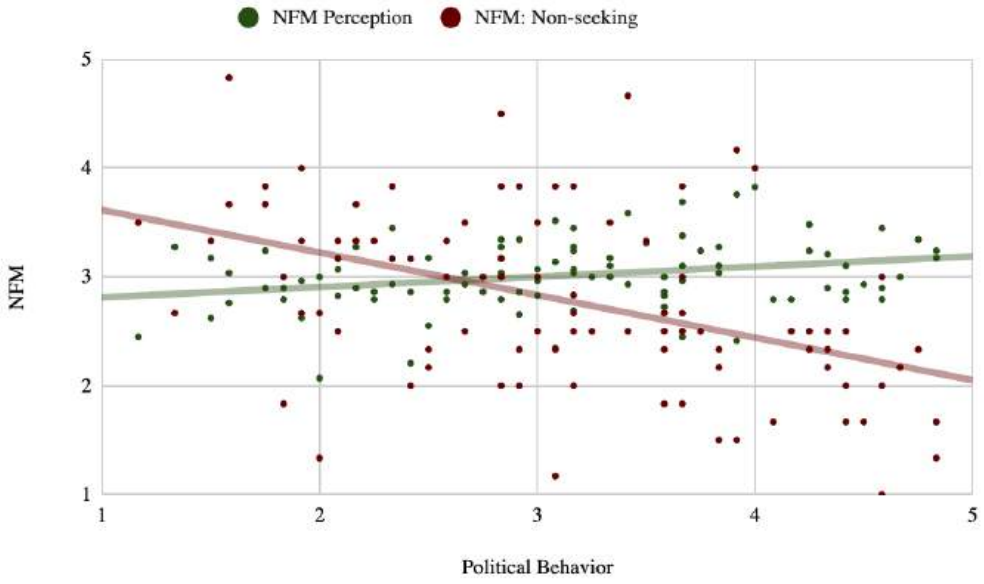


Fig. 15: Relationship between the non-seeking component of the NFM perception and political behavior.

Discussion

Of the hypotheses established, *H4* and *H3* were corroborated—overall engagement demonstrated positive correlations to political behavior, and both political behavior and the NFM perception demonstrated a positive correlation to feed diversity. *H1* was also partially substantiated, as political behavior demonstrated a positive correlation to political and news/current events content, and only engagement with educational content, with no significant relationship to friend/family content. Even less evidence supported *H2*; exposure to only news/current events content had a relationship to the NFM perception, and engagement with news/current events and political content demonstrated a moderate positive correlation. Interestingly, political and news/current events content demonstrated an inverse relationship to the non-seeking component, and exposure to educational content had a negative correlation to both the non-seeking and the well-informed components, thus contradicting *H2*. *H5*, finally, was also partially supported, as the algorithmic reliance component of the NFM perception had a positive correlation to hours spent on social media, but the NFM perception as a whole did not.

These results indicate that social media content consumption has varied implications for political behavior. It had the strongest correlations to 1) engagement with and 2) exposure to political content, followed closely by 3) engagement with and 4) exposure to news/current events content, as consistent with existing literature. Interestingly, findings by Kahne and Bowyer are at odds with this study, as neither FD nor ID activity had a positive correlation to political behavior; if anything, the negative relationship to entertainment content contests their results. Taken together, these findings suggest that the relationship between social media and democratic engagement is not inherently positive or negative, but instead depends on how individuals interact with content within algorithmically curated environments. The positive relationships of political behavior to overall content engagement and feed diversity suggest that active behavior

online, regardless of content type, and well-rounded exposure to content has an impact on political behavior, and may be a point of future research.

Political behavior's relationships to the NFM perception and its components are of greater note. While existing literature often characterizes the NFM perception as uniformly detrimental to political engagement, the present findings suggest that its effects may be multidimensional and contingent upon specific behavioral patterns. This study suggests that individuals are more likely to behave in democratically positive ways if they also are affected by NFM, yet less likely if they aren't active news-seekers. While these findings can only indicate association, not causation, the patterns identified here help clarify a more precise question for future research: whether passive news-seeking attitudes, rather than the NFM perception as a whole, are the key mechanism linking social media use and political disengagement.

Limitations

This study has numerous limitations, and its results must be interpreted accordingly. While this study aimed to sample students aged 16-20 from across Florida, respondents were overwhelmingly high schoolers (aged 16 or 17) from Central Florida. Thus, the results of this study are best understood as patterns within this sample, rather than large-scale generalizations. Furthermore, while this study relied on self-reported data, which was addressed in the methodology through anonymity and standardized questioning, this limitation may still influence this study's accuracy. The design of the survey poses certain concerns as well; while the Likert scale streamlines the standardization of data, it oversimplifies nuances regarding behavior. This includes overlooking the ways users consume content (emotional responses, depth of analysis, etc.). Because this study does not control for content consumption behaviors or other factors of political socialization, there is a possibility that the trends observed in this data occurred as a result of unmeasured confounding variables. Without controlling for such elements, the observed correlations cannot be assumed to reflect independent effects. Finally, due to the correlational design of this study, it is not possible to determine the directionality of these relationships. It remains unclear whether engagement with political content reduces non-seeking tendencies, or whether individuals who are already more politically interested are both more likely to engage with content and less likely to exhibit non-seeking behaviors. As a result, the observed relationships cannot be assumed to reflect independent causal effects.

Future Implications

Of the three types of studies that explore social media and behavior—assessing correlation, creating theoretical frameworks, and investigating causality—more research must be directed towards understanding causal relationships between the NFM perception, political behavior, and social media consumption. Youth political behaviors within this sample were seen to be on par with adults in this study, but further research must be done to understand if this is representative of a larger trend. The findings of this study suggest that the relationship between social media use and political engagement may be less dependent on exposure alone and more

contingent upon the nature of user engagement and consumption behaviors. This distinction aligns with broader theories of media effects, which emphasize active engagement as a key mediator of behavioral outcomes. This may direct future research into understanding how social media consumption habits and perceptions impact behavior. The non-seeking aspect of the NFM perception is a particular point needing further analysis, as these findings indicate that it has the strongest associations to social media content and political behavior. This study contributes to existing literature by disaggregating both content exposure/engagement and the NFM perception into more specific components, highlighting the importance of examining these constructs as multidimensional rather than uniform. Future research should build on these findings by employing causal designs and incorporating controls for key variables such as political interest, in order to better isolate the mechanisms underlying these relationships. To design interventions that can adequately limit political disengagement and non-seeking behaviors, greater investigation into what drives it is necessary. As affective polarization makes American society increasingly desensitized to news outlets offline, online interventions against passive news consumption behaviors become all the more critical.

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Semaglutides, Tirzepatides, and the Future of GLP-1 Receptor Agonists
By Liam McClure

Abstract

This paper reviews the literature on the existing state of GLP-1 receptor agonists and how they interact with the gut and the brain. There is a clear trajectory in the development of these drugs, as they have progressed from single receptor agonists (semaglutide) to dual receptor agonists (tirzepatide). On the horizon are triple receptor agonists undergoing clinical trials. Also noted are caveats for discontinuing the use of GLP-1 agonists.

Introduction

Some of the most popular drugs marketed today are GLP-1 receptor agonists. Top-selling brand names include Ozempic, Wegovy, Zepbound, and Mounjaro. These drugs hold the promise of controlling Type 2 diabetes as well as lowering body weight. In terms of pharmacology, there are two different chemical formulations at play here. First on the market were semaglutides marketed under the names Wegovy and Ozempic, followed by tirzepatides, which are marketed under the Zepbound and Mounjaro brand names.

This paper examines the differences and similarities among these drugs, how they act in the brain, and looks at the next steps in the development of GLP-1 drugs.

But First, What Do GLP-1s Do

GLP-1 is a natural hormone produced in the gastrointestinal tract to increase insulin production while lowering the production of glucagon.[1] Insulin is the main regulatory hormone for glucose in the bloodstream, as it acts as a signal for muscle, liver, and adipose cells to open and accept glucose. It is usually emitted after eating a meal as the body signals that it needs to absorb this to maintain homeostasis. Glucagon is another glucose regulation hormone and acts in much the opposite way of insulin. It allows for glucose to be produced and released into the bloodstream during physical activity or periods of no intake of glucose (think fasting). Both of these hormones are made inside the pancreas, which is signaled to make them by different parts of the body.[2] Natural GLP-1 happens to be one of these signalling molecules from the gut that tells the pancreas to increase its insulin production while dropping glucagon production because there is an excess of glucose in the bloodstream at the moment.

GLP-1 does more than stimulate the pancreas. It also binds to receptors in the brain to signal a feeling of fullness or satiety, which lowers the desire to eat.[3] This effect does not last long as enzymes quickly dissolve these natural hormones, meaning the effect does not last as long.[4] This problem was solved by the creation of the first marketable artificial GLP-1 approved by the FDA in 2005, under the name Exenatide. Exenatide was created with a slight change in the amino acid sequence that resulted in it being able to resist the enzymes in both the brain and pancreas that shut down its natural variant for a longer period of time.[5] At the time, Exenatide

was used to treat patients with type 2 diabetes as it increased insulin production while also producing the feeling of being full.

Semaglutides

One of the two most popular artificial versions of GLP-1s is semaglutide, which is a GLP-1 receptor agonist with a 94% match to the original GLP-1. The change in the 31 amino acid polypeptide is at the Aib8 and Arg34 positions.[6] These modifications allow for the drug to last over 100 hours, which is a significant increase from the natural lifespan of 2–3 minutes. The receptors that semaglutides bind to are located not only in the pancreas, but also in the peripheral and central nervous systems.[7] These receptors activate pathways that cause a reduction in hunger, which allows the body to fully digest food before more is ingested.

Semaglutides were originally designed for type 2 diabetes patients; however, after patients discovered that they caused weight loss due to the suppression of hunger and increased metabolism, more people began to use them as weight loss drugs. This caused increased attention, which led to more studies being conducted about the effects of semaglutides on the body. In clinical trials, semaglutides have been shown to cause significant weight loss over a 30-week period.[8]

Along with affecting weight loss, semaglutides have shown positive benefits to the cardiovascular system. In the SELECT trial, semaglutides were shown to produce a significant 20% reduction in the risk of major adverse cardiovascular events (MACE) and lowered the chance of cardiovascular death.[9] This reduction in cardiovascular risk is attributable to semaglutide's reduction in HbA1c, body mass, and systolic blood pressure.[10] All of these are contributors to heart disease, as they can lead to conditions such as strokes or heart failure. The effect of this is an increase in usage of popular semaglutide brands like Wegovy and Ozempic as cardiovascular medicine.

Tirzepatides

Tirzepatide is the other most widely used drug in this class. Tirzepatide is actually a dual receptor agonist, acting on both GLP-1 and gastric inhibitory polypeptide (GIP) receptors, which means it can bind to two different active sites of both the GLP-1 and GIP receptors.[11] This allows for the stimulation of different effects such as satiety, lowering blood sugar, and improving digestion. The addition of GIP allowed for better regulation of insulin production compared to GLP-1 alone and also increased the effectiveness of the treatment, making it so patients only needed to take doses once a week.[12]

However, the dual action of tirzepatide on the GI system has been a complicated process because of the effect of both mechanisms on the stomach and brain. The medication slows the movement of food from the stomach to the small intestine while simultaneously giving the brain the signal that the person is full. This results in patients feeling nauseous because they feel overly full. These effects usually only occur during the first few weeks of medication or with increased dosage.[11]

Additionally, the balance between GIP and GLP-1 receptor activity is uneven. Studies have shown that tirzepatide's GIP receptor affinity is comparable to native GIP, but its GLP-1 receptor affinity is approximately five times lower than its natural counterpart.[12] This means that GIP effects are more prominently expressed, which may be helpful to the GI system, as GIP is not known to cause the adverse effects of nausea and vomiting that GLP-1 receptor activation can produce.

Difference Between the Two

Tirzepatides and semaglutides have a fundamental difference at the molecular level: they are different molecules altogether. While semaglutides are made of a 31-amino acid polypeptide chain, trizepatides are made of a 39-amino acid polypeptide chain in order to act as dual receptor agonists.[11,12] This increase in the length of the chain has allowed tirzepatide to serve as a dual receptor agonist, utilizing both a glucose-dependent insulinotropic polypeptide and a glucagon-like peptide-1 receptor. Being a dual agonist has allowed tirzepatide to achieve a once-weekly dosing schedule due to its longer half-life compared to semaglutide.

Difference in Efficacy

There is a notable difference in the efficacy of tirzepatide versus semaglutide. The major difference is how they function as receptor agonists. Tirzepatide acts as a dual agonist as it activates both the GLP-1 and GIP receptors simultaneously, while semaglutide acts only on GLP-1 receptors. By activating both GLP-1 and GIP receptors, tirzepatide appears to be more effective for both weight loss and metabolic outcomes relative to semaglutide.

A 2025 meta-analysis of seven studies found that tirzepatide was significantly superior to semaglutide in achieving weight reduction. Participants on tirzepatide had significantly higher odds of achieving at least 10% weight loss compared to those on semaglutide.[13] Additional meta-analyses have found that trispeptide produces roughly 4–4.5 percentage points greater weight loss than semaglutide.[14]

In real-world studies, results with patients are consistent with the findings of clinical studies. While patients using semaglutide lost weight, those using tirzepatide lost more.[14] It should be noted that both drugs are relatively new to the market, and long-term effects have not been fully examined.

Difference in Tolerability

In terms of side effects, both drugs are quite similar, but there are some notable differences. Among the shared side effects are nausea, vomiting, pancreatitis, and diarrhea, all of which are fairly common. These effects are not surprising given that both activate GLP-1 receptors, which in turn affect the digestive system and slow gastric emptying.[15] In general, semaglutide and tirzepatide are well tolerated, and adverse events are mild to moderate in severity.[16]

In terms of their differences, each drug has a slightly different risk profile associated with the GI system. GI events were more frequent with tirzepatide, while semaglutide was significantly associated with gallbladder-related adverse events. Each drug carries a slightly different risk, and because of this, switching from one to another is not uncommon.[16]

A meta-analysis reported that a large percentage of patients experienced at least one adverse effect: 67.8% overall, with 68.0% in the tirzepatide group and 67.1% in the semaglutide group.[17] Generally, the side effects were minor. The SURMOUNT-1 and SURMOUNT-2 trials reported that discontinuation rates ranged from 4.3% to 7.1%, depending on drug and dosage.[17] Overall, there is no clearly superior choice with respect to tolerability, and selection is largely an individual clinical decision.

The Next Step: Retatrutide

Retatrutide is an agonist that is still in clinical trials and represents the next step in the evolution of this class of drugs. Retatrutide is a triple agonist, activating GLP-1, GIP, and glucagon (GCG) receptors simultaneously. While semaglutide activates GLP-1 alone, and tirzepatide activates GLP-1 and GIP, retatrutide activates all three. The addition of glucagon receptor activation increases energy expenditure on top of the appetite suppression that the other two provide.[18]

In terms of tolerability, retatrutide's adverse effect profile is on par with the others. The real difference is efficacy: it outperforms both semaglutide and tirzepatide in every comparison. In Phase 3 studies, semaglutide resulted in roughly 14.9% weight loss at 68 weeks, tirzepatide produced 20.9% at 72 weeks, and retatrutide produced 28.7% at 68 weeks. [18,19]

Retatrutide remains an investigational drug and is not yet available outside of clinical trials. Eli Lilly's TRIUMPH Phase 3 program includes multiple trials expected to be completed throughout 2026, and if results are positive, regulatory submissions to the FDA could follow in late 2026 or 2027.[20]

Conclusion and Cautionary Note

Needless to say, these drugs are relatively new to the market, and the long-term effects have yet to be fully explored. Weight-loss pharmaceuticals have a long history of negative side effects and total demarketing. While this class of GLP-1 agonists holds promise to be life-changing drugs, the whole story is not known at this point. One important fact that is known is that the effect of these drugs disappears if use is discontinued. Given their popularity as weight-loss medications, patients are likely to experience a significant weight regain following discontinuation.

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An Explainable Artificial Intelligence Clinical Decision-Support System for Prehospital Traumatic Cardiac Arrest Based on International Trauma Resuscitation Guidelines

By Doeun Ham

Abstract

Traumatic cardiac arrest (TCA) is a distinct clinical entity whose modern management diverges sharply from that of medical cardiac arrest: contemporary guidelines prioritize the rapid, simultaneous correction of reversible causes—hypovolemia, hypoxia, tension pneumothorax, and cardiac tamponade (the HOTT framework)—over chest compressions and early epinephrine. Despite this consensus, prehospital providers frequently default to the medical-arrest paradigm, and the evidence base itself is muddied by studies that report dismal TCA outcomes while delivering non-TCA care. This paper presents the design and rationale of a clinical decision-support prototype, the TCA AI Assistant, that synthesizes five published guideline sources into a single inferable ruleset and returns a structured, source-cited recommendation in response to a free-text case description. The system couples a large language model—used solely to convert natural-language field narratives into a validated, structured fact set—to a deterministic forward-chaining rule engine of 55 rules across 12 clinical categories. Hard "withhold" gates suppress active-treatment recommendations when termination-of-resuscitation criteria are met, a five-entry conflict registry surfaces genuine inter-guideline disagreement rather than hiding it, and a three-tier output presents a five-second field card backed by collapsible reasoning and evidence layers. The motivating controversy—a 2019 study concluding that pulseless electrical activity "portends death" after TCA, which was criticized for treating its cohort with conventional ACLS rather than reversible-cause-first care—is used throughout as a case study in why a tool that enforces the correct paradigm, and that is honest about evidential uncertainty, may have value. The system has not been clinically validated and must not be used to guide patient care; this paper is a design and rationale contribution, and the limitations and a concrete validation pathway are discussed in full. All source code is openly available.

1. Introduction

Trauma is a leading cause of death worldwide across all age groups, and traumatic cardiac arrest (TCA)—the cessation of effective circulation following major injury—represents its most time-critical endpoint. Reported survival remains low, generally below 10%, with several series and systematic reviews placing mortality above 95% (Carenzo et al.; Schober et al.). Yet the prognosis is not uniform: where the underlying physiology is captured early, survival with good neurological recovery is achievable, and the modern literature has moved decisively away from regarding all TCA as futile (Weegenaar et al.).

The conceptual shift that drives this optimism is the recognition that TCA is mechanistically different from medical cardiac arrest. A medical arrest typically originates in a primary cardiac electrical or pump failure, for which chest compressions and epinephrine are the

mainstays. A traumatic arrest, by contrast, is usually the terminal expression of a small number of rapidly reversible mechanical and physiological insults, summarized by the mnemonic HOTT: Hypovolemia (exsanguination), Oxygenation failure (hypoxia), Tension pneumothorax, and cardiac Tamponade (Weegenaar et al.). Because it is often impossible to identify which insult is causative within the available seconds, guidelines recommend a standardized approach that addresses all reversible causes simultaneously, and they explicitly de-emphasize chest compressions, which may displace clot, worsen thoracic injury, delay definitive interventions, and are of uncertain benefit when the heart is empty (Weegenaar et al.).

This inversion of priorities is counterintuitive for providers trained primarily on medical resuscitation, and herein lies a practical problem. Under the cognitive load of a chaotic scene, clinicians are prone to anchoring on the familiar algorithm—beginning compressions and pushing epinephrine—precisely the behavior the TCA literature warns against (Ly et al.). The author's motivation for this project arose during an internship at a trauma center, where it became apparent that prehospital teams not infrequently approached TCA "in the wrong direction," and where a supervising cardiac surgeon repeatedly emphasized both the prevalence of this error and the unusually contested state of the TCA evidence base (Cho, H.M.). TCA is, relative to its lethality, an under-discussed topic, and—critically—there are no randomized controlled trials establishing its core management; the field rests on observational data and expert consensus (Weegenaar et al.; Carenzo et al.).

These two observations—that the correct paradigm is under-applied, and that the evidence is genuinely uncertain and occasionally self-contradictory—motivate a decision-support tool with two unusual design commitments: it should enforce the reversible-cause-first paradigm deterministically rather than leave it to recall under stress, and it should expose rather than launder the points on which its source guidelines disagree. This paper describes such a tool, the TCA AI Assistant, and the reasoning behind its architecture. Section 2 develops the motivating controversy in detail. Section 3 presents the system design. Section 4 walks through genuine engine output for representative scenarios. Sections 5 and 6 discuss what the design does and does not accomplish, including a frank account of why the system is not yet—and may never, in its current form, be—appropriate for clinical use.

2. A Controversy as Motivation: "Sign of Life or Death?"

The difficulty of reasoning about TCA is crystallized by a 2019 retrospective cohort study by Israr and colleagues, provocatively titled *Pulseless Electrical Activity Following Traumatic Cardiac Arrest: Sign of Life or Death?* The study examined 277 adult trauma patients who underwent prehospital cardiopulmonary resuscitation at two American College of Surgeons–verified Level 1 trauma centers. Pulseless electrical activity (PEA)—an organized electrical rhythm without a palpable pulse—is the most common rhythm encountered in TCA and is conventionally regarded as a "sign of life" that should prompt continued resuscitation. Some authors further advocate point-of-care cardiac ultrasound to detect cardiac wall motion (the

substrate of so-called pseudo-PEA, in which the heart is in fact still contracting) before deciding whether to terminate efforts.

Israr et al. reported that outcomes were uniformly dismal. Of 110 patients presenting with PEA, only one (under 1%) survived to hospital discharge; the presence of cardiac wall motion was associated with survival to admission but not with meaningful survival. The authors concluded that, following prehospital TCA, "PEA on arrival portends death," that cardiac wall motion was not associated with meaningful survival, and—most strikingly—that "heroic resuscitative measures may be unwarranted for PEA following pre-hospital traumatic arrest, regardless of" cardiac wall motion (Israr et al.).

The conclusion is arresting, and it was promptly contested. The central objection—articulated in the prehospital critical-appraisal community and representative of the wider reaction—was not statistical but methodological: the cohort had been managed under conventional advanced cardiac life support (ACLS), which is not the standard of care for TCA. By the study's own figures, approximately 85% of patients received epinephrine and a median of roughly 20 minutes of prehospital CPR was performed, while reversible-cause interventions were largely absent—only about half were intubated, and the field record describes no systematic attempt to decompress chests, control hemorrhage, or replace volume. In other words, the patients were treated for the wrong disease.

Under this reading, the study cannot license the inference its title invites. If a population in hemorrhagic or obstructive arrest is hypoperfused for twenty minutes while receiving compressions and epinephrine—interventions that are, in this context, of doubtful benefit or actively harmful—then its dismal survival measures the futility of the wrong protocol, not the inherent terminality of PEA. The critique's summary is blunt: resuscitation of TCA patients is not futile; it simply must be performed in the right way. The constructive counter-position is that providers must instead address the reversible causes directly—hemorrhage control, airway and oxygenation, chest decompression, and volume replacement—and rely on direct and indirect signs of perfusion to guide effort.

This dispute is the intellectual seed of the present system, for three reasons. First, it is a vivid instance of protocol-confounded evidence: a study whose conclusions are an artifact of the treatment its subjects received rather than of the condition under study. A tool that helps ensure TCA patients actually receive TCA care addresses the upstream cause of such confounding. Second, the controversy concerns precisely the decisions the system must encode—when an organized rhythm warrants continued effort, when chest compressions help versus harm, and when resuscitation should be withheld or terminated—so the design cannot avoid taking defensible positions on contested ground. Third, and most importantly, it establishes the epistemic posture the system should adopt. Where reasonable guidelines and experts disagree, the honest response is neither false confidence nor paralysis, but transparency: state the default action, name the disagreement, and cite who holds which position. That posture is built into the architecture described next.

3. System Design

3.1 Design goals

Four goals shaped the system, each traceable to the problems above:

1. Enforce the correct paradigm. Reversible-cause-first management should be the default the tool produces, not a fact the provider must recall under stress.
2. Be deterministic and auditable. Identical inputs must yield identical outputs, and every recommendation must trace to the specific rule and source guideline that produced it. A field decision-support tool that cannot explain itself is unusable and unsafe.
3. Be honest about uncertainty. Where the underlying guidelines diverge, the divergence must be surfaced rather than silently resolved, because in a field with no randomized evidence, a hidden default is an unaccountable one.
4. Be readable in five seconds. The primary output must be a glanceable field card; depth must be available on demand but never imposed on a provider managing an arrest.

3.2 Synthesized source guidelines

The knowledge base merges the clinical logic of five published sources, chosen to span the major traditions of TCA guidance—civilian prehospital, European resuscitation, military/tactical, governance of termination-of-resuscitation, and a recent integrative review (Table 1). Each rule in the system carries the set of sources that support it, so that the provenance of every recommendation is explicit. Because the sources were written by different bodies for different operating environments, they agree on the great majority of management but diverge on several specific questions; those divergences are handled explicitly (Section 3.6).

Code	Source	Role in the synthesis
FPHC 2024	Faculty of Pre-Hospital Care, RCSEd — Pre-hospital management of traumatic cardiac arrest: 2024 position statement (Scand J Trauma Resusc Emerg Med 32:139)	Civilian prehospital HOTT detail, pediatric/obstetric considerations, termination criteria
ERC 2021	Lott et al. — European Resuscitation Council Guidelines 2021: Cardiac arrest in special circumstances (Resuscitation 161:152–219)	Special-cause ladder, signs-of-life and cardiac-motion criteria, withholding/termination logic
TCCC 2026	Tactical Combat Casualty Care Guidelines 2026 — CoTCCC / Joint Trauma System	Tactical phasing (MARCH), blood-product ladder, needle decompression scope, hypothermia prevention

NAEMSP 2012	NAEMSP & ACS-COT — termination-of-resuscitation position statement for traumatic arrest (governance requirements)	Withholding/TOR governance: physician oversight, deceased-management, local exclusions
Schober 2024	Schober et al. — Traumatic Cardiac Arrest: A Narrative Review (J Clin Med 13:302)	Pathophysiology, pseudo-PEA, resuscitation-before-intubation, epinephrine nuance, exceptions

Table 1. The five guideline sources merged into the knowledge base. The conventional ATLS protocol (American College of Surgeons) is cited within the conflict registry as the recommendation that TCA-specific guidance de-prioritizes; Yamamoto et al. is cited as evidence on the harm side.

3.3 Architecture overview

The system is a web application with a deliberately bipartite structure (fig. 1). A provider describes a case in ordinary language—mechanism, vital signs, examination findings, setting, and provider capability. A large language model (Google Gemini 2.5 Flash, accessed through the Vercel AI SDK) performs only the task of translating that narrative into a structured set of facts conforming to a fixed 43-key schema, validated by a strict Zod type contract. The model is explicitly instructed to set only those facts of which it is reasonably confident, to leave unknowns null, and to ask a single focused follow-up question when a missing fact would change management. It is forbidden from inventing recommendations.

The validated fact object is then passed to a deterministic forward-chaining rule engine, which performs all clinical reasoning: it derives secondary facts, evaluates the ruleset, resolves safety gates, scores the likely reversible causes, assembles a categorized and source-cited report, and surfaces any inter-guideline divergences that the firing rules touch. The model never sees the rules and never decides care; the engine never sees free text. This separation—elaborated in Section 3.8—is the system's central design idea.

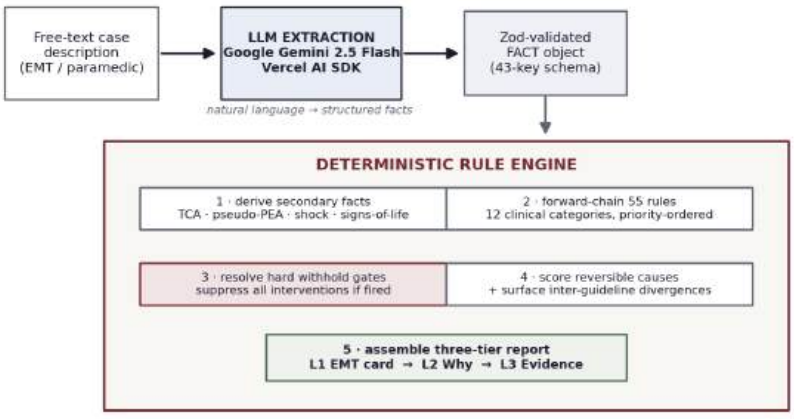


Fig. 1. End-to-end architecture. The generative component performs language understanding only; all clinical decisions are made by the deterministic engine and are fully auditable.

3.4 Knowledge representation

Clinical knowledge is expressed as data, not code. Each of the 55 rules is a plain object with an identifier, a clinical category, an urgency priority, a logical condition, an action string, the set of supporting sources, and an optional pointer into the conflict registry. Conditions are written in a small declarative language of comparators (equality, membership, numeric thresholds) and boolean combinators (all, any, not), which the engine interprets. Representing rules as inert data, rather than as imperative branches, is what makes the system auditable: the entire clinical logic can be read, reviewed, and revised as a table, and every fired rule can report exactly why it fired and on whose authority.

A representative rule, lightly reformatted, illustrates the form:

> id: "C02-DONT-PUMP", category: IMMEDIATE, priority: 2
> when: TCA and not(medical cause) and any(hypovolemia, tension pneumothorax, tamponade is suspected/confirmed)
> then: "Don't pump an empty heart" — chest compressions are lower priority than treating reversible causes in hypovolemic / obstructive TCA.
> sources: [ERC 2021, FPHC 2024, Schober 2024]

The 55 rules are organized into 12 categories that double as the print order of the report, running from the most decision-altering to the most downstream: triage/safety gates, cautions, immediate reversible-cause actions, then airway, breathing, and circulation (the operational expansion of HOTT), procedures (tamponade and thoracotomy), drugs, neurological/disability considerations, special populations (pediatric and obstetric), diagnostics (point-of-care ultrasound), and disposition/transport/post-ROSC care. Within a category, rules are ordered by an explicit urgency priority. This ordering encodes the paradigm directly: when a case is classified as TCA, the immediate-actions block—"address reversible causes simultaneously" and "don't pump an empty heart"—is structurally guaranteed to print above compressions and drugs.

3.5 The inference engine

Given a fact set, the engine executes a fixed pipeline.

Derivation. Before any rule is evaluated, the engine computes secondary facts from the primaries. The core derivation is the definition of TCA itself: trauma, unresponsive, and pulseless together. It also derives peri-arrest (trauma with a weak pulse), hemorrhagic shock, and—clinically the most important—pseudo-PEA, defined as an organized or PEA rhythm with cardiac motion present on ultrasound. If signs of life are not explicitly stated, the engine infers them from responsiveness, pulse, or cardiac motion rather than guessing. This derivation step is where the system operationalizes the very distinction at the heart of the Section 2 controversy: pseudo-PEA is treated as a beating heart to be supported by treating its cause, not as an electrical curiosity to be compressed.

Forward chaining. The engine evaluates every rule's condition against the derived fact set and collects those that fire. Because conditions reference derived as well as primary facts, a

single pass suffices; the design favors transparency over the incremental re-derivation of a classical production system.

Gate resolution. Two rules are designated hard withhold gates, corresponding to the criteria for withholding resuscitation—no signs of life with injuries incompatible with survival or a sufficient no-signs-of-life interval, and the NAEMSP/ACS-COT combination of apnea, pulselessness, and absent organized electrical activity. If either gate fires, the engine discards all active-treatment rules and retains only the triage/safety gates. This is a deliberate safety inversion: when the evidence says to stop, the tool must not simultaneously present a menu of interventions, which would be both confusing and ethically wrong.

Cause scoring and report assembly. Independently of the rules, the engine scores the candidate reversible causes—tension pneumothorax, tamponade, hemorrhage/hypovolemia, hypoxia/airway obstruction, and primary medical cause—using a transparent additive model over the relevant findings, producing a ranked list with bounded confidence percentages. Finally it groups the fired rules by category, attaches the conflict-registry entries that any fired rule references, and constructs the tiered report described in Section 3.7.

3.6 The conflict registry: making disagreement first-class

Synthesizing five guidelines written by different bodies inevitably exposes genuine disagreement. The temptation in a decision-support tool is to resolve such conflicts silently and present a single confident answer. In a field with no randomized evidence, that is precisely the wrong move—it manufactures false certainty and obscures the points a thoughtful clinician most needs to weigh. The system therefore treats disagreement as a first-class object: a five-entry conflict registry (Table 2) records, for each contested question, the position of each source and a stated default resolution. When a rule that touches a contested question fires, the engine attaches the corresponding registry entry to the report's evidence layer, so the provider sees both the default action and the fact that authorities differ on it.

Contested question	Representative divergence	System default resolution
First-line chest decompression	FPHC/ERC prefer thoracostomy; TCCC makes needle decompression first-line by scope; Schober calls the superiority of thoracostomy disputable	Scope-dependent: thoracostomy if the provider is credentialed, otherwise large-bore needle decompression with recheck
CPR duration before termination	NAEMSP notes the science is unclear; ERC sets no fixed time; Schober mentions an optional, non-evidence-based additional interval	No mandated number; terminate once reversible causes are addressed with no ROSC and no cardiac motion, under a locally defined interval and physician oversight

Early epinephrine	The conventional ATLS protocol recommends epinephrine in trauma resuscitation (ACS, ATLS 10th ed.; noted in Yamamoto et al.); Schober/ERC/FPHC de-prioritize it in hypovolemic/obstructive TCA, and Yamamoto et al. report epinephrine associated with increased mortality.	Do not prioritize early epinephrine in hypovolemic/obstructive TCA; reasonable in spinal-cord-injury/neurogenic relative hypovolemia
Crystalloid use	FPHC restricts it to imminent arrest with blood unavailable; ERC treats it as a fallback to blood; TCCC reserves crystalloid largely for burns	Blood-first for hemorrhagic TCA; crystalloid only when blood is unavailable
REBOA / aortic occlusion	FPHC notes an experimental status and a harm signal; ERC calls the role undetermined; Schober reports debated indications	Not routine; only under specific protocols and governance, never delaying definitive hemorrhage control

Table 2. The conflict registry. Rather than hiding inter-guideline disagreement behind a single answer, the system records each contested question, the sources' positions, and a transparent default that the provider can see and override.

3.7 Three-tier progressive disclosure

The report is layered to match the cognitive reality of an active resuscitation. Level 1 (the EMT card) is the default and is designed to be read in under five seconds: a single-line classification headline (e.g., TRAUMATIC CARDIAC ARREST), the most likely reversible cause with a confidence percentage, an ordered list of immediate actions, secondary concerns, a disposition line, and an overall confidence band. To keep this layer uncluttered and safe, the engine strips evidence-mode language—survival statistics, guideline-history debate, the "empty heart" slogan, epinephrine controversy—from the action lines by construction. Level 2 ("Why?") exposes the clinical reasoning: which cause the findings point to and why. Level 3 (Evidence) reveals every fired rule with its identifier, supporting sources, and any attached conflict-registry entry. A provider who needs only the next action never has to read past the first card; a medical director auditing the tool can read all the way down to provenance.

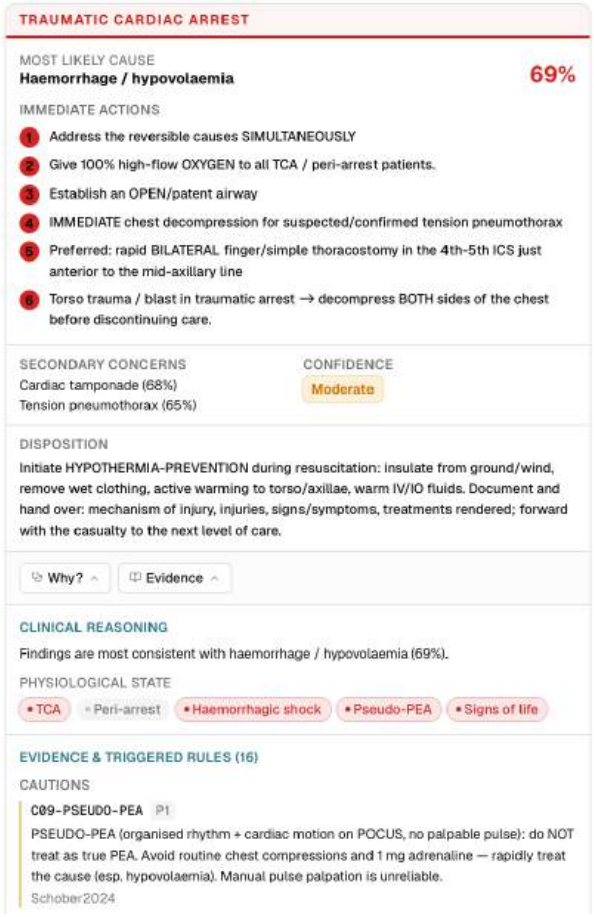


Fig. 2. Report Example of Scenario 1 in Table. 3. EMT Card with level 2, 3 revealed.

3.8 Separation of concerns

The decision to use a language model for extraction but never for inference (fig. 3) is the system's most consequential safety choice. Language models are excellent at the genuinely hard, fuzzy task of mapping a messy field narrative—"stabbed in the left chest, no pulse, belly's rigid, we've got a King airway in"—onto structured facts. They are, however, probabilistic: the same prompt can yield different completions, and they can produce fluent but unfounded clinical claims. Those failure modes are tolerable when confined to fact extraction, where a wrong fact is a bounded, inspectable error that a provider can correct, but they are intolerable in the inference itself, where they would make recommendations non-reproducible and unaccountable.

By contrast, the rule engine is deterministic: identical facts always produce identical output, every line cites its source, and the whole logic is reviewable as data. Placing the fact set as a hard boundary between the two halves means no clinical inference is ever delegated to a stochastic process. The model fixes 'what is true about the patient'; the engine decides 'what to do about it'. This is also what makes the tool teachable and defensible: a recommendation can always be traced back to a named rule and a named guideline, never to an opaque model weight.

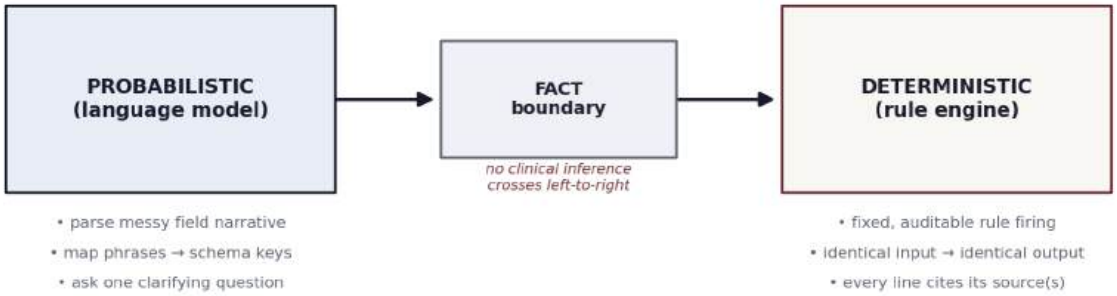


Fig. 3. Separation of concerns. The fact set is a hard boundary: the model never decides care, and the engine never reads free text.

4. Worked Examples

Because the engine is deterministic, its behavior can be exhibited exactly. The traces below are the system's genuine output for four fact sets that probe its core logic; they illustrate the engine's reasoning and ***not*** validated clinical recommendations (Section 6). Table 3 summarizes all four; the first is then narrated.

Scenario (key inputs)	Classification → primary cause	Rules fired	Divergences surfaced	Behavior
Penetrating chest, pulseless, organized rhythm + cardiac motion, suspected tamponade + hemorrhage + tension pneumothorax; thoracostomy-capable	TCA → Hemorrhage / hypovolemia (69%)	16	Thoracostomy; epinephrine	Full reversible-cause workup; pseudo-PEA recognized
Blunt, pulseless, organized rhythm + cardiac motion, suspected hypovolemia	TCA → Hemorrhage / hypovolemia (65%)	13	Epinephrine	Pseudo-PEA caution fires; blood + TXA prioritized
Blunt, pulseless, no signs of life 18 min, asystole	TCA → (withhold)	2	none	Withhold gate suppresses all interventions
Trauma patient, pulseless, shockable rhythm, suspected medical cause	TCA → Primary medical cause (60%)	8	none	Switches to medical paradigm: defibrillate + DO compress

Table 3. Genuine engine output for four scenarios. Note the contrast between the withhold case (interventions suppressed) and the shockable/medical case, where the system deliberately restores chest compressions—demonstrating that "deprioritize compressions" is conditional, not absolute.

4.1 A representative trace

Consider the first scenario: a prehospital patient with a penetrating chest wound, no pulse and no response, an organized rhythm with cardiac motion on ultrasound, and suspected tamponade, hemorrhage, and tension pneumothorax, attended by a provider credentialed to perform thoracostomy. The engine derives TCA, hemorrhagic shock, and pseudo-PEA, then fires 16 rules. Its Level-1 card classifies the case as TRAUMATIC CARDIAC ARREST, ranks hemorrhage/hypovolemia as the leading cause at 69% confidence with tamponade (68%) and tension pneumothorax (65%) as secondary concerns, and lists the immediate actions in paradigm order:

1. Address the reversible causes (HOTT) simultaneously — this takes priority over chest compressions and early epinephrine.
2. Give 100% high-flow oxygen.
3. Establish an open/patent airway.
4. Immediate chest decompression for suspected/confirmed tension pneumothorax.
5. Preferred: rapid bilateral finger/simple thoracostomy in the 4th–5th intercostal space.
6. In torso trauma / blast arrest, decompress both sides of the chest before discontinuing care.

Beneath the card, the circulation block adds external-hemorrhage control, early blood products, a blood-product order, tranexamic acid, and source control; the procedures block flags that resuscitative thoracotomy may be indicated for penetrating injury with recent signs of life; and the diagnostics block notes the role of point-of-care ultrasound. Crucially, the evidence layer attaches two conflict-registry entries—on chest decompression and on epinephrine—so the provider is told, at the point of decision, that the choice between thoracostomy and needle is scope-dependent and that early epinephrine is contested. The pseudo-PEA caution fires explicitly, instructing the team not to treat the organized rhythm with cardiac motion as true PEA: do not default to compressions and a milligram of epinephrine, but rapidly treat the cause. This is the precise management whose absence, in the Section 2 cohort, plausibly drove the dismal outcomes that were then misattributed to PEA itself.

The contrast across the remaining three scenarios is the point. The withhold case fires only the two safety gates and suppresses every intervention. The shockable-rhythm case, where a medical etiology is suspected, reverses the compression guidance—"defibrillate immediately" and "do perform high-quality chest compressions" both fire—demonstrating that the system's de-emphasis of compressions is a conditional consequence of the hypovolemic/obstructive mechanism, not a blanket rule. A tool that got this wrong would be as dangerous as the error it was built to prevent.

5. Discussion

The system's contribution is not a new clinical claim but an architecture for encoding contested, consensus-based emergency guidance in a form that is simultaneously prescriptive and honest. Four aspects deserve emphasis.

Determinism as a clinical, not merely technical, choice. It would have been simpler to let a language model read the case and answer directly. That design fails the auditability requirement and reproduces, at the level of the tool, the very unaccountability that makes the TCA evidence base hard to trust. By confining the model to extraction and routing all reasoning through inspectable rules, the system can justify every line it emits. In a domain governed by consensus rather than trials, where a recommendation's authority is exactly the named guidelines behind it, this traceability is the product.

The conflict registry as epistemic honesty. Most decision-support tools optimize for a single confident answer. The TCA literature does not support that posture on questions such as decompression technique, epinephrine timing, or termination interval. Surfacing disagreement, with attribution, respects the clinician's judgment and mirrors how an experienced medical director actually advises—"do X by default, but be aware the guidelines are split here." It also future-proofs the tool: as evidence accrues, a registry entry can be revised in one place without rewriting the rules that reference it.

A direct answer to the motivating controversy. The Israr cohort's outcomes were plausibly an artifact of non-TCA care delivered to TCA patients (Israr et al.). A tool whose default output, for exactly that presentation, is reversible-cause-first management—blood, decompression, hemorrhage control, oxygenation—and which explicitly recognizes pseudo-PEA as a beating heart rather than a rhythm to compress, is aimed squarely at the upstream behavior that produced the confounding. The same tool refuses to over-claim: it withholds when criteria are met, it names the points of genuine doubt, and it switches to a medical paradigm when the mechanism warrants. The aspiration is modest and specific—to make the right paradigm the path of least resistance under stress, while being candid about what is and is not known.

Relation to prior work. Rule-based clinical expert systems have a long lineage, from MYCIN onward (Shortliffe); the present system's novelty is not the inference paradigm but the combination of guideline synthesis with an explicit conflict registry, and the use of a modern language model strictly as a natural-language front end to a deterministic core. That hybrid lets the tool accept the unstructured input of a real field report while preserving the accountability of a classical expert system.

6. Limitations and the Path to Validation

The most important limitation is stated plainly and without qualification: this system has not been clinically validated and must not be used to guide the care of any patient. The author is neither a physician nor a licensed prehospital provider, and the system's outputs have not been reviewed against real cases by qualified clinicians. The remaining limitations explain why such validation is both necessary and non-trivial.

- No ground truth, by the nature of the field. There are no randomized controlled trials of core TCA management; the synthesized guidelines themselves rest on observational data and expert consensus, and they disagree on the very questions the tool must answer. A tool built on contested inputs cannot be more certain than its inputs, and its "correctness" can only ever be defined relative to a chosen reference standard.
- The extraction layer is a failure surface. The deterministic guarantees apply only downstream of the fact set. If the language model mis-extracts a fact—misreading mechanism, missing a sign of life, or mis-coding a rhythm—the engine will reason flawlessly from a wrong premise. The system mitigates this by extracting conservatively and asking focused questions, but the error mode is real and would need to be characterized empirically before any field use.
- Synthesis fidelity. The mapping from five prose guidelines onto 55 rules and a five-entry conflict registry encodes the author's interpretation. Each rule's condition, action, source attribution, and default resolution requires independent verification by domain experts; a single mis-encoded threshold could be clinically meaningful.
- Scope. The knowledge base targets the prehospital and early in-hospital phases of adult TCA, with limited pediatric and obstetric coverage. It does not address definitive surgical care, and the source labels should be checked against the exact editions intended (for example, the termination-of-resuscitation governance is drawn from the NAEMSP/ACS-COT position; the precise year and citation should be reconciled with the version the implementer adopts).

A credible validation pathway would proceed in stages: first, expert review of the knowledge base itself—having trauma and prehospital specialists confirm each rule, source attribution, and conflict default against the primary guidelines; second, retrospective case vignette testing, running de-identified TCA scenarios with known expert-adjudicated management through the system and measuring agreement, with particular attention to the withhold gates and the medical-versus-traumatic classification, where errors are most consequential; third, characterization of the extraction layer by comparing model-extracted facts against clinician-coded facts across many narratives; and only then, if warranted, prospective evaluation in a simulation environment under medical direction. Each stage gates the next. The present paper is intended to make the first stage possible by laying the design and its assumptions fully open.

7. Conclusion

Traumatic cardiac arrest is lethal, time-critical, under-discussed, and managed by a paradigm that runs counter to the medical-arrest reflexes of many providers—conditions under which both clinical error and confounded evidence flourish. The 2019 "sign of life or death?" controversy shows how readily TCA outcomes can be misread when the wrong protocol is applied and then blamed on the patient's physiology. The TCA AI Assistant is a design response:

a deterministic, source-cited rule engine that enforces reversible-cause-first management, suppresses intervention when withholding is indicated, switches paradigms when the mechanism demands, and—uniquely—surfaces rather than hides the points on which its guidelines disagree, all behind a five-second field card fed by a language model used only to understand the case. The system is a prototype and an argument, not a validated instrument; its value, if any, lies in showing how contested emergency guidance can be encoded in a form that is at once prescriptive enough to be useful and honest enough to be trusted. Whether it achieves that in practice is an empirical question that the openly available implementation is meant to let qualified clinicians answer.

Code and Data Availability

The complete source code—knowledge base, inference engine, and chat interface—is openly available under the MIT License at https://github.com/doeunham17/tca-ai-assistant. The repository documents the five synthesized guideline sources, the 43-key fact schema, the 55-rule knowledge base, and the five-entry conflict registry described in this paper.

A live web deployment of the system is available at https://tca-ai-assistant.vercel.app, allowing users to interact with the complete guideline-synthesized decision-support system through a browser-based interface. The deployed application implements the same knowledge base, inference engine, and explainable reasoning framework described throughout this paper, enabling direct evaluation of the proposed system.

Acknowledgements

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When Investors Know Better:Information, Emotion, and Group Culture in Shenzhen's Attitude-Behavior Gap By Yuchen Xu

Abstract

Chinese retail investors are often described as emotional, speculative, or trapped inside local information bubbles. This paper argues for a more precise and more urgent explanation: many investors already value evidence, global information, and caution, but their behavior is shaped by the groups and cultures in which decisions are made. Using an original mixed-methods survey of 197 Shenzhen respondents, including 124 active A-share investors and a sample in which 48.7% have finance experience, this study examines the attitude-behavior gap between what investors say they believe and what they actually do. The findings are deliberately paradoxical. On one hand, 89.8% of respondents report consulting at least two sources before major decisions, 78.7% seek different or opposing views, and 84.3% read news or opinions originating from non-Chinese sources. On the other hand, among active investors, 77.4% admit making at least one gut-feeling trade in the past year, 62.1% report losses, and 62.1% say they would keep investing after a loss rather than exit. Rather than treating this contradiction as simple ignorance, the paper compares the findings with behavioral finance, social psychology, and group-culture literature. It argues that investor irrationality is not only a private cognitive failure; it is often socially produced through chat groups, family encouragement, status pressure, emotional stories, and cultures where dissent is unsafe or inconvenient. The research contribution is therefore empirical, theoretical, and practical: it documents Shenzhen investors' openness to global information, reframes the attitude-behavior gap as a group-culture problem, and proposes a culture-design framework for converting rational attitudes into repeated social practices. The paper concludes with applications for Shenzhen investor education, high-pressure schools such as SCIE, and organizations seeking healthier decision cultures.

Keywords attitude-behavior gap; Shenzhen; behavioral finance; group culture; psychological safety; critical thinking; foreign language education

Research contribution

This paper moves the question from "Do investors know enough?" to "What group culture makes good judgment easier or harder to practice?" The survey shows that Shenzhen investors are often open, educated, and self-aware; the danger is that social routines can still make impulsive behavior feel normal.

1. Introduction: The Moment Before a Bad Trade

A common investment mistake does not always begin with ignorance. It often begins in a group chat. Someone posted a screenshot of a rising stock. Another person says an uncle, a colleague, or a friend at a securities firm has heard something. A third person adds urgency. For a few minutes, the room feels certain. The investor may know, in a calm moment, that one should

check fundamentals, compare sources, and consider downside risk. But inside the social moment, hesitation feels like weakness and speed feels like intelligence.

This small scene matters because it is not rare. It is the ordinary doorway through which private savings can be exposed to public excitement. The problem is quite precisely because it looks normal: friends sharing tips, family members encouraging one another, online communities reacting quickly to market movements, and investors telling themselves that they can always exit later. A financial mistake is rarely only financial. It can become household stress, family conflict, shame, and a loss of trust in one's own judgment.

This is the puzzle at the center of the present study. Many investors do not lack the vocabulary of rationality. They know words such as diversification, research, risk, and long-term thinking. They can explain, after the fact, why herd behavior is dangerous. Yet under pressure, many still follow gut feelings, social signals, and emotionally charged narratives. The result is an attitude-behavior gap: a gap between the values people endorse and the behaviors they actually repeat.

Shenzhen is an especially useful site for studying this gap. It is a young, mobile, finance-and-technology city, filled with people who are comfortable with innovation and global information. It is not a simple case of isolated investors who have no access to outside perspectives. If attitude and behavior diverge even in Shenzhen, then the problem cannot be explained only by lack of information. Something else is happening: the culture around decision-making is teaching people one lesson while their formal knowledge teaches another. This paper asks three research questions. First, where do Shenzhen investors show gaps between rational attitudes and actual investing behaviors? Second, how open are they to multiple sources, foreign perspectives, and lessons from other countries? Third, what kinds of education and group-culture design could help investors, students, and organizations convert good intentions into better habits?

2. Literature Review and Conceptual Framework

2.1 Behavioral finance: emotion does not replace reason; it bends it

Classical finance often imagines investors as rational actors who process information and choose the best available option. Behavioral finance complicates that picture. Prospect theory shows that people do not experience gains and losses symmetrically; losses often feel more powerful than equivalent gains (Kahneman and Tversky). This helps explain why investors may hold losing positions too long or chase losses instead of calmly exiting.

The disposition effect literature provides a closely related warning. Shefrin and Statman describe the tendency to sell winners too early and ride losers too long, while Odean shows that investors can be reluctant to realize losses. These patterns fit the emotional difficulty of admitting that an earlier judgment was wrong. In practice, an investor may not be choosing between two stocks; psychologically, the investor may be choosing between preserving self-respect and accepting evidence.

Other research shows that individual investors often trade too frequently and with too much confidence. Barber and Odean's work on retail trading suggests that people can mistake activity for skill; their later work on overconfidence shows how confidence can become costly when it increases trading volume. For the present study, this literature matters because many Shenzhen respondents did not simply report risk exposure. They reported precisely the behaviors that behavioral finance would predict: gut-feeling trades, chasing after losses, and social influence.

2.2 Chinese retail investors and market context

Recent work on China emphasizes that its stock market differs from the United States because retail investors play a larger role and government participation is more visible. Tan, Zhang, and Zhang review a large body of research on Chinese trading behavior and emphasize heterogeneity among retail investors, information processing differences, and the institutional context of China's market. This literature prevents an oversimplified conclusion. Chinese retail investors are not one type of person; they vary by information access, capital, education, and experience.

At the same time, retail participation can make emotional and social dynamics especially important. Herd behavior, rumor diffusion, and attention-driven trading do not stay inside individual minds. They move through social networks. Banerjee's model of herd behavior and Bikhchandani, Hirshleifer, and Welch's theory of informational cascades help explain why people may copy others even when private doubts exist. When enough people act as if they know, uncertainty becomes socially hidden.

This point is crucial for Shenzhen. A city can be modern, educated, and globally connected while still producing local cascades. A person can read international news in the morning and still buy a stock at night because a chat group feels urgent. The literature on herding therefore needs to be connected to the daily architecture of information: WeChat groups, finance forums, family advice, influencer commentary, and workplace conversations.

2.3 The attitude-behavior gap: knowing is not the same as doing

The attitude-behavior gap is often discussed outside finance, especially in environmental behavior. Kollmuss and Agyeman show that people can express concern while failing to act consistently with that concern. The concept translates powerfully to investing. An investor can believe in research yet buy after a rumor; believe in risk control yet double down after a loss; believe in multiple perspectives yet ignore a warning that threatens a hopeful story.

This gap matters because it changes what education must do. If the problem were only that investors lacked facts, then adding facts would be enough. But if emotions, status, attention, and group norms interrupt the use of facts, then education must also alter the social conditions under which facts are used. The goal is not only smarter individuals. It is a better information culture.

2.4 Groups, psychological safety, and socially produced irrationality

A group is not just several individuals standing near one another. A group develops roles, rituals, expectations, rewards, and unspoken punishments. Culture is visible not only in what people claim to value, but in what they repeat. A financial chat group may claim to value rational analysis, but if the fastest, loudest, most confident tip receives the most attention, then the lived culture rewards speed and confidence more than evidence.

Psychological safety is central here. Edmondson defines it as a shared belief that a team is safe for interpersonal risk-taking. In investment communities, a lack of psychological safety can make people hide losses, pretend certainty, or avoid asking basic questions. Groupthink research adds another warning: groups can produce shared illusions when members prefer agreement and confidence over disagreement and testing (Janis). Bénabou extends this logic to organizations and markets, arguing that denial and distorted belief can become collective rather than merely individual.

This paper therefore treats investing as a cultural practice. The key question becomes: What repeated actions would make rational investing socially easier? A culture cannot simply announce, "Be rational." It must practice rationality through small routines: a pause before action, a counterargument before every recommendation, a safe way to admit uncertainty, and a norm that a good investor is not the person who sounds most certain, but the person who can test a belief without ego.

2.5 Education, language, and cognitive distance

Education matters, but not only as content delivery. Debate, logic, history, philosophy, rhetoric, and foreign language learning train people to move between perspectives. They ask students to compare claims, test evidence, identify assumptions, and understand that different communities may frame the same problem differently. For investors, this can reduce dependence on one information channel and make dissent less threatening.

Foreign language learning is especially practical in a city like Shenzhen. It allows access to international news, foreign analysts, translated and untranslated research, and examples from other markets. But its deeper value is cultural: it trains the mind to notice that the same event can be described through different categories. Keysar, Hayakawa, and An's work on the foreign-language effect suggests that using a foreign language can reduce some decision biases by creating cognitive and emotional distance. For investors, this does not mean that English automatically makes a person rational. It means that stepping outside one's normal linguistic and cultural frame can make automatic emotional reactions easier to notice.

This educational lens also connects to school culture. The World Health Organization reports that adolescent mental health is a global public-health issue, and the CDC emphasizes that school connectedness can protect student well-being. A school that teaches high-level academic skills while leaving stress, belonging, and help-seeking to chance is also creating an attitude-behavior gap: it may say students matter, while its routines make students feel like performance machines.

2.6 What this study adds to the literature

Existing literature has already shown that investors are vulnerable to biases, that Chinese retail investors operate in a distinctive market structure, and that groups can produce conformity and denial. This study adds a Shenzhen-based mixed-methods perspective that places these themes together. It does not merely ask whether investors are irrational. It asks why rational language can coexist with risky practice.

The key contribution is the finding of information-open irrationality. Many respondents report seeking multiple sources, foreign-sourced information, and opposing views; yet many active investors still trade on gut feeling and social influence. This pattern challenges the simple stereotype that bad investing is caused by closed-mindedness or lack of access. The more disturbing possibility is that even open information environments can fail when group cultures make caution emotionally difficult to practice.

3. Methods

This study used an anonymous Chinese-language survey distributed over three weeks in late 2024 through Shenzhen-focused online channels, including a fintech WeChat group, a Shenzhen finance forum, and snowball sharing. After removing incomplete responses, the final sample contained 197 valid respondents. Of these, 82.7% lived in Shenzhen and 83.3% had lived there for at least two years. Approximately 48.7% currently work or have worked in finance, and 20.8% have a technology background. A total of 62.9% of the full sample, or 124 respondents, were active A-share investors and answered the detailed investment behavior questions.

The survey was designed as a mixed-methods instrument. Closed-ended questions measured investment habits, information sources, emotional influences, foreign-language exposure, critical-thinking education, and reactions to two short scenarios. Open-ended questions asked respondents to explain why people fail to gather comprehensive information, how foreign language learning may matter beyond communication, and which forms of education cultivate multi-perspective thinking.

Quantitative analysis consisted of descriptive frequencies and selected comparisons between investor-only and full-sample responses. Because the sample was non-random and urban, the results should be interpreted as exploratory rather than nationally representative. Qualitative analysis used thematic coding of open-ended answers, with attention to recurring explanations such as lack of time, limited channels, weak expertise, information overload, emotion, and social influence.

Survey structure

Survey area	What it measured	Why it mattered
Investment behavior	Losses, gut-feeling trades, loss response, profit-taking, risk exposure	Shows the behavioral side of the attitude-behavior gap
Information habits	Multiple sources, opposing views, independent bloggers, overload management	Shows whether investors value broad information in principle

Global perspectives	Foreign language, non-Chinese sources, learning from foreign crises, foreign expert warnings	Tests whether Shenzhen investors are more outward-looking than stereotypes suggest
Education	Logic/critical-thinking training, support for debate and reasoning courses	Identifies possible interventions for future investors and students
Scenarios	Data-driven warning vs. emotional friend-loss story	Compares how facts and narratives move caution

Ethics and limits

The survey was anonymous and did not collect exact age or identify financial records. This protects respondents but also limits verification. Self-reported data may contain social desirability bias, especially when respondents describe good habits such as consulting multiple sources. However, the high rate of admitted gut-feeling trades and reported losses suggests that many respondents answered candidly. Future work should compare survey responses with anonymized trading records and expand to other cities.

4. Results

4.1 A paradox: information openness beside risky behavior

The first striking result is that Shenzhen respondents do not appear closed-minded or indifferent to evidence. Among all respondents, 89.8% said they consult at least two sources before major decisions, and 78.7% said they actively seek different or opposing views before major money decisions. A large majority also preferred longer analytical reports over short emotion-driven snippets, with 65.5% choosing longer reports. These findings suggest that the language of analysis is widespread.

Yet the active-investor subgroup shows a much darker behavioral picture. Among the 124 respondents who invest in A-shares, 77.4% admitted that they had made at least one trade in the past year based on gut feeling rather than clear data or analysis. Meanwhile, 62.1% reported investment losses in the previous 12 months, and the same percentage said that after a loss they would keep investing in an attempt to recover rather than cut losses and exit.

This is the heart of the paper. The problem is not that respondents reject reason. The problem is that reason often loses at the exact moment it is most needed. A person can believe in evidence at noon and still follow a rumor at night. If multiplied across thousands or millions of similar decisions, this small psychological gap becomes a social and economic problem.

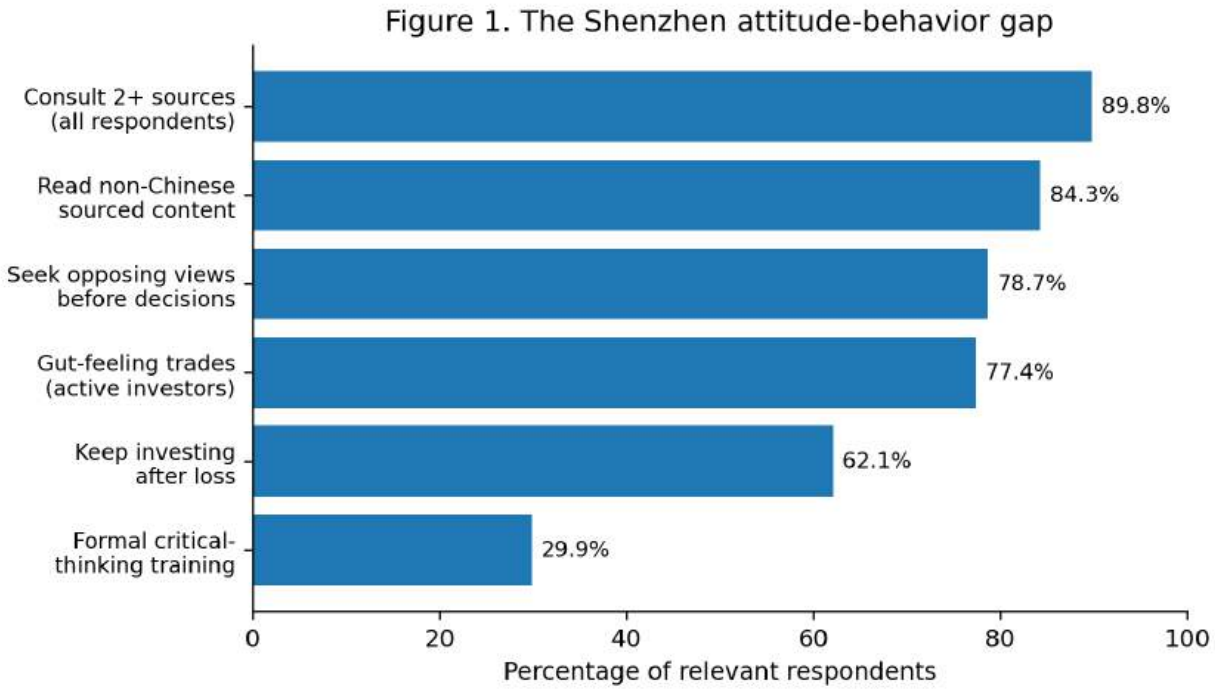


Figure 1. The largest percentages show rational information attitudes; the investor-only items reveal the behavioral gap.

4.2 Social influence is not background noise

The data also show that investment decisions are socially embedded. Among active investors, 60.5% said that family or friends encourage them to invest in stocks, and 44.4% belong to stock-trading chat groups or forums. This means that many investors encounter the market not as isolated analysts, but as members of small information communities. Advice, emotion, status, and pressure travel together.

Respondents were aware of the danger. In the full sample, 89.9% believed that social media hype increases high-risk investing. Yet awareness does not remove exposure. The same person can criticize hype and still remain inside a channel that produces it. This is a classic culture problem: the norm is recognized as dangerous, but the social setting keeps reproducing it.

4.3 Shenzhen investors are more globally open than stereotypes suggest

The openness results were one of the most encouraging findings. A slight majority, 56.4%, reported speaking at least one foreign language. More importantly, 84.3% said they read news or opinions that originate from non-Chinese sources, even when the material is translated into Chinese. In addition, 87.8% said they personally apply lessons from other countries' financial crises, and 86.8% said that warnings from authoritative foreign experts would make them more cautious.

These results complicate the assumption that Chinese retail investors are simply sealed inside domestic narratives. The Shenzhen respondents appear curious about the world and willing to learn from outside perspectives. However, global openness does not automatically

become disciplined behavior. The key issue is translation from exposure to practice: how does an investor move from reading a foreign analysis to actually resisting a local rumor?

4.4 Education demand for critical thinking exceeds actual training

Only 29.9% of respondents reported having systematically studied logic or critical thinking. Another 26.9% had some familiarity, while 43.1% had not studied it at all. This is important because many respondents are already operating in complex information environments. They are not simply choosing whether to buy or sell; they are judging sources, incentives, narratives, risk claims, and emotionally charged examples.

At the same time, 64.5% agreed that learning foreign languages helps people think more comprehensively, and most respondents supported courses such as debate and critical thinking. This suggests a strong gap between the kind of decision environment people face and the kind of training they have received. It also suggests an opportunity: investor education does not need to convince people that thinking matters. Many already believe that. It needs to teach them how to make thinking survive pressure.

4.5 Facts and stories both move caution

The scenario experiment compared two forms of warning. Scenario 1 presented a rational analyst warning: market risks, weak profits, tight liquidity, and uncertain outlook. Scenario 2 presented an emotional story: a friend followed the herd, lost most savings, and experienced regret and anxiety. Both scenarios affected respondents. 86.8% said the analyst warning would make them more cautious, while 79.7% said the friend-loss story would make them more cautious.

When forced to choose which had stronger impact, 59.9% selected the analyst warning and 40.1% selected the friend-loss story. This result is important for intervention design. A purely emotional campaign may feel manipulative; a purely analytical campaign may be forgotten. The data suggest that the strongest education should combine sober evidence with human consequence. People need charts, but they also need to remember what a bad decision can do to a life.

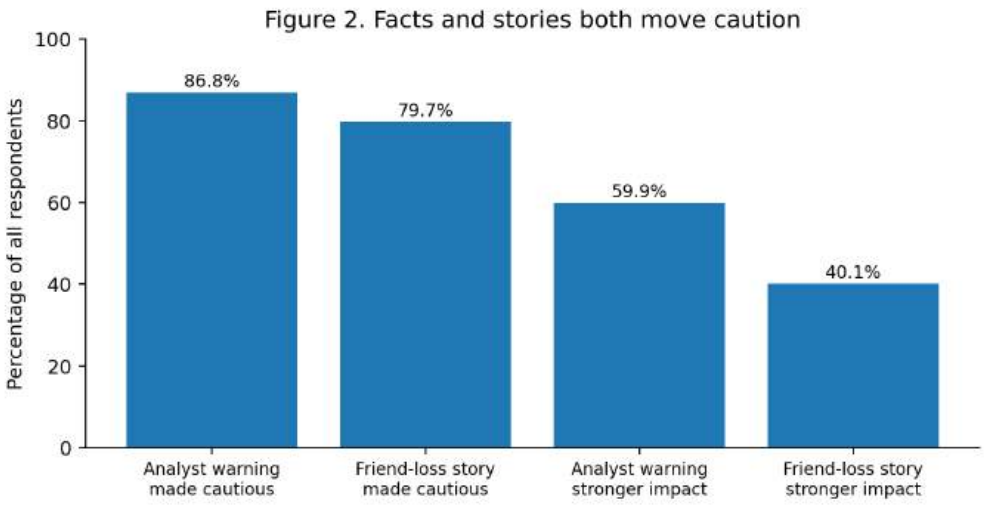


Figure 2. Scenario responses show that analysis had slightly greater reported impact, but personal stories still moved a large minority.

4.6 Qualitative themes: why people still fail to gather full information

Open-ended responses help explain the gap. Many respondents mentioned time cost: proper research is difficult, slow, and sometimes impossible for non-professionals. Others mentioned limited channels or expertise, suggesting that even motivated investors may not know how to evaluate specialized information. A third group emphasized information overload: when too many signals appear at once, people simplify by following familiar sources or group opinion. The most revealing themes were emotional and cultural. Respondents named blind confidence, confirmation bias, following the crowd, laziness, and the desire to recover losses. These explanations show that investors are not unaware of the problem. They can describe it. But the description is not correct. A person may know the name of a bias and still obey it when the market moves.

5. Discussion: Comparing the Findings with Existing Literature

5.1 Confirmation: behavioral finance appears in ordinary Shenzhen practice

The findings confirm several core claims from behavioral finance. Gut-feeling trades reflect overconfidence and limited attention. Continuing after losses reflects loss aversion, the disposition effect, and the emotional difficulty of realizing losses. Preference for social tips reflects herding and informational cascades. In this sense, Shenzhen investors are not outside the classic behavioral-finance story; they are a vivid local example of it.

However, the paper also shows that these biases do not operate in a vacuum. The investor is rarely alone with a spreadsheet. The investor is often surrounded by messages, friends, family, influencers, and a stream of emotionally loaded signals. This means that the unit of analysis should not only be the individual brain. It should also be the small group.

5.2 Extension: the respondents are not information-poor; they are culture-vulnerable

The most important extension of existing literature is the finding that many respondents are not information-poor in the simple sense. They report using multiple sources, reading foreign-sourced material, seeking opposing views, and respecting foreign expert warnings. This is not a picture of total insularity. It is a picture of people who often know what good judgment should look like.

That makes the problem more serious, not less. If investors behaved badly only because they lacked information, the solution would be straightforward: provide information. But if people behave badly even while valuing information, then the problem is more deeply social. It means the market's everyday culture can overpower education. It means investor-protection work must enter the spaces where decisions are socially rehearsed: chat groups, classrooms, family conversations, workplace discussions, and online communities.

5.3 A practical comparison: financial literacy versus decision culture

Financial literacy remains necessary. Investors should understand diversification, compounding, liquidity, fees, and risk. But literacy alone may not change behavior if the decision environment rewards speed, confidence, and belonging. A person who understands risk can still be embarrassed to slow down a group. A person who knows about diversification can still chase a friend's success story. A person who understands loss aversion can still double down because selling feels like failure.

This is why the proposed intervention is not only a curriculum but a culture blueprint. Education should not merely tell investors what to think. It should design the repeated actions that make thinking easier: decision journals, two-source checks, counter-thesis rules, cooling-off periods, rotating skeptics, and group norms that honor uncertainty. In behavioral terms, these are nudges; in cultural terms, they are rituals.

5.4 Why the stakes are larger than one portfolio

The dramatic implication of the data is not that some investors make bad trades. Everyone makes mistakes. The larger problem is that the same pattern can be repeated across families, schools, and organizations: people publicly value rationality while privately living inside cultures that make rationality hard to practice. In a market, this can mean herd buying and panic selling. In a school, it can mean students praising well-being while silently burning out. In an organization, it can mean leaders praising honesty while punishing bad news.

The same cultural mechanism appears in different settings. A dangerous culture does not always look cruel. Sometimes it looks efficient, ambitious, optimistic, or loyal. People want to belong, so they imitate. People fear embarrassment, so they hide uncertainty. People want hope, so they ignore warnings. By the time the consequences become visible, the culture has already done its work.

6. From Harvard Groups and Culture to a Culture Blueprint

Yolanda's Harvard Groups and Culture coursework adds a second intellectual center to the paper. The course direction emphasizes group dynamics, cohesion, cooperation, facilitation, leadership of small groups, and the translation of small-group skills into larger systems. Her Reflection 4 expresses the core lesson in simple terms: culture is designed and practiced, not merely announced; small repeated actions such as how people enter a room, who speaks first, and what behavior is not allowed become the culture itself.

This insight can be translated directly to investor education. If an investor group says it values caution, what happens when someone posts a hot tip? If it values evidence, what happens when nobody has checked the source? If it values humility, what happens when a member admits a loss? The answer to these questions is the culture. Values that cannot be observed in repeated behavior are not yet values; they are decorations.

The Culture Blueprint approach begins with mission, vision, values, induction, rituals, boundaries, and assessment. A good group should know what it is trying to attract and what it must gently repel. An investor-learning group should attract patience, curiosity, and willingness to be wrong. It should repel hot-tip performance, status games, and rumor addiction. A school well-being group should attract calm, confidentiality, and responsible peer support. It should repel gossip, savior behavior, and untrained therapy advice.

Figure 3. Culture-design loop for safer decisions

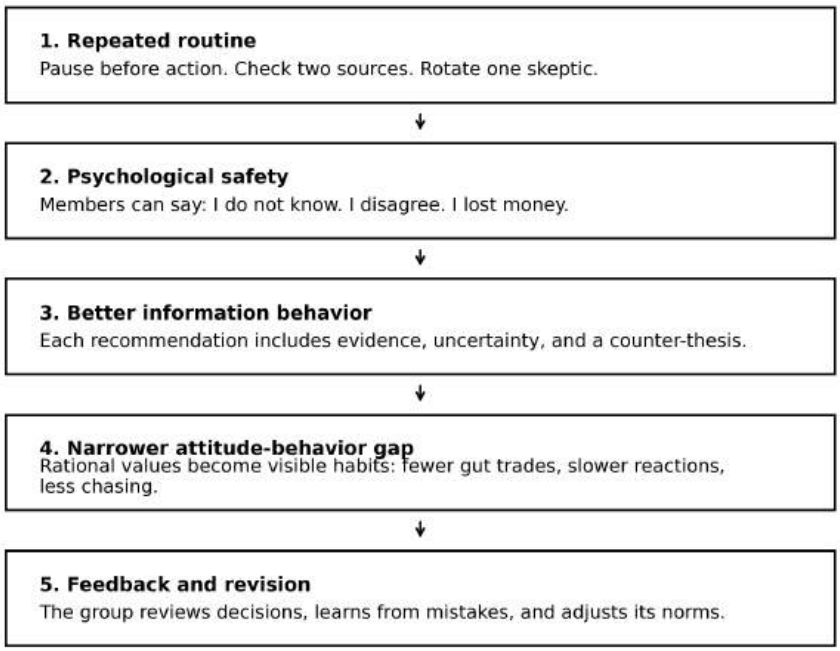


Figure 3. Revised culture-design loop. The graphic uses shorter labels and more spacing so the steps are readable.

6.1 Culture Blueprint table

Blueprint principle	Investor-culture version	School / organization version
Lay the foundation	Mission: help ordinary investors slow down, test evidence, and protect long-term security.	Mission: make care, voice, and responsible support part of everyday group life.
Attract and repulse	Attract patient learners; repel hot-tip performance, bragging, and rumor addiction.	Attract respectful peers; repel gossip, savior behavior, and untrained therapy roles.
Induct and initiate	The first meeting requires a source check, counter-thesis, and emotional-state note.	The first meeting teaches phone-away entry, confidentiality, optional sharing, and referral rules.
Serve and deliver	Every meeting gives one practical decision tool, not just motivational advice.	Every session gives one usable well-being practice and one safe way to seek adult help.
Engage and retain	Members return because the group makes them calmer and less alone in uncertainty.	Students return because the room feels predictable, respectful, and human.
Assess success	Track impulsive trades, counterarguments written, sources checked, and willingness to admit losses.	Track belonging, stress awareness, sleep reflection, help-seeking comfort, and leader debriefs.

7. Applications: Shenzhen, SCIE, and Beyond

7.1 Shenzhen investor education

For Shenzhen, the most direct application is an investor-education program that treats chat groups and social influence as part of the curriculum. A useful program would not only teach concepts such as diversification or valuation. It would train participants to practice a decision protocol before buying: write the claim, list two sources, name the emotion, add a counter-thesis, wait through a cooling-off period, and record what would change the decision.

Finance firms, community centers, online platforms, and schools could adapt this model. A securities company could run a "counter-thesis clinic." A community group could run monthly investment-decision debriefs. A platform could prompt users to compare a bullish and bearish argument before executing high-risk trades. The aim is not to shame retail investors. It is to design a culture where slowness, humility, and evidence have social support.

7.2 Schools such as SCIE: from achievement culture to support culture

The same framework applies to high-pressure international schools such as SCIE. In competitive schools, students may know that sleep, belonging, and mental health matter, yet still live inside routines that reward overwork and silence. The attitude-behavior gap is therefore not only financial. A school can say, "take care of yourself," while every visible reward teaches students to ignore their limits.

A student initiative like Whispering Soul should therefore be designed as a culture rather than a club poster. It needs predictable rituals, phone-away entry, confidentiality boundaries, optional sharing, referral rules, and adult supervision. Peer leaders should not act as therapists.

Their role is to create a safer small-group environment, notice when someone may need adult help, and make help-seeking feel less shameful.

This is where the paper becomes more than a finance study. It becomes a transferable model for social change. If small groups can change how students talk about stress, they can also change how investors talk about risk and how organizations talk about failure. The deep contribution is not one topic. It is the method: build cultures where truth can be spoken earlier.

7.3 Organizations and families

Organizations can use the same principles for risk culture. A company may claim to value transparency, but if employees are punished for bad news, the true culture is silence. A team can create a rotating skeptic role, a pre-mortem before major decisions, and a rule that uncertainty is written down rather than hidden. These practices turn psychological safety from a slogan into a procedure.

Families are also relevant. Many retail investors make financial choices with family influence. Families can create a simple rule: no high-risk investment is discussed only through excitement. Before money moves, someone must ask, "What could go wrong?" and someone must explain the opposing case. Such rituals may feel small, but the survey suggests that small moments are exactly where the gap opens.

8. Recommendations

Recommendation	Practical design
Teach critical thinking through financial scenarios	Use cases where students compare sources, identify incentives, write counterarguments, and explain what would change their mind.
Redesign investor chat groups	Add a group rule: no recommendation without a counter-thesis. Rotate one member each week to play skeptic.
Use both analytical warnings and human stories	Combine charts, data, and credible cautionary narratives. Avoid sensationalism; the goal is sober memory, not fear.
Promote multilingual information habits	Encourage investors and students to compare Chinese sources with foreign-sourced material, including translated research and international crisis histories.
Build psychologically safer learning spaces	Normalize saying "I do not know," "I was wrong," and "I need evidence." Make humility a respected behavior.
Measure culture, not only participation	Collect anonymous pre/post data on impulsivity, willingness to seek opposing views, belonging, stress, and comfort speaking up.

9. Limitations and Future Research

This study has several limitations. First, the sample is concentrated in Shenzhen and likely over-represents educated urban respondents. The findings should not be generalized to all Chinese investors without further research in other cities, rural regions, age groups, and income levels. Second, the data are self-reported. Respondents may exaggerate rational habits or

underreport risky behavior, although the high admission of gut-feeling trades suggests that self-criticism was present. Third, this study does not prove that foreign language learning or critical-thinking training causes better investment behavior. It only shows that respondents perceive these forms of education as valuable and that gaps remain where such training is absent.

Future research should combine survey data with anonymized trading records, follow investors over time, and test actual interventions. For example, one group of investors could join a structured culture-design program using counter-thesis rules and decision journals, while another group receives only standard financial-literacy material. Comparing changes in impulsive trades, information-source diversity, and emotional regulation would help determine whether culture design improves outcomes.

A second future direction is school-based. A supervised student well-being program could measure belonging, stress awareness, sleep habits, and help-seeking comfort before and after a six-session small-group intervention. Such a project would test whether the same culture-design principles that help investors slow down can also help students speak earlier before pressure becomes a crisis.

10. Conclusion: Better Groups, Better Decisions

This study began with a puzzle: Shenzhen investors often know what rational decision-making should look like, yet many still trade impulsively, follow social pressure, and struggle to act on their own principles. The survey results show that this is not because respondents are closed to information. Many are remarkably open to global perspectives, multiple sources, foreign expert warnings, and educational reform. The problem is that knowledge must survive the emotional and social moment of decision.

The most important lesson is that financial education should not stop at information. It should build cultures. A good decision culture makes caution visible, gives dissent a role, slows down emotional contagion, and treats uncertainty as a normal part of thinking rather than an embarrassment. It turns values into rituals. It makes the right action easier to repeat.

This insight extends beyond investing. In schools, it can help students build cultures where stress is noticed earlier and support becomes easier to seek. In organizations, it can help teams tell the truth before mistakes become disasters. In Shenzhen, it can help investors become not only more informed, but more stable, humble, and reflective. The final goal is not simply to produce better investors. It is to build groups where people can think clearly together, even when pressure is high.

Acknowledgment

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Latinamericanism and the Identity Limbo:
The Circumstances that Led to the Western Representation of Latin America Prevailing and Its Similarities to Middle Eastern Representation on the West By André Silva

Abstract

This article suggests the concept of Latinamericanism as a framework for understanding Latin American representation in the Western imagination and the "identity limbo," drawing from Edward W. Said's research on Orientalism while tracing parallels between Middle Eastern and Latin American representations through the lens of essentialism and the construction of an "Us" and "Them" mindset.

Keywords

Latinamericanism, Identity Limbo, Orientalism, Social Whitening, Latin American Identity

On January 03, 2026, the United States of America invaded the Bolivarian Republic of Venezuela to capture its de facto ruler (rather he is or not considered a legitimate ruler being irrelevant for the sake of this research), officially, for ruling over a drug cartel, "De los Soles," translated as *of the suns*, a reference to the symbol present on the uniforms of the Venezuelan generals. Being both a Brazilian Latin American and a Lebanese Arab myself, tracing a comparison between the liberal interventions seen on the Middle East, both today and on the past, with those that happened during the Cold War over the Condor Plan in Latin America, when the USA overthrew democratic leftist-leaning governments in favor of similarly interested dictatorships and the current one being held on the Caribbean State seemed unreasonable not to be done. It is undeniable that the European contact with the Middle East and other parts of the "Orient" is considerably older than that with Latin America. Still, the way the portrayal of the people from these regions has been shaped by colonial rule and cultural production of the Western mass media and academic endeavors are fairly similar and framed just as related international politics, hence the consistent overthrowing of governments in these regions by foreign powers.

Certain issues are fairly more interesting to be discussed and relevant in the current scenario. The first is the generalization of Latin America as one single people when being portrayed or researched, a notion not harmful by itself but that may lead to false generalizations. Following, we may consider how the production of knowledge or culture is made for such a part of the world. And finally, we may discuss the reasons why the change of such generalizations is a rough and slow process that has hardly happened, if not only in contemporary times, in more than 500 years of history.

Even though there are evident similarities, we should also shape the differences. The notion of the existence of Latin America (in European imagination) is fairly recent, while that of the Middle East is vastly older. In *Orientalism*, Edward W. Said cites authors such as Homer and Dante Aligieri to demonstrate how old these notions are. At the time of the Hellenic writer, our

lands were only inhabited by indigenous people who did not have any contact with Europeans. Orientalism existed independent of colonialism, being polished in its favours and wills as it happened. On the other hand, Latin America, as presented today, is a direct product of colonialism and the silencing of indigenous and black cultures; however, it is beneficial to look for a "classical period" through which Latin America is analysed. As it will be seen, it has been fairly common to analyse the Latin American people through the lenses of certain periods when their "whiteness" is questioned.

Understanding such factors, I intend to utilize Said's study and research of "orientalism" to showcase similarities on the occidental understanding of Latin American or "hispanic" lands and oriental—principally Arab and Islamic—people. Additionally, to base such correlations, historic events, colonial-era documents, books, and research will be cited. For such an intent, this paper will be divided into an analysis of the construction of "Latinamericanism" during colonial era, its persistence on post-independence republics and its current form. It would be resolute to offer a chapter on how to solve the issue as one directly affected by it; however, I believe it is as simple and complex as the non-prejudicial access of individuals to the experiences of our people, and I do not know or wish to debate on how to solve prejudice for its own sake, but, I will do so when it comes to identity and its construction on our society.

First European contact with Latin America: "Classical Latinamericanism"

Firstly, I believe it would be useful to briefly describe Said's understanding of Orientalism. Using his own words, it is "a way of coming to terms with the Orient that is based on the Orient's special place in European Western Experience." At its core, it would simply be a field of study, just as scientific as any other field of the humanities, focused on "The Orient" (which in itself is a complex term). Still, as it feeds itself repeatedly of ancient traditions and prejudices rooted on the Occidental comprehension of the topic, there being no space for debate (for those who study the topic tend to be extreme reactionists), it becomes static. And it is this essentialist notion of people, culture, religion—among other aspects of human life—understood as empirical facts, that bears danger.

Said focuses on the exploration of the Arab, specifically, Muslim world. Still, if we recognize that the same conditions that made it possible for Orientalism to be a field of study based on determinist and non-evolving principles of people were also applied elsewhere, we could attempt to comprehend similarities and differences in those places. Orientalism is also an exertion of power. It is an attempt to represent another people so not only the notion of a *we/us* is made stronger but also a *they/them*. In colonial times especially, it was important to establish such ideas; in this context, Latin America and the Middle East share similar stories. Even though Middle Eastern control by foreign power did not start until (arguably) Napoleon's invasion of Egypt in 1798, while Latin America was under Iberian control since 1492, when Columbus landed in the Bahamas—then, San Salvador—both in the western eye had to be subjugated, either for exploration or suppression of "cultural threats."

Latin America was only inhabited by its indigenous populations until 1492, when Europeans arrived. And it still took a considerable amount of time for Latin America to achieve its current land extension (keep in mind that Pedro Alvares Cabral only landed in Brazil eight years later and Columbus, in Venezuela, ten years later). We need to look carefully at how this first stage developed.

From 1492 onward, the first building blocks of Latin American studies were developed by Europeans. Unlike Middle Eastern studies in Europe that tend to focus on classical texts such as the Qur'an, for Latin America, it is early stage colonialism, or times before European colonization, that scholars often recall. When attempts are made to differentiate European and Latin-American cultures, they are often made through the indigenous or black people's cultures. Instantiating such a reality is the Brazilian modernist period of art, when oeuvres such as *Macunaíma* by Mario de Andrade and *Manifesto Antropofágico* by Oswald de Andrade were written. Both of these, when attempting to construct a national identity independent of Europeans, regarded the indigenous person and culture as central to the discussion. In his manifesto, Oswald de Andrade even writes "Tupi or not Tupi, that is the question," citing Shakespeare "to be or not to be, that is the question," acknowledging the European influence on Brazilian literature while referencing the indigenous population of Brazilian coasts, the Tupi.

Another instance where the indigenous populations and cultures were considered a source of pride and nationalism was in the Integralist Movement in the early 30s. Commonly, the political organization is today spoken as "the fascist movement in Brazil." As part of such a context of ideologies, it underlined an extreme nationalism focused on "how to be and act Brazilian." For such, it had to instantiate what it meant to be a "proper Brazilian." The founders of the movement, mainly white men of high social positions, attempted to glorify the image of the indigenous person. When members of the party met each other, they would say "anauê," meaning "hello" in the most widespread indigenous language-family in Brazil, Tupi Guarani. Their image was glorified, but they were not.

Consequently, there was a need at the time to look back into what it meant to be an indigenous person before the Europeans arrived. Still, especially in cases such as that of the Integralist Movement, where white men with no contact with indigenous cultures whatsoever researched the topic, would overly rely on documents created by the very own colonizer, thus legitimizing narratives that have been generationally inherited.

One example we could explore to better analyze the correlation between the indigenous people and how they were seen with the western representation of the modern Latin Americans, is that of the contact between the first Portuguese colonizers and Brazilian indigenous populations. The letter of Pero Vaz de Caminha to the royal family of Portugal is a significant piece to analyze. In it, two main aspects are noticeable. The first is the sauvagerie the indigenous people are perceived to follow, backed by a notion of passivity and natural tendency to follow orders. Quotes (freely translated by me) such as "On their hands, they brought arrows … Nicolau Coelho [a sailor] signaled for them to put the arrows down and they did," and "For

them having such a barbaric nature, you could not comprehend or hear anyone" clearly instantiates the former. Secondly, there is a questionable focus throughout the letter on attempts to describe what the author calls "shames" (the genitals) of the indigenous people. Pero Vaz de Caminha repeatedly writes about how "attractive" the young indigenous women's reproductive parts are and acknowledges a lack of worry with hiding sexual organs. "They were brown, naked, without anything that hid their shames," "with them walked three or four young ladies, really young … with their shames so high, so shaved and so free of unwanted hair, that of looking at them so much, we were not ashamed of doing so anymore," and "her shame (a feeling she did not have), so gracious, that a lot of women in our land [Portugal], would be ashamed, for not having one like hers" are all parts of the letter that exemplify the sexualization of the indigenous women.

All these are particularly interesting when we compare it to the works made by future orientalist writers. Gérard de Nerval, who wrote "Voyage en Orient," while traveling through the Middle East, also reduces the women of the region to their "magical" and "mystical" attraction and sexuality, which, in his opinion, have their desires much more fulfilled than that of women of his land. It is important to note, however, the time between when these two documents were written. The letter is from the sixteenth century and the travel diary of the nineteenth century. Their similarities are undeniable, which also proves Said's idea of an unchanging essence of these types of works.

Parallel to that (and equally comparable to the nineteenth-century work cited above) is the colonization of the fellow Iberian Spanish Empire of the American continent and the documents produced by it. For such, we could also consider the document written by Cristobal Colon to the Treasurer of State at the time, Luis de Santángel (at what is now known as the Letter to Luís de Santángel). When considering the obedience of the indigenous people, Colon states: "If they have something and you ask 'kindly,' they will never say no," and, "they would give what they had just like beasts." The opinion of Colon on the savagery of certain tribes is just as similar to that of Pero Vaz de Caminha as of the previous one. "In that manner, we have not found monsters, of any kind, except one of the Quaris islands, the second on the entrance to the índias, that are inhabited in all its parts by really ferrous people, who eat human flesh" is a particularly interesting example. Additionally, there is a significant aspect that sets this document apart from the former: the idea that the indigenous people saw him and the Europeans as "people from the skies." In the letter, he writes: "Nowadays, I always bring with me that they have as a purpose that I have come from the heavens, even with the many conversations we have had." There is a religious undertone in the document as a whole, but particularly in this part, where the author explores how this comprehension would make it easier to Catholicize the indigenous people of the Caribbean—*indies*, as they were known during this time—and subjugate them to the Spanish king's rule.

The relation to be set here is with the understanding of European researchers or rulers of the Orient as in the "dangers of Muhammadism" and the lack of rationality that guided the Arab people (on their conception). Lord Balfour, Ernest Renan, among others saw the orient as

incapable of government and science, tending to totalitarian forms of government and therefore not only susceptible, but also beneficiaries of a foreign rule. The latter even stated both that "Islamism and science are contradictory" and that "science has always been the enemy of Islam." I believe those statements and those made by Colon have a similar view: either "Oriental people" should or will forcefully (or not, in Colon's perception) submit to a European rule, both acquiring rationality and a superior spiritual philosophy.

All aspects analysed are inherent to the European philosophy on Orientalism. What I would suggest as the reason for this quote-unquote coincidence is the Portuguese desire to sail to "the Indies" and the subsequent intention to classify the new lands as part of such a place, or at least, replacements for such. Even though some scholars argue whether or not there was a confusion made by the portuguese between the native americans and Indians (meaning those of Eastern lands and not of the modern country), it is reasonable to deduce that both them and the Spanish colonizers equated their form of study of such a people with that of "the other Indias," or simply, of the Orient. It should be recognized that whenever there was a reference to the new lands as a whole, it was "the Indies" (note the aforementioned Letter to Luís Santángel).

It would not be a stretch to say that all the cultural build-up on the comprehension of *others* that had already been done by the westerners was derived into that of the indigenous people of South and Central America. To further analyse such a reality, multiple resources are available. One that I find particularly interesting is the *Historia Natural y Moral de las Indias* written in 1589 by Spanish scholar José de Acosta. Although written centuries apart, such a work shares, indubitably, significant similarities with the style of research and Orientalism practiced by Gustave Flaubert in Egypt. Those, in conjunction with the aforementioned letters, paint the picture of the construction of an *Us* and *Them* and a constant effort to maintain that distance.

Flaubert and de Acosta not only follow a similar stylistic format but also have a similar context on their writing. The authors, emphasizing Flaubert's sexual contacts with Arabs, although living among their subjects of study, still treated any and all relationships they created as parts of their greater oeuvre. In speaking and representing other people, they treat opinions relative to their living as constant truth, justifying such a doing through the "bestiality" of the people they are dealing with. It is important to notice however that even though de Acosta explicitly attempts to dismantle that idea, whether consciously or not: "Prove wrong the assumption people normally have of them, of brutal people, and beasts and without any comprehension of anything, or so short minded that they may not even deserve to be called 'minded.'" The authors justify this conjecture by the lack of written texts and monuments of indigenous peoples or the "lack of capability" of Muslims to act without their religion's intervention.

In *La Historia Natural y Moral de las Indias*, there are some specific aspects of "Latinamericanism" that we are able to analyse and trace origins to. These are geographical determinism, lack of reliability of indigenous representation of themselves and a constant attempt to justify their treating as another inferior people (even if I believe that was not the intent of the author originally). De Acosta writes: "But it is better to try to dismantle all that is false

about the origins of the indigenous people, than to determine what is the truth, because there is neither any scripture among the indigenous, or any certain memorials of their founders." He continues: "But, why would one wish to add more to this story, because everything comes full of lies, and empty of reasons? What scholars affirm and write is, that all that we have of memory and relations of these indigenous people goes to as late as 400 years from now." This instantiates de Acosta's ideas on the indigenous people's reliance on orality as something not to be trusted, the burden of empirical facts landing on the European scholar when researching that topic and determining scientific truth.

Secondly, there should be an analysis of the scholar's attempt to rule out any possibility of a past relationship between these people and the Europeans. The author says both that if the indigenous people came from the Europeans, they were of a "lesser kind" that still did not find society (for lack of mental capacity) and his theory on the great flood that the indigenous talk about and his comprehension of the differences between that story and the biblical one (what I see as an attempt to discard any legitimacy on the indigenous religion), stating that it is more related to a great rain as talked by the ancient Greeks, as the following quotes attest:

> "There is within them a big, but one cannot determine if factual or just part of the oral traditions, a great flood [the writer uses a term in Spanish with no direct translation to english that refers only to the biblical flood both now and on the next time is word is used]; is the flood they refer to the universal inscribed in the holy scripture, or if it was any other type of deluge that flooded the regions in which they live, yet the experts of these lands say that there are clear signs that there once was an immense inundation. There more I research with those that know and feel, apparently, the traces and signs of a great flood are not that of Noah, but that of any particular other, like the one Plato used to talk about, or the ones that the Deucálion poets used to write about."

He continues: "There aren't many thousand of years that men inhabit there, and that the first that entered these lands were more of savage man and hunter-collectors, than people of Republics, and polished." In addition to that, there is a wish to substitute the lack of "reliable information" of indigenous people by the study of the lands. José understands that most, if not all, of the aspects of the indigenous culture comes from where they inhabit, as he evidentiates in the following passage: "It does not seem to me that those who discuss about this topic say it wrongfully, that all the knowledge of the things of the Indies depends mainly on the knowledge of the equinoctial; because almost all the differences that a side of the globe has from the other, comes from the properties of the equinoctial [meaning close to the equator]."

Documents written in the colonial period would follow similar patterns and guidelines such as these. Mostly, the scholars would be either Jesuits, who would follow José's example or use similar premises to base their research, or members of the ruling classes, coming from

the colonial power's mainland. For that reason, believing there is no significant variance anymore in the colonial era, we should look to the following point of breach on Latinamericanism, the independence movements of Latin American countries.

The continuation of Latinamericanism: the construction of "Latin America"

Whereas everything already written about is interesting to the discussion, it is important to remember that all of the documents mentioned were constituted before the bare existence of the terms "Latin America," "Hispanic America" and "South America." These regions at the time were mainly referred to as "The New World," "The West Indies" or "Portuguese America," "Spanish America," among other Latin-derived language-speaking parts of America colonized by European countries who had titled their regions with "America." Thus, based on writers such as Miguel Roja Mix, I find it particularly interesting for us to comprehend the representation of Latin America throughout the western world, to comprehend the particular origins of the designated name "Latin America" to these lands, countries and peoples and why did the constructions made previous to its independence prevail even after it. As Mix said: "The history of Latin American identity is also the story of the various names of America and the reasons for which these names were imposed." Therefore, using as a basis Rafael Leporace Farret and Simone Rodrigues Pinto's research on the topic, we may analyse it further.

Since the term "America" first appears as an homage paid by the German cartographer Martin Waldseemüller on his map "Universalis Cosmographia," further discussion on the origin of the name would be null. What surely came to play a significant role is when the people from the (now) Latin American countries started identifying themselves as Americans. Leporace and Simone state that such a phenomenon did not take place until the start of the independence movements in the nineteenth century. Preceding this political movement, the crioulo elites of the Spanish American empire—direct descendents of Spanish colonizers in America—would claim bigger political power by clinging to their European roots. The two writers say one of the most common arguments for a greater political participation of such a movement is that "there was not even a drop of aboriginal blood on their veins." When they perceived a greater political independence was possible and rooted for national movements, they claimed the identity of "Americans," not as part of the land, but as the elite that ruled over it. Ferret and Pinto, when citing the French historian François-Chavier Guerra make the following statement: "the necessity of differentiating themselves from the enemies made it so that the insurgents understand as priorities and one of their most important identity aspects the 'american' identity."

From such a movement, a trend that would be followed repeatedly in Latin-American history would be its attempt to seem more European and therefore, adhere to its terminology and designations of our land. Complimentarily, it would fight against European interests, while also utilizing their comprehension of us, just as when fighting for independence, the colonies (or at least its elites) clinged to the previously rejected "American" identity.

The following step of the development of the name of the region (just as the next analysed topic, the movement for whitenizing "blanqueamento" of our people) is an example of

such a reality. Even though there is a dispute between the acceptance of a Chilean, Francisco Bilbao, or a Colombian, Torres Caicedo, as the inventors of the term "Latin America" (and a today less relevant minority who credit the french Michel Chevalier), it is widely accepted that the term was coined by someone living in France and sharing its ideals, who aspired for a "Panamericanism,"the comprehension that the "Latin descendent" civilizations should unite to fight the expansion of Anglo-Saxon endeavors in both the Americas and Europe. The most important aspect to highlight on that idea, though, was that the French Nation should be the only one capable of heading this objective. It was accepted by the Latin Americans both as a way to fight American Imperialism (with its Monroe doctrine that was firstly against Europeans intervening in American affairs in the continent, with its motto 'America for the Americans' but afterwards turned into a mean to intervene on the rest of the continent for its own favor, something like 'America for the North-Americans') and "enter civilization," as proves the following quote from Farret and Pinto's Research: "the hispano-americans, also with a strategical reasoning in mind, but also with purposes quite different from the first ones: the desire of constructing an idea of an 'us' European that permitted the escape from the 'underdevelopment' and the entrance into 'civilization.'"

Likewise the name "Middle East," the only still used European colonial terminology to divide Asia into three parts (Near, Middle and Far East, having Europe as a perspective), Latin America as it may have been used by its early writers as means to create a new national identity, it was also one to reaffirm both European domination over other cultures already present in our lands, the enslaved people's cultures and any others and a way for the Europeans to justify colonial and post-colonial rule (through a narrative of similarity in origin of the ruling elites) and to reinforce the "Us and Them" narrative. Another interesting aspect of Farret and Pinto's research is their approach to the possible skepticism towards the relation of the name of the region with how it is represented in the international scenario and the "Us and Them" narrative. To clear that possibility, they use the example of the French parts of Canada not being commonly considered Latin Americans even though they spoke (and speak) a language derived from Latin. The reason for such being that the region was a consistent part of the "Western world," there was no reason to differentiate it from the rest of the European world (for having been a French colony, now under a different rule, the English, and not a land that the Empire prospected to have under its wings again).

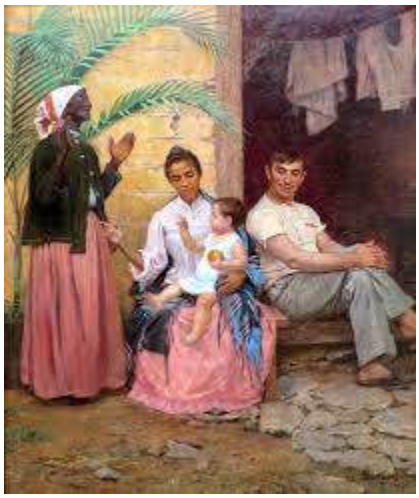
Another movement that could be analysed in order for the argument of the survival of Latinamericanism being based on a wish of the Latin American elites to become "more European," therefore positioning themselves and their populations under a premise of accepting the already imposed and the cultural build up onto that moment is the integration of racial theories on the construction of our nations. A common trend among all these was the process of "whitening of the population," known in Brazil as "Branqueamento populacional" and in Spanish speaking countries as "Blanqueamiento social," Even though we already discussed independence movements, for the sake of historical accuracy, it is valid to also divide this process into two periods: pre and post colonial Latin America social whitening.

Based on Mara Viveros Vigoya's research "Blanqueamiento Social, Nación y moralidad en la América Latina"—who bases her argument on different authors such as Hering, Wade and Leal Léon, all of whom I will also obtain basis—we may say that the Iberian search for a "pure blood" started with the inquisition in the context of the newly formed American societies, transcribed into the new races. "Within the Latin American colonial context, the certification of 'cleanliness'—that reigned over the Iberian Peninsula, demanding one's documentation of ascendency without any 'religious stain' of muslims or jewish people—gradually transformed into the necessity of proving not having black ancestors, 'mullatoes,' 'zambos,' 'quadroons,' etc., visible in skin color and certain physiological traits." (Hering 2007, 2010) Still, as noted in the previous quote, such a process was mainly done through the analysis of phenotypic characteristics; therefore, it was common for non-European ethnicities to attempt to mix with such a culture and people, with their descendents also following European cultures, to ascend socially. "At the same time, the same colonial dynamics that created the castes permitted processes of social ascension through the whitening (blanqueamiento), making it possible for 'indigenous people' and 'black people' to surpass the limits that their condition imposed on themselves by a consecutive miscegenations through numerous generations." (Leal León 2010) Once again, this time not for choice, but for the constant struggle for a better condition of life for themselves or for their descendents, the non-European Latin American attempted to assimilate to the European standards.

Yet, it should be noticed that this process did not take place without a further push of the elite for a greater distinction between the people (that created bigger distinctions and barriers for the "lower classes" to ascend, exacerbating their will to do so, creating a process that feeds back itself). An example Vigoya cites is that of the sexual (unspoken norms of) conduct of the white women and the rules of marriage, with the second, for the author, being a consequence of the former. The author states that the women were seen as those who could bring "intoxicated blood" for the family, and therefore, they should adhere to a strict chastity reserved for marriage (reinforcing religious norms). In her own words: "the castitude or 'virtue of the women' (wives, sisters, mothers, daughters) converts itself therefore in the defining factor of a family's honor." It is important to note as well that it was seen as specially needed to protect the women from the "wild nature of sexual related crimes of the other races" (a concept already discussed earlier in this article), specifically for the inquisition, which controlled tightly sexual relations during the colonial era. "This way, concubinage, adultery and sodomy were sin associated frequently with the 'racialized' population and witchcraft, prostitution and the sexual licentious behaviors" (Wade: 2009: 85) And to maintain the hierarchies present on the society, regulations over marriage became stricter and so did the difficulty to ascend through miscegenation of ethnicities (interesting to note that through colonial courts such as the Justice Palace, in Brazil and petitions to the Spanish Empire, people could legally attain more rights than their descendents if "whitened" enough as Vigoya states).

For the author, the second phase develops out of the contradiction between the Republican ideals of equality before the law and the racial theories of the time. The hierarchical

structures so entrenched into Latinamericanism and the distinctions between the "European" and the "Non-European" on colonial laws needed to be reformed. Therefore, it was restructured to have only one difference: their position when it comes to miscegenation of the population. Believing that through such, the races that boasted "less qualities and social organization" could integrate into the society through marriage with "superior races" and
their adaptation into such a form of societal organization, thus incentivizing such an action. "The miscegenation, as a form of progressive whitening, converted itself into a promise of inclusion to the community of citizens not only through marriage with 'whiter people' but also through adequation to the values and respectability and honor considered proper to the 'white-perceived' peoples." (Moreno Figueroa, 2012)



Another interesting instance of the situation cited above is the painting done by the Spanish who lived in Brazil for forty years, Modesto Bronco, "A Redenção de Cam", The Redemption of Ham (or Cham), in English. Through it, certain aspects of Latinamericanism's functioning can be more thoroughly discussed. Firstly, the name of the painting should be regarded. Ham is, as the Bible's story goes, the youngest son of Noah. He, for reasons that diverge from scholar's interpretation, but mainly achieve consensus on his sight of his father naked and his mockery of the situation, followed by both his brothers looking away
from the father's nudity and covering him with sheets culminated into Ham's curse through his son Canaan, all of his descendents being "condemned into eternal servitude." Later, Chirstian scholars would call all ethnicities (or races as the archaic term was used at the time) they wished to subjugate or colonize "sons of Canaan." The Spanish painter on this frame correlates the Brazilian enslaved people with Ham and their "condition" as eternal servers, damned, to that of Ham. What differs on the artist's view on the issue and that of his contemporaries (say, the pastor Benjamin Morgan Palmer and his attempts to keep racial segregation on a post-Civil War United States citing the same biblical passages used as inspiration for this painting) that did not work on Latin American land is its advocation for a "mixing of the people." From left to right, the painting presents the first generation, a black woman looking at the heavens in a praying motion, her daughter carrying a white baby and a white man, who seems to be the father, in an arrogant regard and position. Two attempts are made here—to convince the spectator that the black people want the "whitening" of the population and to advocate for such a movement. Lotierzo, who analysed the painting wrote: "Brocos "uses a perverse mechanism trying to attribute a volunteering of the black people to be agents of the whitening [blanqueamiento],as if they celebrated this possibility". Additionaly, the doctor and at the time, head of the Brazilian National Museum, in 1911, when in the "Universal

Congress of the Races", used the painting as the cover of one his works on the "whitening process", describing the image as "the 'negro' going to a white, in his third generation, as an effect of the cruising between races", as Murilo Brocolato brilliantly cited on his research around the painting's story.

The painting itself, in conjunction with all the other aspects of post colonial era Latin American society reveal additionally, what makes the Latin American racism different from that of the rest of the world, what contemporary writers such as Oracy Nogueira would call "mark racism"—that is, phenotypes determining one's racial profile, not ancestrality. I argue that the development of this phenomena was an attempt of a non-european society to be looked upon internationally as such, thus not allowing internal reconstruction of society and the perpetuation of stereotypes once enforced to the natives of this land, and/or immigrants that once perceived as "scientific truth" were generalized to the whole of the Latin American population.

Current Latinamericanism

Finally, we arrive at the current form of Latinamericanism. Even before the Cold War, there was a worry by Western powers of intervening in Latin American politics—always in an urge to maintain power structures the way they were. An example of such is found on the establishment of the unequal treaties among principally, the recently independent Latin Americans and the Europeans, mainly British. These constituted a first effort to establish Liberalist economics in this region of the world, in order to flood it with the respective product of the country that established such an agreement. These were mostly done under military pressure, therefore, there was no attempt to hide the understanding of "natural superiority" the so-called Westerners exerted over Latin Americans. Still, most of these efforts did not end by the 1870s and 1880s, when these treaties ended, only to take different forms, hiding under secret actions or indirect actions based on the earlier cultural build-up.

We may analyse, for instance, not only the Banana Republics as a whole, but also, the Banana massacre. The term "Banana Republic" was mainly used by American writers to refer to Central and Southern American countries that relied heavily on the exports of fruits for their economical activities. Most of the companies that explored such an opportunity, although, were American. That created space for political exploitation and lobbying in these countries' governments. The North American influence was made clear when on the 6th of December 1928, the Colombian army sprayed shots at peaceful protestors who were on a strike demanding better working conditions at the United Fruit Company (UFC). Even though at first for a Latin American State firing against its own people, it may be interpreted that there was no foreign intervention; this is not the case. In an effort to continue its benefits of working on the region, the UFC refused to negotiate with workers and left the country without any responses for the deaths they—directly or not—caued, with reports ranging from 40 to 2000 of them and some, even alleging direct American compliance that if there was no Colombian action, their army would directly intervene.

This event, among many other examples, were evidence of a transition that happened. There was no shift on how the Latin Americans were represented, and therefore, of the policies applied to these people and regions. Still, as the world, even moreso, the post-World War II one, started worrying with humanitarian narratives and neo-liberal values, there was a need to validate these interventions through "peaceful" narratives. These caused the prevalence of the idea of “liberal interventionism” over previous forms of the same actions. They justified the military (direct or not) action through the bringing of peace and development to the regions it acted on. This was alluring for the populations both because of its promises of wealthiness and for the elites for their proximity with foreign powers—in the Latin American case, of the never-ending wish of its elite to be considered European at last, whites, at least.

Just as in the Cold War, troops, intelligence, or other forms of support were sent to pro-western governments in the Middle East (Iran, former Persia, in 1953, supporting the strength of the Sha, Syria in 1949, when a Coup was done to establish a favorable government and Lebanon in 1958 when 14000 American troops were sent to the country being examples), this was done in Latin America. The Condor Operation was a plan of the USA to overthrow countries’ governments that were unfavorable to their policies and governing them abroad. Among notable examples, there is the Argentinian dictatorship, the self-named “National Reorganization Process"; the Chilean Dictatorship of Augusto Pinochet and the Brazilian Military Regimen. On all of these, there are certain aspects present, for which the most significant is the convincing of the American government to military officials of the dangers of the South American population under a free democratic government for their inability in auto-governance and violence.

Among secret telegrams sent out from the American Department of State to embassies in Bolivia, Argentina, Chile and Uruguay, we have the following: “We are fully aware of security threats created by terrorist activities within Argentina. It is not the intention of the U.S. Government to attempt to advise the government of Argentina on how best to get its internal security problem under control.B. Activity along lines of 2.B. would have a serious negative impact on Argentine image abroad in general and foreign refinancing efforts of Martínez de Hoz, in particular.” This permits us to analyse the American passivity to the situation. At no point there is a wish to truly aid Latin American countries—for their perception of those is innately negative—there is, although, a wish to explore those and as said, use their, at the time, troubling situation with national security to impose explorational objectives: “For Montevideo: We assume your best approach is to General Vadora rather than to either Acting President or President Designate who apparently know nothing about Operation Condor and, in any event, would probably have little influence on situation.” Here, it is important to note the disregard of democratic institutions in these countries. As previously argued, this was not only for their non-alignment with American policy but also with the northern comprehension of the lack of capability of the “normal Latin American” to exert rational power over themselves.

There is an ambiguity that develops here. Latin America is increasingly seen as a latent part of the "western world," or one that had developed into an increasingly concerning reality while other regions, such as the middle east are seen as incapable of ever being part of the western world and adhere to its values. Even though this seems subtle, it is in such a reality that political discourses and actions differ. The Iberoamerican region was seen as a continuity of the Hispanic and Lusitanian civilization, but one that had fallen to worse conditions "because of the irresponsibility of its own people" as American Secretary of State Kissinger put it on declassified American government documents. For such, the aristocracies of Latin American, descendents of Europeans, were actually seen as possible parts of a modernity, if guided with enough surveillance by some and just as incapable of ruling as the other parts of the population by others (these cases being exemplified respectively at the Argentinian and then Uruguayan cases already cited). When Kissinger analysed the Middle East, in his book *Diplomacy*, he put that these people did not pass by what he calls "the newtonian revolution," what Said analyses as a form for the secretary of State to say that these would not be part of modernity for their lack of rational thinking capability.

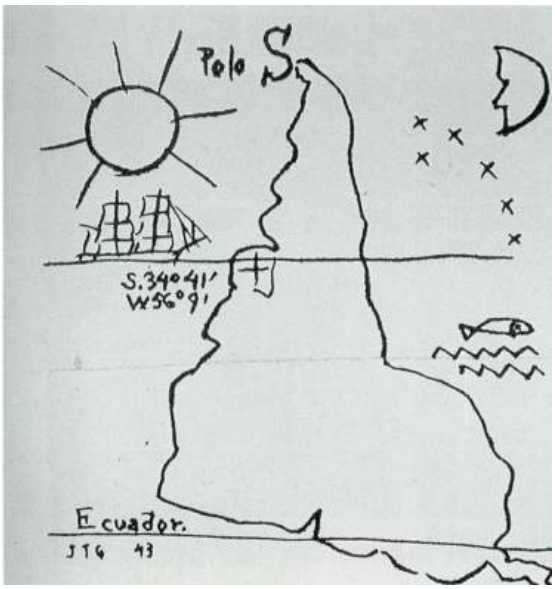
The Latin American is placed therefore in an "identity limbo" we still struggle to solve today. And, in my opinion, it is such a reality that permits the foreign intervention being made so clearly. The Latin American elite still lives with a hope to be seen as part of the developed world, for it has never clearly been understood as part of "the east." Still, it endlessly is seen as an "Other," in between "East" and "West" for its "developing economy," high criminal rates among many other issues.

It is only in Contemporary times that a movement to redefine what it means to be "Latin American" in the first place has appeared. I see equally important segments in this: the inclusion of cultures such as black and indigenous ones in this movement and that of the "proudness" of being from such a region. Representatives of these are Lelia Gonzales, with her concept of "Amefrica Ladina" that incorporates into our name those of the peoples that built our identity and Bad Bunny, who as mainstream artist has increasingly bolster about the beauty of coming from these lands (not undermining his merit, but who also ascended on a western scenario with the aid of collaborations with established North American artists such as Cardi B, on "I like it" and Drake on "mia").

This has not happened without backlash from major political powers. The current president of the United States, Donald J. Trump, for example, after Apple Music's Super Bowl Half Time Show, commented on his social platform, Truth: "Nobody understands a word this guy is saying, and the dancing is disgusting, especially for young children that are watching from throughout the U.S.A., and all over the World," once more reinforcing Latin American culture as sexualized and its language and people as incomprehensible. It is therefore reasonable to understand that action should come from within the region targeting its own values and colonial constructs imposed for centuries of history.

Conclusion

Even though not as ancient as other forms of representation of foreign lands by European and American scholars, Latinamericanism developed its own forms of domination and historical events and values from which to draw justification for their actions. From the portrayal of the indigenous people, to the negligence of the black people's share on the construction of our identity, to the identification of the elite as legitimately European, or white, there is a logic of power that did not fade due to our placing on what I term the "Identity Limbo." We are neither Western enough in the West's eyes or "Eastern" enough in our own eyes. Still, our scholars, political and economical elites are fed by the belief of the possibility of our entrance to the "Developed" western world because of our Iberic (and French in minor scales) heritage. It is such a reality that does not permit our own look to our identity and comprehension as a separate entity that keeps us from questioning established guidelines on the interpretation of our people—such as the extreme sexualization of our women and disregard of the intellectual capacity of our men. It is not my wish to identify a possible solution to said issues, but if I did so, through the current analysis, I may advise the incentive of our people to be one proud whole that identifies with and is proud of its parts. I am not one who would know how to apply this measure but, the conjunction of the work of writers such as Lelia Gonzales, of singers such as Bad Bunny, and painters such as the Uruguayan Joaquin Torres García—who painted the "Inverted America," stating that "our north is the south"—seem to set a trend that makes me look optimistically to the future and the way forward. It is the mix of cultures that has made it who we are and it should not be *it* that puts our population against each other, rather unites it. For such, I am optimistic of a time when "The Identity Limbo" is seen only as a historical reality and not a current social issue.



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Analyzing the Impact of Natural Language Processing Techniques on Sentiment Analysis of Financial News Articles for Predicting Stock Market Movements By Veer J. Langhanoja

Abstract

The integration of natural language processing (NLP) into financial sentiment analysis has emerged as a powerful complement to traditional quantitative forecasting models, which fail to capture the impact of unstructured textual data on market movements. This review examines the evolution of NLP techniques for financial news sentiment analysis, from rule-based lexicon approaches to transformer-based language models, and evaluates their effectiveness in predicting stock market movements. Key methodologies surveyed include bag-of-words models, TF-IDF weighting, n-gram representations, traditional machine learning classifiers, recurrent neural networks, convolutional neural networks, and domain-adapted transformer models such as BERT, RoBERTa, and FinBERT. Findings indicate that transformer-based models consistently outperform classical and earlier deep learning approaches, with domain-specific pretraining on financial corpora yielding F1-score improvements of 5–15% over generic models on benchmarks such as the Financial PhraseBank and FiQA. Hybrid models combining sentiment signals with technical indicators further enhance directional accuracy and risk-adjusted returns. However, significant challenges persist, including annotation bias, limited cross-market generalizability, poor reproducibility across datasets, and the black-box nature of deep learning models that complicates regulatory compliance. This review identifies key research gaps in multilingual coverage, multimodal fusion, uncertainty quantification, and real-time deployment, and outlines directions for future work. The findings suggest that while NLP-driven sentiment analysis offers meaningful predictive value for equity markets, its practical impact depends heavily on dataset quality, evaluation rigor, and the alignment of sentiment labels with realized market behavior.

Keywords natural language processing, sentiment analysis, financial news, stock market prediction, FinBERT, transformer models, machine learning

I. Introduction and Research Context

A. Background and Motivation

The rationale behind introducing sentiment analysis into financial forecasting lies in the market's sensitivity not only to fundamental factors but also to investor sentiment, expectations, and crowd behavior propagated through news and social media. Recent studies have shown that incorporating sentiment data extracted from financial news, reports, and social media platforms like Twitter can significantly enhance the accuracy of stock return and volatility predictions, supplementing traditional price and volume data (Accio Analytics, n.d.; IBKR Campus, n.d.-b). With the advent of real-time text data, machine learning models can effectively transform narrative information into valuable predictive features for trading strategies, potentially yielding higher returns than purely technical strategies (The Blueberry Fund, n.d.). This approach enables

investors and financial institutions to better anticipate market dynamics in the context of various events, manage risk proactively, and comprehend the profound impact of information flow on asset pricing worldwide. The traditional quantitative stock price prediction models are unable to reveal the latent production mechanism due to the assumption of linear relationships with time series data. These models are based on price time series and fundamental factors, so they cannot incorporate the impact of sudden events and news information. Therefore, factor models and time series models are usually mis-specified. The estimated alpha is biased and the models are overfitting the pattern from the data sample. The efficient market hypothesis means finance market prices already contain all information (Baker & Wurgler, cited in the paper). Therefore, it is impossible for classical quantitative models to create excess profit. Unstructured text data over financial news is a collection of textual documents containing financial information, yet devoid of a predetermined data model or schema (Fivetran, n.d.). This form of data is characterized by its free-form representation, encompassing elements such as articles, tweets, and analyst comments. Compared to financial news, structured information such as prices, volumes, or accounting metrics are quantitative values that can be formatted in specific data fields and stored in tabular format for direct statistical and econometric analysis (Fivetran, n.d.; LSEG, n.d.-b). Financial news can provide expectations, sentiment, and detailed information that is not immediately evident in historical time series data, but requires natural language processing, the form of unstructured data, to extract. While more easily digestible by existing models, structured data only depicts information that has already been embedded in markets at the moment, whereas unstructured data such as news can reveal the underlying reasons behind it. Natural language processing can efficiently convert unprocessed textual data such as news, earnings calls, and social media into meaningful metrics like sentiment, topics, and entity-specific signals that can be used in models to predict market movements (IBKR Campus, n.d.-a; LSEG, n.d.-a). By understanding the context, tone, or expressions that are specific to the field of finance (such as "beat" or "bullish"), modern NLP models can catch subtle changes in expectations that simple term frequencies or keyword searches would fail to identify (Accio Analytics, n.d.). Such techniques can be executed in (near) real time across thousands of data sources, enabling investors to monitor news and sentiment before it is fully reflected in market prices (The Blueberry Fund, n.d.).

B. Research Problem and Scope

This review specifically addresses the lack of a clear, unified framework for financial sentiment analysis, where prior work is fragmented across datasets, methods, and application areas. It aims to clarify what exactly counts as "financial sentiment," define the relationship between financial sentiment, investor sentiment, and market sentiment, and organize techniques and applications under a coherent scope. Predicting market movement is harder because prices, volatility, and abnormal returns are driven by many interacting factors (macro news, liquidity shocks, policy changes, order flow), so the mapping from sentiment to returns is noisy and unstable over time (Phoenix Strategy Group, n.d.-a). Sentiment labels or scores only summarize

text, while returns reflect equilibrium outcomes after traders interpret, trade on, and sometimes overreact or arbitrage away the information. Empirical studies find that even when sentiment indexes are predictive, the effect is often state‑dependent (stronger in high‑sentiment or crisis periods), nonlinear, and subject to rapid decay, which makes robust forecasting of direction, volatility, or abnormal returns much more challenging than classifying text polarity (INET Economics, n.d.). Most financial sentiment and return-prediction studies focus on short-term horizons, especially daily and multi-day (about 1–2 weeks) windows, because news and social media effects tend to decay quickly in prices. Intraday horizons (minutes to hours) are also common when using high-frequency news feeds or Twitter streams, particularly in event-driven trading. Longer weekly or multi-week horizons are examined less often and usually in "multi-horizon" setups that compare short- and long-run sentiment effects on returns and volatility. Most studies in financial sentiment analysis concentrate on equities (individual stocks) and major stock indices, since these have rich news coverage, high liquidity, and readily available datasets linking text to price moves (Wright Research, n.d.). A substantial number of papers also consider equity index futures and broad bond or equity ETFs as tradable proxies for market sentiment. Work on commodities (like oil or gold) and real assets/REITs appears, but usually in asset-allocation or diversification contexts rather than pure sentiment–return prediction. Cryptocurrencies are now a growing, but still smaller, segment of this literature, often studied for their strong sensitivity to social-media sentiment and retail-driven flows.

II. Financial News as a Data Source

A. Types of Financial Textual Data

News articles are typically written and edited by professional journalists, so they are longer, more structured, and fact-focused, with clearer context and fewer slang terms or emojis. Social media posts are short, informal, and highly noisy, mixing opinions, rumors, and reactions; they arrive at much higher frequency and can reflect retail sentiment almost in real time. Earnings calls differ from both: they are scripted corporate communications plus Q&A, rich in tone, hedging, and forward-looking guidance, but concentrated around scheduled events rather than continuous flow. Professional outlets like Reuters and Bloomberg follow style guides that enforce formal, concise, and largely objective language, with careful sourcing, limited slang, and controlled use of evaluative adjectives. Their articles tend to use domain-specific terminology, numerals, and longer, syntactically complex sentences to convey precise financial information and context (LSEG, n.d.-b). Blogs and forums, by contrast, are more conversational and subjective, featuring informal vocabulary, slang, emojis, and rhetorical exaggeration, with looser grammar and frequent first-person opinions. This makes professional news more uniform and easier to parse with rule-based or domain-specific NLP, while user-generated content is noisier but can reveal raw, retail sentiment. Author credibility and editorial tone shape how reliable a sentiment signal is because markets react differently to information from trusted, professional outlets than to low-credibility or anonymous sources. Studies show that tone in established news

media (which applies editorial standards and fact-checking) tends to carry more incremental information about expected returns and volatility than comparable sentiment from social media, where hype and noise are pervasive (Henry, 2008). Within news itself, abnormal or strongly emotional tone can drive short-term overreaction and subsequent reversals, so knowing whether a piece is analytical versus sensational helps distinguish informative from potentially misleading sentiment.

B. Temporal Characteristics of Financial News

Markets react to major news sentiment extremely fast: high-frequency studies around earnings and macro announcements show price jumps within milliseconds to minutes of release (Brattle Group, n.d.). At the daily level, several papers find that news and social-media sentiment typically leads same-day or next-day returns and volatility, with effects strongest in the hours after sentiment shocks (IBKR Campus, n.d.-b). Event studies also document elevated trading volume and intraday volatility around the publication time of sentiment-rich stories, indicating rapid incorporation of information into prices. Over longer horizons (multi-day to weekly), sentiment effects often weaken or partially reverse, consistent with initial overreaction followed by correction. Sentiment signals generally decay quite fast: their strongest predictive power for returns and volatility is usually within the same day or over the next 1–3 trading days, after which effects weaken sharply. Empirical studies tracking information or sentiment "half-lives" often find that most of the incremental effect is absorbed within a few days to a few weeks, consistent with rapidly increasing market efficiency over short horizons. Some work suggests that negative sentiment tends to persist slightly longer than positive sentiment, creating more durable predictive power for bad news than for good news in the subsequent days. Over longer horizons (multi‑week to monthly), sentiment still matters mainly for slow‑burn risks and regime shifts, but its marginal forecasting benefit versus other fundamentals declines steadily. Delayed reactions can materially weaken model performance when fixed, short sentiment windows are used. If prices adjust with asset-specific lags (for example, several hours or days after news), models that only look at same-day sentiment will misalign signals and trades, reducing hit rates and risk‑adjusted returns. Empirical work shows that some firms exhibit clear delayed sentiment effects, while others react almost instantly, so a single global lag structure tends to underperform adaptive, asset-specific timing rules. Models that explicitly learn or optimize lag windows (e.g., via genetic algorithms or time‑lag cross‑correlation) achieve higher returns and win rates by better matching sentiment shocks to the actual price-response horizon (Phoenix Strategy Group, n.d.-a).

C. Challenges in Financial News Processing

Financial jargon, sarcasm, and hedging language pose major challenges to sentiment detection because standard models trained on general text often misinterpret domain-specific terms like "beat estimates" (positive) or "toxic assets" (negative), leading to lower accuracy without financial fine-tuning (Phoenix Strategy Group, n.d.-b). Sarcasm and irony—common in

social media or analyst commentary—flip literal polarity (e.g., "Great earnings... not"), which simple lexicon or bag-of-words methods miss entirely, while even advanced transformers need context-aware training to catch them reliably (AltexSoft, n.d.). Hedging phrases ("may," "could," "potentially") dilute sentiment strength and introduce uncertainty, so models without negation/qualifier detection assign overly binary labels, reducing the signal's predictive value for markets. Specialized financial BERT variants like FinBERT improve handling of these by learning jargon and pragmatics from domain corpora, but gaps persist in real-time, noisy sources (Araci, 2020). Generic sentiment lexicons fail in financial contexts because they misclassify common terms that carry neutral or opposite connotations in finance—such as "liability," "debt," or "charge-off," which are often negative elsewhere but routine in reports (Loughran & McDonald, 2011). These lexicons overlook multi-word financial jargon ("beat expectations," "toxic assets") and context-dependent polarity ("profit taking" is neutral-to-negative despite "profit"). They also ignore modifiers like hedging ("potentially bullish") or negations that dilute strength, leading to binary overconfidence on nuanced texts (SAS Blogs, n.d.). Domain-specific lexicons like Loughran-McDonald outperform by design, but generics lack coverage of evolving trader lingo and sarcasm (Loughran & McDonald, 2011). Neutral-sounding articles can still move markets because even "objective" financial news signals that something noteworthy happened, prompting investors to interpret "no bad news" as relatively positive amid uncertainty—"no news is good news" (Pace University Digital Commons, cited in the paper). Studies confirm neutral headlines often trigger modest positive intraday drifts, as they reduce perceived risk without introducing negatives, spurring buying on the margin. Markets also react to the quantitative details (numbers, forecasts) embedded in neutral prose, or to the mere fact of coverage amplifying attention via investor herding, rather than explicit sentiment polarity. Finally, repetition across outlets can slowly incorporate subtle implications (e.g., "stable outlook") that sentiment classifiers miss as neutral.

III. Sentiment Analysis in Finance: Conceptual Foundations

A. Defining Sentiment in Financial Contexts

Financial sentiment is defined more narrowly than general sentiment, focusing specifically on attitudes, expectations, or opinions toward financial entities (stocks, companies, markets, economic indicators) extracted from domain texts, rather than broad emotional polarity in everyday language (Accio Analytics, n.d.). General sentiment analysis treats words like "liability" or "debt" as inherently negative, while financial sentiment recognizes their frequent neutrality in balance sheets or reports, requiring context like jargon, hedging ("could improve"), and market implications (Loughran & McDonald, 2011). It also distinguishes investor sentiment (aggregate mood driving deviations from fundamentals) from textual sentiment (polarity in news/earnings calls) and market sentiment (overall price trend optimism/pessimism) (Baker & Wurgler, cited in the paper; Wright Research, n.d.). Yes, financial sentiment analysis often employs multi-dimensional approaches beyond simple positive/negative polarity to capture

nuances like optimism, uncertainty, risk appetite, fear, or even urgency (LSEG, n.d.-b). Frameworks decompose sentiment into thematic dimensions (e.g., policy optimism, psychological fear, technological risk) or levels (firm-specific vs. industry-wide), showing these predict liquidity, volatility, and spreads better than aggregate scores. For instance, one study extracts micro (firm), meso (sector), and temporal dimensions, improving credit forecasting, while another uses deep learning for six investor sentiment axes like social or climate risk. This granularity reveals how uncertainty might signal downside risk even in "positive" texts, enhancing trading signals. Positive and negative sentiments impact markets asymmetrically because investors exhibit loss aversion, reacting more strongly and persistently to bad news than to equally sized good news, which amplifies downside volatility and return drops (INET Economics, n.d.). Studies across U.S. and emerging markets show negative sentiment often triggers sharper price declines, higher trading volume, and longer-lasting effects (days to weeks), while positive sentiment drives milder rallies that fade faster. This pattern holds especially for speculative assets or during uncertainty, where pessimism signals undervaluation opportunities but also overreactions, whereas optimism fuels bubbles before corrections.

B. Labeling and Ground Truth Construction

In supervised learning studies on financial sentiment, labels are typically assigned manually by human annotators (domain experts or crowdworkers) who read texts like news articles, earnings transcripts, or social media posts and categorize them into discrete classes such as positive, negative, neutral, or sometimes scaled intensities (e.g., strongly positive to strongly negative) (Malo et al., 2014). Annotators often follow guidelines to consider financial context—like company-specific implications or hedging language—rather than general polarity, with inter-annotator agreement measured via Cohen's kappa to ensure reliability (usually targeting >0.6) (Financial PhraseBank, n.d.). Some datasets use crowdsourced platforms (e.g., MTurk) or expert-curated benchmarks like FiQA or SemEval, while others derive "ground truth" labels indirectly from future stock returns (positive if price rises post-news), though this introduces endogeneity bias (Cortis et al., 2017). Advanced setups include multi-label or multi-dimensional schemes for aspects like optimism vs. uncertainty. Using price movements as a proxy for sentiment introduces several key biases. Endogeneity bias arises because prices reflect not just sentiment but also fundamentals, liquidity shocks, and macro events, so labeling text based on subsequent returns conflates cause and effect (Brattle Group, n.d.). Look-ahead bias occurs when models "see" future prices to assign labels, inflating backtest performance unrealistically for live trading. Noise contamination is rampant since short-horizon returns (e.g., next-day) capture unrelated volatility, weakening the sentiment–price link and producing inconsistent training signals across assets or regimes. Finally, asymmetric reaction bias means negative sentiment drives sharper moves than positive, so price-derived labels overweight downside cases and understate neutral texts.

IV. NLP Techniques Used in Financial Sentiment Analysis

A. Rule-Based and Lexicon-Based Approaches

Loughran-McDonald (LM) dominates as the most cited financial sentiment lexicon, with over 2,300 negative, 350 positive, and specialized lists for uncertainty, litigiousness, and modal strength, crafted from SEC 10-K/Q filings to correct generic biases like "liability" as neutral (Loughran & McDonald, 2011; Wharton WRDS, n.d.). Harvard-IV-4/General Inquirer acts as the standard baseline but scores poorly (~75% error rate) on finance due to everyday emotional words misapplied to routine terms. Henry (2008), SentiEcon, and extensions like StockSenti target analyst reports, economic texts, or social media slang absent from LM (Henry, 2008). LM remains the reproducibility benchmark across equities, credit, and earnings studies, often hybridized with BERT for context (Loughran & McDonald, 2011). Rule-based sentiment approaches handle negation by detecting trigger words (e.g., "not," "never," "can't") within a predefined scope (typically 1-3 words ahead) and flipping the polarity score of affected opinion terms, often via simple multiplication by -1 or dependency parsing to identify the exact negated phrase (AltexSoft, n.d.). For intensifiers ("very," "extremely," "slightly"), they apply predefined boost/reduction factors (e.g., +0.5 for "very," -0.25 for "barely") to scale lexicon-based sentiment scores of nearby adjectives or adverbs, though scope errors arise without syntactic analysis. These methods improve baseline accuracy by 5-20% over naive bag-of-words but struggle with complex cases like embedded clauses ("not very good" vs. "very not good") or financial hedging, where rigid rules overflip or miss context (SAS Blogs, n.d.). Static lexicons like Loughran-McDonald struggle in evolving markets because they rely on fixed word lists that miss emerging jargon (e.g., "meme stock," "SPAC unwind") and fail to adapt to shifting connotations—terms like "disrupt" flip from positive (tech boom) to neutral/negative post-2022 (Loughran & McDonald, 2011). Their bag-of-words assumption ignores context changes (e.g., "bear market rally" stays negative despite rally nuance), leading to stale signals as trader lingo and event-driven phrases evolve rapidly via social media and earnings calls. Studies show LM accuracy drops 10-20% out-of-sample during regime shifts (e.g., COVID volatility), as static coverage lags new multi-word expressions and fails to weight frequency by market phase. Dynamic or LLM-augmented lexicons outperform by continuously retraining on recent texts, but static ones remain computationally cheap baselines with known decay in fast-changing conditions. Lexicon-based models are simpler, faster, and more interpretable than machine learning (ML) approaches, relying on predefined word lists to compute sentiment scores without training data, but they typically achieve lower accuracy (60-75% F1) on financial texts due to poor handling of context, negation, and domain jargon (AltexSoft, n.d.). ML models—especially transformers like FinBERT—outperform consistently (80-90% F1) by learning contextual embeddings and financial nuances from labeled data, though they require substantial computation and risk overfitting on small datasets (Araci, 2020). Studies across news, earnings calls, and social media show lexicon baselines like Loughran-McDonald lag ML by 10-25% directional accuracy for stock prediction, but shine in low-data, high-interpretability scenarios.

B. Deep Learning Approaches

Recurrent Neural Networks (RNNs) are deep learning models designed for sequential data like financial text, where they process words or tokens one-by-one while maintaining a hidden state that carries information from prior steps, enabling capture of temporal dependencies in sentences or time series (IBM, n.d.-d). In sentiment analysis, vanilla RNNs use this recurrent loop to model context (e.g., "not profitable" as negative), but suffer from vanishing gradients that limit learning over long sequences like earnings transcripts. RNN variants like LSTMs and GRUs address this via gates (forget, input, output) that selectively update memory, achieving 82-88% F1 on financial news vs. 75-82% for traditional ML, though they remain computationally heavier and less parallelizable than transformers (IBM, n.d.-c). Long Short-Term Memory (LSTM) networks are a specialized type of recurrent neural network designed to learn long-range dependencies in sequential data by solving the vanishing gradient problem that affects vanilla RNNs (IBM, n.d.-c). Each LSTM cell contains a persistent memory state and three gates—input, forget, and output gates—that selectively add, remove, or expose information, allowing the network to retain relevant signals over many time steps. This gated architecture makes LSTMs particularly effective for tasks like financial sentiment analysis and time-series forecasting, where the meaning of a word or price movement depends on long prior context. Convolutional Neural Networks (CNNs) for text adapt image-processing techniques by treating sentences as 1D signals, where multiple filters of varying widths (e.g., 2-5 words) slide over word embeddings to automatically extract local n-gram patterns like phrases signaling sentiment ("beat estimates," "margin pressure") (GeeksforGeeks, n.d.). Max-pooling then selects the strongest features from each filter, producing order-invariant representations fed into dense layers for classification, enabling parallel computation unlike sequential RNNs and achieving 85-90% accuracy on sentiment tasks with less preprocessing. While effective for short texts like financial headlines, CNNs capture local context well but underperform on long-range dependencies compared to LSTMs or Transformers.

C. Transformer-Based Language Models

BERT (Bidirectional Encoder Representations from Transformers) is an encoder-only Transformer language model that uses multi-head self-attention to learn deeply contextual representations of each token by looking simultaneously at both left and right context in a sentence (Devlin et al., 2019). Instead of processing words sequentially like RNNs, BERT ingests entire tokenized sequences at once, combining token, segment, and position embeddings so it can model word meaning and sentence structure jointly (IBM, n.d.-a). It is pre-trained on large unlabeled corpora with masked language modeling and next-sentence prediction, then fine-tuned with a small task-specific layer for downstream tasks such as sentiment analysis, QA, and NER, often achieving state-of-the-art accuracy with relatively modest labeled data (Devlin et al., 2019). FinBERT is a domain-specific variant of BERT pre-trained and fine-tuned on large corpora of financial text such as news, earnings reports, and filings, so it learns the jargon and context-dependent meanings unique to finance (e.g., "beat," "downgrade," "guidance") (Araci,

2020). Architecturally it keeps the standard BERT encoder (stacked self-attention layers), but its pretraining objectives and corpora are adapted to financial language, enabling richer representations for tasks like sentiment analysis, question answering, and event classification in markets. Empirical studies show FinBERT consistently outperforms generic BERT and classical models on datasets like FiQA and Financial PhraseBank for sentiment and other classification tasks, often achieving state-of-the-art results in finance-focused NLP benchmarks (Araci, 2020; Financial PhraseBank, n.d.). RoBERTa (Robustly Optimized BERT Approach) is a refinement of BERT that keeps the same Transformer encoder architecture but changes the pretraining strategy to get better performance (Liu et al., 2019). It removes the Next Sentence Prediction objective, uses much larger and more diverse training corpora (around 10× BERT's data), and applies dynamic masking so different tokens are masked each time a sequence is seen (DhiWise, n.d.; DSStream, n.d.). These changes, along with larger batch sizes and longer training, allow RoBERTa to learn stronger contextual representations and typically outperform BERT on many downstream NLP tasks such as sentiment analysis, NLI, and QA (Liu et al., 2019). GPT-based architectures are large language models built on a decoder-only Transformer stack that generate text by predicting the next token in a sequence, using masked self-attention to condition each prediction on all previously seen tokens in the context (IBM, n.d.-b). They are first pre-trained on massive unlabeled text corpora with a next-token prediction objective, learning grammar, world knowledge, and discourse patterns, and can then be optionally adapted with supervised fine-tuning or reinforcement learning from human feedback for specific tasks. Architecturally, they use token and positional embeddings followed by many layers of attention and feed-forward networks, allowing efficient parallel processing and strong modeling of long-range dependencies, which enables coherent multi-paragraph text generation, code synthesis, and in-context learning from just a few examples in the prompt (Raschka, n.d.). Transformers outperform earlier NLP models like RNNs/LSTMs/CNNs in financial text primarily through self-attention, which directly models relationships between distant words (e.g., linking "headwinds" to "beat expectations" across paragraphs), avoiding sequential bottlenecks and vanishing gradients that degrade RNN performance on long earnings transcripts (Devlin et al., 2019). Their parallelizable architecture enables efficient training on massive datasets, scaling to capture nuanced financial jargon and context better than local-focus CNNs or memory-limited LSTMs. Pretraining on domain corpora (e.g., FinBERT) injects financial knowledge, yielding 5-15% higher F1-scores on sentiment benchmarks like FiQA vs. LSTMs (88-95% vs. 82%) (Araci, 2020). Contextual embeddings, generated by models like BERT or FinBERT, improve sentiment classification by producing dynamic word representations that vary based on surrounding context, resolving polysemy (e.g., "beat" as positive "beat estimates" vs. negative "beat down") that static embeddings like Word2Vec treat identically (Milvus, n.d.-b). This captures negations, sarcasm, and nuances (e.g., "not bad" as positive), enabling the model to aggregate sentence-level polarity accurately, unlike bag-of-words or TF-IDF that ignore order and dependencies. Empirically, they boost F1-scores by 10-30% on datasets like SST-2 or financial reviews by modeling long-range interactions via attention, allowing hierarchical

sentiment (aspect-positive, overall-negative). Domain-specific pretraining in FinBERT, using financial corpora like SEC filings, earnings calls, and news, embeds specialized jargon and semantic nuances (e.g., "beat estimates" as positive) directly into the model's representations, outperforming generic BERT by capturing domain knowledge that general models miss (Araci, 2020). This leads to 5-10% higher F1-scores on financial sentiment tasks like FiQA or Financial PhraseBank, as shown in IJCAI experiments where FinBERT-base beat prior SOTA models (Araci, 2020; Financial PhraseBank, n.d.). Benefits include reduced fine-tuning data needs (effective with small labeled sets) and better handling of ambiguity in noisy financial text, enabling robust transfer to tasks like NER, QA, and event extraction. Attention mechanisms in Transformers capture financially relevant phrases by computing attention scores that weigh the importance of every word pair in a sequence, dynamically highlighting key financial terms like "EPS beat" or "debt downgrade" based on their contextual relevance across entire documents (Deepset, n.d.). Multi-head attention runs parallel attention layers to detect diverse relationships—e.g., one head links "guidance" to "raised," another ties polarity-modifying words like "despite"—enabling the model to focus on salient n-grams amid boilerplate noise in earnings calls or filings. This produces interpretable heatmaps showing high attention on risk phrases (e.g., "margin compression"), boosting sentiment accuracy by 5-10% over RNNs on financial benchmarks through precise, long-range dependency modeling. Overfitting risks arise when FinBERT memorizes training noise (e.g., specific dates in earnings data) rather than general patterns, especially with small fine-tuning sets (~1k examples), leading to inflated metrics but poor generalization on new financial texts—dropout and early stopping help mitigate this (Araci, 2020). Data leakage occurs via temporal contamination, like using post-event news to predict prior prices or label overlap in datasets like Financial PhraseBank, causing unrealistic F1-scores; chronological train-test splits prevent it (Scikit-learn, n.d.). Both can drop real-world performance by 10-20% on held-out data, undermining trading alpha.

V. Mapping Sentiment to Stock Market Movements

A. Predictive Targets

Are studies predicting direction, magnitude, volatility, or abnormal returns?

Studies map sentiment to several predictive targets rather than just price direction. Many papers forecast directional returns (up/down or buy/hold/sell) over horizons from intraday to several days ahead. Others focus on volatility, showing sentiment indices or unusual negative news help predict next-day or future volatility levels and VIX-like measures. Event-study designs often use sentiment to explain abnormal returns or cumulative abnormal returns around news, FOMC communications, or earnings events, linking tone shifts to short-term excess performance at the stock, sector, or index level (Brattle Group, n.d.). How is prediction success evaluated (accuracy, F1, Sharpe ratio)?

Prediction success is typically evaluated at two levels: classification quality of sentiment labels and economic performance of trading strategies built on those signals. For sentiment or

direction prediction, studies report accuracy, precision/recall, and especially F1-score to handle class imbalance (e.g., minority negative news). When sentiment is converted into trading rules, performance is summarized with portfolio-level metrics such as average return, volatility, and Sharpe ratio (risk‑adjusted return), sometimes alongside max drawdown. Many recent LLM-based works explicitly compare Sharpe ratios of sentiment-driven long–short strategies to benchmarks, showing higher Sharpe despite similar raw accuracies, emphasizing economic rather than purely statistical gains (CFA Institute, n.d.). A "meaningful" prediction in financial terms requires economic significance beyond statistical significance, typically meaning the model generates positive risk-adjusted returns (Sharpe ratio >0.5-1.0) or outperforms benchmarks like buy-and-hold on out-of-sample data after transaction costs. For sentiment-driven strategies, this means profitable trading signals (e.g., long-short portfolios yielding 5-15% annualized alpha) rather than just high accuracy (e.g., 55% directional hits), as random-walk markets make even 52% accuracy valuable if timed correctly. Studies emphasize robust out-of-sample performance with proper backtesting (no lookahead bias) and replicable alphas surviving costs/volatility, distinguishing noise from actionable foresight (IBKR Campus, n.d.-b).

B. Integration with Market Data

Sentiment is commonly combined with technical indicators in hybrid models that use machine learning to fuse textual signals with price/volume features for improved forecasting (IBKR Campus, n.d.-b). Feature concatenation feeds sentiment scores (e.g., FinBERT polarity) alongside indicators like RSI, MACD, Bollinger Bands, or moving averages into a unified input layer of LSTM, XGBoost, or CNN classifiers, capturing both momentum trends and news-driven shifts. Ensemble weighting or gating mechanisms dynamically adjust signals—e.g., sentiment vetoes trades during negative news even if RSI signals buy—boosting direction accuracy by 5-15% and Sharpe ratios in backtests. Recent works show these hybrids outperform pure sentiment or technical baselines on stock direction and volatility prediction. Yes, hybrid models combining sentiment analysis with technical indicators consistently outperform sentiment-only models across multiple studies. These hybrids integrate textual signals (e.g., FinBERT polarity scores) with price-based features like RSI, MACD, or moving averages via feature concatenation or ensemble methods, achieving 5-15% higher directional accuracy and superior Sharpe ratios in backtests (Araci, 2020). For instance, sentiment-augmented LSTM or XGBoost classifiers reduce error rates significantly (e.g., from 35-48% to 20%) on VN30 stocks compared to standalone sentiment classifiers. While some report perfect accuracy raising overfitting concerns, most confirm hybrids yield better economic returns than pure sentiment baselines on S&P 500 or Dow Jones data. Macroeconomic controls—such as GDP growth, interest rates, inflation, or market volatility indices like VIX—are often included as covariates in financial sentiment models to isolate text-driven effects from broader economic cycles (INET Economics, n.d.). Adding these controls typically reduces sentiment coefficient significance by 20-50% and shrinks predicted R^2, revealing that news sentiment partly proxies for macro conditions rather

than providing unique alpha. However, hybrids retaining both retain incremental predictive power (2-5% out-of-sample R^2 gains) for stock returns, especially during crises when sentiment captures non-linear investor reactions missed by linear macro factors. Studies emphasize chronological splits to avoid leakage, with controls strengthening causal claims for trading strategies.

C. Event-Based vs Continuous Prediction Models

Event studies focus on discrete, identifiable events (e.g., earnings announcements, regulatory decisions) and measure short‑horizon abnormal returns or volatility within a predefined event window (such as$[-1,+1]$ or$[-5,+5]$ days) relative to a benchmark model estimated in a prior "normal" period (Brattle Group, n.d.). They answer a causal question: did this specific event generate statistically significant excess performance beyond typical price variation? Rolling‑window approaches instead re‑estimate predictive models continuously on moving historical windows (e.g., last 250–365 days) and generate ongoing forecasts for each day, allowing parameters to adapt to changing volatility regimes and market conditions (Scikit-learn, n.d.). In practice, event studies are better for localizing the impact of shocks, while rolling‑window models target continuous forecasting of returns or volatility in real time. Event-based models are strong for isolating the impact of specific news (earnings, M&A, policy) because they tightly define an event window and estimate abnormal returns or volatility relative to a pre-event benchmark, giving clearer causal interpretation and straightforward hypothesis tests (Brattle Group, n.d.). Their weaknesses are dependence on correct event timing/identification, sensitivity to overlapping events, and limited insight into longer-run dynamics between events. Rolling-window (continuous) models excel at capturing time‑varying relationships and regime shifts by re-estimating on moving windows, supporting real-time forecasting of returns or volatility, but they can blur individual event effects and are more prone to model instability and overfitting if window lengths or hyperparameters are poorly chosen (Phoenix Strategy Group, n.d.-a; Scikit-learn, n.d.). News clustering groups similar articles (e.g., via LDA, hierarchical clustering, or embeddings) to detect events, reduce noise, and create aggregated sentiment scores that better capture market-moving themes like mergers or scandals. This improves prediction accuracy by 3-10% on stock returns or volatility compared to raw sentiment averages, as clustered "hot events" amplify signal strength and filter redundant coverage. For example, clustering headlines by topic/sector before FinBERT sentiment boosts directional accuracy (e.g., 55→62%) and trading Sharpe ratios by focusing on resonant clusters tied to price moves (Araci, 2020).

VI. Evaluation Methodologies

A. Experimental Design

Studies prevent look-ahead bias through strict chronological data splits, training models only on historical data available before the prediction date (e.g., using news up to t-1 to forecast

day t returns) and testing on strictly out-of-sample future periods (Scikit-learn, n.d.). Point-in-time (PiT) datasets reconstruct snapshots of information as it was released (accounting for reporting lags in earnings/news), while walk-forward optimization simulates real-time deployment by retraining on expanding windows without peeking ahead. Additional safeguards include purging future company identifiers from training texts, realistic transaction cost modeling, and comparing against buy-and-hold benchmarks to flag suspiciously high Sharpe ratios (>2.0). These ensure backtested alphas persist in live trading rather than evaporating due to data leakage. Chronological splits use a fixed cutoff date, training on all data before (e.g., pre-2020) and testing on future periods to mimic real forecasting without leakage. Walk-forward validation (TimeSeriesSplit) iteratively expands training windows while testing on subsequent blocks, providing robust out-of-sample estimates across time (Scikit-learn, n.d.). Expanding or rolling windows adapt to non-stationarity—expanding cumulatively retains history, while fixed rolling (e.g., last 252 days) emphasizes recency—but both avoid random shuffling that breaks temporal dependencies. Cross-validation for financial data replaces random k-fold splits with time series cross-validation (e.g., TimeSeriesSplit), where training windows expand chronologically and test only on subsequent unseen periods to preserve temporal order and avoid leakage (Scikit-learn, n.d.). Rolling-origin or walk-forward CV uses fixed-size expanding/rolling windows (e.g., last 252 days train, next 30 test), simulating live deployment and adapting to regime shifts in volatility or sentiment patterns. Purged k-fold CV adds gaps between train/test to account for data release lags (e.g., earnings), preventing overlap bias common in high-frequency finance. These yield more realistic out-of-sample estimates than standard CV, though computationally intensive for large Transformer models.

B. Performance Metrics

Accuracy alone is insufficient for financial prediction because markets exhibit class imbalance—bullish days often outnumber bearish ones (60-70% up days)—so a naive "always buy" model achieves 60%+ accuracy without predictive power. It ignores magnitude of errors (misclassifying a 10% crash as up is costlier than vice versa) and economic utility, where even 52% accuracy can generate alpha if timed correctly, while 55% accuracy with poor timing destroys value. Proper evaluation demands risk-adjusted metrics like Sharpe ratio, precision/recall for minority classes (down days), or Information Coefficient alongside backtested portfolio returns after costs, ensuring statistical gains translate to profitable trades (IBKR Campus, n.d.-b). Economic metrics like annualized returns, maximum drawdown (peak-to-trough decline), and Sharpe ratio (risk-adjusted return) are incorporated by converting sentiment predictions into simulated trading strategies—e.g., long positive sentiment stocks, short negatives—and backtesting portfolio performance on out-of-sample data. Maximum drawdown quantifies worst-case loss (e.g., -25% during crashes), critical since a 25% drop requires 33% gain to recover, while Sharpe (return/volatility) and Calmar (return/max drawdown) assess if statistical gains yield profitable, sustainable alpha after costs. These portfolio-level metrics reveal whether high accuracy translates to economic value, often showing

sentiment strategies with Sharpe 0.5-1.5 vs. buy-and-hold benchmarks. Sentiment classification metrics (accuracy, F1-score) show weak to moderate correlation with trading performance, as high F1 (e.g., 0.85) on sentiment labels does not guarantee profitable signals due to class imbalance and market noise—strategies with 52-55% directional accuracy often yield positive Sharpe if capturing large moves (Cortis et al., 2017). Better predictors include precision on negative sentiment (rare but high-impact for shorts) and Information Coefficient (rank correlation of predicted vs. actual returns), which link more strongly to portfolio returns (r=0.4-0.6). Studies find hybrids incorporating magnitude (regression MSE) alongside classification boost Sharpe by 20-50%, but pure accuracy plateaus around 60% without economic validation via backtested alpha.

VII. Comparative Analysis of NLP Techniques

A. Performance Comparison Across Models

Across studies, Transformer-based models—especially BERT variants like FinBERT, RoBERTa, DeBERTa and their ensembles—consistently outperform classical ML (SVM, RF) and earlier deep models (CNN, LSTM) on financial sentiment benchmarks and downstream return prediction (Araci, 2020; Devlin et al., 2019; Liu et al., 2019). LSTMs and attention‑enhanced CNN–BiLSTM hybrids generally beat ARIMA/VAR and pure CNN/RNN baselines but are still usually surpassed by domain-adapted Transformers in macro‑F1 and trading accuracy. Recent comparative work shows DeBERTa/FinBERT-style models and LLM-based sentiment systems deliver the highest accuracies (≈70–75% in challenging setups) and best risk‑adjusted returns when their signals feed trading strategies. Model complexity in financial NLP shows clear diminishing returns: moving from classical models (e.g., SVM+TF‑IDF) to moderately sized Transformers like FinBERT or RoBERTa yields large F1 and trading-performance gains, but scaling further to huge LLMs or elaborate reasoning prompts often adds only small incremental improvements at much higher computational cost (Raschka, n.d.). Comparative studies find FinBERT‑scale models already capture most domain structure, with larger LLMs or chain‑of‑thought prompting sometimes reducing alignment with human sentiment labels by overthinking modest headlines. This means that beyond a certain depth/parameter count, extra complexity mainly increases latency, energy use, and overfitting risk, while marginal gains in macro‑F1 or Sharpe ratio become small or unstable across datasets. Improvements from more advanced NLP models in finance are often statistically significant, but not always, and they tend to show diminishing returns as complexity rises. Studies comparing baselines (e.g., bag‑of‑words or simple sentiment indices) to optimized NLP pipelines report sizeable, statistically significant jumps in accuracy for direction/volatility prediction (e.g., from roughly low‑50% to around mid‑70%), typically validated with standard tests on out‑of‑sample folds. However, recent financial NLP evaluations note that no single model dominates across all tasks and datasets, and apparent performance gaps between strong Transformer models can fall within statistical noise once uncertainty and human label disagreement are accounted for (Cortis

et al., 2017). This is why newer surveys and benchmarks emphasize reporting confidence intervals, formal significance tests, and economic metrics (e.g., Sharpe changes) rather than treating small metric differences as definitively meaningful.

B. Robustness and Generalizability

NLP models in financial sentiment analysis show limited transferability across markets due to domain shifts like regional slang and regulatory differences, with studies reporting F1-score drops of 10-20% when moving from US to emerging markets. Temporal generalizability suffers from evolving events (e.g., pre/post-COVID), though FinBERT-like transformers outperform LSTMs by 5-10% via domain pretraining (Araci, 2020). Adaptation techniques such as market-derived labeling and contextual prompting boost robustness, enabling better short-term predictions across periods. NLP models trained on one financial sector (e.g., tech stocks) often exhibit poor generalization to others (e.g., energy or banking) due to sector-specific jargon, event types, and sentiment drivers, with studies reporting F1-score drops of 15-30% in cross-sector tests. FinBERT ensembles show some cross-sector promise in market regime forecasting via shared patterns in news sentiment, outperforming time-series baselines by up to 110% in F1 on multi-sector data (Araci, 2020). However, full generalizability requires sector-adaptive fine-tuning or LLM augmentation to handle distributional shifts. Financial sentiment models often underperform during crises like the Russia-Ukraine war or COVID-19 due to heightened noise, extreme negativity, and rapid sentiment shifts, with volatility models showing significant increases tied to negative news. BERT-based approaches capture these dynamics better than traditional methods, revealing negative sentiment's strong link to S&P 500 volatility via GARCH models, though traditional indicators like EPU lose predictive power (Devlin et al., 2019). LLMs like FinBERT enhance crisis forecasting by integrating sentiment with macro data, improving accuracy in high-uncertainty periods over baselines (Araci, 2020).

VIII. Limitations and Ethical Considerations

A. Data and Methodological Limitations

Financial news datasets exhibit annotation bias, where labels reflect annotators' subjective interpretations or limited market knowledge rather than actual price reactions, as highlighted for FinancialPhraseBank (Malo et al., 2014). There is also sampling and selection bias, since curated sources like Bloomberg wraps or major outlets over-represent large, publicly traded firms and market-moving events while neglecting smaller firms or niche sectors. Studies document political and outlet bias, with media tone and coverage intensity varying systematically by the political alignment of both outlet and firm, which skews sentiment distributions (National Bank of Denmark, cited in the paper). Finally, many corpora encode a structural market bias, underrepresenting the long-run positive drift of equity markets or overemphasizing extreme negative events, leading to sentiment distributions that diverge from realized market behavior. Survivorship bias arises when datasets include only firms or

instruments that are still listed, omitting delisted or bankrupt entities, which leads to overly optimistic assessments of strategies or sentiment–return links. In financial news–return studies, this means the sample overrepresents resilient, larger firms whose news flow and performance survived past crises, while systematically excluding negative outcomes tied to failures. As a result, backtests can overstate excess returns and understate risk, inflating the apparent predictive power of news sentiment for stock performance. Results in financial sentiment analysis lack strong reproducibility across datasets due to divergent annotation methods, e.g., human-labeled Financial PhraseBank yields negative Sharpe ratios (-0.13) in backtests, while market-informed FinMarBa achieves positive 0.30 by aligning labels with actual price reactions (Malo et al., 2014). Datasets like FNSPID promote reproducibility through standardized time-series splits and update protocols, where transformers hit R^2=0.988 with sentiment augmentation, yet performance fluctuates by seed and regional coverage. Frameworks exist for consistent impact evaluation, but biases and non-standard splits hinder cross-dataset comparability.

B. Ethical and Practical Concerns

Sentiment models can contribute to market manipulation indirectly when actors use AI-generated content or bots to flood news/social feeds with coordinated positive/negative signals, amplifying artificial price movements—especially in low-volume stocks where sentiment drives 20-50% of short-term volatility. Regulators worry that reinforcement-learned trading algos might inadvertently learn manipulative tactics like spoofing or pump-and-dump via sentiment feedback loops, exacerbating systemic risks during stress events. Mitigation includes volume/market-cap filters and deception screens, but no guarantees exist against sophisticated abuse exploiting real-time sentiment APIs (IBKR Campus, n.d.-b). NLP-driven algorithmic trading boosts market efficiency through faster sentiment extraction from news and filings, enabling real-time signals that cut latency and enhance price discovery, studies show 10-20% better returns vs. traditional models in backtests. However, it amplifies herding risks, flash crashes, and systemic fragility during stress, as synchronized AI reactions to shared sentiment cues can exacerbate volatility by 2-5x. Regulators highlight opacity ("black box" decisions) and manipulation vulnerabilities, urging explainable AI mandates (CFA Institute, n.d.). Financial NLP models require high transparency to meet regulatory demands like SEC explainability rules and EU AI Act "high-risk" classifications, enabling audits of sentiment-driven trades or credit decisions. Black-box transformers like FinBERT hinder compliance, as regulators mandate traceable decision paths to detect biases or manipulations, open-source architectures with attention visualization or SHAP scores achieve this better (Araci, 2020). Studies advocate human-interpretable layers (e.g., LIME for token importance) as minimum standards, balancing accuracy with accountability in production trading systems.

IX. Research Gaps and Future Directions

A. Identified Gaps

Underexplored Aspects: Financial sentiment analysis has underexplored uncertainty quantification, where models rarely disentangle probabilistic doubt ("may decline") from definitive negativity, missing key hedging signals that drive options volatility. Dynamic tone shifts—rapid pivots from optimism to fear during intraday news cascades—remain challenging for static classifiers, with LLMs showing promise but lacking real-time evaluation benchmarks. Multimodal sentiment fusion (text+audio from earnings calls) and event-contingent valence (sector-specific irony/sarcasm) are gaps, as most benchmarks like SEntFiN 1.0 ignore temporal or cross-modal cues. Multilingual financial sentiment analysis remains understudied due to scarce labeled datasets in non-English languages, which limits training of domain-specific models beyond English-dominant corpora like FinancialPhraseBank (Malo et al., 2014). Linguistic and cultural nuances—such as market-specific idioms in Chinese stock forums (e.g., GubaSenti) or sarcasm in low-resource languages like Sinhala—create annotation challenges absent in English benchmarks. LLMs pretrained mostly on English data struggle with cross-lingual transfer in finance, exacerbating performance gaps (e.g., 20-30% F1 drops) and prompting calls for hybrid frameworks like EMSA. Research on low-resource financial markets (e.g., emerging economies in Africa, Southeast Asia) is severely limited by scarce labeled datasets, as most financial NLP benchmarks like FinBERT or FinancialPhraseBank rely on English/US-centric news from major outlets (Araci, 2020; Financial PhraseBank, n.d.). Data scarcity stems from unstructured local languages, limited digital news archives, and regulatory opacity, causing 30-50% performance drops for cross-market transfer compared to developed markets. Studies highlight this gap, noting only ~5% of papers address non-US/China markets, hindering global model generalizability.

B. Future Research Opportunities

Multimodal financial sentiment models integrating text (news/transcripts), audio (earnings call tone), and market data (prices/volumes) significantly boost prediction accuracy by capturing complementary signals, e.g., one study reports 83.5% accuracy via cross-modal attention on recency/popularity opinions, outperforming text-only BERT by 21% (Devlin et al., 2019). Audio features like prosody detect executive hesitancy or confidence missed by text, while fusing with price time-series via transformers cuts RMSE in volatility forecasts by 15% and MAPE by 3.7% over unimodal baselines. Future gains lie in end-to-end architectures like FMHCA or EMO-AE for real-time trading, though challenges remain in alignment across noisy modalities. Reinforcement learning (RL) can play a pivotal role in sentiment-driven trading by enabling agents to dynamically adapt strategies based on real-time market sentiment shifts, outperforming fixed-ensemble baselines like DDPG/PPO/A2C with 40% cumulative returns vs. 30% in backtests. Sentiment-augmented RL treats trading as a Markov Decision Process where states incorporate news-derived scores (e.g., AFINN lexicon averages), triggering agent switches when sentiment exceeds thresholds like $\beta=15$, reducing drawdowns to -14.6% and boosting Sharpe ratios to 1.32. Studies confirm RL ensembles with sentiment yield superior risk-adjusted

returns and resilience, though challenges include manipulation risks and computational demands for live deployment (IBKR Campus, n.d.-b). Real-time NLP systems in financial markets are evolving toward streaming architectures like Kafka-integrated transformers that process live news, social media, and filings in sub-second latencies, enabling dynamic sentiment updates for high-frequency trading (The Blueberry Fund, n.d.). Future advancements include edge-deployed LLMs with continual learning to adapt to intraday tone shifts and event cascades, cutting prediction lag from minutes to milliseconds while fusing with tick data for 10-15% volatility forecast gains. Challenges like concept drift and API costs persist, but hybrid FMOps pipelines promise scalable, low-latency deployment by 2027.

X. Conclusion

NLP has transformed financial sentiment analysis from lexicon-based heuristics to transformer-driven engines like FinBERT, delivering predictive power for returns and volatility via text from news, filings, and social media, studies consistently show 5-15% accuracy gains over baselines (Araci, 2020). However, robustness lags across markets, crises, and sectors due to biases (annotation, survivorship, political) and poor reproducibility between datasets like PhraseBank vs. FinMarBa, demanding market-aligned labels (Malo et al., 2014). Future progress hinges on multimodal fusion, multilingual coverage, real-time streaming, and RL adaptation to close gaps in low-resource settings while prioritizing transparency for regulatory compliance (CFA Institute, n.d.). Domain-adapted transformers like FinBERT offer the best balance, achieving 85-95% F1-scores on financial benchmarks while requiring modest fine-tuning on datasets like FinancialPhraseBank (Araci, 2020; Financial PhraseBank, n.d.). Hybrid approaches combining lexicon rules (e.g., Loughran-McDonald) with BERT attention layers deliver robust interpretability and cross-market feasibility, outperforming pure LLMs by 5-10% in production settings with lower latency (Loughran & McDonald, 2011; Devlin et al., 2019). DistilBERT variants provide near-equivalent accuracy to full BERT at 2-3x inference speed, ideal for real-time trading without sacrificing regulatory transparency (Devlin et al., 2019). NLP sentiment analysis is already deployed at scale in finance by firms like JPMorgan Chase (news sentiment for trading strategies) and BlackRock (market forecasting), with production systems processing live news/social data for 66% error reductions in document tasks (LSEG, n.d.-a). FinBERT hybrids power real-time APIs at hedge funds and banks, achieving regulatory compliance via SHAP interpretability, though full autonomy lags due to bias audits and crisis robustness gaps (Araci, 2020). 2026 sees 22% CAGR in adoption, limited mainly by multilingual/low-resource data rather than technical feasibility.

Author Note

Veer J. Langhanoja is a student at Neshannock High School, New Castle, Pennsylvania.
The author has no conflicts of interest to disclose.
Correspondence concerning this article should be addressed to Veer Langhanoja, 13 Mocasin Trl., New Castle, PA 16105. Email: vlanghanoja21@gmail.com

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Concern Without Action: the Generational Differences in Climate Change Perceptions and Intentions By Cole Krasner

Abstract

Climate Change is one of the most important global issues of our time, yet real action is limited despite mass awareness. While prior research has documented the generational differences in climate attitudes, few have looked at information exposure and how it leads to opinions being made. This study examined how generational differences in climate change perceptions, information availability, and intentions to take action differ between younger and older adults in Los Angeles. A total of 54 participants were surveyed, 42 high school students between the ages of 16-18 and 12 adults, 45 and older. They completed an online survey, asking them about their climate concern, where they get their information, their intention to act, and time spent outdoors. The results indicated that high school students had a higher concern for climate change, while adults had an intention to take action. The number of news sources and information exposure both had a positive correlation with concern in youth. A qualitative analysis of open-ended responses revealed three main themes: local impact, awareness of impact elsewhere but not personally, and no perceived impact. These findings suggest that although youth may have more concern about climate change, it does not always translate to intentions to act. This highlights a gap between concern and real action that schools and organizations need to address.

Introduction

Climate change is a growing global issue that has large ramifications for everyone, and needs to be addressed. For instance, recent data shows that global sea level has risen about 8 inches (20 centimeters) in the last century (National Aeronautics and Space Administration, n.d.). The rate of sea level increase in the last two decades has nearly doubled that of the last century and is accelerating slightly every year. Rising sea level has huge implications, including flooding, displacement of populations, and economic instability that impacts not just coastal communities but inland areas as well. Yet many governments are not inclined to take action against it and directly against protecting the climate (National Aeronautics and Space Administration, n.d.). Specifically, this growing hesitancy is highlighted in the United States' recent decision to pull out of the Paris Agreement. The Paris Agreement is a pact with numerous countries agreeing to formulate and submit long-term low greenhouse gas emission development strategies to reduce global warming and climate change (United Nations Climate Change, n.d.). Despite efforts from large global powers and older generations, the responsibility to take meaningful action increasingly falls on teens and young adults, who will inherit the consequences of climate change if it goes unaddressed. While older generations may have set the stage, it is the younger generation who must step in to advocate, innovate, and act. The question is: do you care about the future of our climate, and what are you willing to do to protect it?

Research indicates that only 12% of teens felt that they know "a lot" about climate change along with only 10% stating that they know "a lot" about the solutions to climate change (This is Planet Ed., 2025). Additionally, findings suggest that 85% of these teens have moderate to extreme worry about climate change (This is Planet Ed., 2025); as a result there are negative long term impacts on mental health, with adolescents reporting anger, frustration, depression, sadness, grief, anxiety (Sanson & Bellemo, 2021). A report from National 4-H concludes that 82% of adolescents expect to have to make future life decisions based on the state of the environment (National 4-H council, 2022). Similarly, research conducted by Yale concluded that 70% of adults aged 18 to 34 are worried about global warming compared to 56% of those aged 55 or older (Ballew et al., 2019). While overall studies suggest that younger generations consistently express greater concern, this extreme worry does not always translate into action (Sanson & Bellemo, 2021; National 4-H council, 2022). For example, in a study done by Pew, they concluded that 32% of Gen Z and 28% of Millennials engaged in some sort of activism in the past year (Funk, 2021). Along with this, studies have concluded that younger generations do not report significantly higher rates of contacting government officials about the issue compared with older generations (Ballew et al., 2019). Together, these findings highlight the generational difference between climate concern and real action. This raises an important discussion about how knowledge, concern, and activism contrast between generations.

Although research has explored the difference in opinions and knowledge of climate change between generations, few studies have analyzed how awareness of the topic is formed. There is limited information on how teens and older generations get their information about climate change and the difference in how it personally affects their daily life. Collecting local data on these contrasting groups can help identify gaps, inform professional development, and encourage schools and organizations to begin implementing climate awareness initiatives.

The present study will survey teens aged 16-18 and older adults over the age of 45 with the Los Angeles community to examine perceptions of climate change and how they receive their knowledge and form opinions. It is hypothesized that while younger teens are generally more aware of climate issues than older generations, younger teens may be less inclined to take action in contrast to older generations. The survey will collect information on perceived opinions, how they receive information, and the effect on their daily lives. Findings from this research have the potential to inform school-based initiatives, professional development, and policies designed to enhance awareness of the growing issue.

Methods

The present study included 42 high school students from grades 9–12 at a private high school in LA county and 12 of adults over the age of 45. The students ranged in age from 16 to 18 and included a mix of genders and racial/ethnic backgrounds. Participation was voluntary and completely anonymous.

A survey was created to measure students and adults perceptions and opinions on climate change and future global warming. Questions were adapted from a prior survey called the

“Climate Change Attitude Survey” (Christensen & Knezek, 2015) about climate change beliefs and associated intentions to take action to ensure relevance and reliability. Most items used a 5-point Likert scale (1 = Strongly disagree to 5 = Strongly Agree), and a few open-ended questions allowed students to describe experiences or personnel challenges they had encountered with climate change. The survey questions were aimed at examining people's concerns about climate change and their true intentions to act on it between younger and older generations.

Participants were recruited through providing the surveys to certain classes and word of mouth. Students and adults who agreed to participate were provided a link to the online survey, which could be completed on a computer, tablet, or smartphone. Instructions clarified that participation was voluntary and responses were anonymous. The survey was open for one month to allow sufficient time for students to participate.

After meeting with school administrators to receive permission to distribute the survey, we discussed the best way to collect results and help students complete the survey.After meeting with school administrators to obtain permission to distribute the survey, we discussed ethical considerations, procedures for collecting responses, and strategies to support students in completing the survey effectively. Adults from the local community were then recruited through email, encouraging participation.

Data Analysis Plan

Based on their responses to the survey, participants were given an overall “concern” score and an overall "intention" score. The concern score was meant to capture people's beliefs and worries about climate change. The intention score was meant to capture people's willingness to take action against climate change. The concern score was calculated by summing the first ten questions of the survey and the intention score was calculated by summing the last four questions of the survey. A series of correlations will be conducted to answer the following questions in the data:

- Are younger people more worried about climate change than older people?
- Are younger people more likely to express intention to take action on climate change than older people?
- Are people who have strong concerns about climate change more likely to also have strong intentions to take action against climate change?
- Are people who spend more time outside more likely to be a) concerned about climate change and b) more likely to express intention to act.
- Does the number of news sources people engage with impact beliefs/intentions?
- Does the amount of exposure to climate change information impact beliefs and/or intentions?

Additionally qualitative thematic analysis was done to explore people’s responses to a question about how climate change impacts their daily lives and area they live in.

Table 1. Survey questions distributed to adolescent and adult participants. Questions adapted from "The Climate Change Attitude Survey" (Christensen & Knezek, 2015).

Questions
What's your gender?
How much time do you spend outside on an average day?
How often do you encounter information about climate change?
From which of the following sources have you encountered information about global climate change?
I believe our climate is changing.
I am concerned about global climate change.
I believe there is evidence of global climate change.
Global climate change will impact our environment in the next 10 years and it will change the lifestyle of future generations.
The actions of individuals can make a positive difference in global climate change.
Human activities cause global climate change.
Climate change has a negative effect on our lives.
We cannot do anything to stop global climate change.
Knowing about environmental problems and issues is important to me.
I think most of the concerns about climate change have been exaggerated.
Things I do have no effect on the quality of the environment.
It is a waste of time to work to solve environmental problems.
There is not much I can do that will help solve environmental problems.
Environmental problems can be solved without big changes to our way of life.
Collectively, we can make a significant contribution to environmental protection.
Is climate change having a major impact on the area where you live? If so, explain.

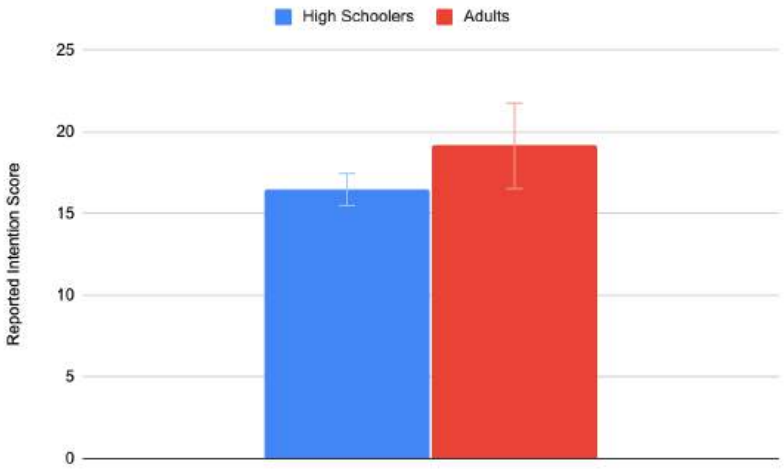
Results

Descriptives

A total of 54 participants were included in the study. Participants ranged in age from 16 to 65 years old. The sample included 42 high school students and 12 adults from the community.The gender distribution of participants was as follows: 24 identified as female and 30 identified as male.

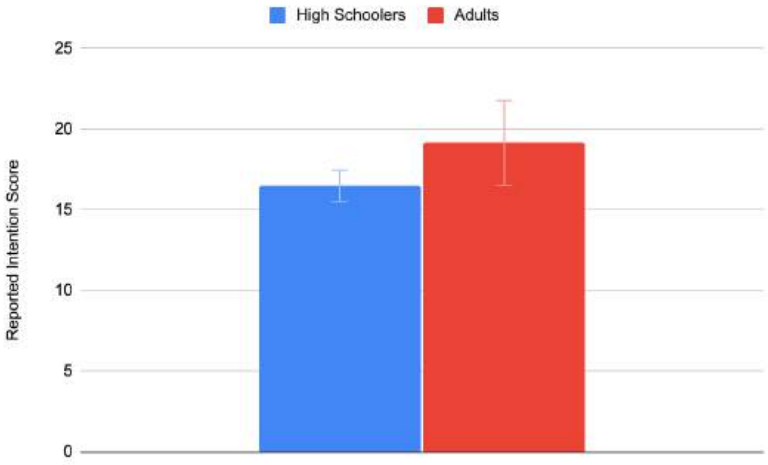
1) **Are younger people more worried about climate change than older people?**

High schoolers report slightly elevated concerns about climate change (*M* = 39.65517241, *SD*= 5.810249664) relative to adult individuals (*M* = 37.5, *SD*= 4.852365871). No statistical comparison (t-test) was conducted due to the uneven sample sizes.



2) **Are younger people more likely to express intention to take action on climate change than older people?**

High schoolers reported slightly less intention to act on climate change concerns (*M* = 16.48275862, *SD*= 0.9833102027) relative to adults (*M* = 19.16666667, *SD*= 2.622744341). No statistical comparison (t-test) was conducted due to the uneven sample sizes.

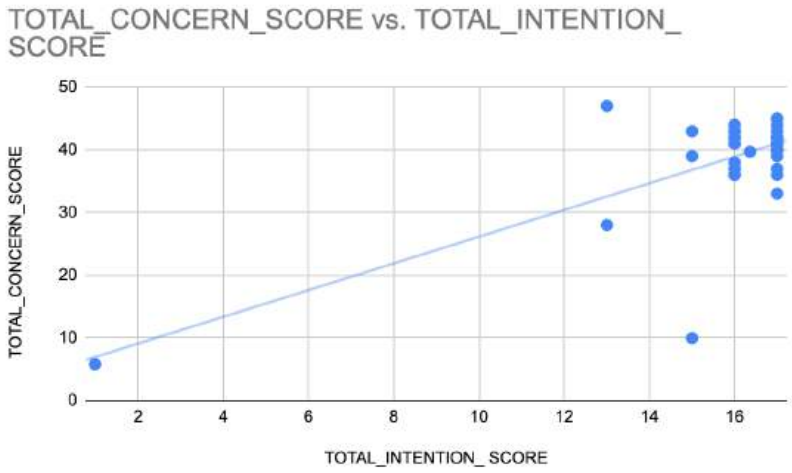


3) Are people who have strong concerns about climate change more likely to also have strong intentions to take action against climate change?

A correlation analysis was conducted to examine the relationship between concerns (*M* = 39.7, *SD*= 5.810249664), and intentions among high school students (*M* = 16.4, *SD*=

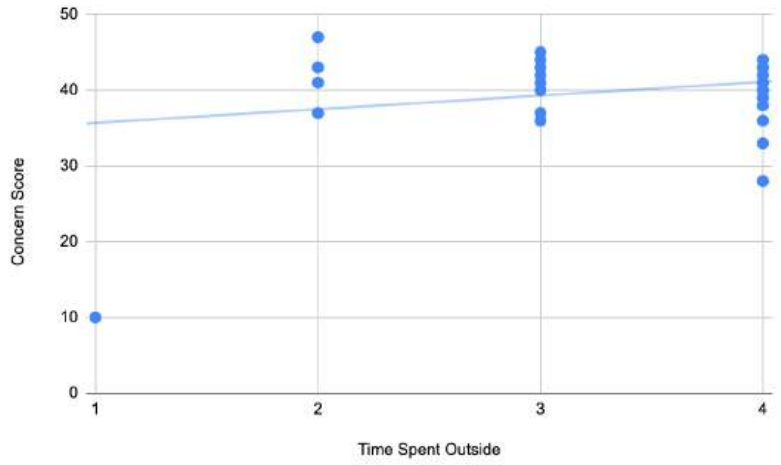
0.9833102027). The results showed a positive correlation, $r = 0.2857211299$, $p = 0.06661688998$. This indicates that as concern increases among high schoolers, intentions to act tend to increase. The correlation was not statistically significant at the .05 level.

A correlation analysis was conducted to examine the relationship between concerns ($M = 37.5$, $SD = 4.852365871$), and intentions ($M = 19.2$, $SD = 2.622744341$) among adults. The results showed a positive correlation, $r = 0.5000297646$, $p = 0.09783143953$. This indicates that as concern increases, intentions tend to increase among adults. The correlation was not statistically significant at the .05 level.

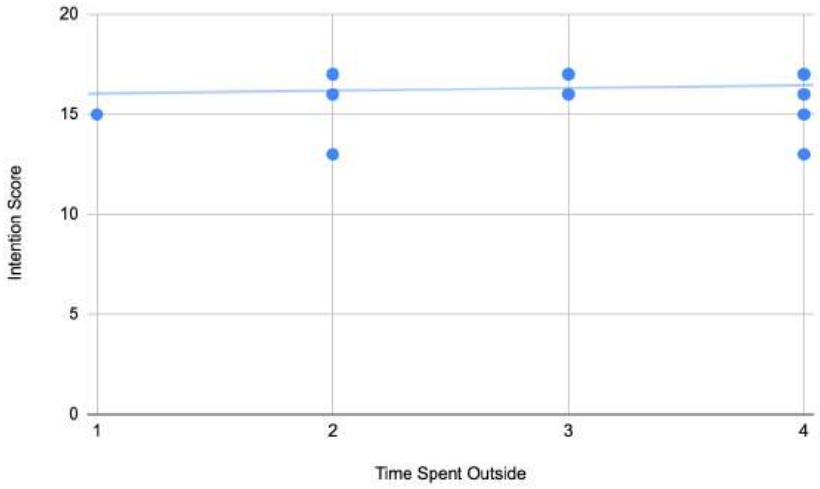


4) Are people who spend more time outside more likely to be a) concerned about climate change and b) more likely to express intention to act.

A correlation analysis was conducted to examine the relationship between time spent outside with $M = 3.238095238$ ($SD = 0.7589956075$), and concern, with $M = 39.73809524$ ($SD = 5.810249664$). The results showed a positive correlation, $r = 0.2357142439$, $p = 0.1328989758$. This indicates that as more time is spent outside concern increases among high schoolers, intentions to act tend to increase. The correlation was not statistically significant at the .05 level.

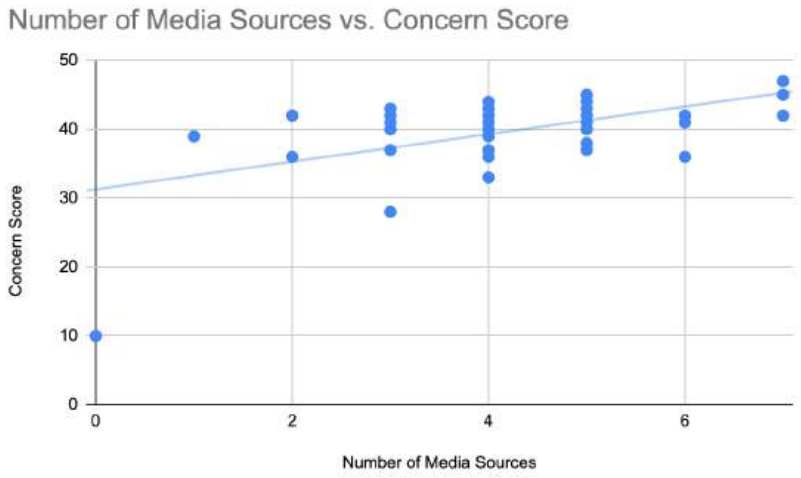


A correlation analysis was conducted to examine the relationship between time spent outside with M = 3.238095238 (SD= 0.7589956075), and intention, with M = 16.35714286 (SD= 0.9833102027). The results showed a positive correlation, r =0.1120468205, p = 0.4799010422. This indicates that as more time is spent outside concern increases among high schoolers, intentions to act tend to increase. The correlation was not statistically significant at the .05 level.

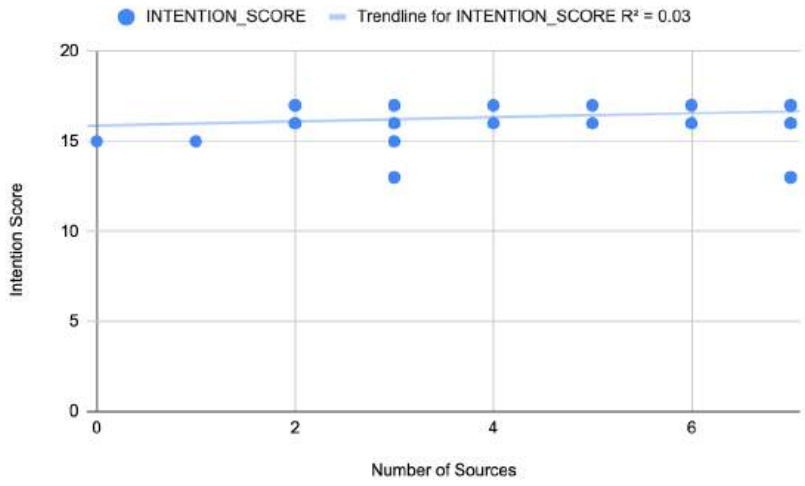


5) Does the number of news sources people engage with impact their beliefs/intentions?

A correlation analysis was conducted to examine the relationship between the number of news sources with M = 4.214285714 (SD= 1.538699392), and concern, with M = 39.73809524 (SD= 5.810249664). The results showed a positive correlation, r = 0.5302346111, p = 0.0003041667373. This indicates that as people engage with more news sources, concern increases among high schoolers, and intentions to act tend to increase. The correlation was statistically significant at the .05 level.



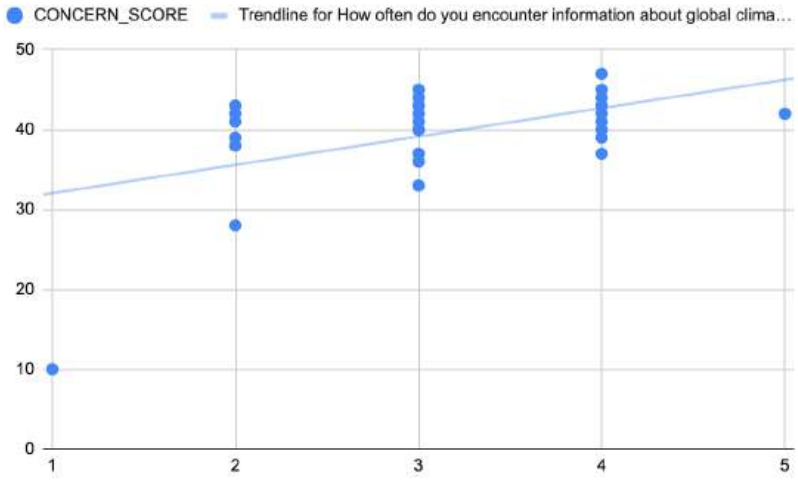
A correlation analysis was conducted to examine the relationship between the number of news sources with $M = 4.214285714$ ($SD = 1.538699392$), and intention, with $M = 16.35714286$ ($SD = 0.9833102027$). The results showed a positive correlation, $r = 0.1738684279$, $p = 0.270807633$. This indicates that as people engage with more news sources, concern increases among high schoolers, and intentions to act tend to increase. The correlation was not statistically significant at the .05 level.



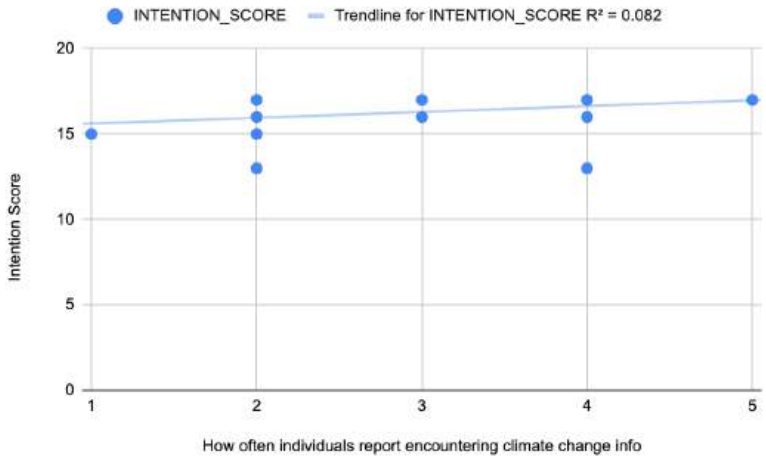
6) Does the amount of exposure to climate change information impact beliefs and/or intentions?

A correlation analysis was conducted to examine the relationship between the exposure to climate change information with $M = 3.166666667$ ($SD = 0.8239306941$), and concern with $M = 39.73809524$ ($SD = 5.810249664$). The results showed a positive correlation, $r = 0.5035401558$, $p = 0.0006754994533$. This indicates that as people are exposed to more information about

climate change, concern increases among high schoolers, and intentions to act tend to increase. The correlation was statistically significant at the .05 level.



A correlation analysis was conducted to examine the relationship between the exposure to climate change information with $M = 3.166666667$ ($SD = 0.8239306941$), and intention, with $M = 16.35714286$ ($SD = 0.9833102027$). The results showed a positive correlation, $r = 0.2859950531$, $p = 0.0663449516$. This indicates that as people are exposed to more information about climate change, concern increases among high schoolers, and intentions to act tend to increase. The correlation was not statistically significant at the .05 level.



Qualitative Analysis

A qualitative analysis was conducted on participants' open-ended responses to the question of whether climate change was having a major impact on the area where they live. Three main themes emerged from the response. The most common theme was “no perceived or lack of awareness,” which 26 participants had responded with. Second was “direct local impact,”

with 21 participants explaining the devastating effects of climate change throughout their community. Lastly, the least endorsing them was "acknowledgment of climate change impacts elsewhere or in the future but not personally," with only 4 participants responding this. Ultimately, these themes together suggest that although many participants are concerned about climate change, a large portion of them are hesitant to take action against.

Discussion

The purpose of this study was to examine generational differences in climate change perceptions and intentions to act among teens and older adults. It was hypothesized that while younger teens would be more concerned about climate change than adults, they would report lower intentions to take action. The results supported this hypothesis. High schoolers reported slightly higher concern scores (39.65) compared to adults (37.5), and adults reported higher intention scores (19.17) than high schoolers (16.48). Overall, the findings suggest that while younger people worry more about climate change, older adults are more likely to express intention to act.

These findings mean that concern about climate change does not automatically translate into action, specifically among younger generations. One possible explanation for this is that teens may feel that they do not have enough power to take action and the scale of the issue is too big, making it hard to go from concern to action. On the other hand, older people may have more life experience and resources that make taking action feel more accessible. Additionally, the number of news sources a person engages with was significantly correlated with concern ($r = 0.53$), suggesting that a greater amount of media influence may play a pivotal role in shaping how worried people may feel about climate change.

One limitation of this study is the small and uneven sample size with 42 high schoolers and only 12 adults, which made it impossible to conduct statistical comparisons between the two groups. Additionally, both groups were from the Los Angeles area and the students attended a private school, meaning the findings may not apply to young people from different regions or socioeconomic backgrounds. The study also relied on self reported survey data, which may not always accurately reflect participants true beliefs or intentions.

Future research should examine generational differences in climate concern and action using a larger and more diverse sample across different regions and school types. Researchers could also explore what specific barriers prevent young people from acting on their concerns, such as feelings of helplessness or lack of knowledge about how to take action. Additionally, political beliefs, community involvement, or direct experience with climate change could enhance and help further explore what drives climate change opinions. Ultimately, understanding what bridges that gap between concern and action is essential for implementing effective climate change education and awareness.

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Exploring Whether Image Enhancement AI is Deceived by Perspective Illusions
By Leo Sato

Abstract

Artificial intelligence (AI) analyzes images using machine learning, specifically Convolutional Neural Networks, to break images down into pixels and identify patterns, features, and objects. [2] Machine learning uses very similar structures to neural networks in human brains. [1, 2] However, whether artificial intelligence processes visual information similar to humans is still unknown. [1] Here, we processed visual illusions through Google's Pixel Camera's enhancement AI to see if artificial intelligence can be tricked similarly to human perception. We found that enhanced AI exhibited algorithmic reconstruction bias by the "Müller-Lyer illusion", causing lines of the same length to be shown at different lengths. These results suggest that machine learning-based image enhancement algorithms can produce physical artifacts that geometrically mirror human optical misperceptions.

Introduction

Artificial Intelligence (AI) has progressed significantly from a mere computational device to a means by which we filter our view of reality. Today's machine learning technologies, especially Convolutional Neural Networks (CNNs), have become adept at processing images in a manner that is much quicker than any human, examining pixels to identify patterns, features, and objects. [3] In fact, these networks are designed in a manner that mimics the structure of biological neural networks in our brains, giving rise to a common belief that AI "sees" the way we do. [1] However, a relevant question still remains: does a similarity in structure imply a similarity in perception?

Traditionally, we've tested artificial intelligence vision by comparing its accuracy with that of human benchmarks on standard image datasets. [2, 4] However, because these performance metrics reveal only what an AI identifies rather than how it interprets the world, the fundamental nature of machine vision remains ambiguous. [3] To test this uncertainty within our own experimental framework, we turned to a foundational tool from cognitive psychology: visual illusions. [1] Visual illusions are not only abnormalities of perception but a failure of comprehension that reveals the shortcuts made by humans when processing visual imagery. [1] In other words, if AI models are trained on real-world spatial data, their mathematical reconstruction of pixels may replicate the same spatial biases that trigger visual illusions in humans. [5] Thus, if we imagine that an AI system can resist those illusions, we must also imagine a fundamentally different form of perception, one that doesn't involve top-down interpretation of context, but only bottom-up mathematical analysis.

In our study, we sought to test the similarity between human perception and artificial perception by using AI systems that are typically used by consumers. We did this through using the image enhancement feature of Google's Pixel 7 Pro camera, which was subjected to perspective-based illusions - specifically, the Müller-Lyer illusion, a geometric shape consisting

of lines with equal length, which are perceived as different lengths by the human brain due to the presence of stylized arrowheads. We found that the AI's image enhancement also distorted the lines' length to match human (mis-)perception. We propose that an AI system that displays human-like cognitive imperfections is easier to relate to and therefore understand. Its imperfections provide us with an essential bridge to connect an incomprehensible system to one that is conceptually comprehensible.

Results

We set up a Pixel 7 Pro camera on a stationary phone stand, placing it 9.5 meters away from printed Müller-Lyer illusions in an indoor setting with natural light. Images were then captured using the camera's 30x Super-Res Zoom and evaluated for signs of illusions (Figure 1).

We compared the original, printed image with the processed image of the Müller-Lyer illusion (Figure 2A). In the Müller-Lyer illusion, the shaft with the inward pointing arrowheads (left arrow) is perceived as longer than the shaft with the outward pointing arrowheads (right arrow), despite their lengths being equal. Strikingly, we observed that in the Super-Res processed image, the shaft on the left arrow similarly appeared longer than the shaft on the right arrow despite them being the same length in the original image. Indeed, we quantitatively compared the length of the shafts and found a difference between their lengths (Figure 2B). We next repeated the experiment multiple times to evaluate reproducibility. In every experiment, the shaft on the left arrow was longer than the shaft on the right arrow (Figure 2C). These results indicate that the difference in shaft length is not coincidental and is a feature of Super-Res zoom.

Conclusions and Discussions

Our findings show that the Google Pixel 7 Pro's Super-Res Zoom alters how identical lines look in the Müller-Lyer illusion. When capturing the illusions from 9.5 meters away at 30x zoom, the AI made one line seem longer, and another appear shorter, just like human perception. Combined, the consistent distortion of shaft lengths across both variants suggests that artificial image manipulation causes malfunctions that resemble human visual misperceptions. This indicates that the AI's pixel interpolation algorithm alters geometric dimensions in a way that aligns with human cognitive biases. The results show how image processing by AI intersects with cognitive psychology.

With Convolutional Neural Networks becoming a key part of consumer cameras, these findings have serious implications for the trustworthiness of AI-enhanced images. Our findings suggest that these AI-enhanced images are interpretations of what we see, not just passive 'cameras'. Trained on massive real-world data sets that contain 3D objects, these networks might be developing certain spatial biases, which, when reconstructing information at high zooms, causes 3D biases to be imposed on 2D objects. This might end up creating glitches that mirror common human perceptual errors.

The AI response matches what humans think, but we cannot necessarily assume that algorithms process information in the same way as human perception. The AI may not be fooled

or tricked by the visual illusion; it could be explained by how the Super-Res algorithm deals with specific edges. For example, when Super-Res handles the overlapping arrowheads, the inner edges versus the outer ones might be processed differently. Inward-pointing arrows get their ends cut off due to aggressive denoising and edge detection. Meanwhile, the outward arrows get their pixels smoothed, making them look like uninterrupted lines. Future studies could explore whether specific parts of the algorithm, like edge sharpening and noise reduction, may be causing these misperceptions.

Methods

Set-up

For this experiment, we used a Pixel 7 Pro (Android Version 16, Camera version 10.3.183.888945295.14) to take pictures at Super Resolution Zoom (using 30 times on the default camera app with default settings), holding the device steady with a phone stand (Essager Phone Stand). We printed the Müller-Lyer illusions (obtained from the website "Illusion Forum" - 6.5cm of vertical line, 2.15cm of the arrow tip) using a printer (Brother HL-1210W) on A4 white paper at a size (length 297mm) in black and white, and placed it on a score stand 9.5m from the phone, in an indoor setting with natural light.

Recording and processing the data

We manually pressed the shutter to take pictures. The image files were transferred to a computer and placed inside Google Slides. We measured the length of the arrows by inserting a line between the tips of the arrows within the illusion, and used Pythagoras' theorem to find the total length (hypotenuse) of the line based on its width and height.

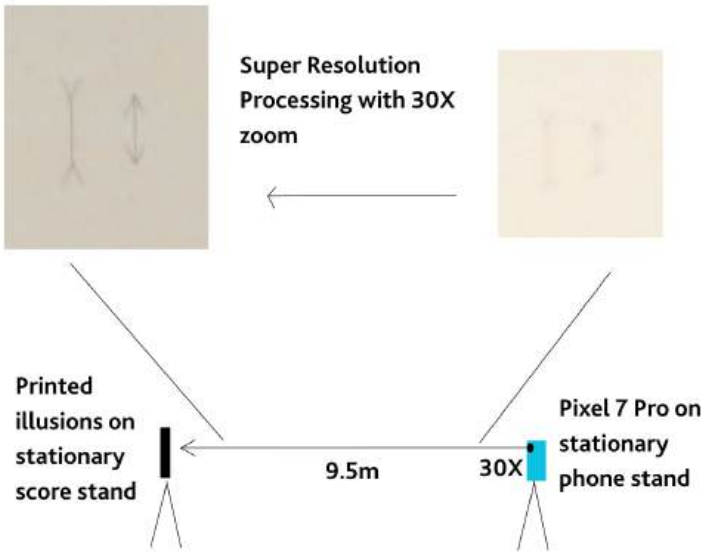


Figure 1: Schema of experiment

Pixel 7 Pro was placed 9.5m away from printed Müller-Lyer illusions. Images obtained from 30x Supe-Res zoom were evaluated for signs of illusions.

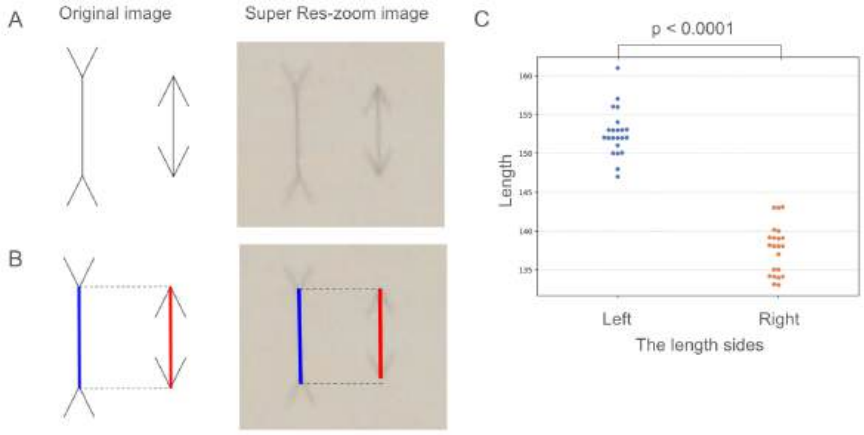


Figure 2: Effect of Super-Res zoom on the Müller-Lyer illusion

A) Visual comparison of unprocessed and Super-Res processed Müller-Lyer illusions.

B) Visual representation of the difference in line length in the unprocessed and Super-Res processed Müller-Lyer illusions.

C) Swarm Plot comparing arrow lengths between the left and right arrow in repeats of Super-Res processed Müller-Lyer illusions (n=22). Statistical significance was evaluated using a two-tailed paired student's t-test; the processed shaft length on the left was significantly longer than the right ($t(21) = 16.05$, $p < 0.0001$).

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The Frailty Gap: Predicting Musculoskeletal and Ocular Degradation in Long-Duration Mars Colonisation Using Linear Interpolation of ISS Baseline Data By C. Kevin Titus

Abstract

Mars colonisation has long been discussed in terms of engineering and propulsion challenges, yet the biological consequences for human colonists remain critically underexamined. This paper analyses three key physiological systems: bone density, muscle mass, and vision, using a linear interpolation model applied to ISS baseline data to predict degradation rates at Martian gravity (0.38g). Results indicate that bone loss accumulates to approximately 15.4% over a 24-month mission with exercise countermeasures, representing a manageable chronic risk. Muscle loss, however, reaches 37.2%, crossing the clinical threshold for sarcopenia and creating potential functional failure in emergency scenarios. Spaceflight-associated neuro-ocular syndrome (SANS), affecting approximately 70% of long-duration astronauts, has no current preventive countermeasure and may cause permanent structural damage. The combined picture suggests that current Mars mission timelines are outpacing the biological research necessary to keep colonists safe.

Introduction

Contemporary discourse surrounding Martian colonisation heavily prioritises aerospace propulsion physics, launch vehicles, and commercial mission architectures. However, the viability of permanent planetary settlement is fundamentally governed by the physiological tolerances of the human organism. Despite these engineering milestones, the long-term adaptation of human physiology to partial gravity remains a critical limiting variable. Human biological adaptation to the Martian environment is virtually non-existent, and when humans are sent to Mars, serious biological consequences should be expected that current mission planning underestimates. This paper examines how bones, muscles, and vision respond to long-term Mars habitation, using existing ISS data and linear interpolation to predict degradation rates at Martian gravity. With NASA targeting the 2030s and SpaceX aiming for as early as 2029 [13], the question of human biological survival on Mars is no longer theoretical; it is urgent. The findings suggest that while bone loss is manageable, muscle loss approaches a critical clinical threshold within two years, and vision deterioration through SANS remains the single most under addressed and potentially permanent biological risk.

Methods

This paper employs a two-part analytical approach. First, baseline physiological degradation rates were collected from peer-reviewed ISS studies for bone density and muscle mass loss under microgravity conditions, both with and without exercise countermeasures. These rates were then used to construct a linear interpolation model predicting equivalent degradation rates at Martian gravity (0.38g), using Earth baseline rates as the upper bound. Second, a qualitative analysis of SANS was conducted using published ISS crew health data, given the

absence of any human partial gravity experimental data. All interpolated values represent first-order approximations and carry inherent uncertainty due to the nonlinear nature of biological systems.

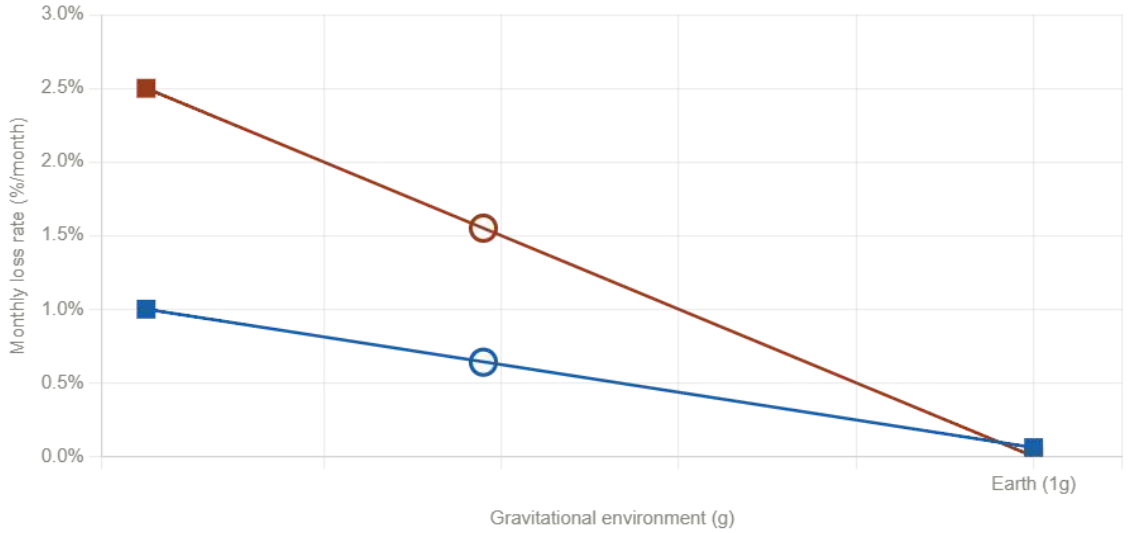


Figure 1. Linear interpolation model for predicting monthly degradation rates at Martian gravity (0.38g). Known ISS (0g, with exercise) and Earth (1g) values serve as endpoints; Mars values are derived by interpolation. The trendlines map the monthly decay rates for muscle mass and bone density with exercise. Projected monthly degradation rates at Martian gravity (0.38g) are explicitly marked at the target intercept.

Results

Bone Density

The primary structural vulnerability of the human frame under prolonged extraterrestrial habitation resides in the skeletal architecture. On Earth, bones do not deteriorate much in healthy adults, as gravity makes sure human bones are constantly working. But in space, bones do not have that much work since they do not have to support the whole body, and gravity is not present. This can be observed on the ISS, where astronauts lose approximately 1.5-2% of their bone density per month without exercise countermeasures [2,4]. Because of this, NASA makes it compulsory for astronauts to exercise for 2.5 hours daily using specialised equipment called the Advanced Resistive Exercise Device (ARED). This brings the loss rate down to approximately 1% per month, still significant, but slower [3].

Mars presents a distinct and largely unstudied situation. At 0.38g, Martian gravity is neither zero like the ISS nor complete like Earth, meaning no human has ever lived under these conditions, and no direct experimental data exists. To estimate the likely bone loss rate, this paper applies a linear interpolation model using known ISS and Earth baselines. At 0g with exercise, bone loss is approximately 1% per month. At 1g, loss is approximately 0.06% per month. Applying linear interpolation at 0.38g yields a predicted loss rate of 0.64% per month

with exercise. Over a 24-month Mars mission, this accumulates to approximately 15.4% total bone density loss.

While significant, this figure is not mission-ending. A 15.4% reduction in bone density is comparable to accelerated aging and increases fracture risk, but it is a manageable chronic condition rather than an acute crisis, particularly if countermeasures developed for the ISS are adapted for Martian use. Bone deterioration, therefore, represents a serious but solvable biological challenge for Mars colonisation.

At a cellular level, bones break down because they are no longer under pressure from gravity. Human bones are maintained by two types of cells: osteoblasts, which build bone and osteoclasts, which break it down. On Earth, these stay balanced because gravity constantly signals the body to maintain bone strength. In low gravity, that signal disappears, osteoblasts slow down, but osteoclasts keep working at the same rate, so bone breaks down faster than it is rebuilt [1]. The body essentially decides it no longer needs a strong skeleton and starts dismantling it. This is why exercise only slows bone loss; it provides some mechanical load, but cannot fully replace the constant pressure of gravity that human bones evolved under.

Muscle Mass

Muscles share the same logic as bones without a gravitational load; they deteriorate rapidly. The problem is that muscles degrade far more quickly than bones. On the ISS without countermeasures, astronauts lose approximately 1.75% of muscle mass per month, and in extreme cases up to 20% in just the first 5-11 days [5,6]. On Earth, healthy adults lose virtually 0%. With the mandatory 2.5-hour daily exercise protocol on the ISS, this comes down to approximately 2.5% per month, still significantly higher than that of bones. Applying the same linear interpolation at 0.38g, predicted muscle loss on Mars with exercise is approximately 1.55% per month, accumulating to 37.2% over 24 months.

This figure is clinically significant. A 37.2% loss in muscle mass crosses the threshold for sarcopenia, a condition defined as severe muscle failure that compromises basic physical function [7]. A colonist at this stage would struggle to walk unaided, be unable to lift equipment or supplies, and could not perform emergency procedures such as rapid habitat evacuation or donning an emergency spacesuit. Perhaps most critically, after two years on Mars, a colonist would likely be unable to survive the physical demands of an Earth return mission, the forces experienced during re-entry and landing alone require muscular strength that would no longer exist. Unlike on Earth, where sarcopenia is treated through rehabilitation in a full gravity environment with medical support, on Mars, the condition has no exit. The environment causing the deterioration never changes, the medical facilities do not exist, and Earth is 225 million kilometres away.

This is where muscles diverge critically from bones. Bone loss at 15.4% is serious but manageable. Muscle loss at 37.2% approaches a functional breakdown threshold. The gap between the two, which this paper calls the frailty gap, means a Mars colonist's structural skeleton may remain relatively intact while the muscular system powering it progressively fails.

This distinction has received almost no attention in current Mars mission planning and represents a significant oversight.

Condition	Loss Rate at 0g	Loss Rate at 0.38g	24-Month Total
Bone (no exercise)	1.75%/month	1.11%/month	26.6%
Bone (with exercise)	1.00%/month	0.64%/month	15.4%
Muscle (with exercise)	2.50%/month	1.55%/month	37.2%

Table 1: Predicted musculoskeletal degradation rates at Martian gravity (0.38g) using linear interpolation from ISS baseline data.

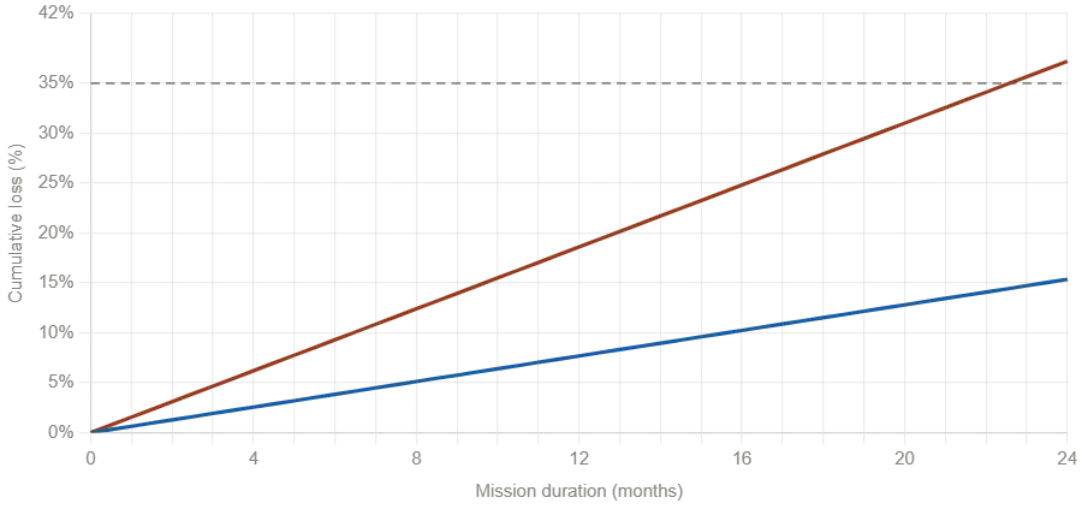


Figure 2. Predicted cumulative musculoskeletal degradation at Martian gravity (0.38g) over a 24-month mission with exercise countermeasures. Trendlines display the projected 24-month cumulative muscle mass loss (37.2%) and cumulative bone density loss (15.4%). The horizontal reference line represents the clinical threshold for functional sarcopenia (35% impairment limit), which is breached by month 23.

Vision — SANS

SANS (Spaceflight Associated Neuro-ocular Syndrome) is a condition in which fluid shifts toward the head in low gravity, increasing pressure behind the eye and causing structural changes that impair vision. On Earth, it is virtually non-existent, but in space, it is alarmingly common; approximately 70% of long-duration ISS astronauts develop it to some degree [8,9]. More concerning, some structural changes, including globe flattening and hyperopic shifts, have been documented to persist for years after returning to Earth in a subset of affected astronauts [12]. Recent studies have also shown that men are approximately three times more likely to develop SANS than women, though the mechanism behind this difference remains unknown [10]. The most critical distinction between SANS and the musculoskeletal risks discussed above is that no effective preventive technique currently exists [11]. Unlike bone and muscle loss, which can be

partially managed through exercise, there is no equivalent countermeasure for SANS. For a long-term Mars mission, SANS appears effectively unavoidable with current technology, and on Mars, unlike on the ISS, there is no return to Earth where the condition might partially resolve.

The practical consequences of SANS on Mars extend far beyond discomfort. A colonist with progressive vision deterioration would struggle to read instrument panels, navigate the Martian surface during EVAs, diagnose equipment faults, or perform medical procedures on fellow crew members. These are not optional tasks; they are daily survival requirements. On Earth, vision deterioration is treated through corrective lenses, surgery, or medication. On Mars, none of these options exists in any meaningful form. More critically, impaired vision during an EVA, a routine but inherently dangerous activity, could directly endanger a colonist's life. A missed step, a misread pressure gauge, a failure to notice a suit breach, any of these could be fatal. Unlike bones and muscles, where deterioration is gradual and partially manageable, SANS can progress unpredictably, and its structural effects on the eye may become permanent long before the mission ends. For a long-duration Mars mission, SANS is not a risk to be mitigated; it is a near certainty to be planned around, and current mission architectures have no plan.

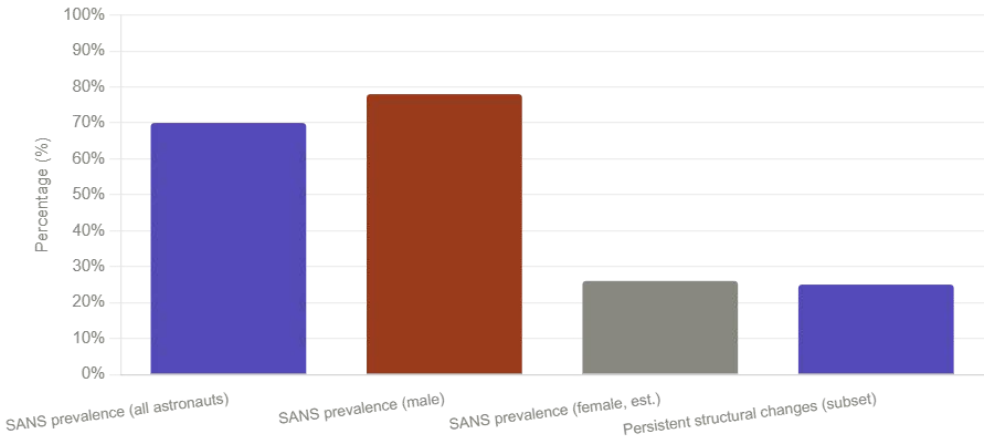


Figure 3. SANS prevalence among long-duration ISS astronauts by sex, alongside the estimated rate of persistent post-mission structural changes. The data contrasts the baseline aggregate prevalence against the distinct clinical risk profiles for male and female flight crew. The final data column tracks the specific subset population experiencing permanent structural ocular damage.

Discussion

Of the three biological systems examined, bones represent the least critical risk, serious but manageable with existing countermeasures. Muscle loss sits in a more dangerous category, crossing clinical failure thresholds within two years and creating emergency scenarios that could prove fatal, but it is at least partially addressable through exercise. SANS is the most dangerous of the three. Unlike bones and muscles, it has no preventive countermeasure, affects the majority of long-duration astronauts, and its structural damage can be permanent. On Mars, where there is no return to Earth and no surgical intervention available, even partial vision loss could compromise a colonist's ability to survive. The combined picture across all three systems is not

one of isolated manageable risks; it is a cascade of deterioration that compounds over time, leaving colonists progressively less capable of performing the basic duties that keeping themselves alive requires.

Conclusion

Mars colonisation should not be attempted as a permanent settlement with current technology. As shown in this paper, even looking at just three biological systems, colonists on a two-year Mars mission would experience 15.4% bone density loss, 37.2% muscle mass loss crossing clinical failure thresholds, and near-certain vision deterioration with no preventive solution. These are not minor inconveniences; they mean colonists would slowly become incapable of performing basic physical duties over time.

This paper has, however, only examined three systems. Mental health, radiation, immune function, and reproduction in partial gravity are all major unsolved problems that weren't even covered here. The biological barrier to Mars colonisation is not one problem; it is many, and humanity has barely begun solving them [14].

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Music's Applications as A Treatment and Prevention for Alzheimer's Disease
By Kushi Aravinda

Abstract

Alzheimer's disease (AD) is a neurodegenerative disease characterized by β-amyloid plaques and tau neurofibrillary tangles in the brain that result in neuronal death, decreasing the amount of grey and white matter in the brain. It does not currently have a cure, but music therapy has been shown through several studies to improve the symptoms of AD such as cognition and memory. Early stages of AD minimally affect areas of the brain that encode musical memory and implicit musical memory stays relatively intact during AD progression. Studies have shown that music therapy may alter secretion of hormones that have been shown to decrease *β*-amyloid peptides, and that practicing music increases grey and white matter in the brain. Music therapy needs further research because there are discrepancies among studies and to ensure that it is a safe treatment method because it may change hormone levels. This review focuses on the possible mechanisms that may explain the effectiveness of music for AD.

Introduction

It is estimated that by 2050, 13.8 million people in the United States may be diagnosed with Alzheimer's disease (AD) ("2019 Alzheimer's Disease Facts and Figures"). AD is a neurodegenerative disease where β-amyloid plaques and tau neurofibrillary tangles form in the brain, resulting in neuronal death (Breijyeh and Karaman; Kumar and Baquer; "Alzheimer's Disease and Its Treatment by Different Approaches: A Review"). Patients with AD exhibit memory loss, impairment of cognitive functions, and personality changes (Andrade-Guerrero et al.; Breijyeh and Karaman). As of now, there is no cure for AD, but there are many possible treatments that are undergoing research such as stem cell-based therapy, nanomedicine, and music therapy ("Alzheimer's Disease and Its Treatment by Different Approaches: A Review"; Matziorinis and Koelsch).

Music therapy is the use of music to reach certain behavioral, cognitive, and emotional goals during the course of the treatment (Wheeler). Music therapy can be administered in two methods: active, such as dancing or playing an instrument, and passive, such as listening to music (Matziorinis and Koelsch). Several studies have shown that music therapy may be a promising treatment for AD (Matziorinis and Koelsch; Fang et al.; Fukui et al.). A study tested the effects of music therapy in addition to drug therapy on improving cognition in people with AD (Wang et al.). They found that although both groups showed improvement, the group that underwent a combination of music therapy and drug therapy showed significantly more improvement than the group that underwent solely drug therapy (Wang et al.). After conducting a double-blind clinical study to see what effect music therapy has on cognitive impairment, a study concluded that music therapy may be used to rehabilitate episodic memory in adults suffering with types of dementia (Moreira et al.). One study tested how playing a musical instrument may be associated with development of dementia or cognitive impairment (Alison Balbag et al.).

After observing the outcomes through twins and controlling for other factors, the study found that playing a musical instrument was correlated with a decreased likelihood of dementia, implying that practicing a musical instrument may serve as a preventative measure against types of dementia and cognitive impairment (Balbag et al.). Although the mechanism for music therapy's success is not fully clear, the evidence from recent studies show that musical practice and music therapy have potential applications in preventing and treating AD. Therefore, in this review we will examine the potential mechanisms why music may be effective for AD.

Hormones

Music therapy has many medical applications, and increasing hormone secretion may be one of them. Testosterone and estrogen have been shown to have various roles in the brain. Estrogen affects the amygdala, hippocampal formation, and the cerebral cortex while testosterone is anxiolytic and antidepressant, and improves spatial abilities (Pompili et al.; Zitzmann; Höfer et al.; Celec et al.). In rats, steroid hormones, including testosterone and estrogen, improve learning and memory (Ranjitsingh). A 2012 study revealed that music therapy increased secretion of 17β-estradiol and testosterone (Fukui et al. 2012), suggesting that a potential mechanism of music therapy may be increased secretion of estrogen and testosterone.

Testosterone

Low testosterone levels are related to cognitive dysfunction in older men and it is also a key characteristic in males with AD (Hogervost et al.). Studies have shown that increasing testosterone levels in patients with AD improves the disease progression (Chéour et al.; Gouras et al.; Bianchi). Animal models have shown that testosterone has a protective effect on neurons because it stimulates microglia phagocytosis which removes the *β*-amyloid depositions, inhibiting the neurons' inflammatory response (Bianchi). Another study showed that treating men with testosterone decreased the secretion of β-amyloid peptides and increased the secretion of sβAPPa, a neuroprotective protein (Gouras et al.). If testosterone decreases amyloid-beta depositions, of which are a main cause of AD, and increases neuroprotective proteins, then increasing testosterone levels in AD patients can improve their cognitive decline. One study conducted with 26 elderly Tunisian male patients with mild AD showed that the levels of testosterone in the saliva had the most significant increase in participants who underwent a combination of music therapy and physical rehabilitation (Chéour et al.). These results show that music therapy increased salivary testosterone concentration more than physical rehabilitation alone (Chéour et al.). Since testosterone levels are depleted in people with AD, increasing them via music therapy may be a noninvasive treatment for AD.

Estrogen

A mouse study testing depleted estrogen's effects on AD found that mice with lower levels of estrogen increased β-amyloid peptide deposition (Yue et al.). Since low levels of estrogen results in increased β-amyloid peptide deposition which can lead to β-amyloid plaques,

then low levels of estrogen can lead to development of AD in women. Therefore, estrogen treatment can be useful in treating AD. A 2014 study tested the effects of 17α-estradiol and 17β-estradiol in reducing scopolamine-induced memory impaired rats that were surgically ovariectomized and found that both 17α-estradiol and 17β-estradiol were effective in improving the rats' induced cognitive impairment (Bansal et al.). In postmenopausal women, 17β-estradiol treatment reduced secretion of certain *β*-amyloid peptides (Gouras et al.). This furthers the claim that increasing estrogen levels in patients with AD will help treat it by improving memory and cognition. Another study with songbirds showed that auditory experiences increased the levels of estrogen in mammalian auditory association cortex (MAAC), suggesting that music therapy may increase estrogen levels in the brain (Tremere and Pinaud). Since music has been shown to affect levels of estrogen (Fukui and Toyoshima), and increasing estrogen can be an effective treatment for AD, then music therapy can be used to improve AD progression.

These studies suggest that testosterone and estrogen levels are significantly decreased in AD patients, resulting in increased *β*-amyloid peptide production and *β*-amyloid plaques (Gouras et al.; Kumar and Baquer; Bianchi). Testosterone and estrogen have a protective effect against the production of *β*-amyloid plaques, therefore, these hormones can help those with AD. Music therapy may be a noninvasive replacement for hormone supplementation since music induces production of testosterone and estrogen in both men and women across separate studies. Music therapy has also been shown to influence memory; auditory training may prevent and even reverse age related cognitive decline according to a 2013 study (Anderson et al.). Since music therapy, testosterone, and estrogen have connections with each other and each of them with the brain, it is plausible that music therapy, testosterone and estrogen, and the brain, may all be directly linked with one another.

Prevention and Treatment of AD Using Music

In addition to musical therapy, long-term musical practice may be protective against age related cognitive decline (Vetere et al.; Román-Caballero et al.; Esfahani-Bayerl et al.). Studies have shown that learning and practicing music over a long period of time may cause structural adaptations in the brain (Esfahani-Bayerl et al.; T Zaatar et al.; Olszewska et al.). For example, a recent study found that there is more grey matter in pianists, specifically in the primary motor cortex, (T Zaatar et al.) while another study found that musicians have more grey matter in the hippocampus (Olszewska et al.). Grey matter consists of a high concentration of neuronal cell bodies and makes up the outer layer of the brain (Mercadante and Tadi). In AD, there is a loss of grey matter and white matter (Schwarz et al.; King et al.; Phan et al.; Dickerson et al.; Grydeland et al.; Weston et al.). White matter connects the neurons of the grey matter throughout the brain through the millions of axons that it is composed of (Fields). When learning music, there is a functional and structural expansion in the number of neural circuits, and repeated practice stabilizes the chosen circuit (T Zaatar et al.). This reveals that learning music and repeated practice of it can form new neural pathways as well as strengthening them. The more neural pathways that are formed, the greater the density of grey matter. This increase in grey matter will

result in an increase in white matter to connect the newly formed neural pathways. Because long term musical practice has shown to increase grey matter (T Zaatar et al.; Olszewska et al.; Weston et al.; Eierud et al.) and white matter (Eierud et al.), and a decrease in grey and white matter is a key characteristic of AD (Grydeland et al.; Weston et al.; Gold et al.), then it can be inferred that long term musical practice is preventative against AD because it increases the grey and white matter in the brain which may decrease the likelihood of developing AD, even with age related decrease in grey and white matter (Giorgio et al.; Terribilli et al.; Ge et al.; Farokhian et al.; Eierud et al.).

Music may also be linked to inducing adult neurogenesis (Slade et al.; Merrett et al.). Adult neurogenesis is when, in the adult mammalian hippocampus, stem and progenitor cells divide and result in new neurons (Cope and Gould). Studies have shown that adult neurogenesis occurs primarily in the hippocampus in most mammals (Ernst and Frisén; Spalding et al.; Tardif et al.; Boldrini et al.), including humans (Ernst and Frisén). Neurogenesis is highly sensitive to environmental stimuli (Boldrini et al.) and certain rewarding experiences stimulate it (Cope and Gould). Musical practice is highly rewarding (T Zaatar et al.) and so music might be able to stimulate neurogenesis. In a mice study where mice listened to music for six hours a day for 21 days, the mice that listened to music showed an increase in brain derived neurotrophic factor (BDNF) levels in the hippocampus compared to control mice that only listened to background noise (Brattico et al.). BDNF regulates neuroplasticity, neurogenesis, and protects neurons from brain atrophy (Slade et al.). A similar mice study revealed that BDNF expression were higher in the mice that listened to different musical tones for two hours per day (Wang et al.). If listening to music increases BDNF levels (Slade et al.; Wang et al.) and BDNF regulates neurogenesis (Slade et al.), then listening to music might indirectly stimulate neurogenesis. In addition, a recent study found that musicians have higher BDNF plasma levels than non-musicians of the same age and gender (Minutillo et al.). This implies that practicing music over time increases the likelihood of neurogenesis; this finding supports the increase in grey matter found in musicians relative to non-musicians (T Zaatar et al.; Olszewska et al.).

From these points, we may assume that there is some connection between music and applications for treating and preventing AD through neuroplasticity.

Discussion

Music therapy may serve as a treatment for AD since studies have shown it can induce secretion of estrogen and testosterone (Fukui and Toyoshima; Fukui et al.; Chéour et al.), and they have protective effects against AD (Bansal et al.; Gouras et al.; Bianchi). A limitation of music therapy as a treatment for AD could be that more studies have to be conducted to find the threshold of estrogen and testosterone that is protective.

Hormone supplementation replaces some hormones in the body with artificial substitutes, but it can have severe side effects such as increasing the risk of certain cancers such as ovarian cancer, colorectal cancer, endometrial cancer, prostate cancer, and breast cancer (Gouras et al.; Asthana et al.; van de Weijer; Genazzani et al.; Ramasamy et al.). Instead of introducing artificial

hormone substitutes to the body, music therapy promotes secretion of estrogen and testosterone which may make it a safer alternative to hormone therapy to increase estrogen and testosterone levels in patients with AD.

Long term musical practice may decrease the likelihood of developing AD because it is shown to increase functional grey and white matter in the brain (T Zaatar et al.; Olszewska et al.; Weston et al.; Eierud et al.). Listening to music may also increase production of BDNF (Brattico et al.; Slade et al.; Wang et al.) which regulates neurogenesis (Slade et al.; Wang et al.). Whether or not neurogenesis occurs in adult humans is a debated topic, but there are still studies with evidence to suggest that new neurons may form in adult human brains (Cope and Gould; Tardif et al.; Slade et al.; Ernst and Frisén; Spalding et al.).

There are discrepancies about whether BDNF levels are affected by music. One study concluded that BDNF levels in the frontal cortex and hippocampus among aging rats are not affected by music and that improved behavioral responses from music exposure over a four month and eight month period are not due to changing BDNF levels (Rizzolo et al.). Other studies found that mice who were exposed to music had increased BDNF levels in the hippocampus (Wang et al.; Angelucci et al.).

The safety of inducing secretion of estrogen and testosterone, the development of new neurons in adult human brains, and music's effect on BDNF levels have to be studied regarding music's applications for AD, but as these findings support, music therapy and long term musical practice may potentially be treatments for and protective measures against AD. New advances in music therapy may establish it as an effective treatment for AD.

Conclusion

Music, including music therapy and musical practice over time, may be effective for treating and preventing AD. This paper suggests that it may have therapeutic potential due to its inducement of secretion of testosterone, estrogen, and BDNF, and because long term musical practice increases functional grey and white matter in the brain. However, further research must be completed to determine if it is a viable treatment for AD.

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Democratizing the Ledger: A Rawlsian Defense of AI-Driven Financial Automation in the Non-Profit Sector By Saanvi Patel

1.Introduction

Small non-profit organizations, particularly those with 501(c)(3) status, solely exist to improve surrounding communities rather than earn or gain profits. However, many of these organizations face significant administrative responsibilities, including bookkeeping, tax reporting, financial recordkeeping, and regulatory compliance. For small, volunteer-run non-profits, these tasks often require financial knowledge and time that they simply do not possess. As a result, money that donors have intended to support community programs is often spent on administrative work instead.

At the same time, advances in artificial intelligence (AI) and financial technology have transformed how businesses manage their finances and paperwork. Large corporations can afford professional accounting software and AI-powered tools that computerize bookkeeping, organize expenses, and reduce errors. In contrast, many locally founded non-profits simply cannot afford these technologies and must rely on manual recordkeeping or outdated systems, making financial mistakes much more likely.

This paper examines the economic and ethical consequences of this technology gap. Using the political philosophy of John Rawls, it contends that providing affordable, simple-to-use financial automation for non-profits is not only economically beneficial but also ethically justified. A lightweight AI financial assistant, such as the proposed "CFO Co-pilot," could help small organizations spend less time on administrative tasks and devote more of their resources to serving their communities.

2. Theoretical Framework: Rawlsian Justice and the Technology Gap

2.1 The Difference Principle Applied to Financial Technology

To understand whether the unequal access to financial technology is fair, observe the political philosophy of John Rawls. In *A Theory of Justice*, Rawls introduces the Difference Principle, which states that social and economic inequalities are only acceptable if they improve the lives of the least advantaged citizens of society.

Today, advanced financial technology is mainly available to foundations that can afford it. Large corporations use AI and automation to reduce costs, improve efficiency, and simplify financial management. Meanwhile, small grassroots non-profits often cannot access these tools because of high software costs and technical barriers.

As a result, organizations that already have sophisticated resources continue to become more efficient, while non-profits that help vulnerable communities remain burdened with time-consuming administrative work. Because this unjust distribution of technology benefits those who are already advantaged rather than those serving society's greatest needs, it does not align with Rawls' Difference Principle.

2.2 The Opportunity Cost of Administrative Burden

From an economic perspective, the administrative work required to operate a small non-profit creates an additional cost that reduces the organization's ability to help people. Since non-profits usually have limited and conservative budgets, every dollar must be divided between supporting their mission and paying for administrative expenses:

Total Capital = Direct Social Impact + Administrative Costs

When volunteers manually record expenses, organize financial documents, and prepare tax filings, mistakes become more prone. Even a small accounting error or incorrect tax submission can result in fines or the loss of important grant funding.

To reduce these risks, many non-profits pay for recording services or accounting software. Although these expenses help organizations remain compliant with financial regulations, they also reduce the money available for community programs, senior services, educational initiatives, all the work the non-profit was meant to do in the first place. In this way, the lack of affordable financial technology becomes more than an inconvenience but it directly limits the positive impact that non-profits can have.

Developing a simple AI-powered financial system designed specifically for non-profits could simplify bookkeeping, automate expense tracking, and assist with compliance reporting. By reducing administrative costs and saving time, these tools would allow small organizations to operate more efficiently and direct a larger share of their resources toward helping the communities they serve.

3. The Conceptual Model: Using Financial Automation as a Practical Solution

3.1 A Straightforward Financial Management System

To address the technology gap discussed in the previous section, this paper analyzes the structure of a generalized, simple financial management framework made specifically for volunteer-run non-profits. Instead of relying on expensive enterprise accounting platforms, this model focuses on budget friendly, simplified tools that reduce manual bookkeeping and automate regulatory compliance through three main steps: data collection, automated expense categorization, and ledger synchronization. (A real-world example of this architecture can be seen in prototypes like the student-designed app "The CFO Co-pilot").

First, users upload basic financial information, such as a photo of a receipt or a short description of an expense, through a simple interface. Rather than requiring volunteers to understand complex accounting principles, the system processes the information automatically. Using natural language processing (NLP), the software identifies the purpose of each transaction. For example, recognizing that "supplies for a senior art workshop" is a program expense—and places it into the correct financial category, distinguishing between direct program costs and administrative overhead. The transaction is then stored in a central database. By automating

these steps, this type of system reduces human error and helps local organizations maintain accurate records without costly professional oversight.

3.2 Technical Challenges and Limitations of Low-Code Solutions

Although building this type of financial framework on affordable, low-code platforms makes it accessible to small non-profits, it also introduces important technical challenges. Financial records must be highly accurate because even small mistakes can create regulatory problems. However, artificial intelligence and language models do not always produce perfect results. For example, if an automated system incorrectly classifies a restricted grant as unrestricted income, it could create financial reporting errors that affect the organization's compliance with tax regulations.

In addition, low-cost database platforms often lack the advanced security features, encryption, audit logs, and scalability found in professional corporate software. While these limitations make lightweight models unsuitable for large-scale corporate financial operations, they do not reduce their value as a proof of concept. Instead, identifying where these simplified automated systems succeed and where they fail provides valuable data for future software developers. These findings can guide future improvements and help create more reliable, open-source financial tools designed specifically for the humanitarian sector.

3.3 Projected Economic Impact on Resource Allocation

The effectiveness of an automated framework can be evaluated by examining how it changes the way small non-profits use their limited resources. Many local organizations use an annual budget of less than $50,000 and have no full-time accounting staff. As a result, they spend a disproportionate amount of their limited time and money managing financial records, preparing reports, and maintaining compliance.

By automating these administrative tasks, a financial system reduces both the number of volunteer hours spent on bookkeeping and the reliance on outside accounting services. Volunteers have more time to focus on community programs instead of paperwork, while organizations face fewer accounting errors and lower compliance risks. As administrative costs decrease, a larger portion of the organization's budget becomes available for its primary mission. Money that was previously spent on bookkeeping software or correcting financial mistakes can instead be invested directly in community outreach, educational programs, senior services, and other charitable initiatives. In this way, financial automation increases the overall social impact of grassroots non-profits, aligning directly with the Rawlsian goal of maximizing benefit for the community.

4. Ethical Discussion

4.1 The Democratization of Institutional Capacity

When evaluating artificial intelligence through a commercial perspective, the main ethical discussion usually revolves around labor displacement or corporate profit optimization. However, applying automation to the non-profit sect significantly shifts the moral landscape. In this context, implementing a simple financial automation framework is an act of institutional democratization. Large corporations routinely use sophisticated technologies to maximize financial efficiency and protect their assets. By lowering the cost and technical barriers to these same capabilities, automated financial tools give ordinary volunteers the structural accuracy of a corporate financial team. This shift balances the playing field, ensuring that grassroots organizations are not penalized by regulatory systems simply because they lack the budgets to do so. Under a Rawlsian framework, this is a clear ethical victory: technology is actively used to empower the organizations that serve the most vulnerable populations.

4.2 The Moral Hazard of Automation and Human Oversight

Despite these benefits, handing financial decision-making over to artificial intelligence introduces moral ethical risks, specifically the problem of over-reliance, or "automation bias." Because financial records require absolute accuracy, allowing a machine learning model to categorize transactions without human verification creates a significant moral hazard. If an automated system misclassifies an expense—such as mistakenly labeling a political donation or a restricted grant—and a non-profit blindly submits those records to regulatory bodies, who is held accountable?

Technology cannot completely replace human stewardship or moral agency. Therefore, the ethical deployment of AI in the humanitarian sector requires a balanced model where automation serves to only assist human decision-making rather than replace it entirely. A responsible framework must include clear verification steps, where the AI flags uncertainties and human volunteers maintain the final authority over official ledgers. By keeping "humans in the loop," non-profits can leverage the economic efficiency of automation while preserving the ethical accountability required to protect public trust and donor intent.

5. Conclusion

The structural divide between corporate financial capability and non-profit administrative burden represents both an economic inefficiency and an ethical failure. Currently, community-level non-profits are trapped in an unfair system, forced to divert their attention away from community programs to manage complex bookkeeping and regulatory compliance. This unequal distribution of technology directly conflicts with John Rawls' Difference Principle, as advanced automation continues to make wealthy corporations more efficient while leaving community-focused organizations structurally left behind.

As demonstrated by automated ledger models, this technology gap is entirely solvable. By automating routine financial tasks like expense categorization and ledger tracking, affordable digital tools can dramatically reduce administrative overhead. This shift allows grassroots organizations to maximize their direct social impact—channeling unlocked funds directly into

senior outreach, educational initiatives, and community development. Ultimately, directing AI innovation toward the non-profit sector does more than just modernize bookkeeping; it aligns technological progress with structural justice, transforming financial automation into a powerful tool for community welfare.

A Mechanistic Framework for Adolescent Cognitive Enhancement ByVishesh Rana

Abstract

It is incredibly common for adolescents to struggle with focus, motivation, and everyday cognitive performance. Much of this comes down to how wildly dopamine regulation fluctuates while the prefrontal cortex is still developing, a baseline issue that gets hit hard by high stimulation habits like doom scrolling. This paper brings together three frameworks, the inverted-U curve, baseline dependency, and reward prediction error system, to figure out exactly why these crashes occur. This paper proposes three highly accessible, low-cost behavioral tools like randomized self-rewards and brief breathwork to guide prefrontal dopamine into its optimal zone. Because this is a theoretical synthesis built on existing literature, it lacks direct empirical data and relies heavily on adult clinical models, pointing to a major need for future field testing directly within high school populations.

Intro

Spend an hour reading developmental research, and the warning signs are clear: constant exposure to hyper-stimulating content ruins an adolescent's attention span and leaves them dealing with serious emotional fatigue. We can map this entire problem out using the classic inverted-U curve model. The core idea is simple: human performance peaks when dopamine hits a happy medium, whereas tracking too low or spiking too high completely derails the cognitive focus. Knowing this can help modulate our dopamine levels to the optimal range so our performances can peak, but the same cannot be said about adolescents because of variables like their starting baseline dependency and their unique Reward Prediction Error system(RPE) which is constantly affected by other variables like social media. Accordingly, this paper seeks to answer the central question: How can a theoretical synthesis of the inverted-U curve, baseline dependency, and reward prediction error models provide a mechanistic framework to support adolescent dopamine regulation and cognitive performance?

Methodology

To build this framework, a conceptual synthesis approach was used to connect separate neurological models of dopamine and apply them directly to how teenagers develop cognitively. Firstly, a comprehensive search in scientific databases including PubMed, GoogleScholar, and ScienceDirect has been performed to find relevant literature. While searching, particular keywords combinations have been used, namely, *"prefrontal cortex dopamine," "adolescent working memory," "inverted-U curve and cognitive control,"* and *"reward prediction error motivation."* The foundation of the paper consists of the works that describe the mechanics of dopamine from the neurological perspective. Particularly, the framework is based on the inverted-U data proved by Weber et al. (2022), the concept of baseline-dependency described by Cools & D'Esposito (2011), and the model of reward prediction error suggested by Schultz

(2016). As most of the studies were performed on adult people or animals, the data has been analyzed and extrapolated on the behavior of adolescents.

Literature Review

1. The Prefrontal Environment and Executive Function

One thing that distinguishes humans from their ancestral counterparts is complex executive functioning. The PFC controls working memory and executive functions tied to human judgment, reasoning, and language comprehension (Cools & D'Esposito, 2011). Unlike its role in reward processing elsewhere, dopamine in the PFC modulates sustained attention within working memory. Dopamine's functional role in the PFC differs from other regions due to high receptor density and diffuse inputs in the prefrontal environment. As described by Cools & D'Esposito (2011): "The PFC contains a large number of DA receptors (8–10) and is highly sensitive to its dopaminergic environment." This occurs through a mechanism that suppresses background neural firing, making dopamine firing more effective. The prefrontal dopamine system is linked to the ventral tegmental area, modulating complex neurocognitive processes rather than direct reward regulation. In contrast, subcortical regions like the striatum have a more direct, pleasure-focused dopamine function.

2. The Inverted-U Curve Model

The Inverted-U Curve model shows how prefrontal dopamine levels affect cognitive performance, with either insufficient or too much prefrontal dopamine levels negatively affecting performance. According to Matthew A. Weber et al. (2022), "The R^2 value for our quadratic model was 0.10 for prefrontal dopamine"; "The R^2 value for this model was 0.26 for prefrontal D1DRs". In this analysis, the R^2 values represent the ratio of variance in performance changes observed in 75 different studies. Approximately 10% of the performance variance could be associated with the inverted-U curve, whereas 26% of the changes were accounted for by prefrontal D1 dopamine receptors, which made them the major driving force behind the observed changes in working memory performance (see Figure 1).

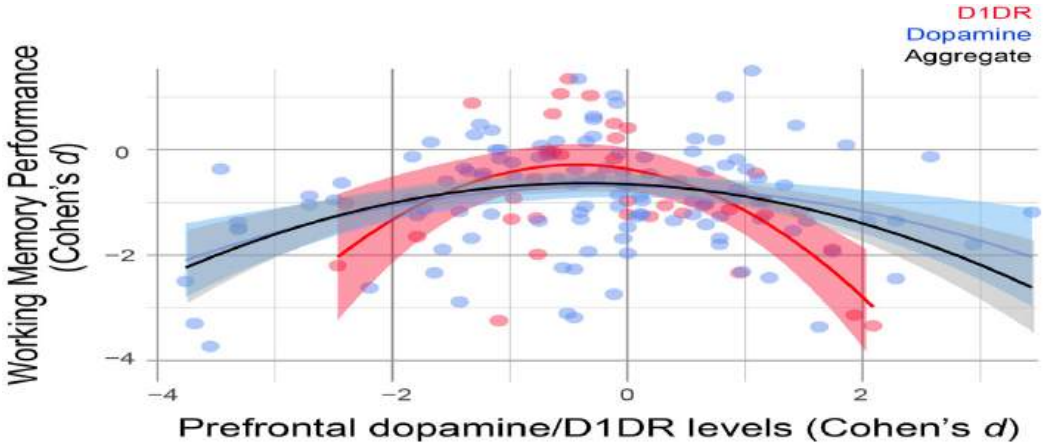


Figure 1 *Empirical quadratic meta-analysis curves mapping the relationship of overall prefrontal dopamine (R^2 = 0.10) and prefrontal D1 receptors (R^2 = 0.26) against working memory performance variance across multi-study datasets (Adapted from Weber et al., 2022).*

The effect of these D1DRs was proven through various in vitro studies such as the one conducted on the PFC-VTA groups mentioned by Cools and D'Esposito (2011) which shows how dopamine concentration affects prefrontal activity following the inverted-U curve pattern. Such studies confirm that when there are lower concentrations of dopamine, there is an up state of prefrontal neuron firing due to low dependency while there are more concentrations of dopamine in the case of higher dependency thus lowering the firing rate. The importance of the Inverted-U curve in prefrontal dopamine is that performance trends could be capitalized on by modulating working memory and attention spans to ensure maximum performance. However, its effectiveness differs among individuals due to various baseline dependencies.

3. Baseline Dependency and Genetic Variations

Essentially, baseline dependency means that the cognitive impact of an intervention depends completely on an individual's initial dopamine levels. The peak of the inverted-U curve, representing optimal performance, depends on baseline dopamine levels and varies from individual to individual. This variability means that a method effective for one individual might impair performance in another. The baseline dependent effect is illustrated in findings from psychopharmacological studies with human volunteers indicating that, "effects of dopaminergic drug administration depend on baseline levels of performance... The drug improved cognition in subjects with lower baseline working memory abilities in the 'un-drugged' state, while worsening cognition in those with higher baseline working memory capacity" (Cools & D'Esposito, 2011). Baseline dependency is also seen through genetic evidence of COMT enzyme polymorphism, where Met allele which is high basal dopamine shows better cognitive performance than Val allele which is low basal dopamine. Cools & D'Esposito (2011) highlight, "Consistent with these assumptions are findings that individuals with the Met-allele (high DA) perform significantly better on tasks requiring cognitive control and working memory than those with the Val variant …" For example, Egan et al. (2001) have shown that the high DA Met subjects make fewer errors on the Wisconsin Card Sorting Test... than do low DA Val subjects. However, this variability is not uniform across all the age groups, since baseline dopamine levels fluctuate more extremely in adolescents than adults due to their developing PFC. This requires more personalized strategies to optimize attention and working memory for adolescents as traditional methods might not be applicable to them. The Reward Prediction Error (RPE) addresses these limitations by providing more dynamic adjustments to reach the optimal zone.

4. Reward Prediction Error (RPE) as a Dynamic Regulator

While the inverted-U curve describes the general relationship between dopamine and performance, the Reward Prediction Error (RPE) system addresses gaps by facilitating real-time adjustments. RPE helps adjust personal strategies to reach the optimal zone. The RPE system is

categorized based on expectation: positive RPE occurs when dopamine levels rise higher than expected, boosting performance, whereas negative RPE occurs when dopamine levels fall below expected levels, resulting in a performance decline. Wolfram Schultz describes these prediction errors in terms of neuron firing, "Positive prediction errors produce dopamine activation, whereas negative prediction errors produce brief pauses in dopamine neuron firing" (Schultz, 2016). RPE acts as a regulatory mechanism for dopamine levels in real-time, optimally positioning an individual along the inverted-U curve. RPE serves as a dynamic starting point for developing personal strategies in adolescents that are trying to reach optimal performance for better working memory and focus. Consequently, RPE sensitivity is heightened in adolescents due to their developing reward system; an RPE strategy that works for one adolescent might not work for another, as their neurological maturity matures at different rates.

Proposed Strategies

Together, the inverted-U curve, baseline dependency, and the RPE model contribute to a high variability in adolescent dopamine regulation, as the PFC is immature and can account for unstable and exaggerated tonic levels compared to adults (Cools & D'Esposito, 2011, p.113). This variability explains why conventional methods for reaching optimal performance are somewhat effective for adults but fail to reach the same effectiveness in improving attention, motivation, and working memory amongst adolescents, largely because they do not account for individual baseline dependency and heightened RPE sensitivity. While these principles also influence adults; the scope of the variability is not as big as when compared to adolescents. Therefore, interventions must be unique and personalized to exhibit positive RPE, while also stabilizing baseline expectations to avoid negative behavioral patterns. This section provides several evidence-based strategies tailored to adolescent brains to help achieve an optimal level of performance in their working memory and attention collectively.

Strategy 1: Variable Reward Schedules (Eliciting Positive RPE)

The first effective strategy is to use a variable reward system following focused study sessions to generate positive RPE and sustain focus and motivation. The practical way to implement this strategy is by creating a list of self-rewards that adolescents enjoy, for example: five minutes of social media break, eating a favorite snack, stretching, or listening to their favorite song. After completing a study session, the adolescent rolls a die or uses a randomizing application. If the die lands between one and four then a reward is selected, but if it lands on five or six no reward is granted. Because an unpredictable reward schedule prevents reward habituation, it results in a positive RPE every time that triggers phasic dopamine bursts and reinforces task management (Schultz, 2016). This strategy is especially effective for adolescents, as this unpredictability keeps the developing brain more highly engaged than a fixed, repetitive reward schedule. This leads to a higher willingness to perform tasks, reduced procrastination, and heightened focus during study sessions.

Strategy 2: Controlled Breathing Protocols (Optimizing the Inverted-U Range)

A second effective strategy to incorporate is brief breathing exercises before study sessions to reduce anxiety and guide prefrontal dopamine towards more optimal levels. Adolescents can perform this exercise by closing their eyes and engaging in controlled rhythmic breathing–specifically inhaling for five seconds and exhaling for five seconds—sustained over three to five minutes. Physical effects of brief breathing exercises include lower emotional arousal and stress; breathing lowers arousal which prevents dopamine from deviating from the optimal zone of the inverted-U curve (Cools & D'Esposito, 2011). Given that adolescent PFC is still developing, it is more vulnerable to stress-related dopamine shifts. This makes breathing a more impactful exercise in controlling and calming adolescents to reach the optimal zone of the inverted-U curve. Regular practice of brief breathing can help adolescents maintain better focus, reduce procrastination, and achieve better work performance.

Strategy 3: Grayscale Configuration and Screen-Time Constraints

Implementing structured screen time limits alongside grayscale mode is another valuable strategy to counter dopamine overstimulation. Adolescents can use screen time limits to counteract the baseline inflation from unrestricted social media use. To implement this strategy, a screen limit should be established for highly distracting apps; a reasonable limit is in between 30-60 mins. In addition, enabling grayscale mode can reduce the visual appeal lowering the dopaminergic drive towards those apps. High-stimulation content on social media platforms–such as doom-scrolling behaviors–causes frequent, large dopamine spikes that push the baseline above the optimal range. This elevation reduces the PFC's capacity for sustained attention. As Cools & D'Esposito (2011) state, "Excessive DA receptor stimulation impairs PFC function by reducing the signal-to-noise ratio of neural representations" (p. 116). Grayscale helps keep the baseline closer to the optimal range by reducing frequent spikes as the muted color palette diminishes the visual appeal and reward-value of the device, thereby reducing frequent spikes. This strategy is specifically useful for adolescents since they are more prone to overstimulation-influenced dopamine shifts compared to adults because of their developing PFC.

Discussions

Adolescents develop this weak cognitive framework through excessive social media use, doom scrolling behaviors, chronic procrastination, and subsequent emotional fatigue. These behavioral patterns lead to frequent spikes in dopamine levels and frequent negative RPE loops, causing motivation to crash after small setbacks. To face these problems adolescents can utilize the following techniques:variable self-rewards to elicit positive RPE and disrupt downward behavioral spirals; brief breathwork to reduce physiological arousal and maintain prefrontal dopamine within an optimal range; and structured screen time limits combined with grayscale mode to reduce overstimulation and stabilize baseline dopaminergic levels. Because these techniques are low-cost and practical, they are highly accessible for adolescents. The

understanding of these interventions derives upon my previous studies in neuroscience and emotions, bridging theoretical insights with real strategies.

This paper builds directly from my summer research with the Polygence program, which explored neuroscience and emotion, as well as foundational knowledge gained through AP Psychology. The Polygence experience introduced me to the core concepts of brain function and emotional regulation, meanwhile AP Psychology provided a broader understanding of cognitive processes and human behavior. This current paper extends those previous efforts by trying to understand specific dopamine mechanisms and the complex framework circled around adolescent challenges. Rather than remaining at a theoretical level like my previous projects, this paper aims to translate those understanding into practical, evidence-informed strategies that adolescents can use to manage motivation, focus, and cognitive performance. The process represents a natural progression from learning foundational neuroscience to applying those learnings to a real-world problem faced by adolescents of this time period.

Limitations

However, the limitations of this paper regarding the suggested strategy and framework for improving the cognitive function of adolescents are also obvious. First of all, it should be noted that this paper is a literature review, and there were no findings obtained through conducting any experiments, surveys or communication with adolescents. Second, the mechanisms proposed in this paper–inverted-U curve and baseline dependency according to (Cools & D'Esposito, 2011) and response prediction error according to (Schultz, 2016)–have only been proven to work among adults. Thus, the application of these mechanisms to adolescents requires special consideration. In addition, the regulation of dopamine is very individual and depends on such factors as COMT polymorphism, environment, stress and lifestyle; therefore, the proposed strategy may not be applicable to some adolescents. However, the three proposed strategies have not been yet applied to adolescents in a controlled manner; therefore, the influence of these strategies, its results and outcome remain unknown. As for the scope of research, this paper concerns the topic of cognitive performance only and ignores such issues as emotional regulation and socio-cultural aspects affecting the functioning of the dopamine system.

Future Directions

While this paper provides a framework and proposed strategies for adolescents, their empirical effectiveness remains to be formally validated. One possible way to test this is by conducting anonymous pre- and post-intervention surveys among high school students to measure changes in motivation and attention. Second, empirical data could be collected by developing a Python-based simulation of RPE and baseline shifts to model the effects of breathing exercises and variable self rewards within a virtual environment. Furthermore, future work could involve designing an application that automates variable-self reward schedules, enabling adolescents to collect their own data and track engagement. Finally, establishing

collaborative studies in high school would help collect vital qualitative feedback from both students and teachers regarding classroom performance. Ultimately, these future directions would help refine the proposed interventions and provide stronger evidence for their practical use in supporting adolescent cognition.

Conclusion

Ultimately, this paper demonstrates how the interaction of inverted-U curve, baseline dependency, and reward prediction error (RPE) provides a valuable mechanistic framework for understanding and addressing cognitive challenges in adolescents. By synthesizing the inverted-U curve, baseline dependency, and reward prediction error system, this paper proposes three practical strategies. First, implementing variable self-rewards after focused study blocks elicits positive RPE, reinforcing motivation and helping to disrupt negative spirals of disengagement. Second, brief, focused breathing exercises before study sessions reduce excessive arousal, helping maintain prefrontal dopamine within the moderate range of the inverted-U curve where attention and working memory peak. Finally, structured screen-time limits combined with grayscale mode prevent excessive dopamine spikes from high-stimulation content, thereby stabilizing baseline predictions and preserving prefrontal cortex function for better focus. Collectively, these strategies offer adolescents accessible, mechanism-based tools to actively manage their dopamine dynamics rather than relying on generic advice.

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The Possibility of Tornado Mitigation By Vaibhav Gaddam

Abstract

This paper evaluates current theoretical and logistical feasibility of combating and mitigating tornadoes. Most meteorological organizations focus on detecting and tracking tornadoes. This study examines methods of thermodynamically destabilizing a tornado through the use of various tools and approaches like cryogenic cooling, thermobaric explosions, and microwave heating. This paper also examines the possibility of leveraging the triboelectric properties of tornadoes in combating and tracking them. This paper judges these combative agents against the energy and resources needed to enact each method and determines that it is not possible to combat a tornado.

Keywords

Tornado Mitigation, Tornado genesis, Cryogenic Cooling, Thermobaric Explosion, Triboelectricity

Introduction

Tornadoes are a violent congregation of atmospheric energy resulting in billions of dollars in damages annually. They are a small part of an enormous storm that can span thousands of miles. Research on tornadoes has been funded and conducted by many different organizations from the U.S. government and private companies for decades, but most research on tornado mitigation or combat has ceased. This was due to how tornadoes and tornado genesis are still not fully understood. However, as our understanding of tornadoes and tornado genesis increases, is it possible to make the shift from tornado observation to intervention?

Pressure Gradient Force is the driving force that perpetuates a tornado as air wants to move from areas of high pressure to low pressure. Pressure Gradient Force is what describes the force causing the air to move in such patterns.

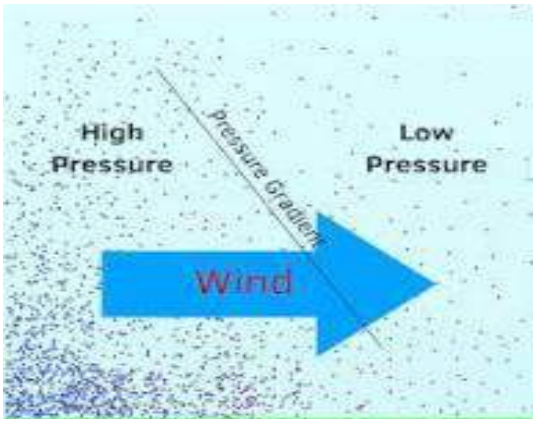


Fig 1

Literature review

1. Capacity to prevent tornadoes

The theoretical capacity to influence, kill, or mitigate a tornado is based upon the idea of disrupting the thermal equilibrium between the tornado's warm updrafts and cold downdrafts. Since tornadoes are driven by this intense convection of winds, any mechanism to oppose a tornado's formation or its lifecycle would require targeting where the ground level air enters the vertical funnel, called the corners. One concept involves adding ultra-cold substances like liquid nitrogen into the tornado's funnel, cooling the warm updrafts effectively choking out the tornado. Research by Concordia University found that temperature drops inside a tornado cause the air density to be 20% lower than normal, and adding liquid nitrogen would amplify this effect causing the vortex to collapse under its own weight choking it out (Wan). However, this concept would need a hundred thousand to millions of tons depending on the tornado's size, vorticity, and humidity according to the NOAA ("30th Anniversary"). Additionally a tornado is only a small part of the large supercell it is a part of, and destroying or weakening the tornado would only be a temporary solution as the parent supercell could resupply or generate a new tornado as was seen with research conducted by the NOAA and AMS when studying how the atmosphere balances changes occur in its energy cycles (Trapp et al.).

Another method of counteracting a tornado would be through the use of thermobaric explosions. The theory behind this idea is grounded in the principle of exploding thermobaric bombs near the corners of the tornado disrupting the convection of the funnel through the force of the explosion and the heating up of the air destabilizing the thermal equilibrium of the tornado. Research by Concordia University explains that a vortex naturally separates hot and cold air to maintain its structure and so by disrupting either one could disrupt the entire vortex. This is known as the Ranque-Hilsch effect (Wan). Furthermore, a thermobaric explosion would also be able to add pressure inside the wind funnel decreasing the pressure gradient inside a tornado causing a decrease in vorticity and thus windspeed of a tornado. Another method of heating the RDF was proposed by Bernard Eastlund using advanced computer simulations at the University of Oklahoma, he suggests that adding 100 million watts of energy to the RDF via microwave transmission from satellites could provide enough heat to increase the buoyancy of the air to prevent the RDF from descending (Eastlund). This study serves as a basis for the idea that microwave beams transmitted from satellites to heat up the funnel's cool downdrafts could disrupt the funnel's structural integrity and convection. This would make it so that the funnel would destabilize and weaken in vorticity and lead to less wind speeds and destruction. This would mainly be in part for the disruption in the thermal equilibrium of a tornado causing it to not be able to form a proper funnel .The primary obstacle in the implementation of this concept would be the precise targeting of hitting the correct region of the tornado.

An important concept in potentially disrupting a tornado's activity is that they generate an electric and magnetic field through triboelectricity from the contact of hail and debris from a tornado. Moreover, in a tornado the bottom of the funnel generates a positive charge while the

top of the tornado generates a negative charge. As a result, this causes the tornado to act like a solenoid, though its overall charge is weak the use of this electrical discharge can be leveraged. Research by John R. Leeman and Ernst D.Schmitter confirms that as the vorticity increases tornadoes emit characteristics of Ultra Low Frequency radiation, in other words low frequency electromagnetic waves (Leeman and Schmitter). As a result piezo-electric and triboelectric generators can be deployed. These generators would be able to interact with the positively charged base exploding and causing an influx of pressure inside the tornado decreasing the vorticity due to the decrease in the pressure gradient force. A major caveat with this concept would be the fact that the generators that would be needed to combat a tornado do not currently exist as most piezo and tribo-electric generators and explosives have only been developed at much smaller scales and the actual effect they would have on a tornado is still questionable as tornadoes are still massive and violent rotating air columns that just so happen to produce an electric field.

2. Delivery

The delivery of cooling agents or other devices like thermobaric bombs produces a monumental challenge.Any theoretical basis for combatting tornadoes requires the need for dispersal and deployment systems. These systems would need a way of entering and approaching a tornado and then be able to properly distribute combative agents. One possibility is by using massive unmanned aerial systems like reused planes near the size of Boeing 747s. These UAS's would in theory approach the tornado high up to get close to the mesocyclone to release agents of combating a tornado so they would hit the tornado near its corners. The success of UAS's would also depend on the use of weather stations and mobile radar units along with storm chasers to identify the correct location to deploy the necessary agents to combat a tornado. However, an issue with deployment is also apparent since the UAS arrives near the road and its stability is in question. Additionally, pinpointing the exact location of the tornado and its internal structure is not perfect as it takes several minutes to update and there is limited visibility inside the tornado as most radar tools use microwaves, which cannot enter the inner funnel of the tornado according to the NOAA ("Severe Weather 101"). However, the use of cell towers to determine when and where a tornado is located is a grounded possibility since cell towers use radio waves which can see the inner funnel of the tornado identifying its structure. Additionally, cell towers would not take as long to update allowing for further accuracy. Cell towers themselves only measure phase shift, intensity, and polarization of radio waves, but paired with the information from weather stations could be used to gain even more detail into the inner structure of a tornado allowing the UAS's to have an easier time deploying their combative agents. This concept was put into practice when NASA conducted an experiment using wireless cell signals to identify moisture in the air and used that information to deduce where a tornado may form (Spencer and Howland). This is also supported by the research by John R. Leeman and Ernst D.Schmitter as they also reported that a tornado's electrical signal could cause interference with other forms of electromagnetic radiation (Leeman and Schmitter).

The second hurdle in delivery of the combative agents would be how the agents would actually make contact with the tornado. There already exist certain ballistic and aerodynamic shells designed to deploy payloads at specific altitudes and pressures. Their accuracy will decrease as they approach a tornado but still provide the desired utility. These are shells with two compartments, an inner and outer shell along with a high ballistic coefficient to not be sent off course due to the tornados inflow. A proof of this can be seen in a NOAA repository reporting on the accuracy of projectiles during different altitudes in the air and under effects of strong winds (Scott, Christopher W). Additionally to maintain the needed temperature to properly store materials like liquid nitrogen, the gap between the inner and outer shell would be separated by a vacuum to ensure limited temperature transfer. This is called the "vacuum effect." This also can be used to keep other combative agents stable like thermobaric bombs and piezo-electric generators. To make sure the payloads are active when reaching the tornado, the use of piezoelectric and triboelectric sensors to detect when the desired level of electric potential is present and to release the combative agent inside the shell is another possibility.

3. Longevity and Reusability

The longevity that each combative agent presents to the weakening of a tornado is short lived as tornadoes are a small part of a supercell, an enormous storm that spans hundreds of miles in length. Attempts to weaken the storm will eventually be regenerated by the parent supercell assuming the tornado will live long enough. This is also why it is out of the question to try and kill the tornado as it requires magnitudes more in energy and resources to kill it and will most definitely be regenerated by the parent storm.

Additionally, the applications and combative agents like the liquid nitrogen and thermobaric explosions are impossible to regenerate and would need to be re-collected, so they would not be able to be used over and over again as it would take an extreme amount of time to regenerate the required amount of the agent as the amount of liquid nitrogen needed to weaken a tornado. However, the actual infrastructure used would be able to be res-used as the fleet of UAS's would be able to regroup after a hypothetical mission, and re-stock on the combative agents. Additionally the infrastructure for using microwaves emitted via satellites can be used over and over again though there exists significant maintenance and usage costs, as there would need to be dedicated space missions to either repair or re-supply the satellite as it will wear and tear over time.

4. Risk of Application

Interfering with the natural progression of a tornado and by proxy its supercell could carry risk of unpredictable scale. Efforts to try and disturb the tornado through thermodynamic intervention could also redistribute energy through the supercell. This could cause the generation of a new tornado or even an increase in intensity of an already existing tornado. An additional side effect would be the damage caused by the combative agents. The scale of energy or materials needed to combat a tornado is astronomical. For example the amount of liquid nitrogen

needed to combat a tornado is within millions of tons, and as a result the excess of liquid nitrogen could disrupt agriculture, ecosystems, and disrupt weather formations, and even cause the formation of hail (“Cyrogenic Air Separation”). On the flip side, the amount of thermobaric explosions needed to combat a tornado would do severe damage to nearby infrastructure and towns that could potentially rival that of the tornado (“GBU -43/B MOAB”). This is due to the fact that tornadoes produce an energy of 62.1 Giga Joules according to the AMS and as a result a similar scale of energy is needed to kill them. Though if the objective is simply trying to weaken a tornado then a smaller scale of energy is needed, though the amount of energy needed is still enormous.

Moreover, this is not even the first attempt to try and disrupt storms like tornadoes as in 1962-1983 the US government paired up with NOAA to try to disrupt hurricanes. This project was called project STORMFURY and used cloud seeding technology to try and condense the storm. This project used planes loaded with silver iodide to try and facilitate the cyclization and condensation of ice and water crystals in the atmosphere (“Project STORMFURY”). This project was eventually put to rest because it was extremely hard to determine if any of project STORMFURY’s attempts had any significant impact on tornadoes and the reproducibility of the results they had gathered. Additionally many of the project's investors besides the USA halted all forms of sponsoring due to the risk of bad publicity if any of these attempts had negative impacts by creating a new tornado. This was seen with the occurrence of hail and smaller reported incidents of storms near the testing sites of project STORMFURY.

5. Cost and Feasibility of Implementation

The feasibility needed to stop or combat a tornado is insurmountable due to the cost and logistics of deploying the combative agents. For example liquid nitrogen costs around $500-$1000 per ton and will vary depending on the delivery distance and storage requirements. To have any effect at mitigating a tornado would require billions of dollars (“Cryogenic Air Separation”). To deploy the necessary UAS’s, it would require a fleet of thousands of them as a single Boeing 747 would cost around 150 million dollars and only hold 140 tons according to Boeing (“Boeing 747-8”) . It would require at least another billion dollars.

Other approaches like thermobaric weapons also have extreme cost as large scale thermobaric bombs like the GBU-43/BMOAB have a cost of $170,000 but ones for an even larger scale of combatting tornadoes would be in the millions (“GBU-43/B MOAB”). Smaller thermobaric weapons that could be deployed from UAS’ would cost $30,000 per unit stated by the U.S Air Force.

Additionally the infrastructure and cost to build a space based satellite that emits microwave beams would be a multi billion dollar project as current satellite programs from NASA and NOAA have a 10 to 13 billion dollar life cycle (“NOAA NESDIS”).

Each of these methods would incur more financial burdens on the USA than the damage tornadoes produce annually, and the logistics of actually deploying all these agents as needed, with either the necessary scale or accuracy are so far currently impossible.

Conclusion

As of recently, it is prohibitively impractical and is not logistically feasible to try and combat a tornado. Even though we know more about how tornadoes form and function it is still too much of a financial, logistic, and environmental burden to try and combat a tornado with the technology of the present day. Additionally even though there have been even more advancements in technology like the production of large UAS systems or remote satellites, it is still not practical or feasible. There are still massive hurdles in transportation and energy scale in which we as a society have not figured out how to accommodate. However, this does not mean that humanity will never be able to combat and mitigate tornadoes as there still exists lots of theoretical precedent and as more and more information about tornadoes is uncovered along with further advancements in technology like better distribution systems or mechanisms to release and control substance mid departure.

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Media and Perceptions of Gender-Based Violence: A Comparative Study of Generation X and Generation Z By Stephanie Yoon

Introduction

For generations, gender-based violence (GBV) has been deeply rooted in societies. However, the ways in which people understand and perceive it have changed. Existing research has attributed this, in part, due to the significant shift in media type and exposure over the years. From newspapers to television to social media, the media has consistently acted as a powerful instrument capable of shaping public opinion and perception, including stories of GBV.

Gender-based violence can be defined as any harmful physical, sexual, or mental act or threat perpetrated against a person based on gender differences (Office for the Prevention of Domestic Violence). This includes sexual harassment and assault, domestic violence, dating violence, and more. For many, the media is a major source of information when individuals have not experienced GBV firsthand. However, the media often influences how stories of GBV are told, shaping how victims are believed. Younger generations increasingly rely on more recent developments of media such as social media, while older generations grew up with print newspapers and television. This generational difference in media consumption habits led to the formulation of the research question: How does the media associate with perceptions of gender-based violence among Generation X compared to Generation Z in the northwest suburbs of Chicago? A hypothesis was also developed: Generation Z will have a lower rate of victim-blaming responses than Generation X, and these results will be in relation to higher exposure to social media.

For the context of this paper, Generation Z (Gen Z) will be defined as anyone born between the years of 1965 to 1980, while Generation X (Gen X) will be defined as anyone born between the years of 1997 to 2012. The 17 year gap between these two generations might seem small, but Gen Z grew up during a time when gender based violence was often marginalized or ignored with mainstream media coverage. However, Gen Z continues to grow with social media movements such as #MeToo and wider public conversation about GBV. Understanding whether these different media environments contribute to different perceptions and approaches of GBV can inform people of how daily tasks such as scrolling online can shape perceptions of large social concepts. In addition, findings can suggest whether media can be used as a tool for positive social change, or if it perpetuates harmful stereotypes and a normalization of violence. These findings can then be used to help inform publishers, content creators, and policy changers.

Literature Review

The media has influenced people's perceptions of numerous complicated social issues including GBV. Especially influencing victim blaming tendencies, what causes violence, and which cases deserve public concern. Research of such media across decades suggests a relationship between how the media frames GBV and how that influences people's beliefs.

Historical media sources revealed that perceptions of GBV have been closely tied to how events of them are expressed in the press. For instance, researchers affiliated with Columbia University found that between 1950 and the 1990s, newspapers around Columbia University, such as The New York Times and Columbia Daily Spectator, often portrayed rape as a smaller issue and instead focused on the race of the perpetrator (Abu-Odeh et al.). Additionally, police largely controlled the narrative and response. In response, rape was not treated as a campus safety problem. This demonstrates how narrative framing shaped public understanding of sexual violence by minimizing its seriousness by treating it as a policy issue rather than a campus safety issue.

Similarly, another peer reviewed study examined Dutch newspapers from 1880 to 1930. This study found that these Dutch newspapers focused mainly on rape cases that were very violent and perpetrated by a stranger, leaving acquaintance rape underreported (Clare). Both of these studies demonstrate how newspapers historically skew narratives which influence what people perceive as "real rape" to their benefit. Additionally, these findings suggest that, historically, newspapers have specifically chosen shocking stories and embellished them further to make more interesting articles and attract more readers.

More recent research shows that although the media environment has changed, biased reporting still exists, impacting public perceptions. A CDC-published study analyzed American newspaper coverage between a recent time period between 2014 to 2017. Their analysis found that prevention strategies were rarely discussed in the articles. Instead, frequently used terms such as "sex scandal," minimized victim accountability (Egen et al.). Similarly, another paper by Dr. Kaitlynn Mendes, a recognized scholar in feminist studies, argues that during the United States and United Kingdom second wave feminist movement, newspapers portrayed feminists as irrational or extreme, shaping public distrust of the movement (Mendes). These findings can be used to explain that media narratives have long influenced the public orientation towards gender issues and can either reinforce or challenge existing beliefs. This suggestion, paired with the findings that recent media rarely discusses prevention strategies and use victim-discrediting language, implies that public modern perceptions of GBV can reflect this through higher victim blaming tendencies.

While powerful, the media is not the only influencer of GBV perceptions; legal frameworks also heavily influence peoples' understandings of gender-based violence. Gendercide explains how old, ancient legal systems treated and addressed women as property (Gendercide), which influenced ancient perceptions as laws tend to be accepted by society as the truth. Although today's law has changed drastically since then, early American legal approaches also minimized domestic violence and treated rape as a private matter. However, the Violence Against Women Act (VAWA), passed in 1994 (US Department of Housing and Urban Development), marked a major turning point as it recognizes GBV as a systemic issue in need to be addressed federally. Legal framework is crucial as journalists and many others turn to legal definitions for language and interpretation in their stories and articles, impacting readers' understandings. With VAWA, society can start to believe GBV as a real, systemic issue and as

previously stated, laws tend to be accepted by society as the truth. With this, VAWA could potentially contribute to a difference in generational perceptions of GBV as Gen X existed before VAWA, while Gen Z grew up with VAWA already established.

As laws began to address GBV, media coverage also began to shift to more structural understandings. However, these shifts occurred unevenly across time and location. As Gen Z was exposed to media during this shifting period, their perceptions and interpretations of GBV may reflect a combination of outdated and developing narratives. This historical progression is why a comparison of generation and perceptions of GBV is relevant. Numerous studies have found a correlation between different age groups and perceptions of GBV. A peer reviewed study conducted by professors at top-ranked Deakin Univeristy found that out of a sample with 512 participants, older adults were more likely to agree that the changes in details of a sexual abuse story indicate lying more than younger adults from Generation Y. They also found that younger generations tend to disagree more than older generations that a lack of distress indicates that the accuser is stating false information (Klettke et al.). These findings align with more broader research that younger generations might have more progressive and trauma aware interpretations of GBV.

However, these generational differences are not always accurate, especially across different countries and cultures. In a 2025 Nigerian study with over 50,000 participants, researchers found that older adults were more disapproving of intimate partner violence than adolescents (Ntoimo et al.), demonstrating that generational trends can vary and are not always uniform. This is why localized studies, such as comparing two generations in one region, are necessary.

Among adolescents, which fall under Gen Z, awareness of digital forms of GBV is growing, especially among girls. A 2024 peer reviewed study found that female adolescents were more able to recognize online GBV (digital harassment and non consensual sharing of images) as harmful more than their male counterparts (Rakhmawati et al.), which could possibly be the result of the fact that females are more likely to experience and internalize online GBV. These findings reflect media environments where digital GBV is very visible.

Gen X grew up during the 1980s and 1990s around popular media choices including newspapers, televised news, and early internet content, many of which reinforced traditional beliefs about GBV, sensationalized stories, and minimized discussion of systemic causes as discussed earlier. Some research has shown a greater adaptation of digital platforms while other research has shown that Gen X maintains more intentional and stable news consumption patterns compared to younger generations (Kruikemeier & Vliegenthart). Overall, Gen X reflects a hybrid, in-between transition between traditional and digital media consumption.

In comparison, research by the nonpartisan Pew Research Center reveals that Gen Z primarily uses more modern, digital forms of media such as Youtube, TikTok, Instagram, and Snapchat. All of these platforms are easy for anyone, including survivors of GBV, to post, comment, and chat with millions of users, facilitating public discourse. According to research by Julia Stoll, a Statista research expert specializing in the media industry, Gen Z spends the most

time consuming media than any other generation (Stoll). These pieces of evidence reflect the change and growth toward shorter forms of algorithm based content. Because these platforms that Gen Z frequently use are algorithm based, Gen Z unintentionally crosses information and due to the short content on these platforms, they come across a multitude of different information everyday that can influence attention and information processing patterns. This is why studies that observe this media shift with perceptions of GBV are needed.

Existing literature demonstrates that media can play a strong role in influencing narratives and perceptions of GBV over the years and that media consumption differs between Gen X and Gen Z. However, there is limited research directly comparing the perceptions of GBV of Gen X and Gen Z within similar cultural context of the northwest suburbs of Chicago and even less research on how specifically the difference in media consumption patterns of the generations correlate with their perspectives of GBV. This study addresses that gap by measuring media type and exposure among Gen X compared to Gen Z while also comparing their perceptions of GBV. These findings may be used to suggest generational differences in GBV to inform prevention, education, and media efforts.

Method

To determine the association between media, generation, and perceptions of gender-based violence, primary data were collected through an analytical cross-sectional survey that was distributed around the northwest Chicago suburbs. According to Sribblr, an analytical cross-sectional survey can be used to collect data from participants at a single point in time to aid in the determination of how or why a certain outcome occurs (Thomas). This survey design was chosen as it allows for simple comparison between the two generational groups at one point in time while also being relatively feasible to conduct. This method design was modeled after a previous peer reviewed study by Bianca Klettke, a cyberpsychology researcher and senior lecturer at Deakin University, and other professors of Deakin Univeristy, who used a cross sectional survey to analyze perceptions of credibility of sexual abuse victims across various generations (Klettke et al.). This alignment justifies the current study's approach as it is based on an established and effective method in measuring perception differences among generations.

The survey used in this study consisted of two independent variables: generation type (Gen X, Gen Z) and media (measured through time spent and platform used). The dependent variable consisted of perception of GBV which was measured using five point Likert scale responses to various statements about or relating to GBV. The full survey can be seen in Appendix A. A response of 1 indicated strong disagreement, a response of 2 indicated disagreement, a response of 3 indicated neutral agreement, a response of 4 indicated agreement, and a response of 5 indicated strong agreement. This five point scale allowed perceptions to be specifically identified and nuanced. In addition, optional open-ended free responses to the question, "How has the media influenced public perceptions of gender-based violence?" were gathered. Some of these statements were adapted from a prior peer reviewed study by the Organization for Security and Co-operation in Europe that analyzed media reporting and GBV

among women, ensuring that each question was purposeful and effective in measuring perceptions of GBV (Organization for Security and Co-operation in Europe Mission to Montenegro). See Appendix A for the full survey instrument.

The variables of the survey address the three major components of the research question, which include generation, media, and perceptions of gender-based violence. Additionally, although Likert scales may not be able to completely capture nuanced perceptions of GBV, a five point scale was used in attempt to combat this. The Likert scale also allowed the data to be standardized to statistically measure and compare generational GBV perspectives that the design and the approach of the study addresses. The standardization of the responses also helps reduce measurement bias, allowing this method design to be more favorable than others.

The participants of the survey were both volunteers and residents of the northwest suburbs of Chicago. Their perceptions were studied using a voluntary response sampling method. The two strata were Gen Z, or people born between the years 1997 to 2012 (Beresford Research) and Gen X, people born between the years 1965 to 1980 (Beresford Research). This choice was justified because the goal of the study was to compare Gen X and Gen Z which can be easily assessed with the stratas.

This survey was distributed via Google Form over a three month time period. To ensure participants were relevant to this study (Gen X or Gen Z living in the northwest suburbs of Chicago), respondents first indicated that they were residents of the northwest suburbs of Chicago and within the Gen X or Z age group before proceeding on to the next sections of the survey. The survey consisted of two sections; the first verified generation, location, and collected media consumption patterns. The second measured perception through five point Likert scale responses to statements about gender-based violence. Some statements were informed by a previous peer reviewed study, that was previously mentioned, ensuring validity and reliability that the wording of each statement was clear and neutral to reduce bias. Additionally, the standardization that the Likert scale provided allowed for consistency. The Google Forms platform was utilized as it allows the data to be completely anonymous and accessible across all devices.

The quantitative data from the surveys were analyzed using descriptive comparative analysis. First, data cleaning was performed to eliminate participants that were not Gen X or Gen Z, or did not reside in the northwest suburbs of Chicago. Then the range of media exposure was quantified (1-2 hours = 1.5 hours, etc.) and averaged for each generation. The average mean from each Likert scale of each generational strata was calculated on Google Sheets and compared. The Likert scale responses to the following statements,“If a victim’s story changes over time, the accusation is less believable” and “A lack of visible emotional distress makes a victim less credible,” were averaged together into a victim credibility mean, as both measure victim credibility. The averages were then compared, which allowed for general trends and relationships of each generation’s perceptions of GBV to be drawn. The qualitative open ended response data were analyzed through thematic analysis. Responses of each generation were read so patterns and themes were identified and compared. This data analysis method aligns with the

online survey design of the method while still allowing the identification of generational differences and relationships among variables.

This method was approved by an Institutional Review Board (see Appendix B) and follows ethical guidelines as all participants were provided with an implied consent statement (see Appendix A) and their responses were maintained completely anonymous as no identifiable personal information besides their generation was collected.

Results

The survey received a total of 61 responses. After data cleaning was performed, 59 relevant responses were analyzed. Of the respondents, 23 identified as Gen X, and 36 identified as Gen Z.

As illustrated in Figure 1, differences in media exposure were evident as Gen X had an estimated average of 3.24 hours exposed to media a day while Gen Z had an estimated average of 4.53 hours. There were also differences observed in media type: 83% of Gen X participants, compared to 97% of Gen Z participants, indicated that social media was in their top three most used media platforms in the past year.

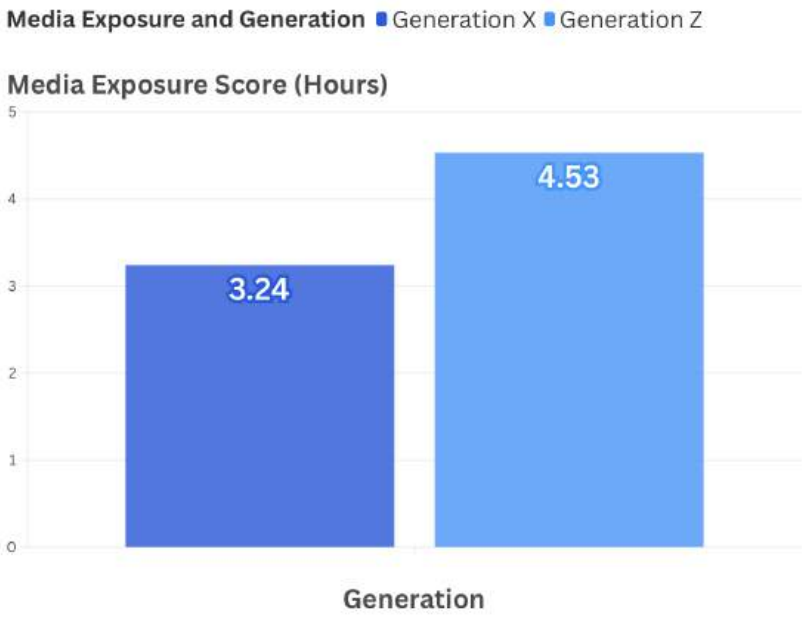


Fig 1: Media Exposure and Generation

In response to the Likert scale statements, the means of each generation were largely similar. The overall means of each generation and the difference between them can be observed in Table 1. The scores of the two statements “If a victim’s story changes over time, the accusation is less believable” and “A lack of visible emotional distress makes a victim less credible,” were averaged together to form a victim credibility score. Gen X had a higher victim credibility score than Gen Z, indicating that Gen X were slightly more likely to believe that a

victim's credibility was lower if their story changed over time or showed less emotional distress. Gen X tended to slightly agree more that GBV is a serious problem and that media reporting influences people's perceptions of victims (see Figure 2).

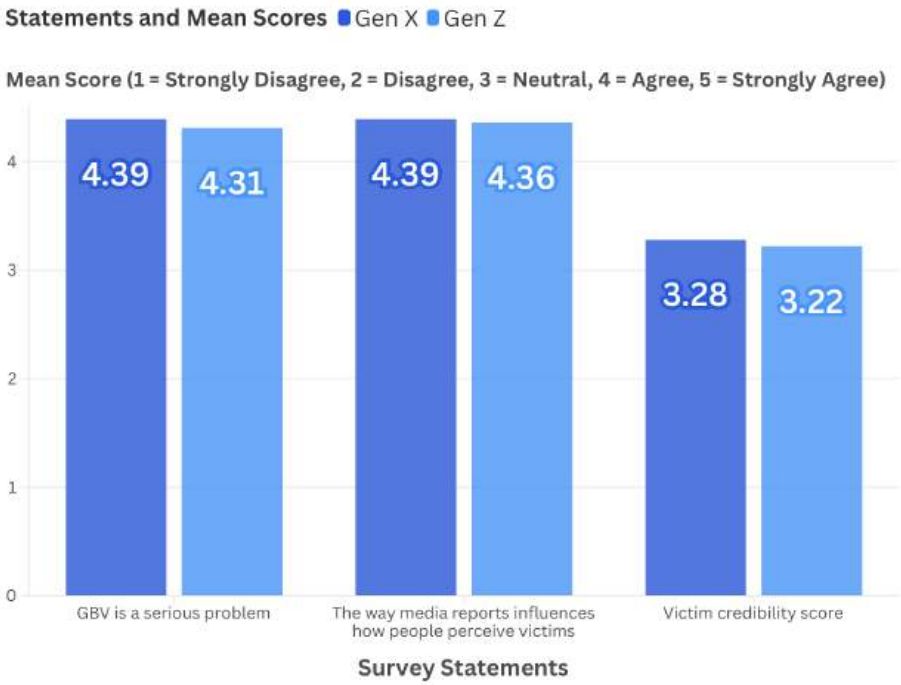


Fig 2: Statements and Mean Scores

Compared to Gen X, Gen Z had a higher agreement in response to statements about social media raising awareness of GBV and the influence of online discussion on their personal views of GBV. However, both generations remained in the neutral, 3 to 4 range and the difference between the generations was miniscule.

Table 1. Difference of Mean Scores by Generation
Note. 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

Variable	**Gen X Mean**	**Gen Z Mean**	**Difference (Gen X - Gen Z)**
Media exposure score	3.24	4.53	-1.29
Victim credibility score	3.28	3.22	0.06
GBV is a serious problem in society	4.39	4.31	0.08
Media influences people's perceptions of victims	4.39	4.36	0.03
Media coverage often places too much responsibility on victims	3.52	3.61	-0.09

Social media has increased awareness of GBV	3.43	3.50	-0.07
Online discussion/activism has influenced my views on GBV	3.35	3.54	-0.19
Media encourages people to speak up against GBV	3.52	3.53	-0.01

The free responses to the question, "How has the media influenced public perceptions of GBV?", were analyzed and two similarities between the generations were found. The first similarity was the identification of the media as a tool to raise awareness of GBV. While both generations described this, nearly all of Gen Z respondents specifically attributed this to social media, while Gen Z referred more generally to "media". The second similarity observed was the ability of the media to facilitate both online and in person discussion about GBV.

However, differences were evident. Overall, the Gen X responses were more critical of the media. One respondent described the media as a "double edged sword," capable of spreading awareness, but also able to spread skewed narratives. Although not all Gen X participants used the term "double edged sword" to describe the media, numerous other Gen X respondents also wrote about the duality of the media. Additionally, Gen X emphasized the dangers of the media with its use of sensationalism and bias, prioritizing profit over the truth. In comparison, Gen Z respondents had a more positive view of the media, discussing the ways social media can amplify survivor voices, amplify authentic encounters, and facilitate online discussion. Gen Z also tended to write about personal, specific encounters on social media that changed their perceptions.

Discussion

The purpose of this study was to compare the association of media with the perceptions of GBV between Gen X and Gen Z. Overall, the results suggest that despite generational differences in media consumption habits, both generations have similar fundamental beliefs of victim credibility and perceived seriousness of gender based violence.

Gen Z reported higher usage of social media and overall media consumption and had lower victim credibility scores (indicating lower victim blaming tendencies). This finding is similar to previous research that suggests that media environments influence how people encounter narratives of gender based violence (Jjuuko et al.). Gen X spent their childhood with newspapers and televised news while Gen Z continues to grow up with social media where it is more common to encounter survivor stories, activism, and awareness campaigns. Despite this, the hypothesis that Gen Z will have lower victim blaming tendencies (indicating lower victim credibility scores) in relation to higher exposure to social media, was only partially supported. While Gen Z did report higher exposure to social media and had lower victim credibility scores, the difference of the scores between the two groups was minuscule of 0.06. This suggests that media exposure alone may not be a strong factor in determining victim blaming attitudes within this sample.

A similarity between the groups was the finding that both generations indicated high perceived seriousness of GBV with their responses primarily being in the 4 to 5 range. This may be a result of media exposure as the qualitative, free response data described encounters with GBV through the media. This aligns with larger and more recent online activism campaigns such as the #MeToo movement which has led to an amplification of survivor voices online as well as overall more media coverage of GBV. This could also be attributed to the recognition of the need of GBV to be addressed federally through VAWA (passed in 1994). This suggests that higher media coverage of GBV and changes in legal interpretation are both possible motivators of this high perceived seriousness.

Subtle differences were observed in the generations' insights into the influence of social media on increasing awareness of GBV. Gen Z participants were more inclined to agree that social media increases awareness of GBV and that personal encounters with online discussions and activism had influenced their perceptions. The qualitative results showed alignment with these results, making this distinction even more clear. Gen Z responses were more specific towards social media and its ability to raise awareness by providing platforms for survivors to share authentic, genuine experiences with GBV. Their agreement with the influence of social media could be due to the fact that the majority of Gen Z participants in this sample indicated social media as their main source of media. This also reflects existing research by research analysts at Pew Research Center: younger generations experience content, which can be related to GBV, in more participatory digital environments (Anderson & Jiang). Gen X responses tended to be more focused on concerns regarding sensationalization and misinformation. Paired with their reported usage with more traditional forms of media such as televised and written news, these findings reflect previous research that traditional media often frames GBV as sensationalized incidents rather than having structural causes (Egen et al.).

Overall, these results contribute to understanding the media's influence on perceptions of GBV, suggesting that generational differences in media consumption may not necessarily translate into drastic differences in perceptions of GBV in all geographic areas, contrary to previous research. While the media may play a role in shaping awareness and discussion of GBV, its influence on deeply held fundamental perceptions is more complex and can be the result of additional social factors. This indicates a weak association between media type and exposure with perceptions of GBV. Understanding this distinction is significant for informed media usage as it is important for educators, policymakers, and media creators seeking to use the media as a tool for social change.

However, there are several limitations when interpreting these results. For instance, because voluntary response sampling was used, self selection bias can be present. The individuals that voluntarily chose to participate in the survey could already have a stronger interest or awareness in this topic than the general population. Additionally, this study was conducted in the northwest suburbs of Chicago which not only limited the sample size, but can make adapting these results to other regional or cultural contexts difficult. The quantitative

results are also limited as the self-reported Likert scale data may not have fully captured nuanced attitudes towards GBV, although a five point scale was used.

Conclusion

Despite these limitations, the results provide some evidence that there is a weak association between media consumption patterns and generational differences in perceptions of gender-based violence in the northwest suburbs of Chicago. Keeping this in mind, future research could use a larger, more balanced sample to provide more accurate and universal conversation surrounding Gen X and Gen Z perceptions. Additionally, closer research specific to factors other than media type and exposure could be conducted to determine factors that more closely associate with generational perceptions of GBV.

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Western Interior Sea: Marine Life Before and After the K-Pg Extinction By Minki Suh

Introduction

Landlocked states like Kansas or Nebraska conjure images of vast corn fields, and never a rich marine ecosystem. But these states were once home to majestic sea creatures millions of years ago. During the Cretaceous period (143.1 to 66 Million Years Ago), there existed a vast seaway in what is now central North America for 34 million years. This seaway is called the Western Interior Seaway. It was formed before the continental drift shaped the modern North American continent. The Western Interior Seaway was 1,000 km (620 mi) wide, but it was shallow compared to the other deep oceans. At its deepest, the Seaway was only 800 or 900 meters (2,600 or 3,000 ft) deep. There were abundant amounts of plankton in this environment, which allowed the development of a thriving and diverse ecosystem. And while there were animals familiar to us, such as sharks, fish, and sea birds, the Western Interior Seaway was also home to giant marine reptiles.

Unfortunately, these marvellous creatures went extinct due to the K-Pg extinction at the end of the Cretaceous, 66 Million Years Ago. Due to this period of mass extinction, the Western Interior Seaway experienced a significant loss of life. The unique sea creatures of the Western Interior Seaway were thus lost to time (Everhart, 5-13). Although the K-Pg may have happened due to an unexpected circumstance of a natural disaster, the sudden loss of such a diverse ecosystem comes to modern humans as a grave warning about our own contemporary marine ecosystem. Just as the Western Interior Seaway experienced radical changes due to the K-Pg extinction, we must be aware of the negative effects on our current ocean ecosystem.

The Western Interior Seaway

The Western Interior Seaway was formed by linking the Arctic Ocean and the Gulf of Mexico during the early Cretaceous period after the rise in global sea-level. Before the formation of the Western Interior Seaway, the Western Interior Foreland Basin formed in the Middle Jurassic, when it was still a landmass instead of an ocean (Slattery et al., 22). The Western Interior Seaway was then formed by the severe fold-and-thrust belt, which refers to the mountain belt that formed due to the movement in the tectonic plates. The crust bent downward, the weight of the mountains sinking the land. However, the basin wasn't formed solely because of the mountains, but mainly, according to Liu, "in response to mantle flow effects associated with Farallon plate subduction; several different configurations of subduction have been proposed (Liu et al., 555)." Additionally, the land also changed its shape as it sank down. The plate was physically sinking down the central North American area into an uneven shape. Even though soil erosion and the weight of the mountain ranges have been suggested as possible factors, the primary reason why the Western Interior Basin descended below the sea level was because of the pull caused by the sinking slab. Therefore, the movement of the tectonic plates was the main factor in the formation of the Western Interior Seaway (Liu et al., 557).

The resulting seaway that split North America produced an environment in which countless ancient marine life thrived until the end of the Cretaceous, disastrously concluding with the K-Pg extinction event. The relative shallowness of the Western Interior Seaway created a unique and flourishing ecosystem where the abundance of algae and plankton in the seaway ensured a rich amount of oxygen for schools of fish to thrive, naturally attracting larger predators who fed on those smaller fish species. The sheer diversity of large predators suggests that the Western Interior Seaway was a fertile environment that could feed and support all those species of ever-voracious carnivores with plenty of food to go around (Everhart, 74). Invertebrate animals were also found in vast numbers at the Western Interior Seaway. The bottom of the Western Interior Seaway was covered with layers of various invertebrates such as shellfish, oysters, and other small filter feeders. The now-extinct ammonites and other cephalopods also made up a prominent portion of invertebrates in the ecosystem. Some of these cephalopod fossils exhibit bite marks of unidentifiable predators, suggesting that life was tough even for these small swimmers, and predators were always just around the corner in the Western Interior Seaway (Everhart, 29-29, 31-32, 38).

Mosasaurs

The Mosasaurs were the most iconic among those predators of the Western Interior Seaway. With some species reaching longer than the *Tyrannosaurus rex*, the Mosasaurs seemed to have been terrifying apex predators within their ecosystem. Mosasaurs were a group of marine reptiles that lived solely during the Late Cretaceous period (100~66 Million Years Ago). While the infamous *Tyrannosaurus rex* ruled the earth, the Mosasaurs were the masters of the Cretaceous seas. They were the top predators in the Western Interior Seaway and in all of the Earth's oceans at the time. Their evolution and marine adaptations towards the early Cretaceous quickly allowed them to grow into massive sizes, ousting the sharks as the dominant apex predators of the oceans in the Cretaceous, including the Western Interior Seaway (McCormack et al., 234).

The ancestors of Mosasaurs were a group of terrestrial lizards known as aigialosaurs, who lived near the ocean during the Late Jurassic period and the early Cretaceous (Everhart, 160-161). Additionally, their close lineage, *Dallasaurus*, from around 92 Million Years Ago, had a primitive tail configuration, which was something that the Mosasaurus also inherited. Additionally, anatomical evidence suggested that the mosasaurus evolved within the Anguimorpha, a major group of lizards. Even though many studies have stated that mosasaurs are indeed lizards, scientists still debate where the mosasaurs fit in the reptile family. However, on the other hand, there were huge disagreements. While snakes and varanid lizards possess long and deeply forked tongues, Heloderma and Lanthanotus, the two highly distinct genera of lizards, belonging to the superfamily of Varanoida, had forked tongues with a fleshly base. The position of Mosasaurs within this reptile family can change the conclusion of how their tongues were formed, and our understanding of the Mosasaurs (Schulp et al. 362). Scientists could not find out exactly what their tongues looked like due to the lack of fossil evidence, but there are

some other inferences that can be made. It was that the mosasaurs might have used their jaws, instead of tongues, for the prehension of food. All Mosasaurs were likely to have mobile quadrates, mobile bones in the back of the skull, but according to Schulp, “only the basal species had kinetic skulls”. The mobility of the upper jaw was not the needed part for the prehension of food. While the smaller reptiles, such as scleroglossan lizards and varanoids, had upper jaws, a bigger species, Mosasaurus, likely lost the mobility of their upper jaw due to their big size (Schulp et al., 367).

The physical characteristics of Mosasaurs also made them a unique group of apex predators. Some Mosasaurs reached up to 50 feet in length, depending on the species, which is about the length of a bus. Their size allowed them to become the top predators of the ocean. And like their snake and monitor lizard relatives, mosasaurs were scaled; their scales were slightly smaller than the scales of prairie snakes (Badlands National Park). At the end of the Cretaceous period, the Mosasaurs were still prospering. Even though the smaller sizes of Mosasaurs went extinct due to the temperature rise towards the late Cretaceous period, the huge ones were still dominating the ecosystem. However, they inevitably met their ends with the coming of the K-Pg extinction. Mosasaurs would have been the most vulnerable species to the decline of their prey because they needed enough prey to hunt for themselves to survive (Ashworth). Without these mighty and unique Mosasaurs patrolling the seas, the history of marine life in the Western Interior Seaway would have been very different.

Elasmosaurs

Besides the Mosasaurs, the Western Interior Seaway was home to another group of bizarre marine reptiles. The Elasmosaurs were a group of long-necked swimmers with small heads, who fed on the schools of fish and cephalopods such as ammonites. They are found all across the globe. Elasmosaur fossils have been discovered in Europe, Oceania, and even in Antarctica. In the Western Interior Seaway, Elasmosaurus has been found since the 18th Century and continues to be discovered throughout North America (Everhart, 129).

Elasmosaurus could reach up to 14m long and weigh up to 7 tons. They were part of a family of plesiosaurs, a group that includes the largest marine reptiles from the Cretaceous period. Generally, they had very long necks and serpentine heads (Learn). Since their discovery, paleontologists have wondered how the Elasmosaurus would have used their long neck. Early paleontologists and artists from the 19th Century suggested flexible, serpentine movement of their necks, but this flexibility was questioned by the researchers of the 20th Century. Everhart suggests that while other predators of the Western Interior Sea, such as sharks, mosasaurs, and xiphactinus, would have been fast attackers, the elasmosaurs would have relied on their long necks to pursue schools of small fish instead (Everhart, 129, 132-134). One of the recent studies has suggested that the elasmosaurs’ necks had relatively rigid rod-like structures. And the function of their long necks remains a mystery. Some old reconstructions have mentioned that the elasmosaurs had necks that were almost unable to bend. The two current dominant hypotheses concerning the function of the Elasmosaurs’ necks are as follows. The first

hypothesis suggests that their long necks helped them to put their heads between rocks to hunt fish inside the crevices. Another interpretation was that the length of their necks attracted their mates: the longer their necks, the more likely they were to find mates. Zammit et al. suggest high flexibility in the neck structure of Elasmosaurs, based on their neck vertebrae structure. Their studies have shown that Elasmosaur necks were highly flexible, "with approximating 75–177° in a ventral plane, 87–155° dorsal, and 94–176° lateral depending upon the thickness of cartilage reconstructed between each vertebra" (Zammit et al. 124-125, 129). With their long, elegant necks, it would have been a breathtaking sight to see a group of Elasmosaurs feasting on a school of fish.

Xiphactinus

Beyond marine reptiles, the Western Interior Seaway naturally had diverse fish species as well. But these fish were not ordinary, small, or harmless fish that modern humans are used to. The Western Interior Seaway was home to strange and dangerous predatory fish, such as Xiphactinus. Xiphactinus was one of the largest bony fish ever found in the Cretaceous period. They were of crocodylian origin, and their fossil assemblage includes multiple teeth and a few vertebrates. They ranged from 15 to 20 feet with noticeably developed teeth protruding from their jaws. Their terrifying jaws and teeth allowed Xiphactinus to be a voracious predator of the Western Interior Seaway. The fossil record shows that other fish and seabirds were swallowed whole by Xiphactinus and were snared inside its upturned jaw, which was lined with multiple large teeth. A 13-foot-long Xiphactinus could open its jaws wide and swallow creatures that were up to 6 feet long. And estimates have shown that the Xiphactinus could swim up to 60km/hr. And based on their body shape, the researchers also suggested that they could leap out of the water as well (Stewart et al., 611).

A fossil tooth of Xiphactinus embedded in the bones of plesiosaur has revealed how Xiphactinus also hunted large marine reptiles as well. A new study by Drumheller et al. has revealed secrets of ancient food chains of the Western Interior Seaway that were uncovered from a tooth that was sitting inside a museum for years. This fossil was already known from Alabama's Mooreville Chalk and was housed in a museum. The team could interpret the Xiphactinus' aggressive behaviors based on this fossil evidence, but finding the exact species responsible for the bite mark was difficult. Based on the fractures on the teeth fossil, the fossil record has shown that the Xiphactinus bit the bone of the Pleisosaur (Drumheller et al. 1-2). Since Xiphactinus were thought to have preferred swallowing their prey whole, Drumheller et al. interpreted these Xiphactinus teeth inside a Plesiosaur bone as evidence of a fight. This evidence thus shows how dynamic and violent the interspecific relations were in the Western Interior Seaway.

Sharks

Xiphactinus weren't the only predatory fish in this seaway. Just as modern oceans are full of sharks, the Western Interior Seaway was also home to these marine predators. Sharks are a

very ancient lineage of fish and have existed long before the Western Interior Seaway even formed. They first evolved in the Devonian period, roaming the ocean as active predators ever since. The Western Interior Seaway was no exception, as large and powerful sharks were ever-present in the ecosystem.

Cretoxyrhina, or commonly referred to as “Ginsu Sharks”, were the most dominant sharks of the Western Interior Seaway. Ginsu sharks supposedly preyed on Mosasaurs based on the fossil evidence. The fossil evidence of a Mosasaur bone shows various scars and shark teeth embedded in its vertebrae and ribs. The interpretation as to whether this Mosasaur was attacked by sharks or was dead and later had its corpse eaten by opportunistic scavenger sharks is a matter of debate. Some interpret the evidence as scavenging behavior, arguing that the Ginsu shark was merely feeding on the dead carcass of a Mosasaur. Everhart brings up the discovery of a Tylosaurus skull with shark teeth embedded in 1991 to back up his argument that the sharks indeed preyed upon Mosasaurs. This Mosasaur was roughly 7m long. Although its skull had a few teeth of Ginsu sharks embedded in the bones, the evidence suggests that it survived the attack and recovered, meaning that sharks were attacking a live Mosasaur. Other, even larger, Tylosaurus fossil specimens also had bite marks from shark teeth (Everhart, 48, 50-53).

The evidence abounds. More and more fossil evidence of sharks attacking Mosasaurs has been found in the Western Interior Seaway since then. Mosasaurus bones with bite marks from sharks have been found with traces of healing after an attack, implying that this animal has been actively attacked by a shark while alive and escaped. (Rothschild et al., 2005). However, this dynamic changed towards the late Cretaceous period. Ginsu sharks noticeably went missing in the later fossil records, and so did other large shark species of the Western Interior Seaway. The sharks were giving away their seat as the apex predator of the Western Interior Seaway ecosystem to other predators such as the much larger and deadlier Mosasaurs (McCormack et al., 236). These fossil records show the dynamic competition within the Western Interior Seaway, and how flourishing the environment was that sharks and other predators were constantly competing to become the biggest and toughest.

Hersperornis

So far, these diverse animals of the Western Interior Seaway ecosystems have been fully aquatic. The abundance of this environment, however, attracted originally terrestrial animals into the ecosystem as well. And they would develop semi-aquatic features over time. One of the most successful semi-aquatic adaptors at the Western Interior Seaway was the Hesperornis. Hesperonis were the first known birds to fully adapt to the marine environment. Appearing in the early late Cretaceous, they were flightless and had very small arms, and relied on foot propelling swimming. Fossils of Hesperonis are widely distributed in the northern hemisphere, and they demonstrate the rapid diversification in body size and aquatic adaptations that occurred within the group (Bell and Chiappe, 1-2).

Hesperonis’s most apparent evolutionary adaptations were its flightlessness and semi-aquatic body plan. Fossil evidence shows that the forelimbs of Hesperonis were small and

vestigial, proving that they were entirely flightless. Instead, Hesperonis had the complete adaptation to a foot-propelling diving style. Unlike most of the birds, Hesperonis had legs positioned in the far back of their body and their lower legs extended backward from their knees, which made it easier for them to propel underwater using their powerful legs (Bell and Chiappe, 21). The avian neck structure of Hesperornis also functioned as an adaptation for various semi-aquatic and terrestrial behaviors. This neck plays a significant role in feeding, nest building, preening, and other behaviors. While it is difficult to interpret their usage solely based on the fossil evidence, referencing current semi-aquatic birds with long necks allows us to reconstruct the behavior of Hesperornis. The modern foot-propelled diving birds use their long necks to increase their maneuverability underwater. Foot-propelled diving birds that swim with their long necks experience less water resistance than wing-propelled divers that swim with their necks pulled back. Studies have found that birds swimming with their long necks extended have low drag coefficients at high speeds, but higher drag coefficients at low speeds. And while those modern foot-propelled diving birds are usually found in shallow freshwater, wing-propelled divers are more common in open marine habitats. In general, wing-propelled divers are capable of much deeper dives than foot-propelled divers. Hesperonis fossils have been found in a variety of environments, ranging from freshwater to marine deposits. Although the place where the fossil is found is not always where the organism lived, fossil remains are more likely to be transported into deeper water than shallower water after death. Therefore, this suggests that Hesperornis primarily lived in marine environments and were marine diving birds (Bell and Chiappe, 88).

Based on these fossil records, Hesperonis possibly led a lifestyle similar to that of the modern penguins. Penguins today are excellent fast swimmers, but they are vulnerable to predators such as sharks or killer whales. Hesperornis, with small wings and no means to defend themselves, must have been just as vulnerable to predators as the penguins are. The large marine predators of the Western Interior Seaway, such as mosasaurs, xiphactinus, and sharks, would have often preyed on hesperornis. Evidence for this comes from a fossil record that was found in Pierre Shale of South Dakota, where Hesperornis fossils were found inside the stomach of a mosasaur, and the bite marks on the bones of Hesperornis (Martin et al., 23-25).

Thank you submitting your manuscript the dynamic nature of th western thank yous thank you so much for submitting yuujr

Extinctions, both past and present

The sheer diversity of life, especially the giant predators, in the Western Interior Seaway is a glimpse into the abundance and fertile nature of its ecosystem. Then what happened to this environment? Why are the awesome predators of the Western Interior Seaway no longer with us? The movement of the tectonic plates slowly receded the Seaway as the two plates closed in on each other, eventually creating the Rocky Mountains and the vast Midwest plains as they lifted the ocean flow upwards. Followed by these tectonic movements were constant volcanic eruptions that covered the earth with volcanic ash. These eruptions were obviously disastrous to

all life near them and may have hampered the flourishing of life in Late Cretaceous North America, including the Western Interior Seaway. But the collision and eruption took place over millions of years, and the fossil record shows that both the dinosaurs and the marine life of the Western Interior Seaway weathered these challenges. The sudden disappearance of these unique marine reptiles of the Western Interior Seaway could not be explained by these disruptions, according to Everhart (Everhart, 262-264). This mass extinction could have only been so disastrous that it radically altered the climate and the environment of the ocean before these animals could fully adapt. And the climate change that led to this mass extinction carries a grim reminder of our own climate change, and how we should prevent our own mass extinction with the lesson from the Western Interior Seaway.

All good things must come to an end. Even a thriving and abundant ecosystem such as the Western Interior Seaway faced a great extinction that wiped out the majority of its iconic marine animals. The K-Pg extinction towards the end of the age of the dinosaurs also had a disastrous effect on marine life as well. The discussion of the extinction within the Western Interior Sewaway ecosystem will not only show how such massive and powerful animals ultimately perished, but also serves as a warning to the 21st Century, where climate change and human pollution are causing our own mass extinction of marine life (Kaiho et al., 1). The Cretaceous-Paleogene extinction (K-Pg) was a significant mass extinction event that happened about 66 million years ago. This event marked the boundary between the Cretaceous period and the Paleogene period, signifying the end of the non-avian dinosaurs. This mass extinction event was caused by a large asteroid, unleashing an immense cataclysmic impact on the Earth. It was the largest impact crater that was known on Earth. It was estimated to be six miles wide when the asteroid hit the surface, striking at what is now the Yucatan Peninsula in Mexico. This led to catastrophic and immediate impacts on the planet, such as tsunamis, firestorms, and drastic climate changes (Ruth). The impact of the asteroid also caused what is called the “impact winter.” The impact caused a major decline in the temperatures of the sea surface temperatures that lasted for months to decades. There was a formation of dust and asteroids by the impact, which blocked the incoming sunlight. This winter seemed to be the major driver of the mass extinction because it prevented photosynthesis on many planets and caused unforeseen changes in the temperature of the planet (Vellekoop et al., 7537).

Only 12% of the land-dwelling animals survived the impact, while 90% of the marine animals survived. Marine animals could fare better than terrestrial animals because, while there were significant changes in the surface of the ocean, there was little immediate change in the deep sea. The cooling of the surface of seawater, however, could have disturbed the food web of the shallow marine dwellers, including the Western Interior Seaway, such as ammonites, inoceramids, and marine reptiles. After the impact in the water, the lakes, rivers, and oceans protected the organisms from the initial heat because the surface of the water blocked most of the thermal energy. However, the bigger threat to the marine environment came afterwards when impact winter came. Even if most of the organisms survived at the moment that the asteroid struck, the food web that relied on plankton started to collapse. At the moment when the asteroid

struck, most of the land animals died, at the moment and also the marine animals that lived near the surface of the water, but the deep-sea reptiles died slowly as the food web collapsed, rather than dying instantly because of the asteroid. Freshwater ecosystems, however, experienced much fewer extinctions. Since freshwater organisms fed on dead organisms, they had a habitat to survive in because they could access deep water, and were already adapting to the environment. In the ocean, the plankton started to decrease dramatically, causing a ripple effect throughout the marine ecosystem. Many large animals, such as mosasaurs or plesiosaurs, went extinct because their food sources were lost. Even if the seafloor was very deep, the communities became much less diverse. The recovery was slow and took millions of years to recover. However, the impact of winter was not the only cause of the extinction. Scientists once thought that the K-Pg extinction was mainly caused by the acids from the asteroid impact, which blocked the sunlight and caused a global winter, and stopped photosynthesis. However, new research has shown that the aerosols could not possibly remain in the atmosphere for that long to explain the extinction. This leaves the cause of the extinction unresolved since animals such as crocodilians, birds, and mammals survived while the rest of the dinosaurs and many marine reptiles went extinct. The study instead provides that soot produced by the impact was the real factor behind the mass extinction. This is because soot can remain in the stratosphere for years and block sunlight. The scientists have studied molecules similar to the soot on rock layers from Haiti and Spain and used climate models to test this hypothesis. They came to the conclusion that the massive cloud of soot might have been the major driver of the extinction (Kaiho et al., 1-2).

A few handful of animal groups survived the K-Pg extinction, despite massive damage to their own taxonomic diversity. The most prominent examples of these survivors are the sharks. Modern oceans are dominated by the ground sharks, which include bull sharks, tiger sharks, hammerheads, and they count for more than 250 species. In contrast, mackerel sharks, which include great white makos, are much less diverse today, only numbering around 15 species. However, during the Cretaceous period, this balance was very different. Mackerel sharks were far more diverse than the ground sharks during the Cretaceous. This balance only shifted after the K-Pg extinction, implying that the sharks also endured sudden changes in their environment, but nonetheless survived. It was not that no sharks went extinct. Many species of sharks indeed went extinct, but they proved to be more ecologically flexible than the other marine reptiles. For example, many sharks could switch prey or scavenge, whereas the large marine reptiles, such as Mosasaurs or Pleisosaurs, relied on abundant fish and other marine reptiles (Pickrell). This was one reason why animals familiar to us today, such as sharks, could withstand the planet-wide extinction event, while the ancient marine reptiles of the Western Interior Sea withered away.

The asteroid impact that led to the K-Pg extinction also caused enormous climate change throughout the planet. And this disturbance in the Earth’s climate had disastrous consequences for the marine ecosystems. Brugger et al. created a climate simulation model to measure how the world's climate, especially the ocean, was impacted by the Chicxulub impact. The annual simulated mean surface air temperature, according to their model, dropped approximately 20 ℃ around the equator. The simulation has also shown that the global temperatures decreased by at

least 27 ℃, causing the surface temperature of the ocean to suddenly drop as well (Brugger et al., 422, 425-426). Ammonites went extinct at the end of the Cretaceous period due to the asteroid impact, as well as 90% of species of calcium carbonate-shelled planktons. Other shelled animals during the K-Pg extinction that did not possess calcium carbonate shells were less affected by the acidification, which raises the possibility that the ocean acidification, a side effect of the asteroid, might have been the cause of several calcifying organisms' thinning. A recent study has stimulated possible mechanisms from the impact on seawater acidification, which led to the weakening of ancient seashells such as ammonites. Tyrrella et al. also utilized simulated models to measure how the impact affected the ocean during the K-Pg. They focused on ocean acidification, the increase in acidity in the ocean's pH level. The wildfires caused by the impact released massive amounts of CO_2 into the Late Cretaceous atmosphere, contributing to the acidification of ocean water (Tyrrella et al., 6556-6558).

The total extinction of animals on the lower food chain, such as the ammonites, meant disastrous consequences for the predators of the upper food chain. Compared to the ocean acidification during the Cretaceous period, the modern state of ocean acidification is not that much better. According to Ocean Acidification, the research suggested that the modern ocean acidification level has increased over the 200-plus years since the industrial revolution began. In this highly acidic ocean water, some creatures died out while others adapted to the environment. As the level of CO_2 increased from human activity, such as burning fuels and changing land use. As this increased, the amount of carbon dioxide in the ocean has increased as well. This caused a depleting amount of carbonate ions and corals, which the planktons needed to build their shells. Over the past 150 years, the average pH level has dropped from 8.2 to 8.1, which represents a 30% increase in acidity. Scientists predicted that by the end of this century, ocean acidification might drop by 0.3 units more (Ocean Acidification).

Even though the shifts are happening over thousands of years, the increasing ocean acidification will cause wide-ranging consequences for marine life and the global economy. However, there are some solutions to this ocean acidification problem. Since we know that acidification is caused by carbon emissions, we know that we have to advance the global transition to clean energy (Hu). As an aftermath of the asteroid impact, the whole world experienced an impact winter, soot in the atmosphere, a pause in photosynthesis, ocean acidification, and the mass extinction of many species, especially the marine reptiles. However, we are experiencing similar situations due to severe climate change, not caused by an asteroid, but our own doing. The extinction of diverse lifeforms in the Western Interior Seaway should serve as a warning of the destruction of our own environment. The collapse of the ecosystem in the Western Interior Seaway during the K-Pg extinction showed how rapidly organisms can be lost under extreme ecological conditions. Today's climate change may have a different cause, but it is still raising concerns with a similarly large-scale ecological disruption. The seashells of today are being hurt by ocean acidification as well, this time caused by our own emissions of CO_2 into the atmosphere (Feldman). This eerie similarity to the ocean acidification during the K-Pg extinction is just one of many warnings from the demise of the Western Interior Seaway

ecosystem. The rise and fall of the diverse ecosystem in the Western Interior Seaway thus serves as a wonderful tale of how dynamic marine life can be, and how easily it can be lost. The climate change of our own era is awfully similar to the K-Pg mass extinction that led to the demise of the Mosasaurs, Elasmosaurs, and various other species covered in this essay. Even today, we lose one species on Earth every hour (WWF). And if we are to prevent another mass extinction, we must value our own marine life, as much as we are fascinated with the ancient ecosystem of the Western Interior Seaway.

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The Economic Impacts of FDR's New Deal Banking Reform on America during the Great Depression: an Analysis By Aaron Arora

Abstract

This research paper serves as an analysis, and seeks to analyze the banking reform of President Franklin Delano Roosevelt's New Deal program in the 1930s - which was a policy agenda aimed at relief, reform and recovery from the adverse effects fostered by the Great Depression. This paper focuses on the economics of the banking sector specifically, and how New Deal Banking Reform was able to help alleviate the adverse effects on the Depression economy through analyzing two key New Deal outcomes: an increase in the number of banks in place, as well as an increase in confidence Americans had in their banking system. Through thorough primary and secondary source research and analysis, encompassing economic ideals such as the reserve requirement ratio, unemployment metrics, gross domestic product (GDP) changes, and monetary policy, this paper highlights that FDR's banking policies were a key factor that helped America's economy recover during the Great Depression.

Introduction

It is no secret - that the economic state of America today can be characterized in many different ways. While different social and political viewpoints may view our economy in different ways, one thing is certain: America's economy is more well off today than during the start of the Great Depression. With rapid rises in unemployment and a global depression at play, American President Franklin D. Roosevelt saw himself front in center, attempting to solve one of the deepest recessions in American history. After the federal election in 1933, FDR sought to resolve this crisis through his New Deal program, which was a policy agenda aimed at relief, reform and recovery from the adverse effects fostered by the Great Depression. The New Deal, lasting until 1938, was a key factor that helped America's economy recover during the depression (Encyclopedia Britannica). In specific, FDR's banking reform was an instrumental aspect of the American effort to recover from the depression. President Franklin D. Roosevelt's banking reform helped reopen American banks and increased American citizens' confidence in their banking system; FDR's banking policies were a key factor that helped America's economy recover during the Great Depression.

Reopening of American Banks

Firstly, FDR's banking reform helped reopen American banks, which helped America's economy recover during the Great Depression. After the start of the depression, the American economy faced a 29% decrease in gross domestic product, 1 in 4 Americans were unemployed by 1933, and 1 in 3 banks had shut down; it is clear - the American economy was severely impacted in a negative manner during the Great Depression (Donohue).



Fig. 1. Unemployment in the United States, 1890–1970
Source: Bureau of Labor Statistics. *Historical Statistics of the United States: Colonial Times to the 1970s*, Part I, U.S. Government Printing Office, 1975, Series D 85–86, p. 135.

Indeed, to further quantify, Adam Cohen, a historian in his book *Nothing to Fear: FDR's Inner Circle and the Hundred Days that Created Modern America*, explains that America was no longer able to continue reliable manufacturing. Additionally, key industries such as auto and steel were running at under 1/5 of their total capacity. Cohen puts it best, "people leapt at the mere possibility of a paycheck" (Donohue). With the extreme levels of economic hostility exemplified, it is clear - that America was at an extreme level of economic disequilibrium. Specifically, as over 33% of banks were not in operation, this contributed to the magnitude of the economic recession (Donohue).

President FDR recognized this, and decided to prioritize the banking sector, and helped to reopen these banks. The way he did this was by declaring that the banking crisis was an emergency. FDR, on his first full day of office, declared what would be known as a Federal Bank Holiday; all banks in the nation would close. To address this emergency - FDR declared that there should be "action, and action now" (Donohue). Correspondingly, FDR created the Emergency Banking Reform Act, or EBRA. The EBRA was created to "provide relief for the existing national emergency in banking" (Emergency Banking Reform Act). The EBRA was passed on March 9 - only 4 days after taking office and was primarily created for rehabilitation. Through this approach of reopening, FDR was able to not only reopen existing banks at higher operation efficiency, but increase the amount of banks nationally by reopening banks that had shut down from the depression. Through the EBRA, FDR used a tiered approach to reopen banks. His policy dictated that banks should only reopen when they were sufficiently able to operate. FDR first reopened the 12 banks in the Federal Reserve cities, and for all other banks, he used government regulators and examiners from the bureaucracy to clear banks for reopening. FDR prioritized opening banks when fully able, and this approach allowed for the increased reopening of banks and increased amounts of banks available in the United States.

With the use of the EBRA and Bank Holiday - FDR was able to reopen banks in the United States; indeed, as the Federal Reserve Board of St. Louis contends, the total amount of US banks when FDR took office was 14,523, with around 1 in 3 inactive. In just 2 years, in 1935 - the EBRA and Bank Holiday helped the amount of US banks increase to 16,893 banks. With the reopening of banks, especially community banks, nationally - America saw a net increase in economics (Federal Reserve Board of St. Louis).

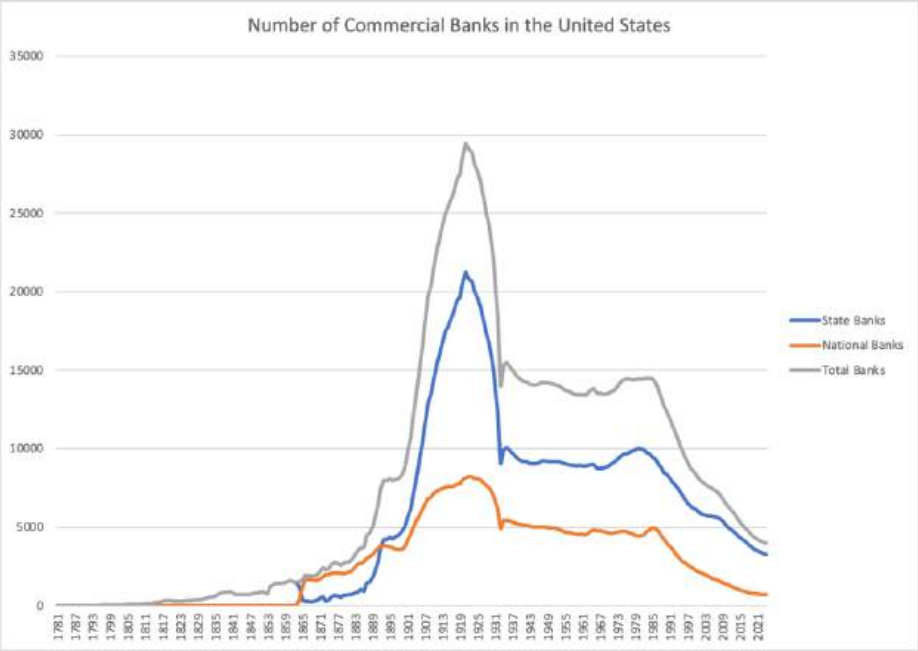


Fig. 2. Number of Commercial Banks in the United States
Source: Hubbard, Glenn, and Tony O'Brien. "The Rise and Decline in the Number of U.S. Banks." *Economics in Context*, Hubbard O'Brien Economics Blog, 27 May 2025, https://hubbardobrieneconomics.com/2025/05/27/the-rise-and-decline-in-the-number-of-u-s-banks/.

As the Federal Reserve Bank of Kansas City explains, community banks boost local economies: bankers in the community are able to develop relationships with individuals, and overall are able to understand the social and economic dynamic of the people living in areas near banks. Further, bank owners and managers in community banks are often residents of the area in which they establish their bank. Therefore, this proximity and relationships fostered help to increase local economies as bankers are able to have a cohesive understanding of the local economy and do their part to increase the health of each local economy (Federal Reserve Bank of Kansas City). Additionally, increased community banks help increase credit for small businesses and help to recover during times of stressful economic circumstance. Naturally, as each local economy has more and more banks reopening, this compounded effect helps to improve the nation's economy as a whole.

Additionally, reopening banks is linked to reduced income inequality, which additionally helped America come out of the Depression. As Science Direct explains, increase in banking activity, such as reopening banks, leads to a decrease in income inequality; one of the metrics that researchers Guilherme Cruz and Claudio Oliveira de Moraes used to derive this study is the Gini coefficient (Guilherme Cruz and Claudio Oliveira, ScienceDirect). For context, the Gini coefficient is a microeconomic term that measures income inequality. Additionally, according to Josh Brivens from the Economics Policy Institute, increases in inequality lead to decreased economic growth as evidence reveals decreases in aggregate demand due to higher levels of income inequality (Josh Brivens, Economics Policy Institute). Because banks are able to decrease income inequality, macroeconomically, this will lead to increased economic activity. In contrast to the study by the EPI, decreased income activity will consequently lead to increased aggregate demand. Increased aggregate demand helps countries alleviate from recession. Therefore, as FDR increased the amount of banks in America through reopening, this factor was instrumental in America's eventual overcoming of the Great Depression.

Lastly, reopening banks across America helped the nation recover from the Great Depression as more jobs were created. As the FRB of Kansas City additionally contends, banks help to increase the economic health of the economy by providing employment, and increase prosperity (Federal Reserve Bank of Kansas City). As FDR and his New Deal policy helped to increase the quantity and quality of banks, more banks naturally led to more individuals being hired as bankers and managers to run and maintain banks. Increased opportunities to work, helps to boost the economy as this means that the economy will move closer towards full employment: maximizing its production possibilities - and boosting economic activity. As the unemployment rate will fall, more people will be able to be employed and gain money, which they will be able to further spend on other businesses. Indeed, this positive effect on the American economy can be seen by the plummeting of the unemployment rate from 25% to under 15%, and a net increase in America's GDP from 877.431 during the start of the New Deal, up to 1214.869 by 1938 (Federal Reserve Bank of St. Louis).

DATE	VALUE
1929-01-01	1191.124
1930-01-01	1089.785
1931-01-01	1019.977
1932-01-01	888.414
1933-01-01	877.431
1934-01-01	972.263
1935-01-01	1058.836
1936-01-01	1195.251
1937-01-01	1256.503
1938-01-01	1214.869

Fig. 3. Real Gross Domestic Product
Source: "Table Data - Real Gross Domestic Product." Federal Reserve Bank of St. Louis, https://eh.net/encyclopedia/the-u-s-economy-in-the-1920s/. Accessed 6 July 2026.

Overall, FDR's New Deal banking policies including the EBRA, Bank Holidays, and plans of reopening banks at greater numbers and strength, as well as the positive impacts resulting from this such as increased understanding of local economies, decreased income inequality and unemployment rate helped to alleviate the nation from the economic recession. These factors and their economic impacts helped America's GDP increase by over 38.5% in the 5 years of the New Deal alone (Federal Reserve Bank of St. Louis). Therefore, FDR's banking policy of reopening America's banks was a key factor that helped America's economic recovery during the Great Depression.

New Banking Policies Increase Confidence

Further, FDR's banking policies were a key factor that helped America's economy recover during the Great Depression as they increased American citizens' confidence in their banking system. FDR instituted this through the creation of various government programs through the use of deficit spending. In particular, the Glass-Stegall Act, and its creation of the Federal Deposit Insurance Corporation (FDIC) were imperative to instill confidence in Americans about their banking system.

The Glass-Stegall Act was a New Deal reform created by FDR which made the split between commercial banking and investment banking. It was also made to "regulate interbank control" and "to prevent the undue diversion of funds into speculative operations" (Glass-Stegall Act). One of the factors that led the depression to start was the fact that banks would invest consumers' money poorly into the stock market. By drawing the line between commercial and investment banking, Americans gained confidence in using banks, as there was increased transparency regarding how different types of banks would be able to use the money given to them. Commercial banks would provide services like mortgage loans and deposits: these banks were banned by law from any forms of stock market investment. Because of this clear divide, individuals had increased transparency regarding where every dollar went. Consequently, more Americans were able to use banks without the fear of their money being drained. Therefore, as Americans were able to have increased confidence regarding banking - they were able to use the banks more, and have a safe haven to house their money and monetary assets; by having reserves to store and build wealth, America recovered from the Great Depression.

Additionally, a major provision resulting from the Glass-Stegall Act was the establishment of the FDIC. As the World Almanac explains, the FDIC was created directly for the purpose of instilling confidence into Americans regarding their banking system. This system was created to minimize adverse effects regarding the depositing of money into banks. One of the ways that the FDIC aimed to do this was to guarantee 2,500 dollars in insurance for depositing money into banks. This would be done through insurance premiums made by banks that were members of the FDIC. Additionally, FDIC made sure that the additional laws created by acts such as Glass-Stegall that aimed to protect banks' customers were being followed. The FDIC made sure this was done through monitoring, and investigating banks. Because the FDIC created such safeguards, it became a symbol of consumer confidence if a bank was a member of the FDIC. Posters and stickers determining that an individual is part of the FDIC were placed in front of banks - and this signified to consumers that the bank is a safe place to safeguard and put money in as well as take loans from. With reform such as the FDIC and the Glass-Stegall act, Americans gained confidence in their banks.

These policies laid out by FDR directly helped to increase economic activity and reduce the impacts of the depression. Because of the increased confidence of Americans, individuals deposited more money into banks. When banks receive money, they keep a portion of it as required reserves, called the reserve requirement ratio (RRR), but they are able to lend out 1-RRR to other banks and individuals. This creates an increase in money: the person who originally deposited the money is still in monetary ownership of the money, but that same money creates excess revenue by lending it. If another individual deposits money, there is an increase in the supply of money created through these transactions. This macroeconomic concept is called the money multiplier - which increases the supply of money. More money due to increased confidence by Americans helped the nation recover from the recession as more money is available. Because American confidence increased, more people put money into banks (Lumen Learning). Naturally, due to the concept of the money multiplier previously explained, America

was able to increase its GDP through this mechanism; this was possible due to the confidence of financial security that FDR's programs such as the FDIC and Glass-Seagall Act provided. Consumers were given the financial insurance of their money, and at the same time banks were able to increase the money in the nation. This can be further quantified by the increase of the money supply from a value coefficient of 1.42 in 1933, to an increase to 5.25 2 years later, showing an increase in the money supply according to the Federal Reserve Bank of St. Louis (Federal Reserve Bank of St. Louis).

FDR was able to provide such confidence not only through these reforms - but by his fireside chats, or radio broadcasts by the president himself - to the American people. He decided to explain this idea of banks being able to increase the money supply and often used lay-man terms so the American public could easily understand. For example, to explain the money multiplier effect, he explained that the "bank puts [...] money to work to keep the wheels of industry and of agriculture turning around" (Donohue). It is the balance of explaining the expansion of the economy through banks while simultaneously ensuring that the individual citizen's money will be insured through federal programs such as the FDIC, that promoted increased confidence and input from the American public into the nation's banking. Correspondingly, America saw increased supply of money - and an effective increase in economic activity. Overall, through the Glass-Stegal Act, the incorporation of the FDIC, and balancing between concepts of the money multiplier and individual financial safety, which FDR explained to Americans through fireside chats, FDR was able to instill confidence in Americans regarding the banking system.

Conclusion

From the beginning of FDR's presidency, through his New Deal programs - the banking reform that the president orchestrated helped the nation recover from economic turmoil. Specifically, he did this through reopening banks which increased their quantity, and instilling the American people's confidence in the banking system; these tactics helped to boost America's economy, and helped the nation recover from the Great Depression. Through these reforms, America was able to recover, regrow and stabilize economically; while bipartisan criticisms of our economy exist today, if it were not for FDR and his banking reform, our economy may still be stuck in one of the deepest recessions in American history.

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Beyond the Silence: Mental Health Challenges, Solutions, and Potential Role of AI Among Asian American Youth By Daniel Gao

Abstract

Mental health challenges among youth have become an increasing public health concern in the United States. In particular, Asian American youth may face additional challenges related to academic pressure, family expectations, and cultural stigma surrounding mental health. This study examined the mental health challenges, help-seeking behaviors, and potential solutions for Asian American youth while also exploring the potential role of artificial intelligence (AI) in supporting youth mental health. A mixed-methods approach was employed by integrating three sources of data: a statewide youth mental health dataset from the AIM Ideas Lab, a local high school survey, and interviews with Asian American students from a local high school. Findings from all three data sources consistently identified academic pressure as one of the primary contributors to students' mental health challenges. Cultural stigma, family expectations, and limited help-seeking behaviors were also identified as significant barriers to accessing mental health support. In addition, the findings emphasized the importance of culturally responsive mental health services, increased awareness, and stronger communication within families and schools. Furthermore, the study suggests that AI-assisted mental health tools may enhance existing support systems by providing accessible, timely, and culturally appropriate resources, but AI should complement rather than replace licensed mental health professionals. These findings highlight the importance of collaborative efforts among schools, families, communities, healthcare providers, and policymakers to better support the mental well-being of Asian American youth.

Keywords Asian American youth; mental health; academic pressure; family expectations; cultural stigma; help-seeking behaviors; artificial intelligence (AI).

Introduction

When I was young, I often interacted with the daughter of one of my mom’s closest friends. She was one year older than me. Later we moved apart, so I did not see her for many years. Several years later, my mom took me back to the city where we lived before. During the visit, my mom met her friend and heard that her daughter had been struggling with mental health problems. She had withdrawn from school and had been staying at home for more than a year.

I was shocked by this news. In my memory, she was always smiling when we talked, and I could not understand how her life had changed so dramatically. I did not have a chance to talk to her, because she was not willing to meet people outside of home. Later, my mom explained that academic pressure, peer pressure, and parent expectations have contributed to her struggles.

This visit made me reflect deeply on what had happened. It also sparked my interest in understanding the growing mental health concerns within our community.

My experience made me realize that mental health challenges among young people may be more common than many people think. National data indicate that youth mental health has become a growing concern in the United States. According to the Centers for Disease Control and Prevention (CDC), approximately 40% of high school students reported persistent feelings of sadness or hopelessness in 2023. In addition, about 20% of students seriously considered attempting suicide. These statistics highlight the significant emotional struggles many youth face, and demonstrate the urgent need for greater awareness, support, and intervention.

While mental health challenges affect youth of all backgrounds, Asian American youth deserve focused attention because they often face unique cultural and social circumstances that can influence their mental well-being. Although Asian Americans are frequently perceived as a successful and well-adjusted population, this stereotype can sometimes mask the mental health struggles experienced by many young people. As a result, the challenges faced by Asian American youth may receive less attention than they deserve.

Many Asian American youth experience high academic expectations, strong family obligations, and pressure to meet cultural standards of success. At the same time, mental health concerns may be overlooked because of stigma surrounding mental illness and reluctance to seek professional help. Furthermore, some youth may struggle with issues related to identity, belonging, and balancing multiple cultural environments. Together, these factors can create barriers to seeking support and may contribute to mental health challenges among Asian American youth.

Given the growing concerns surrounding youth mental health and the unique challenges faced by Asian American youth, this study seeks to examine the factors that influence mental well-being among young people. To better understand these issues, this study draws upon multiple sources of evidence, including survey data collected from students at my high school, interviews with students from diverse backgrounds, and a nationwide youth mental health dataset involving approximately 3,000 high school students. By combining personal perspectives with quantitative and qualitative data, this study aims to provide a broader understanding of youth mental health challenges and their impact on Asian American youth. In addition, this study explores potential solutions and the role that AI may play in supporting mental health awareness, education, and access to resources.

Literature Review

Recent research has documented a growing mental health crisis among youth in the United States. Studies have reported increasing rates of anxiety, depression, and emotional distress among young people over the past decade. According to data from the Centers for Disease Control and Prevention (CDC), a substantial proportion of high school students report persistent feelings of sadness or hopelessness. Researchers suggest that a variety of factors contribute to these trends, including academic stress, social pressures, family expectations, and concerns about future success. In addition, the widespread use of social media has raised concerns about its impact on youth mental well-being. While social media can provide

opportunities for connection and self-expression, excessive use has been associated with increased feelings of loneliness, anxiety, low self-esteem, and social comparison.

Furthermore, the COVID-19 pandemic caused many existing mental health challenges through school closures, social isolation, disruptions to daily routines, and uncertainty about the future. Together, these findings suggest that youth mental health is influenced by a complex interaction of academic, social, technological, and environmental factors, highlighting the need for effective support and intervention strategies.

While many of the factors affecting youth mental health are experienced across different populations, researchers have found that Asian American youth often face additional cultural and familial pressures. One commonly identified factor is the high value placed on academic achievement, which may create significant stress and anxiety for some students. Family expectations regarding educational success, career choices, and personal behavior can further contribute to emotional pressure. In addition, Asian American youth may attempt to balance traditional family values with the norms and expectations of American society. Many Asian American youth also face challenges related to identity development as they navigate multiple cultural environments and seek a sense of belonging. Together, these factors may influence mental well-being and contribute to unique mental health experiences among Asian American youth.

Academic pressure is one of the most frequently discussed factors influencing the mental health of Asian American youth. Research suggests that many Asian American youth experience strong expectations regarding academic achievement and future career success. These expectations may come from parents, schools, peers, or broader cultural values that emphasize education. While academic motivation can encourage positive outcomes, excessive pressure may contribute to anxiety, depression, stress, and emotional exhaustion.

This pattern is reflected in previous studies of Asian American youth and young adults. In a qualitative study of Asian American young adults, Lee et al. (2009) found that participants often reported pressure to meet parental expectations for academic success and to live up to the "model minority" stereotype. Many participants described feeling stressed by expectations regarding college majors, career paths, and future achievement. The study also found that academic success was often closely associated with family approval and cultural expectations, such as being a “good” son or daughter.

Research suggests that many Asian American families place a strong emphasis on academic achievement. Traditional cultural values and parental expectations often encourage youth to pursue educational success and view academic excellence as an important pathway to future opportunities (Chang, 2017). Some Asian American youth may feel a strong responsibility to achieve academically because they view educational success as a way to honor their parents and repay the sacrifices their families have made. In addition, researchers have argued that the model minority stereotype may place additional pressure on Asian Americans by creating expectations of exceptional academic achievement. Failure to meet these expectations can contribute to stress, anxiety, and psychological distress. Together, these findings suggest that

academic pressure and achievement culture may play a significant role in shaping the mental health experiences of Asian American youth.

In addition, family expectations and intergenerational conflict are also important factors influencing the mental health of Asian American youth. Researchers have found that differences in cultural values and levels of adaptation between parents and youth may contribute to family conflict and emotional distress. A literature review by T. Yu et al. (2025) found that greater parent-child acculturation gaps were often associated with higher levels of depressive symptoms and other mental health concerns among Asian American youth. The review also suggested that family conflict may serve as an important pathway through which cultural differences affect youth mental health.

These findings are supported by earlier research on Chinese American families. Researchers have suggested that youth in immigrant families often adapt to the surrounding culture more rapidly than their parents, leading to differences in values, beliefs, and expectations. In a study of Chinese American adolescents and their parents, Juang et al. (2007) found that greater discrepancies between parents and adolescents regarding parental control were associated with higher levels of depressive symptoms. The researchers further found that family conflict partially explained this relationship, suggesting that disagreements arising from differing expectations and cultural perspectives may contribute to emotional distress among youth. These findings highlight the important role that family relationships play in shaping youth mental health.

Moreover, identity development and a sense of belonging are also important factors influencing the mental health of Asian American youth. Research has shown that a strong sense of ethnic identity may contribute to positive psychological well-being among youth. Gartner et al. (2014) found that ethnic identity was positively associated with self-esteem among Asian American youth. The researchers also reported that cultural socialization, including messages that promote knowledge and appreciation of one's cultural heritage, was positively associated with both ethnic identity and American identity. These findings suggest that family cultural practices may play an important role in helping youth develop a healthy sense of belonging.

These findings are further supported by other researchers. Many youth navigate multiple cultural environments as they balance their family's cultural traditions with the values and expectations of broader American society. This process may create challenges related to identity, belonging, and self-understanding. T. Yu et al. (2025) suggested that maintaining a strong connection to one's cultural heritage can promote positive mental health outcomes. The researchers found that cultural identity and enculturation were associated with higher self-esteem, stronger parent-child relationships, and lower levels of depressive symptoms among Asian American youth. These findings suggest that a healthy sense of cultural identity may serve as an important protective factor for youth well-being.

Furthermore, mental health stigma remains a significant barrier to help-seeking among Asian American youth. S. Yu et al. (2025) found that Asian American adolescents reported higher levels of stigma toward seeking mental health support than their Latinx peers. The study

further found that stigma reduced the likelihood that Asian American youth experiencing emotional distress would seek support from adults, suggesting that concerns about stigma may discourage youth from reaching out for help when they need it. Researchers have also noted that cultural factors may contribute to help-seeking barriers. The authors discussed how concerns about maintaining family reputation, "saving face," and fear of negative judgment from others may make some Asian American youth reluctant to disclose mental health concerns or seek professional support. Together, these findings suggest that stigma and cultural expectations can create significant barriers to accessing mental health support among Asian American youth.

Together, these studies demonstrate that Asian American youth face a range of mental health challenges related to academic pressure, family expectations, identity development, and barriers to help-seeking. While previous research has provided valuable insights into these factors, continued investigation is needed to better understand how contemporary youth experience these challenges in their daily lives.

Methods

This study adopts a mixed-methods approach by integrating three sources of evidence: (1) a statewide youth mental health dataset from the AIM Ideas Lab, (2) a local high school survey, and (3) semi-structured interviews with students. Together, these sources provide broad, community-level, and individual perspectives on youth mental health.

1. Nationwide Dataset

I participated in the AIM Idea Lab last year as part of a group of high school students conducting research on youth mental health. The AIM Ideas Lab is a Youth Participatory Action Research (YPAR) program that centers teens as experts on youth mental health. High school students across California volunteered as youth researchers to conduct research and develop recommendations to address the youth mental health crisis. More than 300 AIM Ideas Lab youth researchers across California collaborate to research youth mental health and make recommendations to policymakers, researchers, and their communities on how to address the youth mental health crisis.

I collaborated with other youth researchers to design a survey to understand key mental health challenges, factors affecting teen wellbeing, support systems, barriers to accessing help, and potential solutions to improve youth mental health in communities. The survey included both quantitative and qualitative questions to capture measurable data and participants' personal experiences. To protect participants' privacy, the survey was anonymous and all results were reported in aggregate. The survey collected responses from a total of 3911 participants, using a mixed-method approach, including word-of-mouth, text messaging, and social media outreach. All respondents were high school students in California.

Because I have already been working on my own research on youth mental health within my high school community, including developing my own survey and conducting interviews, participating in this statewide collaborative research truly significantly strengthened my own

work and provided valuable new perspectives. Working alongside the mentor and other youth researchers broadened my understanding of youth mental health beyond my local community and allowed me to investigate the issue from a statewide perspective. I am grateful for the opportunity to participate in the AIM Idea Lab and to collaborate with dedicated youth researchers on this meaningful project.

2. School Survey

To support this research and collect first-hand data, I conducted a survey at my high school. Approximately 30 students participated in the survey, representing grades 9 through 12. The survey consisted of ten questions, including eight multiple-choice questions and two open-ended questions. Data were collected during lunch periods and after school. Hard-copy surveys were distributed in person and collected after completion. In addition, a QR code linked to the survey was posted on the school's wellness center bulletin board, allowing students to access and complete the survey using their cell phones. This approach helped increase participation and provided multiple options for students to respond.

It is important to note that the school survey included students from diverse racial and ethnic backgrounds and was not limited to Asian American participants. The purpose of the survey was to gather broader perspectives on youth mental health within the school community. While the survey results do not specifically represent the experiences of Asian American youth, they provide valuable context regarding common mental health challenges faced by youth. These findings are supplemented by existing research on Asian American youth mental health as well as additional data sources examined in this study.

3. Student Interviews

In addition to the survey, I conducted in-person interviews with high school students to gain a deeper understanding of perspectives on mental health within Asian American communities. A total of 18 students participated in the interviews, representing diverse Asian backgrounds, including Chinese, Korean, Indian, and Vietnamese students. Interviews were conducted during lunch periods and after school. The interview consisted of seven questions focusing on two primary areas: how Asian families respond to mental health challenges among family members, and students' perspectives on mental health and mental health support. The interviews provided qualitative insights that complemented the survey findings and helped explore cultural factors that may influence mental health experiences among Asian American youth.

While the school survey included students from diverse racial and ethnic backgrounds, the interview participants were all of Asian heritage, allowing for a more focused exploration of issues relevant to Asian American youth mental health.

Findings

This section presents findings from three data sources: the AIM nationwide youth mental health dataset, a local high school survey, and interviews with Asian American high school students. Together, these sources provide both quantitative and qualitative evidence regarding the mental health experiences of youth.

Statewide Findings

The AIM statewide youth mental health dataset included responses from 3,911 high school students across California and examined students' mental health, academic experiences, help- seeking behaviors, and perceived solutions. Several consistent patterns emerged regarding academic pressure, self-care practices, and utilization of school mental health resources.

Analysis of the AIM statewide youth mental health dataset revealed a notable imbalance between students' academic commitments and time devoted to self-care. A significant majority of respondents (80.5%) reported spending at least one hour on homework during a typical school day, whereas only about half (51.8%) reported spending more than one hour relaxing or engaging in self-care activities. These findings suggest that students generally dedicate more time to academic responsibilities than to activities that support their physical and emotional well-being. In addition, fewer than ten percent of students (9.4%) reported experiencing little or no overwhelm in their daily schedules, while the majority indicated feeling overwhelmed for one to four days each week or even every day. Together, these findings demonstrate that high academic demands and limited opportunities for relaxation are common experiences among high school students in the statewide sample.

The dataset further identified academic pressure as the most prominent source of stress among high school students. When asked to identify the aspect of their lives that felt most stressful or out of balance, respondents most frequently cited school and academic responsibilities. Many students described homework, coursework, examinations, and overall academic expectations as the primary contributors to their daily stress. Consistent with these responses, a large proportion of students also reported feeling overwhelmed on a regular basis, indicating that academic demands substantially affected their overall well-being. Collectively, these findings suggest that school-related responsibilities dominate many students' daily experiences and represent a major challenge to maintaining positive mental health.

Moreover, the dataset also revealed important patterns in students' help-seeking behaviors and perceptions of school mental health resources. Overall, students were unlikely to utilize mental health services available at their schools, despite reporting high levels of stress and frequent feelings of overwhelm. Responses to open-ended survey questions indicated that many students were unaware of the mental health resources available on campus, while others described school wellness centers as uncomfortable or unwelcoming environments. Even among students who knew that support services existed, many expressed reluctance to use them. In addition, 31.0% of respondents reported that they would choose to manage stressful situations on their own rather than seek help from an available adult. When asked about barriers to seeking support, 63.6% of students indicated that they believed their personal problems were "not serious

enough" to warrant professional help. These findings suggest that although school-based mental health resources are available to many students, multiple barriers—including limited awareness, discomfort with available services, and reluctance to seek help—may reduce their utilization.

Overall, the AIM dataset indicates that students experience substantial academic pressure while dedicating relatively little time to self-care. Although mental health resources are available in many schools, numerous students remain reluctant to seek support because of limited awareness, discomfort, or the belief that their concerns are not sufficiently serious. These findings provide an important statewide context for comparison with the local school survey and interviews presented in the following sections.

School Survey Findings

Results from the local high school survey (N=30) revealed that mental health challenges are common among students. Overall, 76.6% of respondents reported experiencing at least one mental health challenge during the past year. Anxiety and academic stress were among the most frequently reported concerns. In addition, 60% of respondents indicated that they felt overwhelmed by academic or family expectations either “often” or “very often”, suggesting that stress is a common experience among students at the school. Furthermore, 26.6% of respondents reported experiencing loneliness.

When experiencing mental health challenges, 63.3% of respondents reported seeking support from friends, making friends the most common source of support. In addition, 40% of respondents reported seeking help from families, while 16.6% of respondents reported seeking help from school counselors or mental health professionals. Additionally, 20% of respondents indicated that they did not seek help from any source.

Among the six students who reported not seeking help, 66.7% indicated that they believed their problems were not serious enough to seek support. In addition, 50% reported stigma or shame as a barrier to seeking support, while 33.3% reported family discouragement, and 16.7% identified cultural beliefs as a barrier to seeking support.

Responses to Question 7 indicated that cultural background influenced how mental health was discussed within many students' families. Overall, 36.6% of respondents reported that their cultural background strongly influenced family discussions about mental health, while 40% indicated that it had some influence. Meanwhile, 10% reported that cultural background had little influence, and 10% indicated that it had no influence. A small percentage of respondents (3.3%) were unsure. These findings suggest that cultural background played an important role in shaping discussions about mental health within families for many students.

Responses regarding school mental health services were mixed. Overall, 20% of respondents believed that the school provided culturally responsive mental health support, while 46.6% felt that the support was only somewhat culturally responsive. In contrast, 23.3% of respondents indicated that the school did not provide culturally responsive support, and 10% were unsure. These findings suggest that although some students viewed the school's mental

health services positively, many perceived that the school did not provide sufficient culturally responsive support.

Analysis of the open-ended responses to Questions 9 and 10 revealed several recurring recommendations for improving mental health support. Students most frequently suggested increasing access to school counselors, providing more culturally responsive mental health services, offering mental health education workshops, organizing mental health awareness events, and reducing academic pressure. Several respondents also recommended creating a more open and supportive school environment for discussing mental health concerns.

School Interview findings

Analysis of the interview responses revealed a few themes regarding how Asian American families respond to mental health challenges. Most participants reported that when a family member experiences mental health issues, parents are more likely to encourage them to study harder, get more rest, or focus on solving practical problems rather than seek professional support. Approximately 13 of the 18 interview participants indicated that mental health is rarely discussed openly within their families. Participants described that emotional struggles are often handled privately, reflecting a reluctance to discuss mental health issues within the family or with others outside the household.

Participants also described the types of support provided by their families. Many explained that parents tend to offer practical forms of assistance, such as providing for educational needs, meals, clothing, or other daily necessities, but are less likely to provide emotional support or encourage conversations about psychological well-being. In addition, many participants reported that their parents were often reluctant to seek professional mental health services, which they believe was influenced by cultural stigma surrounding mental illness, concerns about bringing shame to the family, and, in some cases, the financial cost of mental health services. Overall, these interview findings suggest that cultural beliefs and stigma may influence how many Asian American families recognize, discuss, and respond to mental health challenges, potentially creating barriers to seeking professional support.

Participants also discussed how cultural values shape attitudes toward mental health challenges within Asian American families. Many students explained that strong academic expectations and the importance of maintaining family honor may discourage individuals from acknowledging emotional struggles or seeking help.

Another theme was the difference in perspectives between generations. Many participants reported that older family members often viewed mental health challenges as a sign of personal weakness or a lack of resilience, whereas younger participants were more likely to view mental illness as a health condition that deserves understanding and professional support. These responses suggest that generational differences in beliefs about mental health may influence communication within families and affect students' willingness to seek help when experiencing mental health challenges.

Discussion

The findings from the statewide dataset, local school survey, and student interviews revealed a few consistent themes regarding youth mental health. Across all three data sources, academic pressure emerged as one of the most significant stressors affecting students. Many students also reported barriers to seeking mental health support, including cultural stigma, family expectations, and the belief that their problems were not serious enough to seek professional help. In addition, many students indicated that cultural background influenced how mental health was discussed within many of their families. Together, these findings highlight common challenges affecting the mental health of Asian American youth.

Both the statewide dataset and the local school survey identified academic pressure as a major contributor to students stress, while interview participants further described how academic achievement and family expectations influence their mental well-being.

Consistent with previous studies, many students in the present study reported reluctance to seek professional mental health support. Survey findings indicated that some students believed their problems were not serious enough to seek help, while others identified cultural stigma, family discouragement, and cultural beliefs as barriers to accessing mental health services. These findings may reflect persistent stigma and cultural values surrounding mental health issues that emphasize emotional self-control and family privacy.

The present study found that many students believed their cultural background influenced how mental health was discussed within their families. This finding is consistent with previous research suggesting that cultural values play an important role in shaping attitudes toward mental health and help-seeking behaviors among Asian American youth. Studies have shown that intergenerational differences in cultural beliefs and acculturation can create communication challenges between parents and children, making conversations about mental health more difficult. In addition, cultural stigma surrounding mental illness may discourage open discussions of emotional struggles, as some families may fear bringing shame to themselves or being negatively judged by others. These communication barriers may contribute to delayed help-seeking and reduced use of mental health services. Together, these findings highlight the importance of culturally responsive mental health services, encouraging open communication, and improving understanding of mental health within Asian American families.

In summary, an important strength of this study is that similar patterns emerged across multiple sources of evidence. The statewide dataset identified academic stress and reluctance to seek help as widespread concerns among California students. These findings were also reflected in the local survey, where students reported high levels of stress and frequently sought support from friends rather than professionals. Interview responses further illustrated how academic expectations, cultural beliefs, and family attitudes shaped students' mental health experiences.

Implications

The findings of this study have important implications for schools, families, communities, and policymakers seeking to improve mental health challenges among Asian

American youth. First, schools should expand access to school counselors and wellness center staff, and provide culturally responsive mental health services that recognize the diverse cultural backgrounds of students. Second, increasing the availability of trained mental health professionals who understand cultural differences may help reduce barriers to seeking support and foster trust among students. Third, schools should also implement regular mental health education workshops, organize awareness events, and initiate peer support programs to reduce stigma, improve understanding of mental health, and encourage students to seek help when needed. In addition, school teachers should participate in professional development activities that help them recognize students' early signs of mental health concerns and respond with cultural sensitivity.

Beyond schools, families and communities also play a critical role in promoting youth mental health. First, hosting parent education workshops can help families better understand common mental health challenges faced by youth and encourage more open and supportive communication at home. Second, community organizations and healthcare providers can further support Asian American youth by offering culturally appropriate mental health resources and services tailored to the needs of Asian American families. Third, at the policy level, increased investment in school-based mental health services, culturally responsive counseling resources, and youth mental health education programs may help address both existing mental health issues and future needs. Together, these efforts can contribute to creating a more supportive environment in which Asian American youth feel comfortable discussing mental health concerns and seeking appropriate support.

The Potential Role of AI in Supporting Youth Mental Health

Artificial intelligence (AI) has the potential to complement existing mental health services by providing accessible and timely support for youth. Unlike traditional counseling services, AI-powered mental health tools (e.g. AI chatbots, virtual assistants, and mood-tracking apps) are available 24 hours a day, allowing students to access support whenever they need. AI chatbots and virtual assistants can provide anonymous conversations, which may encourage students who are reluctant to discuss their concerns because of stigma or fear of being judged. In addition, AI technologies can offer personalized treatment strategies, recommend appropriate mental health resources, and provide multilingual support that may improve accessibility for Asian American youth and their families.

AI may also contribute to the early identification of students who are experiencing mental health challenges. Through analyzing students' symptoms, conversations, or behavioral changes, AI systems may help identify students who may benefit from professional mental health support before their symptoms become more severe. Furthermore, AI-assisted screening tools may help students seek appropriate mental health resources more efficiently, promoting early intervention and support.

Despite these potential benefits, AI should be viewed as a supplement to, rather than a replacement for, licensed mental health professionals. AI systems cannot fully understand the

complexity of human emotions, cultural experiences, or complex life situations, and they may occasionally generate inaccurate or inappropriate responses. In addition, concerns regarding privacy, data security, and ethical use of personal information should be carefully considered when implementing AI-based mental health tools. Therefore, AI should be used as one component of supporting youth mental health, rather than a diagnostic tool.

Limitations

This study has a few limitations that should be considered when interpreting the findings. First, the local high school survey included only 30 participants from a single high school, which may not be representative of other schools or populations. Second, the student interviews were conducted with Asian American students from one high school, and their perspectives may not represent the experiences of all Asian American youth. Third, the survey and interview data were based on self-reported responses, which may be influenced by personal perceptions and bias. Fourth, the data were collected at a single point in time. As a result, the findings cannot determine how students' mental health experiences and attitudes may change over time. Despite these limitations, the use of multiple data sources, including the statewide dataset, local survey, and student interviews, provides a more comprehensive understanding of the mental health challenges and support needs of Asian American youth.

Future Research

Future research should build upon the findings of the present study by including larger and more diverse samples from multiple schools and different states to improve the generalizability of the findings. In addition, although this study included Chinese, Korean, Vietnamese, and Indian American participants, future research could further examine the mental health experiences of different Asian American ethnic groups to better understand potential similarities and differences across communities. Long-term research that follows students over time would also provide valuable insight into how mental health experiences, help-seeking behaviors, and cultural influences evolve throughout adolescence. Furthermore, as AI continues to develop, future research should evaluate the effectiveness, accessibility, and ethical considerations of AI-assisted mental health tools in supporting Asian American youth while ensuring that these technologies are used as a complement to, rather than a replacement for, professional mental health services.

Conclusion

This study examined the mental health challenges, help-seeking behaviors, and potential solutions for Asian American youth. It also explored major factors contributing to these challenges, such as academic pressure, cultural influences, and family expectations. To provide a comprehensive understanding of these issues, the study integrated three sources of data: the AIM statewide youth mental health dataset, a local high school survey, and interviews with Asian American students from a local high school. Together, these data sources revealed that academic

pressure remains a major contributor to mental health challenges, while cultural stigma and family expectations continue to create barriers to accessing mental health support. These findings underscore the importance of developing culturally responsive strategies to better support the mental well-being of Asian American youth.

The findings of this study highlight the need for collaborative efforts to address the mental health challenges faced by Asian American youth. Reducing academic pressure, challenging the stigma surrounding mental health, and fostering open communication within families are essential steps toward creating a more supportive environment for young people. Schools can play a vital role by expanding access to culturally responsive mental health services, promoting mental health education, and organizing awareness programs or events that encourage students to seek help without fear of judgment. At the same time, families and communities should work together to support open conversations about mental health and reduce cultural barriers that may discourage help-seeking. As AI continues to evolve, AI-assisted mental health tools may further enhance existing support systems by providing accessible, timely, and culturally appropriate resources. However, AI should complement, rather than replace licensed mental health professionals. By combining the efforts of schools, families, communities, healthcare providers, and emerging technologies, society can better support the mental well-being of Asian American youth and help them thrive.

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The Effect of Heritage Language Preservation on the Identity Formation of Second-Generation South Asian Immigrant Youth in the San Francisco Bay Area

By Naina Rewal

Abstract

In increasingly multicultural societies, many second-generation immigrant adolescents navigate the complex balance between maintaining their heritage culture and integrating into mainstream society. This study examines the research question:"What role does heritage language preservation play in the identity formation of second-generation South Asian immigrant youth in the Bay Area?" The research employs a mixed-methods design combining survey data and semi-structured interviews among second-generation South Asian teens living in the Bay Area. Quantitative analysis using multiple linear regression revealed a significant positive relationship between heritage language engagement and ethnic identity development. Identity emerged as the strongest outcome associated with heritage language use, while language attitudes, family use, and reading ability were not statistically significant predictors. Qualitative findings further contextualized these results, demonstrating that heritage language is primarily learned within the home and functions as a symbolic anchor to culture and family.

Introduction

In an era of unprecedented global migration, the concept of "home" for second-generation immigrant adolescents is often defined not by a single geography, but by a negotiation between heritage culture and mainstream integration (Berry, 2005). For many youth in multicultural hubs like the San Francisco Bay Area, this negotiation is mediated through language. While English serves as the primary tool for academic and social mobility, heritage language, the tongues of parents and ancestors, frequently persist as symbolic anchors to cultural origin. However, as immigrant families assimilate over generations, these languages often face the threat of attrition, a process that is rarely just linguistic.

As scholars have noted, the loss of heritage language can create a "cultural gap" between generations, complicating the internal architecture of a young person's self-concept (Portes & Rumbaut, 2001). While existing literature has frequently emphasized the cognitive or academic benefits of bilingualism, there is a critical need to examine the relationship between heritage language preservation and identity formation among second-generation South Asian immigrant youth in the San Francisco Bay Area, as youth-centered research on this population remains limited.

This study seeks to bridge the gap by centering the lived experiences of second-generation South Asian immigrant youth. By examining the relationship between linguistic maintenance and personal belonging, this research addresses the question: What role does heritage language preservation play in the identity formation of second-generation South Asian immigrant youth in the Bay Area? Through a mixed-methods lens, this paper argues that

while variables such as ReadAbility or FamilyUse fluctuate, the internal link between language and identity remains the most significant predictor of cultural engagement.

Literature Review

I. Search Strategies

Sources were located via examining a variety of academic databases and applying the filter of peer-reviewed research to ensure credibility of sources used. Keywords used while researching include; native language preservation, South Asian identity, bicultural youth development, and Bay Area diaspora.

II. Identity Formation: Acculturation and Biculturalism

Literature on immigrant psychology has repeatedly identified bicultural integration as the optimal developmental pathway for a positive correlation in identity formation of immigrant youth. Canadian psychologist at Queen's University, John Berry, has created a seminal acculturation model that provides the conceptual map for examining the immigrant youth experience (Berry, 2005). Berry proposes the idea that immigrant individuals typically navigate between two dimensions: the desire to maintain heritage culture and the desire to engage with the host culture. His model concludes that the optimal pathway is biculturalism, where an immigrant group values and maintains their heritage culture while also positively engaging and participating in the wider host culture (Berry, 2005). For example, a teen immigrant who identifies as South Asian but grew up in the U.S may still speak their native language, such as Hindi, at home, while still being fluent in English and engaging in American social life.

In essence, biculturalism is associated with a positive view on self-identity, rather than assimilation or separation, which is the concept of trying to fully drop one's culture in order to adopt the host one. When biculturalism is successfully achieved in the individual, we see reports of higher self-esteem, lower rates of mental health issues, and improved academic and social functioning in each participant.

III. Ethnic Identity Development in Adolescence

Building on the acquisition theory, Phinney's model of ethnic identity development gives further insight into how immigrant youth form their identity. Phinney conceptualizes the idea of ethnic identity as a dynamic process involving exploration and commitment, particularly occurring during adolescence. This period is marked by heightened self reflection, increased awareness of social categories, and a greater exposure to discrimination. Research suggests that adolescents who successfully explore and commit to their ethnic identity exhibit greater psychological well-being, including higher self-worth and lower depressive symptoms (Phinney, 2003). For second-generation South Asian youth, ethnic identity exploration may involve learning about cultural traditions, religious practices, family histories, and, critically, heritage languages.

Language often serves as both a symbol and a vehicle of ethnic identity, reinforcing a sense of belonging to a cultural group. Phinney emphasizes that ethnic identity development doesn't occur in isolation, but is rather shaped by contextual factors such as family, peers, schools, and community environments. In regions like the San Francisco Bay Area, where South Asian communities are very prevalent and culturally visible (Bay Area Census, 2020), youth may have increased opportunities for ethnic affirmation. However, even with supportive environments youth experiences tension between cultural expectations at home and norms within American society.

IV. Heritage Language Preservation and Identity

Heritage language preservation plays a key role in ethnic identity formation and bicultural competence. It is often defined as languages spoken within the family or community that differ from the dominant social language (Valdés, 2001). For second-generation immigrant youth, proficiency in a heritage language often declines across generations due to schooling in English dominant environments and societal pressures. Despite this trend, research indicates that maintaining heritage language proficiency is associated with numerous social benefits. Wong Filmore (2000) argues that language loss can disrupt family communication, intergenerational bonds, and a broad cultural transmission. When you lose the ability to communicate effectively with parents or grandparents, family cohesion and emotional support may suffer.

Conversely, studies show that heritage language maintenance strengthens family relationships, promotes cultural continuity, and reinforces ethnic pride (Tseng & Fuligni, 2010). For South Asian families, heritage languages often carry religious, moral, and cultural significance, serving as the basis for storytelling, rituals, and values. Youth who retain proficiency in these languages may feel more connected to their cultural roots and experience a stronger, more coherent sense of identity.

V. Family Language Practices and Intergenerational Dynamics

Family language practices significantly influence heritage language retention. Parents who consistently use the heritage language at home and emphasize its importance are more likely to have children who maintain proficiency (Guardado, 2002). However, this process is often complicated by power dynamics and the children's desire to assimilate socially. Second-generation youth may resist speaking their heritage language due to fear of being perceived as “different” or “foreign” by peers. This resistance can create intergenerational tension, as parents may interpret language rejection as a rejection of cultural values. Studies have found that such conflicts negatively affect adolescents' emotional well-being in family relationships (Fulgini, 2000).

At the same time, families that adopted flexible, supportive approaches, encouraging bilingualism rather than enforcing rigid language rules, tend to foster more positive outcomes. These families framed bilingualism as an asset rather than an obligation, allowing you to develop linguistic competence without associating it with shame or pressure.

VI. Language, Academic Outcomes, and Cognitive Development

Beyond identity and family dynamics, heritage language preservation has been linked to positive academic and cognitive outcomes. Research on bilingualism suggests that bilingual individuals demonstrate enhanced cognitive flexibility, and executive functioning (Bialystok, 2011). These cognitive advantages may contribute to improved academic performance and problem-solving skills. Immigrant youth bilingualism can also enhance educational engagement by validating their cultural backgrounds within academic spaces. When schools recognize and support students' linguistic diversity, youth are more likely to feel valued and motivated. However when heritage languages are stigmatized or ignored, students may internalize negative beliefs about their cultural identities.

In the context of South Asian youth in the Bay Area, access to heritage language schools, religious institutions, and community organizations can play a critical role in sustaining bilingualism. Language schools and cultural programs provide structured opportunities for language learning while reinforcing cultural pride.

VII. Psychosocial Well-Bring and Mental Health

The intersection of language, identity, and mental health has received increasing scholarly attention. Studies indicate that immigrants who have maintained strong connections to their heritage culture, including language, report lower levels of depressive symptoms and greater life satisfaction parentheses and at all periods, (Yoon et al., 2013). Heritage language proficiency serves as a buffer against discrimination by anchoring youth in a stable cultural identity.

In contrast, language loss and cultural disconnection have been associated with identity confusion, feelings of alienation, and increased vulnerability to mental health challenges second-generation youth who feel caught between cultures without a sense of belonging may experience heightened stress during adolescence, a developmental period already characterized by emotional volatility.

Additionally, the preservation of a heritage language may foster a sense of emotional safety and validation within both familial and community context. While second-generation immigrant youth are able to express themselves in their native language, particularly and emotionally charged or culturally nuanced situations, they may experience greater emotional regulation and perceived social support.

VIII. Gaps in Literature

While extensive research exists on cultural identity formation, and bilingualism, several gaps remain. Much of the existing literature aggregates immigrant youth into broad racial or ethnic categories, limiting nuanced understandings of specific groups such as South Asian Americans. Additionally, a few studies focus explicitly on second-generation youth within specific geographic contexts, such as the Bay Area, where cultural density and resources may shape unique experiences. Furthermore, quantitative studies often measure language proficiency

without exploring subjective youth experiences and meanings attached to language use. There's a need for qualitative research that centers youth voices, capturing how they perceive native language preservation in relation to identity belonging and development.

IX. Summary

Existing literature strongly supports the role of biculturalism and heritage language preservation in fostering positive identity formation and youth development among the immigrant population. Theoretical frameworks such as the acculturation model and Phinney's ethnic identity development theory highlight the importance of maintaining heritage language and gauging with the host society. Empirical studies demonstrate that heritage language proficiency strengthens family relationships, supports academic and cognitive development, and promotes psychosocial well-being. However, gaps remain regarding the lived experiences of second-generation South Asian youth, particularly within culturally rich regions like the Bay Area. To build upon prior research and address these gaps, the present study examines how native language preservation influences identity formation and youth development among second-generation South Asian immigrant youth in the Bay Area. By centering youth perspectives, this research aims to contribute a more nuanced understanding of language, cultural, and identity within immigrant communities.

Methods

I. Research Design

This study employed a mixed-method design combining quantitative survey data with qualitative semi-structured interviews to examine the relationship between heritage language use and identity development among second-generation South Asian adolescents in the San Francisco Bay area. By utilizing a mixed methods approach, it allows for the exploration of both measurable relationships between variables and the lived experiences underlying those relationships.

The quantitative component consisted of an online survey measuring demographic information, heritage language usage, and the ethnic identity using adapted items from the Multigroup Ethnic Identity Measure (MEIM) to provide a standardized measure across diverse South Asian populations for data reliability. The MEIM provides a way to analyze and study ethnic identity using survey questions across large groups (Phinney, 1992). The qualitative component consisted of semi-structured interviews designed to explore participants' personal narratives surrounding language learning, family relationships, and cultural belonging. The mixed-methods design allowed for the identification of statistical relationships between language use and identity measures.

Participants

Participants were recruited through informal community networks and school-based outreach in the San Francisco Bay area. Eligibility criteria required participants to be 13-18 years

old, identify as second-generation South Asian, and currently live in the San Francisco Bay area. A total of 36 participants completed the survey and four participants volunteered for follow-up interviews. Survey participants ranged from 15 to 17 years old (M=16). Approximately 69.4% of participants identify as female and 30.6% identify as male. Due to the relatively smaller sample size, a key limitation that may arise is selection bias which will then result in my data to be less representative to the overall population of South Asian individuals. Ethnic backgrounds included Indian, Pakistani, Bangladeshi, and Sri Lankan heritage. The majority of participants reported that at least one parent held a bachelor's degree or graduate degree. Common heritage languages reported included Hindi, Punjabi, Gujarati, Telugu, Tamil, Urdu and Bengali. Interview participants were selected from survey respondents who indicated willingness to participate in additional qualitative research. Pseudonyms were assigned to protect confidentiality.

II. Instruments

The survey consisted of five sections: Consent, Demographic, Heritage Language Usage, Ethnic Identity Measures, and Attitudes Towards Language Preservation. The questions used a combination of multiple-choice responses and Likert-scale items. Likert items were scored from 1 (strongly disagree) to 5 (strongly agree).

III. Interview Protocol

Five semi-structured interviews were conducted to examine how participants narrate their experiences with heritage language and identity. Interviews lasted 8 to 10 minutes and were conducted via Zoom, see The interview questions focused on language, learning emotional associations with language, identity formation, and social dynamics which can be seen in Table 1 below.

Theme	Questions
Language learning	Can you describe how you learned your native language growing up? Who primarily taught or modeled the language for you? Was it learned formally, informally, or both?
Language usage	How often do you use your heritage language now and in what settings? Does usage change at home versus school?
Emotional associations	What emotions do you associate with speaking your heritage language? Can you recall a moment that shaped those feelings?
Cultural identity	How has your ability to speak your native language shaped your connection to your culture?
Family relationships	How does language affect your relationship with family members?
Social perception	Have you ever felt judged for how well you speak your heritage language?
Identity formation	Do you feel your heritage language shapes your identity?
Reflection	What do you think people misunderstand about heritage language use?

Table 1: Interview Questions

IV. Procedure

Participants were first provided with an online consent form explaining the purpose of the study, confidentiality protections, and volunteer participation. Participants under 18 were required to provide parental consent. After consent was obtained, participants completed the online survey, which required approximately 2 minutes. At the end of the survey, participants were invited to volunteer for interviews. Those who agreed were contacted via email to schedule a semi-structured interview session. All interviews were recorded with permission and later transcribed prior to analysis using the built-in Apple application: Voice Memos. The application was used on iPhone and MacBook.

V. Qualitative Data Analysis

Interview transcripts were analyzed using thematic analysis, which focuses on identifying and analyzing patterns within participants' personal stories and experiences (Ahmed et al., 2025). Thematic analysis is particularly useful in identity research because it allows researchers to examine how individuals construct meaning from their experiences and how these experiences shape their sense of self. The analysis process occurred in three stages. First, transcripts were read multiple times in order to identify recurring themes related to language learning, family relationship relationships, and cultural belonging. Second, segments of text were coded using a coding framework developed based on emerging patterns within the interview, such as a sense of personal identity, confidence from speaking the heritage language, and the pressure from family to be fluent. Third, codes were grouped into broader thematic categories in order to interpret how heritage language experiences contribute to identity development. The thematic codes used can be seen in Table 2 below.

Code	Short Name	What it covers
DOMES-STRONG	Domestic Stronghold	Language as something that exists almost exclusively within the walls of the home or with specific family members
LING- GATEKEEP & PRESSURE	Linguistic Gatekeeping and Pressure	The feeling of being judged for "bad" speaking or the pressure to perform well in front of the community.
SIT-FLUEN	Situational Fluency	Using the heritage language for "easy" or "emotional" things, but switching to English for "complex" or "intellectual" topics.
IDEN-ANCH	Identity Anchoring	The belief that the language is the "key" or "bridge" to their culture, outfits, movies, and holidays.
GEO-SAFETY	Geographic Safety	How the physical location (Bay Area vs. Ohio vs. East Coast) affects the comfort level of speaking the language.

Table 2: Thematic Analysis Codes

VI. Quantitative Data Analysis

Survey data was analyzed using multiple linear regression to examine the relationship between heritage language use and ethnic identity development. Linear regression was selected because it allows for the evaluation of multiple independent variables and its contribution to variation in a dependent variable (Roustaei, 2024). According to North Carolina State University, the dependent variable is defined as what you are measuring in your research study, in this case that will be "Identity." However, in terms of my independent variables, those will include "SpeakHome," " ReadAbility," "FamilyUse," and "Attitude."

Findings

A multiple linear regression analysis was conducted to examine the relationship between heritage language exposure and outcomes related to identity and confidence. The results indicate that Identity was the only statistically significant predictor (p=0.022), suggesting a meaningful positive relationship between heritage language engagement and identity formation.

For reference, the p-value as defined by the NIH as the "Probability that the observed effect within the study would have occurred by chance if, in reality, there was no true effect" (Shreffler & Huecker, 2023). In contrast, Attitude (p=0.168) and FamilyUse (p=0.064) did not reach statistical significance, although FamilyUse approached the threshold, indicating a potential but inconsistent relationship. positive association between heritage language engagement and ethnic identity development. For further clarity, Attitude ($\beta = .187$, $p = .168$), FamilyUse ($\beta = .121$, $p = .064$), and ReadAbility ($\beta = .019$, $p = .728$) were not statistically significant predictors. Although FamilyUse approached significance, the relationship did not meet the conventional threshold of $p < .05$. These findings suggest that heritage language is more strongly associated with identity formation than with functional language proficiency or family language practices alone. These values can be seen in Table 3.

Variable	Coefficient	Std Error	t-stat (Coeff/SE)	P-Value (T.DIST.2T)
Identity	0.462	0.192	2.4	0.022
Attitude	0.187	0.132	1.41	0.168
FamilyUse	0.121	0.063	1.92	0.064
ReadAbility	0.019	0.054	0.35	0.728

Table 3: Multiple Linear Regression Variable

Overall, these findings suggest that heritage language is more strongly associated with identity formation than with generalized confidence, as seen in Figure 1.

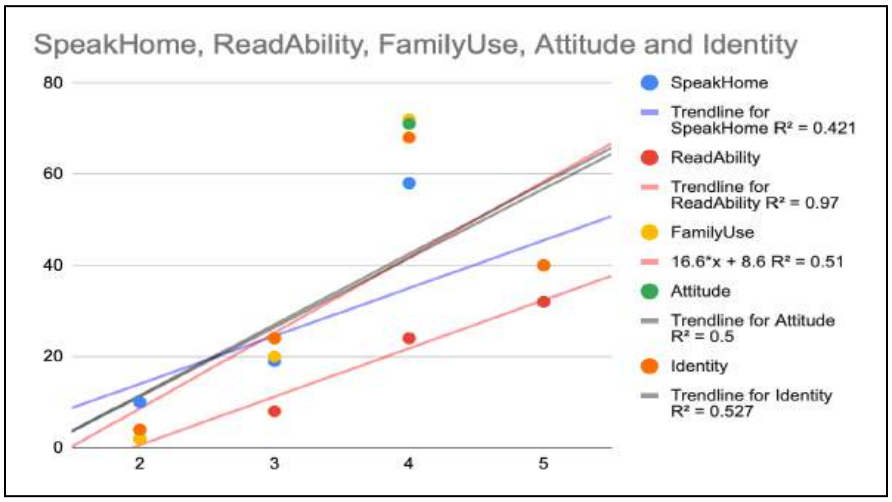


Fig. 1: Multiple Linear Regression Model

Qualitative findings further contextualize these results by revealing consistent patterns in how participants experience heritage language. First, heritage language acquisition was primarily rooted in the home environment, often taught informally by parents or grandparents. Participants described language as something that "starts in the home," reinforcing its role as a domestic and familial practice rather than a socially integrated one. The following themes used for thematic analysis can be seen in Figure 2.

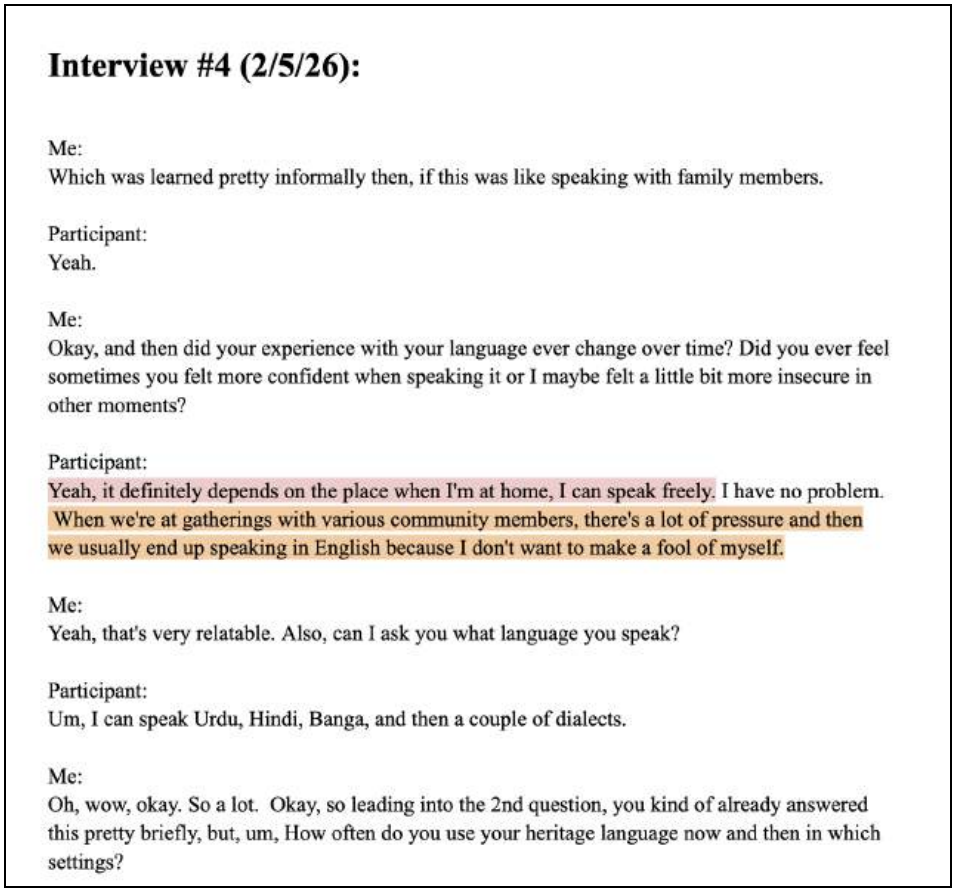
A	B	C	D	E	F	G	H	I	J
Interview #	Date	Power quotes							Theme
1	1/29/26	1. "My grandmother... was the main one who taught me." 2. "I never went to a formal school for my 2nd language." 3. "It's easier to communicate with my grandparents... It's also really fun to curse."							DOMES-STRONG
2	2/1/26	1. "My parents had a very strict policy that I don't speak English at home... they'd get mad at me." 2. "I feel like I can fully assimilate [in India]... they can't necessarily tell that I'm American." 3. "Once I moved to the Bay Area... people were feeling they weren't Indian enough."							GEO-SAFETY
3	2/1/26	1. "I learned [Punjabi] through my nanny who speaks Punjabi... she doesn't understand English." 2. "I've always felt confident... it's never been something that's gone into my social life." 3. "I like keeping [the two worlds] separate... they are just like 2 different sides of me."							SIT-FLUEN
4	2/5/26	1. "When we're at gatherings... we usually end up speaking in English because I don't want to make a fool of myself." 2. "I feel like I'm upholding this innate responsibility to my family to preserve their heritage." 3. "It starts off in the home, if you start speaking it at home... then you'll basically get that familiarity."							LING-GATEKEEP
5	2/10/26	1. "Being able to speak a second language and being able to honor that my culture..shaped kind of a pride." 2. "I feel like it's super important in terms of my own personal identity of just being a descendant of South Asian immigra 3. "I've I feel like there's never I've never had a reason to think of my knowing my native language so negatively.."							CONF-GAP

Fig. 2: Thematic Analysis

This localization limits the extent to which language contributes to public identity, even while it remains deeply meaningful on a personal level. Additionally, geographic context emerged as a significant factor influencing language use and comfort.

Participants who lived in more diverse areas, such as the Bay Area, reported greater acceptance and confidence, while those who used to live in less diverse environments described how they felt pressure to assimilate. These findings suggest that linguistic confidence is not inherent to ability but it's instead shaped by external social environments.

Participants also demonstrated patterns of situational fluency, selectively using languages depending on context and topic. Heritage languages were commonly used for emotional or relational communication, such as speaking with family members, while English was preferred for academic, political, or complex discussions. This division indicates that language proficiency is not uniform but context-dependent, further complicating its relationship with confidence. Moreover, many participants described experiences of linguistic gatekeeping within their own cultural communities. Individuals often felt judged based on their fluency, leading them to avoid spreading their heritage language in group settings due to fear of embarrassment. The following can be seen in Figure 3.



Interview #4 (2/5/26):

Me:
Which was learned pretty informally then, if this was like speaking with family members.

Participant:
Yeah.

Me:
Okay, and then did your experience with your language ever change over time? Did you ever feel sometimes you felt more confident when speaking it or I maybe felt a little bit more insecure in other moments?

Participant:
Yeah, it definitely depends on the place when I'm at home, I can speak freely. I have no problem. When we're at gatherings with various community members, there's a lot of pressure and then we usually end up speaking in English because I don't want to make a fool of myself.

Me:
Yeah, that's very relatable. Also, can I ask you what language you speak?

Participant:
Um, I can speak Urdu, Hindi, Banga, and then a couple of dialects.

Me:
Oh, wow, okay. So a lot. Okay, so leading into the 2nd question, you kind of already answered this pretty briefly, but, um, How often do you use your heritage language now and then in which settings?

Fig. 3: Section of Interview from Participant #4

This dynamic positions language as a marker of authenticity, where fluency determines belonging and legitimacy within the cultural group.

Despite these challenges, participants consistently identified heritage language as a central component of their cultural identity. Language served as a symbolic anchor, connecting individuals to traditions, media, and familial relationships, even when fluency varied. This finding aligns directly with the quantitative results, reinforcing that identity is the strongest and most consistent outcome associated with heritage language. However, the relationship between language and confidence was more complex. Many participants reported that their heritage language did not significantly impact their confidence in school or border social settings. Instead, confidence was primarily affected within cultural contexts, where fluency influenced feelings of inclusion or inadequacy. This pattern reflects a "confidence gap," in which individuals may feel secure in external environments but experience reduced confidence within their own cultural communities due to language proficiency, can be seen in Figure 4.

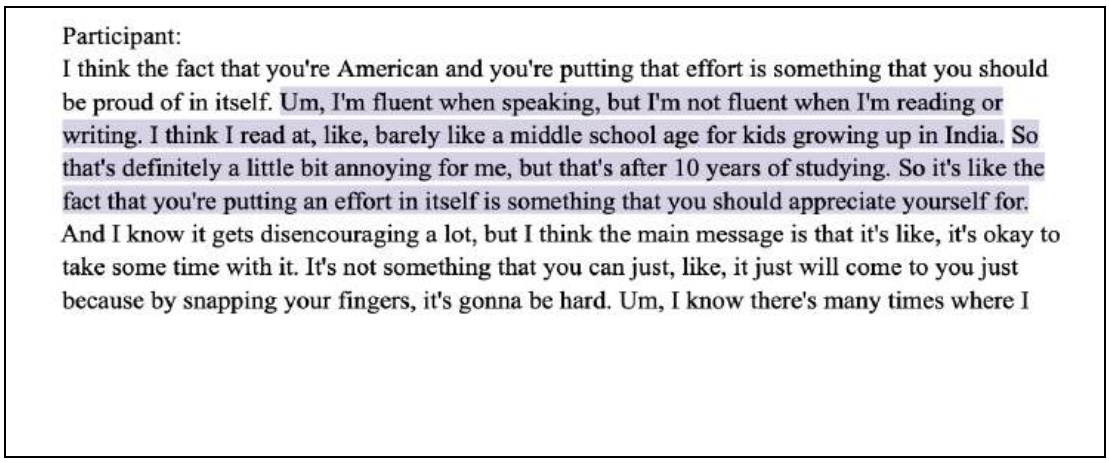

Participant:
I think the fact that you're American and you're putting that effort is something that you should be proud of in itself. Um, I'm fluent when speaking, but I'm not fluent when I'm reading or writing. I think I read at, like, barely like a middle school age for kids growing up in India. So that's definitely a little bit annoying for me, but that's after 10 years of studying. So it's like the fact that you're putting an effort in itself is something that you should appreciate yourself for. And I know it gets disencouraging a lot, but I think the main message is that it's like, it's okay to take some time with it. It's not something that you can just, like, it just will come to you just because by snapping your fingers, it's gonna be hard. Um, I know there's many times where I

Fig.4: Section of Interview from Participant #2

As a whole, these findings challenge the assumption that heritage language always enhances confidence despite varying personal experiences. While language plays a critical role in identity formation and cultural connection, its impact on confidence is situational and socially constricted. Heritage language functions less as a direct driver of self-esteem and more as a boundary marker that shapes belonging and authenticity within specific contexts. Ultimately, confidence is influenced not simply by whether individuals speak their heritage language, but by how, where, and with whom that language is used.

Discussion

This study sought to examine the role of heritage language preservation in the identity formation of second-generation South Asian immigrant youth in the Bay Area. Through a mixed-methods design, the findings reveal that heritage language functions primarily as a symbolic anchor to cultural identity rather than a generalized driver of confidence. Both the

quantitative and qualitative results offer a nuanced picture of how language mediates belonging, authenticity, and self-concept among this population.

The most notable quantitative finding was that Identity was the only statistically significant predictor of heritage language (p=.022), while variables such as ReadAbility, Attitude, and FamilyUse did not reach significance. This suggests that the relationship between heritage language and identity is not primarily driven by functional proficiency or even family pressure, but rather by an internalized sense of self. This aligns closely with Phinney's (2003) model of ethnic identity development, which frames identity as an active, explanatory process rather than a passive outcome of language exposure. This finding is further supported by Berry's (2005) acculturation framework, which emphasized that successful bicultural integration depends not only on behavioral participation in both cultures, but also on internal identification with them. In this study, heritage language appears to operate less as a technical skill and more as a symbolic mechanism through which youth affirm their biocultural identity. Even when participants demonstrated limited proficiency, the language itself retained meaning and marker of cultural belonging. This reinforces the idea that identity is not contingent on fluency, but rather on the personal and emotional significance individuals attach to the language.

The qualitative findings deepen this interpretation by illustrating how heritage language is primarily situated within the private sphere of the home. Consistent with prior research on family language practices (Guardado, 2002; Wong Filmore, 2000), participants described language acquisition as informal and intergenerational, often rooted in communication with parents and grandparents. However, this domestic confinement also limits the language's visibility in public and academic contexts. As a result, heritage language contributes more strongly to internal identity formation than to outward expressions of confidence or social capital.

Additionally, the emergence of "situational fluency" complicates traditional understandings of language proficiency. Rather than reflecting a fixed level of ability, participants' language use shifted depending on context, supporting emotionally driven interactions while deferring to English for complex or institutional communication. This aligns with existing literature on bilingual cognitive flexibility (Bialystok, 2011), but also suggests that linguistic competence alone does not determine identity outcomes. Instead, the meaning attached to when and why a language is used becomes more significant.

The theme of linguistic gatekeeping further highlights the social constraints surrounding heritage language use. While prior studies (Tseng & Fulingni, 2010) emphasize the role of language in strengthening cultural pride, this study reveals a parallel dynamic in which language can also act as a boundary that excludes individuals who do not meet preceding standards of fluency. Participants' experiences of judgment within their own cultural communities demonstrate that heritage language can simultaneously foster belonging and create internal divisions. This tension helps explain why language did not emerge as a significant predictor of confidence in the quantitative model.

Moreover, the identified “confidence gap” extends existing research on psychosocial well-being (Yoon et al., 2013) by showing that confidence is not universally enhanced by heritage language maintenance. Instead, confidence is context-dependent, often decreasing in cultural settings where expectations around fluency are heightened. This challenges the assumption that bilingualism inherently promotes self-esteem and suggests that social context plays a critical moderating role. Collectively, these findings suggest that heritage language preservation should be understood not as a direct causal factor in identity formation, but as a part of a broader, dynamic system involving family, community, and social environment. While language remains a powerful symbolic anchor, its effects are mediated by how individuals interpret and experience it within different contexts. This reinforces the importance of centering youth perspectives, as the meaning of heritage language is not fixed but actively constructed through lived experience.

Ultimately, the findings suggest that heritage language functions less as a technical skill and more as a symbolic mechanism through which youth affirm their cultural identity. Even when participants demonstrated varying levels of proficiency, heritage language retained significant emotional and cultural meaning. These findings reinforce the idea that identity is not contingent upon fluency but rather on the personal significance individuals attach to their heritage language.

Limitations

Several limitations should be considered when interpreting the results of this study. First, the relatively small sample size (n=36 for the survey and n=4 for interviews) limits the extrapolition of the findings to the broader population of second-generation South Asian youth. The use of convenience sampling though community networks and school-based outreach may also introduce selection bias, as participants who chose to participate may already have a stronger interest in connection to their heritage language and identity. Additionally, this study is geographically limited to the San Francisco Bay Area, a region known for its high cultural diversity and strong South Asian community presence.

This unique context may not reflect the experiences of youth living in less diverse environments, where access to cultural resources and community support may differ significantly. Another limitation lies in the reliance on self-reported data, which may be subject to social desirability bias or inaccuracies in participants' perceptions of their language use, identity, and confidence (Gower et al., 2022). Furthermore, while the quantitative analysis identified relationships between variables, the cross-sectional design of the study does not allow for a conclusion about causation. Finally, the qualitative component included a small number of interviews which, although rich in detail, may not capture the full range of experiences within this population. Future research with larger and more diverse samples, as well as longitudinal designs would provide a more comprehensive understanding of how heritage language influences identity development over time (Caruana et al., 2015).

Fulfillment of Research Gaps

This study addresses several important gaps in existing research on heritage language and identity among immigrant youth. While prior studies highlight the benefits of heritage language maintenance, much of the research focuses on broad ethnic categories or relies heavily on quantitative data, limiting insight into individual experiences. For example, research has shown that heritage language use supports family relationships and identity development, but often does not explore how youth personally interpret these experiences or how they vary across communities (Filmore, 2000). By focusing specially on second-generation South Asian adolescents in the San Francisco Bay Area, this study provides a more culturally and geographically specific perspective that is often missing in the literature. Additionally, by incorporating qualitative interviews, this research centers youth voices and captures the nuanced, context-dependent ways language shapes identity and belonging. Through its mixed methods design, this study expands on existing literature by demonstrating that heritage language functions not only as a communicative tool, but also as a complex social and emotional one.

Implications

The findings of this study have important implications for educators, families, and community organizations working with second-generation South Asian youth. First, the strong link between heritage language use and identity formation suggests that promotion of language maintenance can support positive self-concept and cultural connectedness.

For educators, schools should move beyond viewing heritage language as an optional or extracurricular skill and indeed integrate it into culturally responsive programming. For example, schools could implement structured after-school heritage language programs that combine language learning with cultural activities such as storytelling, film, discussion, or cultural arts. Research suggests that heritage language maintenance is most effective when supported not only within families but also through broader institutional and community efforts (Inan & Harris, 2025). Additionally, incorporating multilingual elements into classroom instruction, such as bilingual projects or culturally relevant texts, can validate students' identities and increase engagement. These approaches directly address this study's findings that language is often confined to the home, limiting its role in public identity formation.

At the policy level, school districts and local education boards could adopt policies that formally recognize heritage languages as assets rather than deficits. Expanding programs such as the Seal of Biliteracy would institutionalize support for bilingualism. Given the study's finding that confidence is context-dependent, policies should also prioritize inclusive classroom environments by funding teacher training in culturally responsive instruction.

Finally, these implications highlight a broader need to reframe how heritage language is understood in immigrant communities. Rather than measuring success solely through proficiency, stakeholders should recognize language as a symbolic and relational tool that supports identity formation. Studies show that heritage language contributes to identity construction, emotional well-being, and social navigation, even when proficiency levels vary. By

addressing both the identity-anchoring role of language and the socially constructed “confidence gap," educators and policymakers can create more inclusive systems that promote not only bilingualism, but also belonging and cultural continuity.

Conclusion

This study demonstrates that heritage language preservation plays a significant role in shaping the identity of second-generation South Asian immigrant youth in the Bay Area, functioning primarily as a symbolic anchor rather than a direct source of confidence. While quantitative findings highlight identity as the strongest predictor of language engagement, qualitative insights reveal that this relationship is deeply influenced by context, particularly through the presence of a “confidence gap” and the privatization of language within the home. Ultimately, these findings suggest that heritage language is less about proficiency and more about meaning. By centering youth experiences, this study underscores the importance of fostering environments that support both cultural expression and inclusive belonging, contributing to a more nuanced understanding of identity formation in multicultural societies.

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Predicting If Your Dream Job Is At Risk Of AI By Noah Kim

Intro

Artificial Intelligence (AI) is continuing to advance rapidly, and there is a real concern: will AI replace human jobs? Technology is already seen taking over simple jobs like manufacturing and cashiers through self-checkout machines. According to ALM Corp, around 40% of jobs in the world are at risk of AI, and about 60% in high-income countries. AI is slowly integrating itself into helping jobs like AI suppoårt chats, and it's only a matter of time until AI starts to take over more. These new developments have brought attention to which careers are most at risk and how people can prepare for a new and more automated future. Recent research by Frey and Osborne in 2013 suggests that 47% of jobs in the U.S. that involve tasks that could be automated using technology are at high risk of replacing jobs, while jobs that require emotional intelligence, human interaction, and complex decision-making are at less risk. However, it is still challenging to determine what jobs are vulnerable to AI. As a result, by providing the model with a manually labeled dataset of jobs categorized by automation risk, the AI can learn to score new job descriptions independently. By giving the AI Bot either the job title, job description, or a link to the job, the AI will evaluate the job based on a risk score, which indicates the likelihood of AI disruption.

Literature Review

Since the emergence of AI technologies, much attention has been paid to the possible risks involved. One of the pioneering works in the field was Frey and Osborne's (2013) article, in which it was predicted that 47% of all jobs in the United States are at high risk of automation. Their research has shown that jobs associated with routine tasks are more vulnerable to automation compared to others. Following the mentioned idea, the McKinsey Global Institute (2017) has developed another framework based on tasks instead of entire occupations. Such a task-based approach is more accurate in determining automation threats since jobs having the same name will have unique tasks involved. In evaluating specific tasks, researchers are able to establish which activities are at risk of automation and which need human action. As it appears from the study, though complete automation of jobs will happen in a few decades from now, 60% of jobs consist of at least 30% of automatable tasks. Furthermore, the World Economic Forum (WEF) has addressed the issue of the consequences of automation, such as the elimination of jobs on a large scale. According to WEF's "The Future of Jobs Report 2025", the number of eliminated jobs because of the technological revolution is 85 million vs 97 million jobs created, meaning only 12 million jobs were gained. One of the most influential theoretical approaches that can help identify potential risks related to automation includes the classification proposed by Autor, Levy, and Murnane (2003). According to these authors, there are four kinds of activities in terms of the level of routines and the nature of the tasks performed: routine cognitive, routine manual, non-routine cognitive, and non-routine manual. The significance of this framework is evident because it enables an assessment of the strong and weak sides of current AI

developments. For example, machine learning has demonstrated tremendous effectiveness in routine cognitive operations, such as data analysis and recognition. In contrast, the effectiveness of machine learning in carrying out non-routine activities, including those requiring physical presence and decision-making in an uncertain environment, not to mention emotions and soft skills, is much lower. This framework is crucial for the current research because it forms the basis for the job automation analyzer. Some recent developments in NLP allow researchers to use NLP algorithms for analyzing large amounts of information, including jobs and labor market statistics. NLP makes it possible to find patterns in unstructured texts, and thus it helps identify what skills and what kinds of work may be in demand or become outdated. The connection between automation and jobs can be found using NLP by analyzing job descriptions and estimating the level of potential impact of AI on certain types of jobs and the processes involved. The biggest challenge associated with this method of analysis is that all current approaches are aggregate-level approaches that look at the industry or even category of jobs as a whole, rather than considering specific job advertisements. By operating at the individual job posting level, the model can produce personalized risk assessments that existing research cannot. While previous studies in this field have made significant contributions to knowledge regarding the risks associated with automation, they are subject to many limitations. Current studies employ various occupational or industry-wide categories to examine possible risks but do not analyze variations within each occupation. As a result, these studies are not suitable for individuals trying to assess their automation risks in a particular occupation. The model proposed by this research addresses the above limitation and employs a machine learning algorithm that operates on the job description level. Job posting texts are processed using natural language processing algorithms, while machine learning algorithms provide predictions regarding automation risks based on the data collected. Moreover, this model produces easily understandable results.

Methodology

To assess the degree of jobs' vulnerability to automation by AI algorithms, we have compiled a data set of 25 jobs within 4 industries: healthcare, technology, skilled trades, and professional services. Such industries were deliberately chosen in order to create a set of occupations which vary in their degree of susceptibility to automation. Even though the data set is a bit small, this is intentionally thought out. The research team compiled jobs from different industries that all have a different risk profile. In a way, there are occupations which can be classified as high-risk, medium-risk, and less risky. To make the evaluation process easier and more effective, several important parameters have been included into the dataset. First of all, the job title and a set of typical tasks have been identified for each occupation. Second, there is the ground truth risk score from 1 to 10, which shows the degree of automation susceptibility of the particular job. Moreover, each job was decomposed into individual tasks, and these tasks were categorized into two different types of tasks: those that could be automated by an AI system and those that depended on humans. Tasks like pattern recognition, data processing, and analysis, among others, are categorized as tasks that can be automated by AI. On the other hand, tasks that

require the physical presence of a person and manual skills, emotional thinking, as well as decision-making in an uncertain environment cannot be automated. The two-category approach allows for easy assessment and also fits within the existing labor economics research framework. The determination of the risk scores for each occupation required finding the ratio of AI-automated tasks to total tasks in that occupation. These risk ratios were then scaled to 1-10 to find the standard risk scores for every occupation. In order to conform to previous studies on this topic, verification of these risk scores was carried out using the findings in the study conducted by Frey and Osborne (2013). The employment of anchor jobs is also used to verify and determine the risk scores. Risk scores assigned to occupations characterized by routine jobs that were at high risk, such as bank tellers, had very high risk scores (9/10). On the contrary, jobs involving lots of social interaction and imagination, like music therapists, were considered less risky (1/10).

Results

The algorithm was tested via several job descriptions from various industries in order to determine the ability of predicting risks of the described positions being automated. During the test, the accuracy of the prediction for the amount of AI automation vulnerability was above 80%. This result shows that the approach used by the framework and its scoring technique is a valid way of predicting the risks of automation based on a job description. So, for instance, a medical coder performing routine analytical work was at greater risk of automation than nurses within the same industry. In order to analyze the behavior of the model better, a feature importance analysis was performed via a Random Forest method. As a result of the analysis, it became clear that the percentage of automated actions was the most important feature among those used in the model for making predictions. Additionally, some jobs where 60% or more of tasks could be performed by AI machines were at high risk of being included in the highest-risk occupation category. Secondly, jobs requiring employees' presence or making real-time decisions and interacting directly with other people were characterized by a very low probability of automation. Jobs of this kind included health care professionals, counselors, or skilled workers who required personal interaction. At last, it appeared that the probability of automation appeared more than an industrial classification of a particular occupation.

Discussion

The outcome of this experiment indicates that the higher the degree of automation, routine, and data-driven tasks, is at higher risk to AI automation. The jobs that include tasks related to pattern recognition, processing, and other routine activities tend to be rated higher. At the same time, occupations that need human interaction, ethical considerations, creativity, and judgment tend to get significantly lower ratings. These results confirm the hypothesis that AI operates most efficiently in repeatable and structured environments. The obtained results are also consistent with numerous studies conducted in the field of labor automation. Yet, in contrast to those studies that analyze the threat of automation in a certain industry or occupation group, this

model estimates the risk of automation for each particular job description. The evaluation is performed based on the tasks specified in the job description. Thus, a task-oriented approach to automation allows getting more precise results and confirms that jobs in one industry may have different levels of automation risk. From the findings, it is clear that automation by AI is bound to change jobs rather than do away with jobs in the near future. The development of AI could make many professions move away from repetitive and administrative jobs into more people-centered tasks that make use of skills that have an advantage in comparison with robots' skill set. This isn't a certainty, as other technologies like the ATM, for example, did not get rid of bank tellers; rather changed what tellers did. Therefore, people might be forced to focus their attention on other skills that give them an edge over robots, like effective communication, leadership skills, adaptability, and problem-solving skills. It should be noted that automation does not imply job loss but rather evolution of some jobs to accommodate the technology. The use of AI will make work easier through improvement in productivity; however, judgment and personal touch will remain crucial in most cases. For instance, there are professions such as those in the healthcare profession, counseling, teaching, and crafts that will not disappear anytime soon. In conclusion, there is a likelihood of flexibility in the workforce because of increased need for collaboration between man and robot, interpretation of results provided by robots, and judgment in ambiguous conditions. The results of this research can have profound effects on both students and professionals who are currently working in some job position. The findings of this study have uses for students when it comes to choosing careers. Besides being influenced by salary and the need to fill existing jobs, the effects of automation on certain professions should be taken into consideration too. It was revealed that the jobs that involve a high degree of creativity, leadership, flexibility, and critical thinking are less vulnerable to automation than jobs involving repetitive actions or predictable results. This means that regardless of the particular career choice, students might develop these human skills and therefore increase the chance of remaining irreplaceable by robots or computers in their profession. As opposed to simply learning new skills, future jobs should require cooperation, emotional intelligence, and reasoning capabilities. At the same time, this model could be used by professionals to estimate automation risk associated with their job. The analysis of the tasks performed allows identifying the risks of becoming redundant and, therefore, finding ways to adapt to the change, retraining, specializing, etc. This means that, while being a prediction instrument, it can encourage people to react to the threat of technological changes.

Limitations & Future Work

While the proposed model yielded encouraging results, there are several aspects that must be discussed. Firstly, the dataset involved just 25 job descriptions, which is not sufficient to train a model for use at scale. In this regard, it can be stated that although the chosen job descriptions were diverse and included a variety of fields and levels of automation vulnerability, in a real-life application, hundreds and even thousands of descriptions would be required. Furthermore, labels applied to task descriptions within the dataset were assigned manually. Specifically, the task had

two categories, namely AI-automatable and human-dependent tasks. The process of categorizing each task is based on academic research; however, such labels may vary depending on the researcher and involve a degree of subjectivity. There are several ways to make this research even better. First, it may become more effective if trained on a more voluminous dataset based on information obtained from ONET. O*NET (Occupational Information Network) is a public database that is managed by the U.S. Department of Labor and holds information about occupational tasks, skills, work activities, and job requirements for thousands of jobs that may prove extremely useful when building a better model. Furthermore, one may think about developing a web-based tool for risk assessment that would enable users to paste any job description or its title, as well as a link to the job posting, and instantly get an answer. The application should have a user-friendly design and be easily accessible to everybody who needs to know about risks of automation at work.

Conclusion

Artificial intelligence is currently changing how businesses operate, providing an opportunity for automation of certain job duties. Previous academic studies have found that many jobs include duties that can be automated because of their repetitive nature. Expanding on the knowledge obtained by previous studies, the current paper presents a machine-learning job posting analyzer that can assess the risk of automation for particular job postings. The job task automation risk analysis model was applied to a set of 25 occupations representing different industries. Based on the model results, tasks were classified as being either AI-automatable or human-dependent, and respective scores were calculated. It was concluded that jobs including more routine tasks had higher scores, while those that required emotional intelligence or interpersonal interaction scored lower. The results of this study complement previous literature in the field of labor economics, offering a unique perspective on analyzing automation by looking at personalized information rather than industries or occupational categories alone. While there are limitations in the data set used and in the current state of artificial intelligence development, the study highlights the possibility of using natural language processing and machine learning techniques to build useful predictive models. In the end, the results of the study show that the future of work will likely depend not only on technology but also on the unique qualities of human beings, which are difficult to replicate using artificial intelligence.

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The Blueprint of Personality: How Neurological Variation Shapes the Five Universal Personality Dimensions By Nicole Suryadi

Abstract

This literature review synthesizes current research on the neurobiological foundation of personality traits, delving into how variations in brain structure, neural functions, and neurochemical activity contribute to the unique disposition of individuals. Extraversion is associated with heightened sensitivity in the brain's dopaminergic reward system, motivating individuals to seek out social desires and interactions, whereas introversion is linked to higher cortical arousal, defined as a higher sensitivity to external stimuli, and larger volume of grey-matter in the prefrontal cortex. Conscientiousness is correlated with structural differences in the prefrontal cortex, with individuals with higher conscientiousness showing larger volume in the PFC, and enhanced connectivity between executive and default mode networks, supporting structured goal-directed behavior. Rationality is connected to strong prefrontal cortical activity and reduced activity in limbic structures such as the amygdala, reflecting more logical and analytical processing. Neuroticism is associated with increased or inefficient activity in the limbic system, specifically the amygdala and anterior cingulate cortex, as well as higher cortisol release mediated by the hypothalamic–pituitary–adrenal axis, leading to greater emotional reactivity and sensitivity to stress. Lastly, openness to experience is linked to elevated dopaminergic function and efficient interaction between executive and default mode networks, facilitating cognitive curiosity and creativity. To summarize, these findings highlight that a portion of personality is biologically pre-determined by neuroanatomical differences.

Introduction

Is personality biological? Personality traits, which are stable individual differences in behaviors, cognition, and emotion, are assumed to have a neurobiological basis. Research aims to identify the neuronal foundation of human personality, often examining how brain structure, chemistry, and function contribute to these enduring characteristics (DeYoung et al.).

Across psychology, there has been a recurring pattern in how personality is classified. Many personality frameworks, such as the Big Five, Five Factor Model, NEO Personality Model, and typological systems such as Myers-Briggs Type Indicator, organize individuals among similar fundamental dimensions: neuroticism, extraversion, openness to experience, rationality, and conscientiousness (Toledo and Carson). This paper explores how neurological variation and brain chemistry contribute to the development of the five convergent personality dimensions; however, it is important to note that brain chemistry and structure are not the only factors that determine personality — environmental experiences, development, and cultural influences also play significant roles in shaping an individual's characteristics.

Literature review

Introversion and extroversion

This review synthesizes current research investigating the neurobiological connections between specific brain regions and neural networks to the five personality dimensions.

A common misconception about these two traits is that extroverts are simply outgoing and introverts are shy. However, it is more accurate to define extraversion by an individual's engagement with external stimuli, a preference for stimulating activities, and the tendency to gain energy from social interaction, while introversion is characterized by a preference for internal experiences, a more subdued and less stimulating environment, and a tendency to gain energy from solitude (DeYoung et al.).

However, rather than it being two distinct binary traits, introversion and extraversion heavily lie on a scale from extreme introversion to extreme extraversion—meaning people fall on a spectrum with intermediate patterns reflected in gradations of neural activity (Depue and Collins).

One of the most well-established neurological underpinnings of extraversion is its association with the brain's reward system. Extroverts have a more sensitive dopamine system (Depue and Collins). The brain releases dopamine in response to rewarding experiences such as food, sex, and socializing, producing positive emotions and feelings of desire that motivate individuals to pursue these goals (Booker; Watson et al.). This leads extroverts to seek out social experiences and stimulating interactions to maximize reward, excitement, and positive emotions.

Furthermore, Cornell researchers held a week-long study of 70 young adult males, participants received methylphenidate — a dopamine-releasing stimulant — and results showed that extroverts exhibited strong associative conditioning, linking lab cues to rewarding feelings; in contrast, introverts showed little evidence of this effect (Booker). This heightened sensitivity to dopamine-mediated reward cues drives extroverts' approach behaviors and social engagement, showing that they notice rewards more and engage in goal-directed actions more vigorously to obtain them, like socializing (Forsman et al.).

Moving on to brain regions and structures, introverts and extroverts exhibit distinct patterns of cortical arousal. Eysenck's Model proposed that introverts tend to have a higher cortical arousal — defined by sensitivity to external stimuli. This heightened arousal makes introverts more easily overwhelmed by stimulating environments, hence explaining their preference for a less stimulating, quieter, subdued atmosphere. Conversely, extraverts, characterized by a lower baseline cortical arousal, actively seek out external stimulation to achieve an optimal level of arousal (Watson et al.).

Lastly, introverts have been suggested to have greater grey-matter volume in certain regions of the prefrontal cortex compared to extroverts. Grey matter is a major component of the central nervous system — composed of neural cell bodies, dendrites, and unmyelinated axons. Grey matter is associated with abstract thought and decision-making, contributing to the introverts' enhanced cognitive processing and self-reflection, as the prefrontal cortex is crucial for executive functions and internal thought. A neuroimaging study conducted by researchers reported individuals scoring higher on introversion showed greater cortical volume in the

prefrontal cortex (Forsman et al.). In contrast, extroverts had lower grey-matter volume in the prefrontal cortex, which correlates with their tendency for faster, more superficial information processing and active decision-making (Lei et al.).

Conscientiousness

Conscientiousness is defined by a tendency towards self-discipline, orderliness, and the pursuit of goals, reflecting an individual's capacity for impulse control and organized behavior. They can be broken down into two sub-traits: Industriousness which refers to the ability to pursue long-term future goals, and Orderliness which refers to the ability to follow rules (DeYoung et al.). Similar to introversion and extroversion, an individual's conscientiousness lies on a spectrum of low to high.

Conscientiousness covaries with volume in the lateral prefrontal cortex. The prefrontal cortex, particularly the dorsolateral and dorsomedial regions, is central to executive functions: planning, decision-making, working memory, and impulse control. Conscientiousness levels have been positively associated with cortical volumes within the dorsolateral prefrontal cortex in younger cohorts, indicating a neuroanatomical basis for these traits (Rodriguez et al.). A thicker PFC provides greater processing capabilities for complex executive functions, enabling individuals to plan ahead, organize well, prioritize tasks and long-term goals (DeYoung et al.).

Other than its association with the prefrontal cortex, conscientiousness has been linked to the default mode network and the functional connectivity between certain brain regions (Rueter et al.). The DMN, comprising regions such as the medial prefrontal cortex and the angular gyrus, is primarily involved in internal, self-directed thought such as planning or imagining future scenarios — it handles mental simulations of thinking about what you could or should do, processes critical for maintaining long-term goals and organized behavior. Conscientious individuals tend to exhibit stronger functional connectivity or a more coordinated brain network within the DMN (Passamonti et al.). When there is a strong communication between the DMN and executive networks like ECN (Executive Control Network), internal goals can be effectively translated into external, goal-directed actions.

A Goal Priority Network (GPN) fMRI study was conducted to investigate the neural correlates of conscientiousness in a sample of 218 adults. The study examined functional connectivity within and between subcomponents of the GPN. In particular, a subnetwork (ICN-1) comprising the dorsolateral prefrontal cortex (dlPFC), anterior insula, and dorsal anterior cingulate cortex (dACC) demonstrated that higher synchrony within this subnetwork was associated with higher conscientiousness ($r = 0.22$ from a range of -1 to +1), indicating a modest but evident relationship between network connectivity and the trait (Rueter et al.).

Rationality

Rationality is best understood as a derived construct rather than a canonical Big Five trait as it is an intermediate between the Thinking—Feeling dimension used in Cognitive Functions and the Agreeableness trait in Big Five. Rationality is often associated with cognitive control

processes that suppress emotional interference and facilitate deliberate thought. The key components of rationality are the ability to evaluate objectively, make decisions logically, and utilize systematic reasoning. Those with higher levels of rationality tend to prioritize logic over emotions, demonstrating a capacity for dispassionate and objective analysis. Meanwhile, those with lower levels of rationality tend to consider others' emotions more, make decisions based on values, and are more prone to emotional biases.

Neurobiologically, the neural underpinnings of rationality are often investigated through their relationship with brain regions involved in cognitive control, such as the prefrontal cortex, and those associated with emotional processing, like the amygdala. The prefrontal cortex, as mentioned earlier, is known as the executive center, responsible for tasks such as planning, decision-making, working memory, and impulse control (Friedman and Robbins). Because of this, individuals with stronger prefrontal cortical activity generally demonstrate higher levels of rationality.

In contrast, individuals with lower rationality often exhibit greater activity in limbic structures, suggesting a stronger influence of emotional salience on their decision-making processes. The amygdala, in particular, plays a major role for processing emotions — particularly fear and reward, which can lead to decisions driven by immediate emotional responses rather than logical evaluation (Sodhi). While this form of decision-making is not inherently "irrational", it reflects a value-based and emotion-oriented approach, in contrast to the purely utilitarian calculations characteristic of high rationality (Rolls).

According to the Dual-Process Theory, human reasoning operates through 2 interactive systems: System 1, which is fast, intuitive, and emotion-driven, controlled by the Limbic System; And System 2, which is slow, deliberate, and rational, controlled by the prefrontal cortex (Rolls). A popular experiment in measuring the difference between System 1 and System 2 thinking is the Cognitive Reflection test (CRT). The CRT presents 3 questions that trigger an immediate, intuitive answer produced by System 1 that is often incorrect, and a more reflective, analytical answer produced by System 2 (Verweij et al.). One of the questions is, "A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball. How much does the ball cost?" — System 1 triggers an immediate, intuitive answer ($0.10), whereas System 2 enables careful reasoning to reach the correct solution ($0.05). This illustrates the differences in rationality between the two systems.

Finally, emotional sensitivity and agreeableness also influence rationality. Individuals who rely on feeling-based processing tend to show heightened activity in the anterior insula, a region responsible for subjective empathetic responses and emotional awareness — compared to the objective functions of the prefrontal cortex (Gu et al.). Similarly, oxytocin, often referred to as the "bonding hormone", is a neuromodulator in the central nervous system that is responsible for enhancing emotional responses and promoting social bonding (Geng et al.). Together, heightened insula and oxytocin release contribute to a more empathetic, feeling-driven orientation.

Neuroticism

This trait describes the degree of an individual's emotional stability, which refers to a person's ability to remain stable and balanced, and a person's tendency to experience negative emotions, such as stress, anxiety, or worry (Weed and Kwon). However, neuroticism strictly should not be correlated with mental health disorders; it reflects a normal personality dimension, not a clinical diagnosis. Individuals who have low emotional stability levels tend to be more sensitive to stress and more reactive to emotional stimuli, whereas those high in emotional stability levels tend to be more even-tempered and less affected by fluctuations in their environment.

Neuroimaging studies consistently show increased activity and structural variations in the amygdala, anterior cingulate cortex, and other limbic systems, which are at the core of the brain's emotion-processing and reactivity systems (DeYoung et al.). The anterior cingulate cortex, in particular, plays a major role in the brain's emotion-regulation and conflict-monitoring system — including motivation, decision making, and monitoring stress or threat (Stevens et al.). In individuals high in neuroticism, heightened or inefficient ACC activity may intensify emotional reactivity and stress sensitivity, making it more difficult to regulate negative emotions and make decisions under conflict. Similarly, individuals high in neuroticism have altered functional connectivity between the amygdala — the brain's emotional processing center — and frontal networks, which reduces the efficiency of top-down regulation of emotions. This helps explain why these individuals are more prone to anxious or heightened stress responses (Deng et al.).

An fMRI study with 50 healthy female participants grouped them into high and low neuroticism based on the Eysenck Personality Questionnaire. Participants viewed emotional pictures under two motivational conditions: approach (stimuli perceived as moving toward them) or avoidance (stimuli perceived as moving away). Low-neuroticism participants tended to avoid the negative stimuli, whereas high-neuroticism participants tended to approach them. The study found a significant disconnection between the right amygdala and the dorsomedial prefrontal cortex (dmPFC) in high-neuroticism individuals ($t(42) = 5.20$), suggesting weaker top-down regulation of emotion in these participants (Deng et al.).

Neuroticism is also linked to the hypothalamic-pituitary-adrenal (HPA) axis, the body's central stress-response system. They involve three key parts of the body working together: hypothalamus — detects stress and releases corticotropin-releasing hormone (CRH), pituitary gland — responds to CRH by releasing adrenocorticotropic hormone (ACTH), and adrenal glands — respond to ACTH by releasing cortisol, the body's major stress hormone (Cleveland Clinic). This leads to cortisol release, which causes short-term stress response changes in the body — acute exposure potentially improves focus and alertness; however, chronic overexposure can lead to stress-related behaviours, irritability, or anxiety. Individuals high in neuroticism often show heightened HPA-axis reactivity and slower cortisol recovery, contributing to increased emotional volatility, greater susceptibility to anxiety, and stronger response to everyday stressors (Dziurkowska and Wesolowski).

Openness/curiosity

Openness to experience, often linked with curiosity, creativity and intellectual exploration, represents a personality dimension characterized by a willingness to learn new ideas or perspectives. People high in openness enjoy novel conceptual frameworks, imagine possibilities, and engage in abstract thoughts. Meanwhile, those who are low in openness prefer concrete, practical information and established routines, often exhibiting a more conventional cognitive style (Raya et al.).

Neurobiologically, this trait has been linked to differences in dopamine function. Dopamine is known as the "salience coding system" which helps the brain detect novel or meaningful stimuli — dopamine release increases motivation to explore and support cognitive and behavioral processes needed for exploring the environment or ideas (DeYoung). Studies indicate that elevated dopamine levels in the mesocortical dopamine pathways — which connect the midbrain to the prefrontal cortex — are associated with higher openness scores, suggesting a neural mechanism for enhanced cognitive flexibility and divergent thinking (Raya et al.).

Furthermore, openness has been consistently associated with differences in DMN (Default Mode Network) and ECN (Executive Control Network) functional connectivity. The DMN supports self-generated thoughts such as imagination, mental simulation, and semantic integration — functions closely related to creative thinking (Chen et al.). The ECN, in contrast, is responsible for executive functions such as cognitive control, attentional regulation, and decision-making. Research indicates that individuals higher in openness show enhanced DMN-ECN functional connectivity which signifies greater integration between internal thought processes and goal-directed cognition (Raya et al.). This enhanced connectivity is crucial for cognitive exploration, as the DMN generates new internal ideas while the ECN evaluates and organizes them, enabling individuals to generate novel ideas, construct new perspectives, and engage in imaginative pursuits (DeYoung).

A large-scale meta-analysis of ten independent fMRI datasets (N=2433) demonstrated that more frequent switching between DMN-ECN integration and segregation states significantly predicted higher creativity, with seven out of ten of the datasets showing a positive effect. The authors reported a consistent inverted-U relationship, indicating that optimal, not excessive, connectivity switching was associated with the greatest creative performance (Chen et al.).

Conclusion

In summary, current research strongly supports the idea that personality is deeply intertwined with neurobiology. Differences in brain structure, neural networks, and neurochemical pathways contribute to the five universal personality dimensions — extraversion, conscientiousness, rationality, neuroticism, and openness. Across these traits, patterns consistently emerge: dopamine sensitivity shapes reward-seeking and sociability, prefrontal regions support planning and cognitive control, limbic activity influences emotional reactivity, and large-scale networks such as the DMN and ECN enable creativity and future-oriented

reasoning. The variations in brain structures, activities, and networks highlight a biological foundation for personality.

However, while neurochemical and neural variations likely underlie and contribute to the aspects of these Five Universal Personality Dimensions, it does not fully determine the entirety of personality expression, which is profoundly shaped by the psychological and social environment.

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Deepfake Threats and Countermeasures in News Coverage By Emily Subin Yeon

1. Introduction

Recently, artificial intelligence deepfake technology, which is used to synthesize politicians or celebrities into videos around the world, has become an increasingly big problem. In particular, deepfakes are being abused to create fake news, manipulate the media, create riots, and create pornography beyond memes to make people laugh, have simple fun, entertainment, and satire. "Acquaintance humiliation," a crime that involves manipulating and distributing videos targeting acquaintances, shows that deepfakes are becoming involved in serious social problems in the future, as seen in the N Room incident. (Kim et al. 2020)

Deepfake is a compound word of deep learning and fake, and is a technology that uses artificial intelligence to create fake photos, videos, and audio that are difficult to distinguish from the real thing. Recently, it has been used for negative purposes such as producing pornography and defamation, causing social controversy. (Mika Westerlund, 2019)

Deepfake technology has the potential to be used innovatively in various fields such as film, education, and medicine. However, as it has been confirmed that deepfake content existing online is overwhelmingly illegal and pornographic, it is causing a serious problem in that there are increasing cases of abuse for negative purposes. In particular, deepfake technology is now provided as applications and services that can be easily accessed by non-experts, creating an environment in which anyone can abuse it.

In this way, despite the potential for positive use of technological developments, deepfakes are acting as a serious social threat as they are used as a tool for crime, and the role of media reporting on this is becoming increasingly important. News media play an important role in informing the public about the problems caused by deepfake technology and its social impact, and thereby seeking prevention and response measures. In particular, news articles serve as important material in describing the characteristics of deepfake technology, crime cases, and social response measures. (Park Joo-il, 2020) Therefore, this study reviews the definition and operating principles of deepfake technology and analyzes the characteristics of deepfake-related technology as revealed in media reports and major crimes and damage cases that occurred related to it. In addition, by examining ways to prevent and respond to crimes caused by deepfakes in the news, we aim to suggest ways to use deepfakes healthily and safely.

2. Background

Deepfake is a technology that utilizes artificial intelligence to merge images or synthesize videos, creating fake content so sophisticated that it is difficult to distinguish from reality (Mika Westlund, 2019). Deepfake utilizes deep learning technologies such as GANs (Generative Adversarial Networks) or autoencoders; GAN technology is an algorithm that uses AI deep learning to create data similar to the original through iterative execution by pitting a generative model—which aims to create data indistinguishable from the original—against a classification model—which identifies differences from the original—in competition. (Choi et al. 2022)

A portmanteau of "Deep Learning" and "Fake," it first gained attention in 2017 on the American social network platform Reddit when an anonymous user with the ID "Deepfakes" posted obscene videos featuring the faces of celebrities (Rebecca, 2019). There are broadly two types of fake videos generated by deepfakes: face reenactment, which transmits one person's facial expressions or emotions to another person's face, and face replacement, which completely replaces one person's face with another's. (Kim et al. 2020)

While this technology initially required computer graphics or advanced editing skills, the recent popularization of artificial intelligence has made it easily accessible without specialized knowledge. Anyone can create deepfake content using mobile applications and simple software, and the popularization of this technology is particularly increasing the potential for misuse for criminal purposes (Park Ju-il, 2024). Recently, deepfakes have been causing social controversy as they are used for negative purposes, such as the production of pornography and defamation. However, deepfakes, which are currently being misused for criminal purposes, also possess various advantages that allow them to be utilized in diverse fields.

While deepfakes are utilized as an innovative tool in fields such as film, advertising, and healthcare, as mentioned earlier, it is also leading to serious crimes. For instance, with the recent popularization of artificial intelligence, crimes involving the production and distribution of photos and videos capable of causing sexual humiliation without the victim's consent using deepfake technology are rampant. The range of targets and perpetrators is expanding, as evidenced by the case of a high school student who was brought to trial for compositing a real female student's face onto a nude photo and distributing it. (EXT01). According to the "Status of Damage from Deepfake Fake Videos in Schools" released by the Ministry of Education in Korea in 2024, the cumulative number of students affected by deepfakes in South Korea from January to June was tallied at more than 800, demonstrating that deepfake technology is acting as a major social problem in the educational field as well (KBS04). Furthermore, according to data from the National Police Agency in Korea, the number of teenage suspects in 2026 deepfake sex crimes surged from 91 in 2023 to 548 in 2024 and 829 last year. This represents an increase of more than nine times in just three years. Consequently, the spread of deepfake sex crimes has been identified as a particularly serious problem. (EXT23)

According to previous research, deepfake technology has been used as an innovative tool in many industries, including various business sectors such as film, advertising, healthcare, and fashion. As such, despite its potential utility, deepfake technology is accompanied by serious ethical issues and social threats. Previous studies have addressed the fundamental principles and ethical issues of deepfake technology, and some have proposed technical approaches to detect or prevent it (Rana et al. 2022). However, research on specific cases, such as digital sex crimes, and systematic response measures to address them is still lacking. This study aims to fill the gaps in existing research by analyzing actual cases of deepfake technology misuse and its criminal impact, and by proposing prevention and response strategies derived from these findings.

3. Method

News is defined as ‘timely information regarding the interests of many people or the public interest that is distributed through the media.’ Therefore, analyzing the information in news articles is a suitable method for this study. Accordingly, for this study, we utilized news from South Korea’s public broadcasting companies and news articles reported in daily newspapers. To this end, we utilized the BigKinds (https://www.bigkinds.or.kr/) service, which is South Korea’s news analysis service that combines big data analysis technology with article databases provided by the Korea Press Foundation, to collect and provide nationwide news big data. From the 178 articles reported between June 27, 2024, and June 27, 2026, we excluded 34 articles with duplicates or low relevance to select the final 42 articles for the paper from the remaining 115. The keyword was set to “Deepfake,” and only news articles in the category of incidents and accidents were collected as data. The collected data was analyzed to examine the threat of Deepfakes and countermeasures through content analysis. Each cited article was coded and indicated using short symbols. The articles are organized in the order of label name and news title with a link.

4. Result

4.1 Threats

4.1.1 Political Manipulation

Deepfake technology is a product of the advancement of artificial intelligence. While it was initially used for positive purposes such as entertainment and content creation, it has recently been causing serious problems due to invasion of privacy, financial crimes, and political misuse (EXT03). Deepfake videos spread rapidly through digital platforms such as social media and Telegram, causing social unrest. Above all, deepfake technology is so sophisticated that it is difficult to distinguish between reality and fakery, posing a risk of distorting trust by making people believe that falsehoods are true through fake videos. This has been used politically, resulting in instances where candidates' images are manipulated, and misinformation is provided to voters (EXT22).

In fact, ahead of the primary election in New Hampshire, there have been cases where deepfake false content was used to directly or indirectly influence elections, such as President Biden’s voice call encouraging party members to abstain from voting, a video of a famous Indian actor supporting a specific political party, and an audio file of a British Labour Party leader making abusive remarks. Accordingly, discussions on regulating deepfake political content are proceeding in various ways, including amendments to the Public Official Election Act, regulations under the election laws of some U.S. states, and voluntary regulations by companies.

In South Korea, the production and distribution of deepfake videos were banned starting 90 days prior to the election through an amendment to the Public Official Election Act, while in the United States, regulations regarding election campaigns utilizing deepfakes are being implemented under the election laws of some states, such as California and Texas. (Jung, 2024)

Also, A photo of South Korean President Lee Jae-myung and U.S. President Donald Trump taken at the 2026 G7 Summit became part of a deepfake controversy. Some online users claimed that the actual photo was fake, alleging that it was an edited version of a photo of former President Yoon Suk-youl and Trump. However, the truth was the opposite. The photo of President Lee Jae-myung and Trump was real, while the photo of former President Yoon Suk-youl and Trump was a manipulated image. This case has affected people's perception of truth and made it easier for them to spread manipulated political information (EXT24).

4.1.2 Financial Fraud, Impersonation, and Blackmail

In addition, deepfake technology is being exploited for crimes involving the extortion of money (EXT03). Incidents are occurring where the faces of family members or acquaintances are synthesized to create a kidnapping scenario in order to demand money, or where a specific person's face is superimposed onto pornography and distributed. For example, there have been cases where a family member's face was synthesized to make it appear as if they had been kidnapped, and money was demanded from the parents. In particular, famous celebrities and public figures are frequently targeted, which severely damages the victim's privacy and reputation. Deepfake technology is also used to mimic voices for fraud crimes such as voice phishing, and is being utilized as a means to amplify social conflicts, such as the dissemination of false information.

4.1.3 Digital Sexual Exploitation

Sex crimes involving the misuse of deepfake technology are a particularly serious problem, as videos produced without the victim's consent induce sexual humiliation and generate widespread harm (EXT01). South Korea is cited as a major victim of deepfake sexual exploitation worldwide, and the situation calls for an urgent social response, as related complaints are surging. According to the results of a government-wide complaint analysis system released by the Anti-Corruption and Civil Rights Commission on the 21st, an average of 50 complaints related to deepfake sex crimes were received monthly from January to October 2024. This represents an increase of approximately 1.7 times from the monthly average of 30 cases in 2023. Notably, in August of this year, complaints reached 213 cases—a staggering 6.1-fold increase compared to a year ago—due to deepfake incidents centered around university campuses. Recognizing the severity of the situation, the Commission issued a "Complaint Alert" regarding deepfake sex crimes and urgently recommended that relevant agencies strengthen enforcement and punishment, as well as establish a victim protection system. South Korea is known to be the most vulnerable country to deepfake sex crimes globally. According to a 2023 report by the U.S. cybersecurity firm Security Hero, 53% of global victims of deepfake sexual exploitation were Koreans. In particular, Korean singers have become major targets of this crime. The Korean singer who suffered the most damage was exposed to approximately 1,600 instances of deepfake sexual exploitation, with cumulative views reaching 5.61 million. (EXT04)

Deepfake sexual crimes are spreading not only to celebrities but also to ordinary people, including teachers and students, amplifying anxiety over the potential misuse of personal photos.

It was recently confirmed that 11 local council members in Daegu city in South Korea received threatening emails containing obscene material created using deepfake technology. The emails, titled "Important Document," featured deepfake images of the victimized council members superimposed onto the body of a man hugging a woman. The emails contained highly threatening content, such as "I have evidence of your crimes," "You know what kind of impact this will have," and "Contact me immediately." Both the photo and the text were identical to the emails received by the victimized council members on the 13th. It is reported that if the victims replied to the email, the sender demanded cryptocurrency worth $50,000 in exchange for deleting the illegal composite images (EXT10). As deepfake crimes targeting celebrities have been rampant and now local council members have become targets, there are analyses suggesting that the targets could expand to include National Assembly members or high-ranking public officials in the future. Accordingly, it is being pointed out that in addition to strengthening penalties for deepfake crimes and mandating watermarks, measures regarding platforms that serve as distribution channels for deepfake composite images must also be prepared (EXT11).

4.1.4 Youth and School Deepfake Circulation

Furthermore, as the damage from deepfake sexual exploitation spreads to teachers and students, an increasing number of teachers are expressing a desire to have their photos removed from student graduation albums due to growing concerns that they, too, could become victims. A survey conducted by the Korean Federation of Teachers' Associations targeting approximately 3,500 kindergarten, elementary, middle, and high school teachers nationwide revealed that 93% of the responding teachers—that is, 9 out of 10—are concerned about deepfake crimes involving graduation photos. Consequently, 20% stated they do not want to include their homeroom teacher's face in the yearbook, and 15% stated they do not include their teacher's photo in class group photos either (MBC04).

A student A at a high school in Gwangju city in South Korea is suspected of synthesizing obscene images with face photos posted on social media by 20 students from the same school between June and August of the year 2024, and storing the composites on his mobile phone (EXT16).

While "Telegram" is frequently identified as the social media platform where various sexually exploitative materials are distributed, a fact-finding survey conducted by the Ministry of Gender Equality and Family of Korea last July (July 2023) revealed that IDs for "LINE," "Discord," "KakaoTalk," and "Instagram" are also being used (MBC06). One Telegram chat room had approximately 200 participants, and some of them created and shared composite images using photos of teenagers. In another incident, police arrested a man in his 20s who committed secondary harm by directly creating deepfake composites using personal information of victims leaked in a chat room for humiliating acquaintances, and sending these photos. It was

revealed that this man sent the composite images to the victim and even threatened them by making multiple phone calls while hiding his caller ID (KBS03).

4.2 Countermeasure

4.2.1 Technological Response

One method to combat deepfakes is a program that detects fake videos created by deepfakes. The authors of the paper (Rossler et al. 2019) created a Large Scale Facial Forgery Database to help develop algorithms for detecting fake videos created by deepfakes and introduced an algorithm that automatically detects them.

4.2.2 Government Monitoring

The Korea Communications Standards Commission (KCSC) announced that the number of reports, requests for correction, and referrals for investigation has increased in tandem as a result of follow-up measures taken one month after the announcement of the "Comprehensive Measures Against Deepfake Sex Crime Videos." By doubling its monitoring staff to strengthen continuous monitoring of major distribution channels, the monthly number of requests for correction regarding deepfake sex crime videos rose to approximately 1.5 times (2,352 cases) compared to 2023 (1,519 cases). As an additional preemptive measure to prevent the distribution and spread of deepfake sex crime videos, the KCSC initiated a rapid response, including coordinated and linked monitoring, through cooperation meetings and the signing of business agreements with four national victim support organizations, as well as local governments and education offices. Furthermore, the KCSC expects that the compliance rate of target operators with requests for correction will also increase, as it has reiterated the need for voluntary measures regarding deepfake sex crime videos distributed overseas through working-level meetings with global platform operators and letters requesting cooperation. The KCSC has established a foundation for continuous cooperation through the opening of a dedicated channel on Telegram and an initial face-to-face meeting, as well as by activating an additional hotline for constant contact with dedicated staff, regularizing working-level consultations, and engaging in multifaceted cooperation and proactive measures against illegal information. The KCSC once again requested external attention and support, stating that an increase in specialized personnel is urgently needed to ensure the comprehensive measures continue to proceed without setbacks. (EXT19)

4.2.3 Victim Support

Local governments are also recognizing the severity of the deepfake issue and establishing response systems in cooperation with relevant agencies. The Seoul Metropolitan Government, the police, the prosecution, and the Seoul Metropolitan Office of Education held a signing ceremony for a "Joint Response Agreement on Deepfakes for Children and Youth." This marks the beginning of establishing a four-party hotline system. The agencies discussed

immediate deletion and victim support, the development of joint lesson plans, and the operation of preventive education and campaigns. If a crime or victimization is confirmed at a school, the matter will be promptly forwarded to the Seoul Metropolitan Government. Subsequently, rapid support will be provided for the deletion of harmful photos and videos. The City and the Office of Education are promoting the "Stop! Deepfake" campaign. They are also considering installing safety reporting channels on school websites and other platforms. Previously, the City established a hotline with the Korea Communications Standards Commission and operated a 24-hour deletion support system. It also opened a "Deepfake SOS Dedicated Counseling Channel" in a KakaoTalk open chat room. According to the City, 278 cases of victim counseling and reporting have been processed through the Seoul Digital Sex Crime Safety Support Center since its establishment. (EXT20)

4.2.4 Legal Response

The amendment to the Act on Punishment of Sexual Violence proposed by Representative Kim is known as the "Act on Strengthening Punishment for Deepfake Sex Crimes." It establishes provisions to punish individuals who possess, store, or view fake videos of sexual exploitation, such as deepfake sex crimes. This bill was introduced amidst criticism that there is a legal vacuum due to the lack of regulations punishing users of deepfake sexual crimes, even though "deepfake" technology—which uses AI deep learning to superimpose a specific person's face onto another video—has emerged as a serious social problem due to its misuse in sexual exploitation materials. With the bill being discussed and passed in the National Assembly, it is expected that students will realize the severity of deepfake crimes, while awareness will spread that appropriate sanctions and social attention are necessary for rapidly evolving AI technology. (EXT21)

5. Discussion and Conclusion

This study has observed the definition and operating principles of deepfake and analyzed the major crimes and damage cases presented in media reports. The research results indicate that deepfakes cause various social problems, including privacy infringement, financial crimes, and political misuse; in particular, deepfake sexual offenses were identified as the most serious issue causing harm. Proposed countermeasures include the development of deepfake video detection programs and algorithms, multifaceted cooperation and proactive measures against illegal information, the establishment of a foundation for continuous cooperation, the conduct of campaigns, and amendments to the Act on the Punishment of Sexual Violence Crimes to strengthen penalties for deepfake sexual offenses. However, current measures have limitations as they focus primarily on post-crime handling—such as detection, deletion, and punishment—after a crime has already occurred. Furthermore, since deepfake detection technology operates only after the content has already been produced, preventative measures aimed to stop the crime itself remain insufficient. Therefore, proactive prevention measures are necessary, such as nationwide education specifically targeting youth, to deter access to or attempts to access deepfakes.

Furthermore, regarding deepfake cases involving adolescents, while discussions and systems for punishing perpetrators are being strengthened, compensation for victims remains lacking. Since adolescent victims may not easily access compensation procedures due to limited financial resources or legal knowledge, practical support must be established for those in legal and financial blind spots.

In conclusion, as AI technology continues to advance rapidly and deepfake production becomes easier, the corresponding systems and technologies must also evolve agilely. At the same time, we must seek a healthy and safe direction for deepfake utilization by strengthening ethical education for users and establishing clear boundaries regarding what is socially unacceptable.

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Appendix

Label	Translated English Title	Article Link
	Extras	
EXT01	“National Assembly Passes the Deepfake Sexual Crime Prevention Act”	https://view.asiae.co.kr/article/2024111419454938625
EXT02	“Deepfake Sexual Crimes and Our Collapsed Digital Safety”	https://www.ksilbo.co.kr/news/articleView.html?idxno=101411
EXT03	“Deepfakes as a Double-Edged Sword: Preventing Misuse and Finding Proper Uses”	https://www.idaegu.co.kr/news/articleView.html?idxno=482248#google_vignette
EXT04	“TWICE and NewJeans Also Targeted by Deepfake Sexual Crimes: Complaints Rise 1.7 Times in One Year”	https://www.seoul.co.kr/news/newsView.php?id=20241121500138
EXT05	“Man in His 30s Sentenced to One Year in Prison Again in Appeal Trial for Distributing and Stalking in the Inha University Deepfake Case”	https://www.etoday.co.kr/news/view/2421714
EXT06	“Inha University Deepfake Distribution and Stalking Offender Receives Prison Sentence Again in Appeal Trial”	https://www.hankookilbo.com/News/Read/A2024112111250004345
EXT07	“Seoul Police Issue School Bell Warning on Youth Gambling and Deepfakes During Winter Break”	https://www.fnnews.com/news/202411191114159923
EXT08	“Law Firm Daeryun Launches Cybercrime Team to Respond to Deepfake Sexual Crimes”	https://www.ajunews.com/view/20241119100844415
EXT09	“Editorial: Deepfake Threats Targeting Local Council Members Show Anyone Can Become a Target”	https://www.segye.com/newsView/20241118513539#google_vignette
EXT10	“Number of Deepfake Victims Among Daegu Local Council Members Rises to Eleven”	https://www.imaeil.com/page/view/2024111819444956297
EXT11	“Deepfake Damage Spreads Among Local Council Members: Two Cases Also Reported in Busan”	https://www.busan.com/view/busan/view.php?code=2024111816163771597
EXT12	“Increase in Pseudo-Media and the Threat of Deepfakes Require a Rapid Response”	https://www.edaily.co.kr/News/Read?newsId=03260326639087032&mediaCodeNo=257
EXT13	“Three Daegu Dong-gu Council Members Threatened with Deepfakes: ‘We Will Respond Strongly’”	https://www.asiatoday.co.kr/kn/view.php?key=20241118010008902
EXT14	“Did You Commit Prostitution? Deepfake Threats Sent to Thirty Local Council Members”	https://www.chosun.com/national/2024/11/18/ALRMU5G7BZGGRLBMWOQAIDDYGY/?utm_source=bigkinds&utm_medium=original&utm_campaign=new

EXT15	“Undercover Investigations Become Possible for Adult Deepfake Cases as Sexual Violence Punishment Act Passes the National Assembly”	https://www.viva100.com/article/20241115500003
EXT16	“High School Student Referred to Prosecutors for Creating Deepfake Sexual Exploitation Images Using Friends’ Faces”	https://www.hani.co.kr/arti/area/honam/1157618.html
EXT17	“Teenager Creates Deepfake Sexual Exploitation Images Using Photos of Female Peers”	https://www.chosun.com/national/national_general/2024/09/09/LDI2FDMYUNEHJGXOT5QK34C64Y/
EXT18	“Deepfake Abuse Reaches Schools: What Measures Can Stop It?”	https://www.djtimes.co.kr/news/articleView.html?idxno=106390
EXT19	“KCSC Says One Month After Deepfake Measures, Correction Requests Increased 1.5 Times and Investigation Referrals Increased 2.4 Times”	https://v.daum.net/v/20241018112451569
EXT20	“More Than 600 Victims: Government and Local Authorities Rush to Prepare Deepfake Countermeasures”	https://v.daum.net/v/20240911060244081
EXT21	[Top Legislative Award] Kim Han-kyu: “Deepfake Punishment Legislation Is an Example of the National Assembly Fulfilling Its Responsibility”	https://v.daum.net/v/20241128145421782
EXT22	“Deepfakes Threaten the 2024 Election: A War Between Truth and Falsehood”	https://contents.premium.naver.com/maekyung/jobschool/contents/240220141928316op?from=news_arp_article
EXT23	“Teen Deepfake Crime Suspects Increase Ninefold in Three Years… Warning Signs of a Youth Crisis”	https://v.daum.net/v/20260624150351549
EXT24	“Is the Photo of President Lee and Trump Fake? ‘Deepfake’ Becomes a Tool for Social Engineering Attacks”	https://v.daum.net/v/20260626111417107
KBS News		
KBS01	“Gambling Site Organization Worth Four Trillion Won Caught After Hiding Faces with Deepfakes During Gambling Broadcasts”	https://news.kbs.co.kr/news/pc/view/view.do?ncd=8106434&ref=DA
KBS02	“Pornographic Deepfake Threats Reported Against Local Council Members in Gwangju”	https://news.kbs.co.kr/news/pc/view/view.do?ncd=8104760&ref=DA
KBS03	“Two Arrested for Distributing Deepfake Pornography and Committing Secondary Victimization”	https://news.kbs.co.kr/news/pc/view/view.do?ncd=8079025&ref=DA
KBS04	“Over 800 cumulative student victims of ‘deepfake crimes’… 509 reported cases”	https://v.daum.net/v/HDcvuShLSP?f=p&utm
NBC News		
MBC01	“New Deepfake Scam Emerges Using Fake ‘Daughter Kidnapping’ Video for Blackmail”	https://imnews.imbc.com/replay/2024/nwtoday/article/6654114_36523.html
MBC02	“Seoul National University Nth Room Case: Ten-Year Prison Sentence”	https://imnews.imbc.com/replay/2024/nwtoday/article/6651528_36523.html
MBC03	“President Yoon Calls for Strong Response to Digital Sexual Crimes and Strict Punishment for Crimes Against People’s Livelihoods”	https://imnews.imbc.com/replay/2024/nw1200/article/6648301_36486.html
MBC04	“Graduation Albums Without Homeroom Teachers Amid Growing Fear of Deepfakes”	https://imnews.imbc.com/replay/2024/nwtoday/article/6646676_36523.html
MBC05	“Celebrity Deepfakes Detected: Most Sellers and Buyers Are Teenagers”	https://imnews.imbc.com/replay/2024/nwtoday/article/6638413_36523.html
MBC06	“Teenagers Share Sexual Exploitation and Deepfake Content Through Discord”	https://imnews.imbc.com/replay/2024/nw1200/article/6633965_36486.html
SBS news		
SBS01	“Deepfakes Become a Major Industry and Begin to Interfere Seriously in Elections”	https://news.sbs.co.kr/news/endPage.do?news_id=N1007855895&plink=ORI&cooper=ETC
SBS02	“Police Investigate Telegram Corporation for Alleged Assistance in Deepfake Sexual Crimes”	https://news.sbs.co.kr/news/endPage.do?news_id=N1007855895&plink=ORI&cooper=ETC

Creatine Does Not Positively Affect the Performance of Tennis Players: Do Nutritional Supplements Improve Competitive Tennis Performance? By Alman Mogal

Abstract

Tennis is a physically demanding intermittent sport that requires repeated bursts of speed, rapid changes of direction, powerful strokes, and short recovery periods between points. Creatine supplementation is widely used because it can increase intramuscular phosphocreatine stores and support rapid adenosine triphosphate (ATP) resynthesis during short, high-intensity exercise. Although creatine is well supported in resistance training and repeated high-power activities, its tennis-specific benefits remain unclear. This review evaluates peer-reviewed studies on creatine supplementation, muscle performance, sprinting, and tennis-specific outcomes such as serve velocity, groundstroke velocity, and movement performance. Current tennis-focused studies do not show statistically significant improvements in serve speed, forehand or backhand velocity, or sprint performance after creatine supplementation. However, the evidence base is limited by small sample sizes, isolated testing environments, and outcome measures that may not fully represent actual match play. Creatine may still have conditional value for maintaining performance during fatigue, but larger and more sport-specific studies are needed before it can be considered a clearly proven supplement for competitive tennis performance.

Introduction

Tennis is one of the most physically demanding individual sports because it combines short explosive movements, repeated changes of direction, precise stroke production, and sustained concentration over long matches. A player may sprint forward for a drop shot, recover laterally to the baseline, hit a powerful groundstroke, and then repeat the sequence after only a brief pause. Because of this intermittent pattern, tennis places stress on both anaerobic energy systems, which support short bursts of effort, and aerobic recovery systems, which help athletes repeat those efforts across an entire match.

Creatine is a naturally occurring nitrogen-containing compound synthesized from amino acids and stored mainly in skeletal muscle. It is also consumed through foods such as meat and fish and is commonly taken as a nutritional supplement. Creatine is popular among athletes because it can support rapid ATP resynthesis during repeated high-intensity activity, especially when phosphocreatine stores are challenged (Cooper et al.; Wax et al.). In sports that rely on maximal strength, power, and repeated short efforts, creatine supplementation has been associated with improved training adaptations and performance outcomes.

Because tennis requires repeated explosive movements and powerful strokes, it may seem logical that creatine would improve tennis performance. However, tennis performance is more complex than a single strength or sprint test. It depends on timing, coordination, technical skill, tactical decision-making, fatigue resistance, and efficient movement in multiple directions. This review examines whether the known physiological benefits of creatine translate into measurable tennis-specific improvements. Based on the current evidence, creatine supplementation has not

consistently produced statistically significant improvements in tennis-related outcomes such as serve velocity, groundstroke velocity, or sprint performance (Pluim et al.; Op't Eijnde, Vergauwen, and Hespel).

Biological Mechanisms of Creatine

To understand why creatine is used by athletes, it is important to first understand ATP. ATP, or adenosine triphosphate, is the primary energy-carrying molecule used by cells. During exercise, ATP is broken down to release energy for muscle contraction. This process is essential for actions such as sprinting, changing direction, jumping, and swinging a racquet. However, muscles store only a limited amount of immediately available ATP, so ATP must be rapidly regenerated during intense activity.

The phosphocreatine system helps restore ATP quickly. When ATP loses a phosphate group, it becomes adenosine diphosphate (ADP). Phosphocreatine can donate a phosphate group back to ADP through the creatine kinase reaction, helping regenerate ATP during short, high-intensity efforts (Cooper et al.). This system is especially important during brief explosive movements when the body needs energy faster than slower metabolic pathways can provide it. Creatine supplementation can increase muscle phosphocreatine availability, allowing the phosphocreatine system to support ATP resynthesis during repeated bouts of intense exercise (Cooper et al.; Wax et al.). During lower-intensity activity or rest periods, aerobic metabolism helps restore phosphocreatine stores so that the muscles are prepared for the next intense effort. This mechanism explains why creatine is often effective in activities involving repeated high-power output, such as resistance training sets, repeated sprints, or short explosive movements.

In tennis, this mechanism appears relevant because points often require short bursts of movement followed by brief recovery periods. However, tennis is not simply a repeated sprint or weightlifting event. The sport also requires technical precision, coordination through the kinetic chain, stroke accuracy, anticipation, and decision-making. Therefore, the biological plausibility of creatine does not guarantee that creatine will produce measurable improvements in tennis performance.

Creatine and General Muscle Performance

Creatine has stronger evidence in resistance training and muscle performance than in tennis-specific performance. Resistance training requires muscles to work against external loads, such as during squats, leg presses, or bench presses. These exercises involve repeated contractions that consume ATP, making the phosphocreatine system highly relevant. In this context, creatine supplementation can help athletes complete more work, maintain power output, and improve training adaptations over time (Kreider; Wax et al.).

A systematic review and meta-analysis by Burke et al. found that creatine combined with resistance training produced small additional increases in regional muscle hypertrophy compared with resistance training alone. Other research has also linked creatine supplementation with

improvements in strength, power, and repeated high-intensity exercise capacity (Kreider; Wax et al.). These findings help explain why athletes in many sports use creatine as part of their training routine.

Studies of trained athletes also support creatine's general role in repeated power production. For example, research on athletes performing repeated high-power resistance exercises has reported improvements in body mass and muscular power after creatine supplementation (Kreider). These results are relevant to tennis because stronger legs, hips, trunk muscles, shoulders, and arms can contribute to movement efficiency and stroke production. However, improvements in gym-based strength do not necessarily transfer directly to match performance.

This distinction is important. A tennis player may improve strength in a controlled exercise but still show no measurable improvement in serve velocity, groundstroke accuracy, or court coverage. Tennis strokes require a coordinated kinetic chain from the legs through the hips, torso, shoulder, arm, racquet, and ball. A supplement that supports muscle power may be useful in training, but tennis performance also depends on whether that physical capacity can be expressed through precise timing and technique under competitive conditions.

Creatine, Sprinting, and Tennis Movement

Movement is central to tennis performance. Players must accelerate, decelerate, slide or shuffle laterally, recover position, and change direction repeatedly. Straight-line sprinting speed can be useful, but tennis movement is rarely a simple linear sprint. Most points involve short distances, multidirectional footwork, and quick reactions to the opponent's shot.

Creatine may slightly improve some forms of short sprint performance in general athletic contexts. For example, Skare, Skadberg, and Wisnes reported improvements in sprint performance among male sprinters after creatine supplementation. Such findings suggest that creatine can sometimes support explosive movement. However, tennis-specific studies have not shown the same clear benefit.

Pluim et al. studied competitive male tennis players using a creatine loading and maintenance protocol and measured tennis-specific training outcomes, including sprint performance. They found that creatine did not significantly improve 20-meter sprint performance compared with placebo. Similarly, Eijnde, Vergauwen, and Hespel examined elite tennis players and found no meaningful improvement in multidirectional shuttle-running performance after creatine loading. These results suggest that creatine's general effects on explosive exercise may not translate directly into measurable gains in tennis movement.

One reason may be that tennis movement depends more on agility, positioning, reaction time, balance, and change-of-direction skill than on straight-line speed alone. Even if creatine improves lower-body power, that improvement may be too small or too nonspecific to affect how quickly a player reaches the ball during realistic rallies. Another possibility is that existing studies did not fully capture situations where creatine might matter most, such as late-match fatigue or repeated high-intensity movement under competitive pressure.

Creatine and Groundstroke Performance

Groundstrokes and serves are among the most important measurable skills in tennis. Serve velocity, forehand velocity, backhand velocity, and stroke accuracy can influence a player's ability to control points. These outcomes require coordination across the whole body. Power begins with the legs, transfers through the hips and trunk, and continues through the shoulder, arm, racquet, and ball. This sequence is often described as the kinetic chain.

Because creatine can improve power output in some high-intensity activities, it may seem likely that it would increase stroke velocity. However, available tennis-specific evidence does not show a significant improvement. Pluim et al. found that the creatine and placebo groups showed similar changes in serve, forehand, and backhand velocity, with no statistically significant advantage for creatine. Op't Eijnde, Vergauwen, and Hespel also found that creatine loading did not significantly improve serve or stroke performance in tennis players.

These findings suggest that increasing phosphocreatine availability alone may not be enough to improve tennis stroke production. A serve or forehand is not just a strength task. It depends on timing, racquet path, ball contact, rhythm, footwork, and body coordination. If these technical factors are already highly developed, especially in competitive or elite players, the additional benefit from creatine may be difficult to detect. In other words, creatine may support a physical component of performance without producing a visible improvement in the final sport-specific outcome.

Another important issue is fatigue. Many studies measure strokes in controlled conditions rather than after a long simulated match. Creatine might not increase a player's peak serve speed in a fresh state, but it could theoretically help maintain stroke quality during repeated high-intensity points or late in a match. Current evidence has not tested this possibility thoroughly enough to make a strong conclusion.

Individual Differences in Response

Not all athletes respond to creatine supplementation in the same way. Differences in baseline muscle creatine levels, diet, sex, training status, and creatine transporter activity may influence how much creatine an athlete stores and whether supplementation leads to measurable performance changes (Schoch, Willoughby, and Greenwood; Syrotuik and Bell).

Diet is one example. Because dietary creatine is primarily found in animal products, vegetarian athletes may have lower baseline creatine stores and may experience greater increases after supplementation than omnivorous athletes (Lukaszuk et al.; Burke et al.). This means that creatine might affect some tennis players more than others depending on their usual diet. Sex-based differences may also matter. Some research suggests that males and females can differ in resting intramuscular creatine and phosphocreatine concentrations, and that women may experience performance benefits from long-term creatine intake during resistance training (Forsberg et al.; Vandenberghe et al.). However, tennis-specific creatine research has not adequately examined whether male and female players respond differently in match-relevant outcomes.

Training status may further influence results. Elite athletes already have highly developed movement skills, conditioning, and technical efficiency. Because their performance is already optimized, they may have less room for improvement from a supplement than recreational players. This could partly explain why studies involving trained or elite tennis players do not show large effects.

Discussion

The current evidence does not show a statistically significant effect of creatine supplementation on tennis-specific performance. However, this should not be interpreted as proof that creatine has no possible value for tennis players. Instead, the existing research should be viewed as preliminary. Only a small number of tennis-specific studies are available, and many use small sample sizes. Small studies may lack the statistical power needed to detect modest but practically meaningful changes.

A major limitation is the gap between laboratory or isolated performance tests and real match play. Tennis performance is multidimensional. It includes repeated acceleration, deceleration, lateral movement, technical execution, shot selection, emotional control, and decision-making under pressure. Linear sprint tests and isolated stroke-velocity tests provide useful information, but they may not fully represent the demands of competitive tennis. Another limitation is the principle of specificity. Improvements in resistance training or short sprint performance do not automatically transfer to tennis performance. Creatine may help an athlete produce more force or complete more high-intensity work in training, but the athlete must still convert that physical capacity into effective on-court movement and stroke production. Without tennis-specific adaptations, the performance benefit may remain small or undetectable. The timing of fatigue may also be important. Tennis matches can last for hours, and performance often declines gradually through repeated points, rallies, and games. If studies test athletes only in a fresh state or without realistic match fatigue, they may miss the situations where creatine could be most useful. Future studies should examine whether creatine helps players maintain movement quality, stroke velocity, stroke accuracy, and recovery during fatigue-inducing match simulations.

Supplementation protocols should also be carefully controlled. Creatine typically requires a loading phase of about 20 grams per day for five to seven days or a longer period of daily supplementation at about three to five grams per day to increase muscle creatine stores (Cooper et al.; Wax et al.). Studies that use insufficient dosage, insufficient duration, or poorly controlled adherence may underestimate potential effects.

Future research should use larger sample sizes, competitive tennis players, and more realistic tennis-specific testing designs. Useful outcomes would include repeated-sprint ability with short recovery periods, change-of-direction performance, lateral movement efficiency, serve and groundstroke velocity under fatigue, stroke accuracy, and simulated match play. Researchers should also examine whether diet, sex, baseline creatine status, and training level affect

responsiveness. These improvements would provide a clearer understanding of whether creatine can meaningfully enhance tennis performance or mainly support general training adaptations.

Conclusion

Creatine has not been shown to produce significant improvements in a tennis player's performance. The biological mechanisms of creatine occur through the process of ATP production, as discussed earlier in this paper. These mechanisms help explain why many tennis players use creatine. They also help explain why creatine is most effective in exercises that focus primarily on the lower-body muscles, such as the thighs and legs, during resistance training and exercises such as the leg press, which may be important for maintaining tennis performance over the long duration of a match.

Current evidence has not consistently demonstrated statistically significant improvements in tennis performance following creatine supplementation. However, this should not be interpreted as evidence that creatine has no effect on tennis performance. The available literature is limited to only a small number of studies, many of which include relatively small sample sizes. As a result, these studies may lack sufficient statistical power to detect small but practically meaningful improvements. Therefore, the absence of statistically significant differences should be interpreted cautiously, and current findings should be considered preliminary rather than definitive.

A major limitation of the existing research is that many studies rely on performance measures that may not accurately represent the demands of competitive tennis. Several investigations have focused on outcomes such as linear sprint speed or resistance-training performance. While these variables provide useful information about physical capabilities, they do not fully capture the multidirectional nature of tennis movement. Tennis players frequently perform short accelerations, decelerations, lateral movements, and rapid changes of direction during points. Consequently, improvements in straight-line sprint performance or gym-based strength measures may not necessarily translate into meaningful improvements during match play.

Another limitation is the use of highly controlled testing environments that lack ecological validity. Tennis performance is influenced by a combination of physical, technical, and tactical factors. Laboratory-based assessments often isolate a single physical characteristic, such as strength or power, while excluding important aspects of tennis performance, including stroke execution, movement efficiency, and decision-making under competitive conditions. This disconnect may limit the ability of existing studies to detect performance changes that are relevant to actual match play.

Several factors may explain why significant improvements in tennis performance have not been consistently observed. First, the principle of specificity suggests that physiological adaptations do not automatically transfer from one activity to another. Although creatine has been shown to improve performance in repeated high-intensity exercise and resistance training, these benefits may not directly enhance complex tennis movements or overall match

performance. Improvements in muscular strength or power may be insufficient to produce measurable changes in a sport that depends on multiple interacting performance factors.
Second, the performance tests used in current research may not adequately target the physiological mechanisms through which creatine exerts its effects. Creatine increases intramuscular phosphocreatine stores and enhances the rapid resynthesis of ATP during repeated high-intensity efforts. Therefore, its benefits may be most apparent during situations involving repeated explosive actions or accumulated fatigue. If testing protocols do not place sufficient demands on these energy systems, potential performance benefits may remain undetected.
Fatigue may be particularly important when evaluating creatine's effectiveness in tennis. Matches often involve prolonged intermittent activity with repeated high-intensity efforts over an extended period. Under these conditions, creatine may help maintain power output or reduce performance decline rather than improve peak performance. However, many existing studies do not include fatigue-inducing protocols or realistic match simulations, making it difficult to determine whether creatine provides benefits during the later stages of competition.
Future research should address these limitations through larger sample sizes and more sport-specific testing protocols. Studies should recruit trained or competitive tennis players and use established supplementation strategies, such as a loading phase of approximately 20 grams per day for five to seven days followed by a maintenance dose of three to five grams per day, or an equivalent long-term supplementation protocol. Researchers should also use outcome measures that better reflect tennis performance, including repeated-sprint ability, change-of-direction performance, lateral movement efficiency, stroke velocity and accuracy, and performance during fatigue-inducing match simulations. Such approaches would provide a more comprehensive assessment of whether creatine supplementation can meaningfully enhance tennis performance.

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