Title: Decoding state vaccination rates using intelligence quotient, income, and political affiliation

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Abstract:

The objective of the study was to evaluate the risk factors associated with lower COVID-19 vaccination rates in the United States. The study evaluated the effect of red-blue political affiliation, and the effect of the US state's average intelligence quotient (IQ) and per capita income on states vaccination rates. The study found that states with concomitantly lower income along with lower intelligence quotient (IQ) are less vaccinated while the states with higher income have higher vaccination rates even among those with lower intelligence quotients. These findings stayed significant after adjusting for red-blue political affiliation where states with red political affiliation have lower vaccination rates. Further study is needed to evaluate how to stop online misinformation among low-income low intelligence quotient states and whether such an effort will increase overall vaccination rates in the United States.

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Introduction:

Online misinformation surrounding the COVID-19 vaccine is the major obstacle in fighting the coronavirus pandemic. Loomba et al. conducted randomized controlled trials in the UK and the USA, showing how exposure to online misinformation around COVID-19 vaccines affects intent to vaccinate to protect oneself or others. [1] The study found that some sociodemographic groups are differentially impacted by exposure to misinformation than others, and scientific-sounding misinformation was found more strongly associated with declines in vaccination intent. Policymakers are struggling to stop online misinformation while the COVID-19 pandemic is taking thousands of lives worldwide. Though a prior study found that certain socio-demographic groups are more vulnerable to online misinformation, no prior study looked at average state intelligence quotient (IQ) and per capita income as well as political affiliation as risk factors for accepting online misinformation.

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Method:

The US State's percentage of the population fully vaccinated was considered as a surrogate's measure for accepting online misinformation among the mass population in any US state. The US vaccination data were obtained from the NPR website as of the 15th of July 2021 [2]. The State level per capita income for the year 2010 to 2014 was collected from the U.S. Census Bureau data [3], and US State's average IQ scores were obtained from the McDaniel study published in 2006 [4]. McDaniel estimated State IQ from the National Assessment of Educational Progress (NAEP) standardized tests for reading and math (administered to a sample of public school children in each of the 50 states). The means of the standardized reading scores for grades 4 and 8 were averaged across years as well as the means of the standardized math scores for all 50 US states. Thus, State IQ used in this study was estimated using the average of mean reading and mean math scores [4]. The 50 US States 2020 presidential elections results data (red-blue political affiliation) were collected from the Politico website election result map [5]. The red political affiliation was coded as zero and blue political affiliation was coded as 1 for the purpose of the study.

All these five data sets were merged using Python data analysis software. In addition, all IQ, per capita income and state vaccination rates were ranked in order to demonstrate trends in the scatter plot. The US States were ranked 1 to 50 based on the average intelligence quotient (IQ), where rank number 1 was the highest intelligence quotient (IQ) and 50 being the lowest. The US vaccination data were ranked from 1 to 50 where rank number 1 was the highest fully vaccinated state and 50th being the lowest. The State level per capita income was ranked from 1 to 50 as well where rank number 1 was the highest per capita income and 50 being the lowest. The correlation matrix, univariate analysis, and multivariate analysis were conducted using the Stata data analysis software.

Results:

A total of fifty (50) US states were considered in the data analysis. The average US full vaccination rate was 47.5% (±8.5) by July 15th, 2021), the average US population IQ was 100 (±2.71), and the average per capita income was $28,889.

Table 1 shows state's per capita income and income rank are strongly correlated with percent fully vaccinated with correlation coefficients 0.69 and -0.71, respectively. This indicates states average income has a parallel relationship to state's vaccination rates which means vaccination rates increase with increase of income. Again, states intelligence quotient rank and average intelligence quotient were also significantly correlated with percent fully vaccinated with correlation coefficients of 0.45 and -0.47, respectively. This indicates the intelligence quotient has a parallel relationship with vaccination rates which means vaccination increases with the increase of intelligence quotient. The correlation between red-blue affiliation and intelligence quotient were statistically not significant ($p>0.05$) but red-blue affiliation was highly correlated with state vaccination rates and state per capita income with correlation coefficient of 0.77 and 0.59, respectively with a p value of <0.001.

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Table 1: Correlation matrix of the variables used in the analysis: Demonstrating effect of population average intelligence quotient (IQ) and per capita income on percent fully vaccinated.

	Vaccination Rank	% Fully Vaccinated	IQ Rank	Average IQ	Income Rank	Per capita Income	Red-blue Affiliation
Vaccination Rank	1						
% Fully Vaccinated	-0.99 <0.001	1					
IQ Rank	0.45 <0.001	-0.47 <0.001	1				
Average IQ	-0.44 <0.002	0.45 <0.001	-0.98 <0.001	1			
Income Rank	-0.72 <0.001	-0.71 <0.001	0.56 <0.001	-0.55 <0.001	1		
Per Capita Income	-0.71 <0.001	0.69 <0.001	-0.52 <0.001	0.52 <0.001	-0.97 <0.001	**1**	
Red-blue Political Affiliation	-0.78 <0.001	0.77 <0.001	-0.18 <0.21	0.16 <0.26	-0.60 <0.001	0.59 <0.001	**1**

Figure 1 demonstrates there is a decreasing trend of states' populations who are fully vaccinated among populations with lower intelligence quotients (IQ). These lower vaccination rates can be an indication of accepting online misinformation about vaccination among the state with low intelligence quotient (IQ). The association has an R square value of 22.48% which means 22.5% variability of the vaccination is explained by the state population intelligence quotient.

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Fig 1: Scatter plot of percentage of the US states total population fully vaccinated by state rank of IQ scores

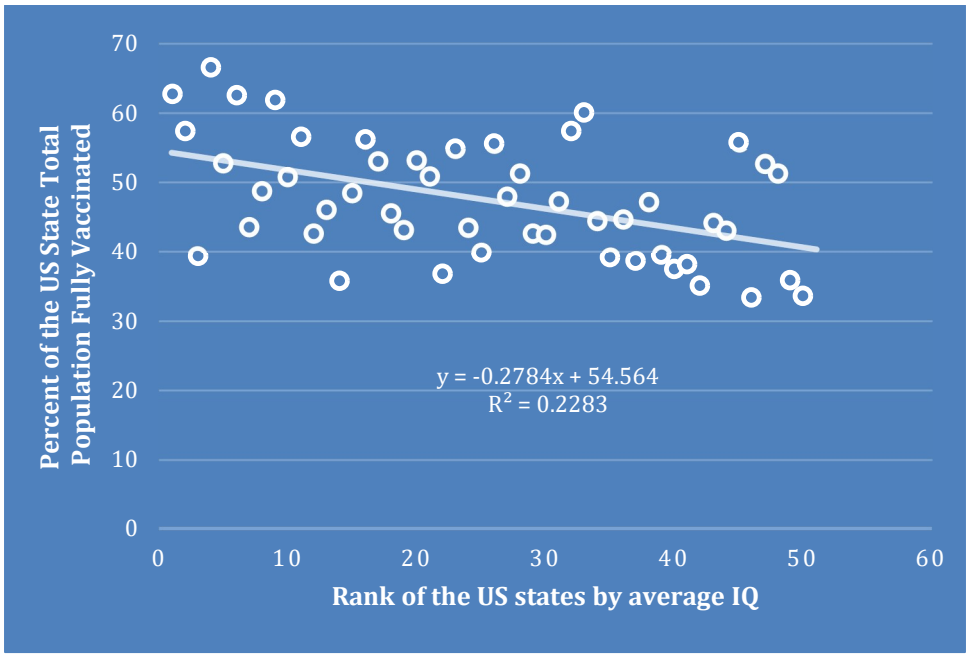

Figure 2 demonstrates there is a decreasing trend of population vaccination rates among the US states among lower-income populations. These lower vaccination rates can be an indication of accepting online misinformation about vaccination among low-income populations. This association has an R square value of 49.9% which means 49.9% variability of the vaccination is explained by income.

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Fig 2: Scatter plot of percentage of the US states total population fully vaccinated by state's rank of per capita income.

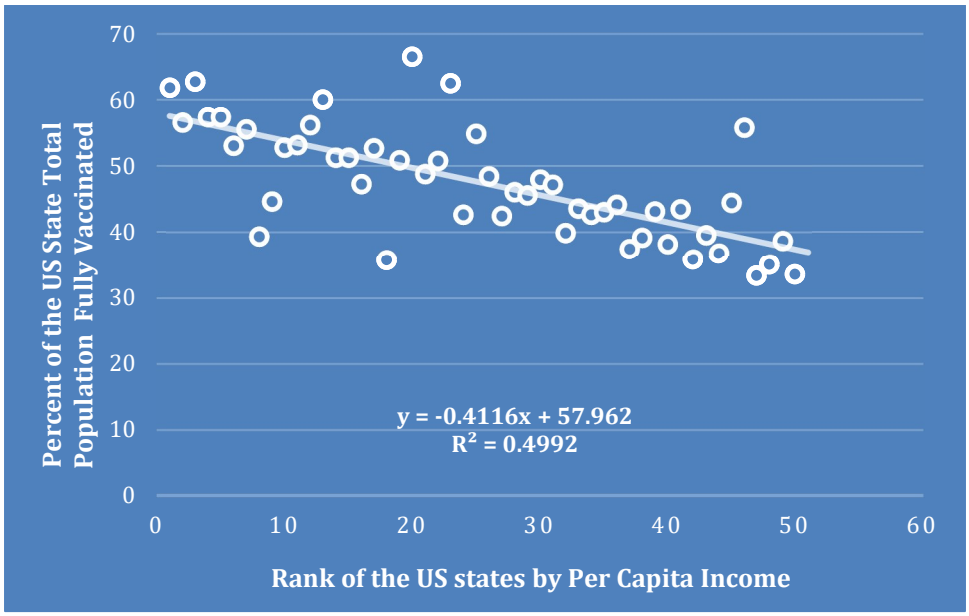
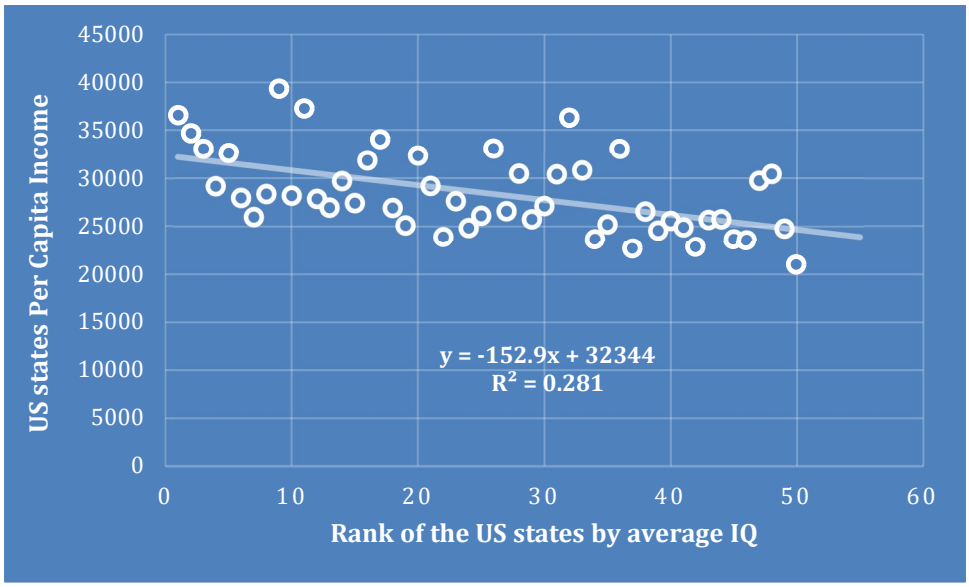


Figure 3 demonstrates there is a decreasing trend of per capita income among populations with lower intelligence quotients (IQ). Previous studies also reported national wealth strongly correlates with its population average IQ scores [6]. According to the current study, the population intelligence quotient explains 28.1% of the variability of the population income.

Fig 3: Scatter plot the US states per capita income by state rank of IQ scores



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A multivariate analysis of the state's percent vaccination was conducted using the independent effect of intelligence quotient, per capita income, interaction effect of average intelligence quotient and per capita income and red-blue affiliation as predictor variables (Table 2). When the effect of average intelligence quotient (IQ) and per capita income was entered in the model, all variables were non-significant. But when the main effect of average intelligence quotient (IQ) and per capita income were removed from the model, the cross-over interaction effect of average intelligence quotient (IQ) and per capita income and red-blue affiliation were found strongly significant. The R square for the final model was 0.70 indicating 70% variability of vaccination was explained by these predictors. This means the effect of per capita income on the vaccination rate is opposite depending on the value of intelligence quotient. These findings were further explained in Table 3. The regression model R square value with only the cross-over interaction effect of average intelligence quotient (IQ) and per capita income was 0.49 indicating the red-blue political affiliation explaining 21% (R square = 0.21) variability of the final model.

Table 2: Regression analysis demonstrating the effect of the product of average intelligence quotient and per capita income on percent fully vaccinated (R square = 0.70).

Variables	Coefficient	Standard Error	Lower Limit	Upper Limit	P-value
Product of Average IQ and Per capita Income	0.71	0.18	0.35	1.06	<0.001
Red-blue Political Affiliation	9.39	1.63	6.01	12.58	<0.001
Constant	22.79	4.69	13.35	32.24	<0.001

Given that this study found a significant cross over interaction effect (opposite effect) of average intelligence quotient (IQ) and income while predicting percent fully vaccinated, the quartiles of the intelligence quotient (IQ) and income were sorted by percent fully vaccinated in Table 3. The study findings show a 38.8% vaccination rate among lowest income quartiles with lowest intelligence quotient group but among the highest income quartiles with highest intelligence quotient the vaccination rates remain highest which was 55.2%. Such a cross over interaction effect showing opposite effects of intelligence quotient (IQ) and income on vaccination rates is a

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very intriguing and unique finding and will be very interesting research topics for state policy makers. This study finding demonstrates that states with a concomitantly lower income and lower intelligence quotient are the most vulnerable and accepting online misinformation regarding COVID-19 vaccination.

Table 3: Demonstrating percentage of full vaccination (accepting online misinformation) by quartiles of intelligence quotient and income

Quartiles	IQ Quartile 1 >102.8	IQ Quartile 2 (100.85 – 102.8)	IQ Quartile 3 (102.8 – 98.6)	IQ Quartile 4 (< 98.6)	Total
Income Quartile 1 (>$30,830)	55.2% (±8.5) n=6	54.2% (±1.8) n=3	54.5% (±6.8) n=4	n=0	54.7% (±6.5) n=13
Income Quartile 2 ($27,546 – $30,830)	54.3% (±10.0) n=5	47.2% (±10.1) n=3	49.3% (±2.8) n=2	52% (±1.0) n=2	51.3% (±8.1) n=12
Income Quartile 3 ($25,229 – $27,546)	44.9% (±1.8) n=2	44.7% (±4.4) n=3	43.1% (±3.6) n=4	43.0% (±4.1) n=4	43.7% (±3.4) n=13
Income Quartile 4 (<$25,229)	n=0	41.2% (±3.8) n=3	41.6% (±4.1) n=2	38.8% (±7.8) n=7	39.9% (±6.3) n=12
Total	53.2% (±8.8) n=13	46.8% (±7.1) n=12	47.7% (±7.1) n=12	42.1% (±7.6) n=13	47.5% (±8.5) n=50

Table 4 shows the following southern states Alabama (AL), Arkansas (AR), Louisiana (LA), Mississippi (MS), South Carolina (SC), Tennessee (TN) and New Mexico (NM) have concomitantly lowest intelligence quotient along with lowest income. These states also have the lowest vaccination rates of 38.8% in the United States.

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Table 4: Demonstrating red-blue political affiliation in 2020 presidential election by group of states by quartiles of intelligence quotient and income.

Quartiles	IQ Quartile 1 >102.8	IQ Quartile 2 (100.85 – 102.8)	IQ Quartile 3 (102.8 – 98.6)	IQ Quartile 4 (< 98.6)
Income Quartile 1 (>$30,830)	CT, MA, MN, NH, NJ, ND	CO, VA, WA	MD, NY, RI, AK	None
Income Quartile 2 ($27,546 – $30,830)	VT, ME, WI, IA, KS	OR, PA, WY	DE, IL	CA, HI
Income Quartile 3 ($25,229 – $27,546)	MT, SD	MO, NE, OH	MI, NC, OK, TX	AZ, GA, NV, FL
Income Quartile 4 (<$25,229)	None	ID, IN, UT	KY, WV	NM, AL, AR, LA, MS, SC, TN

Discussion:

There is a pandemic of COVID-19 among the unvaccinated in the United States. The southern United states of Alabama (AL), Arkansas (AR), Louisiana (LA), Mississippi (MS), South Carolina (SC), Tennessee (TN) and New Mexico (NM) have the concomitantly lowest intelligence quotient along with lowest per capita income and have the lowest vaccination rates of 38.8% in the United States while average fully vaccination rates were 47.5% (on July 15th, 2021). The effect of income and intelligence quotient remains significant even after adjusting for red-blue political affiliation where red political affiliations have significantly lower vaccination rates compared to those of blue political affiliations.

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Online misinformation about COVID-19 vaccination possibly led to lower vaccination rates among many US states. Prior research on misinformation was related to the context of the 2016 US presidential election [7,8]. The current study found lower vaccination rates possibly related to accepting misinformation among the red politically affiliated US states. There is a strong cross over interaction effect of low income and low intelligence quotient indicating states with the lowest income quartiles have lowest vaccination rates (i.e., most affected with online misinformation about COVID-19 vaccination) if they have the lowest intelligence quotient. The study also found the state population with the highest income quartiles does not get affected by online misinformation even when those have a lower intelligence quotient. This is a unique cross over interaction effect and no other study reported similar findings in the past.

The study also found during univariate analysis that income explains almost 50% of the vaccination variability with state's with lower income trends to be less vaccinated. Another univariate analysis showed the states with lower intelligence quotients are less likely to be vaccinated compared to those with high intelligence quotients and intelligence quotients explain 23% of the vaccination variability. Similarly, the red-blue political affiliation of states explains 21% variability in the final multivariate model while the final multivariate model explains 70% variability of the United States vaccination rates.

It is possible that even if certain individuals within the same state have a high intelligence quotient (IQ), they may be vulnerable to misinformation as traditionally such misinformation propagates through their friends, families, and acquaintances in society. Roozenbeek et al. reported that higher trust in scientists and higher numeracy skills (which is the ability to use, interpret and communicate mathematical data, maybe equivalent to intelligence quotient) were associated with lower susceptibility to COVID-19 related misinformation. The study demonstrated a clear link between susceptibility to misinformation and vaccine hesitancy and suggests interventions aiming to improve critical thinking and trust in science may be a promising avenue for future research [9]. It is possible that the socio-demographic group with lower intelligence quotient and income fails to interpret scientific data themself and depends on their trusted news source to understand scientific or mathematical data. This may lead to acceptance of online misinformation leading to lower vaccinations among the population with low income along with low intelligence quotient groups in the United States.

The current study used state average data instead of individual data to find predictors of reduced vaccination which was used as a surrogate measure for accepting misinformation. It is possible that certain geo-political or state population data reflects a more accurate picture than individual data given that misinformation needs a society or group-level enabler in order for the misinformation to propagate across the state.

Conclusion: The southern United States including Alabama (AL), Arkansas (AR), Louisiana (LA), Mississippi (MS), South Carolina (SC), Tennessee (TN) and New Mexico (NM) have the lowest vaccination rates in the United States. The states with concomitantly lower income along with lower intelligence quotient have decreased vaccination rates after adjusting for red-blue political affiliation indicating these states are more vulnerable to online misinformation surrounding

COVID-19. The study also found that states with red political affiliation have significantly lower vaccination rates. Further study is needed to evaluate how to stop online misinformation among lowest income-lowest intelligence quotient states and whether such an effort will increase overall vaccination rates in the United States.

Conflict of Interest: The author has no conflict of interest to disclose.

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