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The Effect of Unobserved preferences and Race on Vaccination Hesitancy for COVID-19 Vaccines: Implications for Health Disparities

Eline M van den Broek-Altenburg[1], Adam J Atherly[1], Stephane Hess[2], Jamie Benson[1]

1 Larner College of Medicine, University of Vermont, Burlington.
2 Choice Modelling Centre and Institute for Transport Studies, University of Leeds, United Kingdom

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ABSTRACT

Background: Reducing the extra burden COVID-19 is having on people already facing disparities is among the main national priorities for the COVID-19 vaccine rollout. Early reports from states releasing vaccination data by race show that White residents are being vaccinated at significantly higher rates than Black residents. Public health efforts are being targeted to address vaccine hesitancy among Blacks and other minority populations. However, health care interventions intended to reduce health disparities that do not reflect the underlying values of individuals in underrepresented populations are unlikely to be successful.

Objective: To identify key factors underlying the disparities in COVID-19 vaccination.

Data sources: Primary data were collected from an online survey of a representative sample of the population of the four largest U.S. states (New York; California; Texas; Florida) between August 10 through September 3rd, 2020.

Study Design: Using latent class analysis, we built a model identifying key factors underlying the disparities in COVID-19 vaccination.

Principal findings: We found that subgroups among Black residents are not hesitant at all.

Conclusions: Results suggest that other factors, potentially institutional, are driving the vaccination rates for these groups. Our model results help point the way to more effective differentiated policies.

Keywords: COVID-19, vaccination rates, vaccine hesitancy, health disparities, individual preference heterogeneity

INTRODUCTION

Reducing health disparities has become a national priority (1-3), especially during the COVID-19 vaccine roll out. On December 14, 2020, the first Americans received a COVID-19 vaccine outside the ongoing clinical trials. As the supply of vaccines is limited, the Centers for Disease Control Prevention (CDC) advisory committee in immunization practices (ACIP) has recommended that initial supplies of COVID-19 vaccine be allocated to healthcare personnel and long-term care facility residents, followed by frontline essential workers and people aged 75 years and older (4). Among their three main goals for who should be offered COVID-19 vaccines, the first is to reduce the extra burden COVID-19 is having on people already facing disparities.

Research has consistently shown that the COVID-19 pandemic is disproportionally affecting those who are in already disadvantaged situations or groups (5, 6). Early data from the COVID-19 pandemic showed that Blacks and Latinos in the US were three times more likely to contract COVID-19 than White residents and nearly twice as likely to die from it (7). This is reflected in initial barriers to vaccine access (8). Early reports also show disparities in vaccination rates; Blacks have been receiving COVID-19 vaccinations at dramatically lower rates than White Americans in the first weeks of the rollout (9). In the states that have released vaccination data by race, White residents were being vaccinated at significantly higher rates than Black residents, in some cases two to three times higher (10). Recent reporting data also showed that the share of vaccinations among Blacks and Hispanics is smaller than their share of deaths in their states, while for Hispanics, it is also smaller than their share of COVID-19 cases(9).

The reason for the differing rates of vaccinations is unclear. The inequality could be caused by structural or systematic racism (11); it could be also be caused by higher vaccine hesitancy among Black and Hispanic communities (12, 13). It has been recommended that health care providers engage with these communities to overcome vaccine hesitancy and provide appropriate public health information (14, 15). But these collective efforts do not acknowledge that vaccine hesitancy can be caused by a myriad of underlying differences among subgroups – or that the difference could be due to factors other than hesitancy. Potential other factors range from easily observable attributes, such as lack of income or education, to attributes that are harder to observe such as effects of structural or institutional racism.

METHODS

Data and Study Design

Our data are based on a survey of a representative sample of the population of the four largest U.S. states (New York; California; Texas; Florida). Respondents were sampled from an online Qualtrics panel from August 10 through September 3rd, 2020, and were representative with respect to the state and U.S. population in terms of age, gender and race.

Participants were asked to imagine a situation where a number of vaccines for COVID-19 had been developed. These vaccines would have undergone all required testing and received regulatory approval for use in humans. They were then faced with six scenarios, or choice tasks, where in each task, two possible vaccines were described with seven attributes:

- Risk of infection: the number out of every 100,000 vaccinated people who would still get infected when coming in contact with an infected person.
- Risk of serious illness: the number out of every 100,000 vaccinated people who, if infected, would develop serious symptoms.
- Estimated protection duration: the expected length of time that the protection provided by the vaccine will last before a new course of vaccination is needed.
- Risk of mild side effects (such as numbness or a rash at the injection site, or a headache): the number of people out of 100,000 that suffer mild side effects from the vaccine.
- Risk of severe side effects (such as an allergic reaction requiring further medical treatment): the number of people out of 100,000 that suffer severe side effects from the vaccine.
- Waiting time: how long people need to wait to obtain the vaccine for free.
- Fee: how much people need to pay to obtain the vaccine immediately.

The vaccines also varied by two key population attributes:

- Population coverage: the share of the population that have already been vaccinated, and;
- Exemption from international travel restrictions: the exemption from COVID-19 related travel restrictions for vaccinated people. This includes quarantine in some countries prior to and/or following travel.

In each scenario, respondents were asked to choose whether to either pick one of the two offered vaccines or choose to not be vaccinated. If they chose one of the vaccines, they would have the option to wait and be vaccinated for free or to pay for immediate vaccination. The levels for the attributes that describe the vaccines that respondents were asked to choose between varied across the choice tasks.

Our initial sample was 475. We excluded observations with an unrealistic pattern of always choosing the option on the left (n=22) and missing demographic information [age, race, income, or education] (n=1) for a final sample size of 452.

Analytic Approach Addressing Health Disparities

Pursuing health equity means pursuing the elimination of health disparities between all groups in a given category [12]. Typical value assessment methods in health, including cost-effectiveness and health outcomes, generally account for health disparities by using observed differences between the most advantaged group in a given category (income, race, et cetera) and disadvantaged groups. Standard analysis of a "representative" sample – including underrepresented populations – yields average effects across the entire population.

There are a number of methodological approaches available that incorporate differences in individual preferences. In particular, notwithstanding extensions to non-linear specifications, the utility for a given alternative (say i) is typically given as a linear in attributes specification, such that:

$$V_{i,n,t} = \beta_n{}' x_{i,n,t} = \sum_{k=1}^{K} \beta_{n,k} x_{i,n,t,k} \quad (1)$$

In this notation, we have that $x_{i,n,t,k}$ is a specific attribute (the k^{th} attribute out of K) of alternative i, as seen by person n in choice situation t. The parameter $\beta_{n,k}$ captures the marginal utility for person n in response to this attribute. Imagine for example that attribute k relates to the efficacy of a vaccine. We would then expect that $\beta_{n,k}$ is positive, i.e. that, as efficacy of a vaccine increases, so does its utility. The subscript n on $\beta_{n,k}$ reflects the fact that different individuals will have different sensitivities to changes in the attributes.

In the simplest type of random utility model, the Multinomial Logit (MNL) model, which serves as the starting point for what follows, the probability of person n choosing option i in task t is given by:

$$P_{n,t}\left(i \mid x_{n,t}, \Omega \right) = \frac{e^{V_{i,n,t}}}{\sum_{j=1}^{J} e^{V_{j,n,t}}}, \tag{2}$$

where Ω groups together the different model parameters. Returning to the above example of efficacy increasing for vaccine i (out of J vaccines), this would imply that $V_{i,n,t}$ increases too, and as a result, the probability of person n choosing that vaccine, becomes larger.

In the simplest approach, interaction terms can be used to allow differences in preferences across different groups. As long as the differences in preferences relate to differences in observed decision maker characteristics, this will be an effective approach.

A subtler problem is the inclusion of unobserved preferences. Mixed Logit models rely on using continuous statistical distributions to represent unobserved heterogeneity.

Unobserved factors that affect preferences such as personality traits (e.g. extraversion) [13], personal values such as universalism, spirituality, moral values, [14], distressing uncertainty, emotional distress, or religious affiliation or beliefs are often ignored, although there are models available that can account for such differences. For example, “mixed” multinomial logit models (MMNL) allow variation in preferences based on both observed and unobserved characteristics. Applications of MMNL in health include, but are certainly not limited to, estimating switching costs for health insurance[15], analyzing patient preferences for provider choice [16], and analyzing patients' responsiveness to quality when choosing hospitals. There have also been numerous studies using MMNL models to analyze preferences for specific treatments or health services, such as for diabetes care [17], men's preferences and trade-offs for prostate cancer screening and patient preferences for managing asthma [18].

A different approach is to use discrete (rather than continuous) distributions and probabilistically segmenting a sample population into different segments, such as Latent Class Analysis (LCA). In a model with S different *classes*, each class would then be characterised by a different vector of parameters, say Ω_s for class s. This could for example capture the existence of one class of individuals who are particularly sensitive to efficacy, while another class is more sensitive to side effects. If we knew with certainty that person n falls into class s, then the choice probability would simply be given by $P_{n,t,s}(j \mid x_{n,t}, z_n, \Omega_s)$, where this would be given by Equation (2) when using an underlying MNL model inside each class. However, the actual class allocation is not observed deterministically, and a LC structure consequently uses a class allocation model, where respondent n belongs to class s (out of a total of S classes) with probability $\pi_{n,s}$, where $0 \leq \pi_{n,s} \leq 1 \; \forall k$ and $\sum_{s=1}^{S} \pi_{n,s} = 1, \forall s$.

These class allocation probabilities can vary across individual decision-makers as a function of their observed characteristics, i.e. $\pi_{n,s} = h(z_n, \gamma)$, where γ is an additional vector of estimated parameters, and z_n are characteristics of the decision maker. Returning to the above example, this model component might, for example, explain that patients with pre-existing health conditions are more likely to fall into the class that is more sensitive to side effects, while respondents with higher education levels might be more likely to fall into the class that is more sensitive to efficacy.

In contrast with the simple MNL model, the log-likelihood function uses a weighted average across separate sub-models (one for each class), with the weights given by the class allocation probabilities, such that:

$$LL(x, z, \Omega, \gamma) = \sum_{n=1}^{N} log \sum_{s=1}^{S} \pi_{n,s} \left[\prod_{t=1}^{T} P_{n,t,s}(\mathrm{Y}_{n,t} \mid x_{n,t}, \Omega_{\mathrm{s}})\right] \quad (5)$$

where this is now also a function of the vector of parameters γ used in the class allocation model, and where $\Omega =< \Omega_1, \dots, \Omega_S >$, and where $Y_{n,t}$ is the observed choice for person n in task t.

LC models capture both observed and unobserved heterogeneity in preferences and are relatively new in health [19]. LCA has been used to examine differential health preferences such as pharmaceutical preferences [20, 21], physician preferences [19, 22], patient-centered care [23], to differentiate language used in palliative care consultations [14], and specific treatments or diseases such as tuberculosis infection preventive treatment [24], community pharmacy asthma services [25] and HPV vaccines among adolescent girls [26].

Traditionally, subgroup analysis in health aims to determine heterogeneous treatment effects. In many applications, the subgroups will be homogeneous in their response, but it is possible to also allow for further heterogeneity within a class. Crucially, membership in the subgroup may differ by health disparities. For example, there could be a subgroup of individuals who are hesitant to receive a COVID-19 vaccine. That group will act similarly – not based on health disparities – but membership within the group could be more likely for disadvantaged populations [27]. The application of these methods in health can be valuable to support policy development and clinical practice, especially to account for individual drivers of health disparities.

The key analytic problem is thus the need to include in our model unobserved factors that affect preferences. To do this, we used a Latent Class Analysis (LCA), which addresses the issue of unobserved preferences by probabilistically segmenting a sample population into different groups or "classes".

RESULTS

Vaccine Hesitancy

Overall, 15.7 percent of respondents indicated they would not accept a COVID-19 vaccine, either because of attribute levels or regardless of its attributes. Of these, 14.7 were White and 2.4 percent were non-White (1.3 percent Blacks, 0.5 percent mixed race and 0.5 other). Of Black residents in the sample, 10.9 percent were in this group completely unwilling to consider a vaccine, regardless of any other factor. Of White respondents, 16.8 percent would not consider a vaccine, a higher proportion than among Blacks.

Of the 10.9 percent of Blacks who indicated they would not consider a vaccine, 60 percent said that vaccines will need to go undergo more testing before they would trust them, 20 percent said “I prefer obtaining immunity naturally without vaccination” and 20 percent “I do not believe in the benefits of vaccination.” These motivations are different among Whites, where 37.7 percent answered vaccines would need to undergo more testing; 31.1 percent said they preferred obtaining immunity naturally without vaccination; 11.5 percent said they do not believe in the benefits of vaccination; 6.6 percent said the options offered were not good enough compared to not being vaccinated; 3.3 percent said that “enough people will accept vaccination so I will benefit from herd immunity” and 9.8 percent had some other reason.

The 15.7 percent of respondents who indicated they would not accept a COVID-19 vaccine were excluded from the analysis.

Sample Characteristics

Table 1 reports the sample characteristics for gender, age groups, race, income, education, smoking status, whether or not respondents had a chronic condition, their smoking status, drinking status and whether or not they were more likely to take risks than others (self-assessed) among those who indicated a willingness to consider a vaccine.

Our sample included 50.6 percent females; 21.1 percent of respondents aged under 30; 17.8 ages 31-40; 29.2 percent aged 41-50; 12.4 percent aged 51-60 and 19.4 percent aged above 60. In our sample, 76 percent of respondents were White and 24 percent non-White; of which 9.6 percent were Black, 5.7 percent Asian, 4.7 percent Mixed and 2.6 percent ‘other’. We compared sample characteristics to U.S. Census data using chi square tests and we found that the sample was representative at the 5 percent significance level for gender, age, race and education.

Latent Class Analysis

The latent class analysis showed that three was the appropriate number of classes to fit our data. The model probabilistically segmented respondents into a class with an overall preference for the paid vaccine options (Class 1); a class dominated by respondents who were most likely to choose the no vaccine option (Class 2) and a class that highly valued the free vaccine options (Class 3). Class 1 thus predominantly represents "anxious" individuals, class 2 the "evaluative" individuals and class 3 the "cost-conscious" individuals.

Table 2 reports the predicted vaccine take-up based on the 3-class Latent Class Analysis, overall and by race. The results show that approximately 11% of the overall sample that would consider a vaccine would ultimately choose to forgo vaccination once they considered potential side effects, while 60% would accept a vaccine but would be unwilling to pay even $100 for it and 30% would like immediate access and would be willing to pay for quicker access. There was little difference in the proportions across races, except that whites reported a lower overall willingness to vaccinate.

Table 3 presents a more nuanced breakdown by class. In Class 1 ("Anxious"), 62 percent of respondents preferred a vaccine option that would require them to pay a fee, but not wait. In Class 2 ("Evaluative"), 52 percent of respondents chose the "no vaccine" option most often, meaning that they did not like the other options[1] given to them. In Class 3 ("Cost-Conscious"), 89 percent of respondents preferred vaccine options that were given for free, but with a wait time.

Table 3 also shows predictions of class membership based on socio-demographic characteristics and class differences from the survey sample mean[2]. We found that there are 8 percent more Blacks in Class 1 ("Anxious"), compared to the sample mean, but 2 percent fewer in Class 2 ("Evaluative")and 5 percent fewer in Class 3 ("Cost Conscious"). In other words: relatively more Blacks prefer vaccine options with a fee but no wait time and fewer Blacks prefer free vaccine options with a wait time or no vaccine options.

The opposite is true for Asians: there are 10 percent fewer Asians in Class 1 ("Anxious") then the sample mean, 42 percent fewer Asians in Class 2 ("Evaluative") and 24 percent more in Class 3 ("Cost-Conscious"). There are thus relatively more Asians than the sample average to prefer free vaccine options with a longer wait time or no vaccine. We found a similar pattern for respondents with mixed or other race.

Table 4 reports the results of the latent class model including interactions with socio-demographic characteristics in the class membership model[3]. We found that non-Whites in Class 2 ("Evaluative" -- the class with and overall preference for no vaccine) were less

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[1] This is after we deleted respondents from the analysis who had stated that they were unwilling to consider any vaccine option at this time.

[2] To get a better understanding of the socio-demographic make-up of individual classes, we used posterior analysis to produce a membership profile for each class.

[3] LCA explores deterministic heterogeneity by incorporating explanatory variables as multiplicative interaction terms .

likely to choose an option that involved paying a fee than Whites within that class. We also found that non-Whites in Class 2 (“Evaluative”) were significantly less likely to shift to an option with a longer wait time. In other words: non-Whites in Class 2, the class with the strongest overall preference for the no vaccine option, were less willing to pay and less willing to wait for a vaccine than Whites within that class.

Household income was considered as income elasticity for cost (fee) sensitivity, with a separate interaction for missing data for income. We found that those with a higher income (>$75,000) in Class 2 were less likely to be sensitive to changes in the fee for a vaccine. Respondents aged above 60 in Classes 2 and 3 were more sensitive to the risk of illness attribute than those under 30, and non-Whites were also more sensitive to this attribute than Whites in Classes 2 and 3. We also looked at whether non-Whites were also more sensitive to mild side effects, the risk of infection and duration of protection with a vaccine, but we found no significant difference with Whites in those classes.

Preference Order

Respondents in the survey were also asked to select reasons for getting a COVID-19 vaccine. Figure 1 shows the reported reasons for getting vaccinated, by race. Overwhelmingly, respondents across all races answered first “to protect myself. This was followed by “to protect my family” and “protect the general public”, although fewer Blacks picked this answer than Whites, Asians, Mixed and other races. Fewer Blacks than others also picked “because it was recommended by public officials” and “because it was recommended by doctors”. They were more likely to choose “because it was recommended by family” as a reason to get vaccinated.

DISCUSSION

In this study, we sought to understand low vaccination rates among racial minorities. Overall, we found that individuals who identify as Black had lower rates of vaccine hesitancy than those who identify as White. This was true overall, by latent class and within latent class. This suggests that, contrary to what is currently being reported, Blacks are not universally more vaccine hesitant. Combining the respondents who would not consider a vaccine (17%) with those who would consider one but ultimately choose not to vaccinate (11%), our findings indicate that more than 1 in 4 (28%) persons will not be willing to vaccinate. The no-vaccine rate is highest in Whites and lowest in Blacks.

This finding initially seems contrary to the widely reported lower vaccination rates for Blacks. But what this study shows is that Black Americans, holding other factors constant, are more likely to vaccinate than White Americans. Yet other factors are not constant. Vaccine hesitancy varies by many other factors, including age, income and education. Class 2 ("Evaluative" – the highest "No Vaccine" class) membership is higher among those between ages 41 and 60, lower income (under $20k per year) and, particularly, lower levels of education. The lower actual rates of vaccine hesitancy among Blacks are thus not necessarily a reflection of perceptions of racism, but rather reflect differences in preferences by income and education that cut across races, with Black Americans more likely to be in these low SES groups. Blacks, then, are simply more prevalent within the already hesitant subgroups. Thus, to increase vaccination rates among Blacks, it will be necessary to focus attention on reasons for hesitancy among persons with less education and lower incomes.

This research also shows that grouping non-whites into broad categories like "Persons of Color" misses important differences among different racial groups and elements of identity intersectionality. Asians were far less likely to be in the Evaluative class and far more likely to be in in the Cost-conscious class. The preference structure for Asians is markedly different than for Blacks.

One limitation of the segmentation analysis is that, due to sample size, we were only able to measure "non-White" effects within classes so we cannot report the effect of Blacks within classes. The analysis thus assumes homogeneous preferences among non-Whites for the within class analysis. It also does not take into account differences in ethnicity. However, the (posterior) class profile analysis shows that Blacks generally prefer vaccine options without a wait time, while other races represented in our sample had overall preferences for "no fee" options or "no vaccine" options". This suggests that Blacks within Class 2 may be even less willing to wait and less willing to vaccinate as the effects measured may be partly offset by the preferences of other non-White respondents. Another potential limitation is that some of the racial effects may be modified by income and education. Given the distribution of income, more work needs to be done to separate racial and income disparities.

CONCLUSIONS

Lower rates of vaccination among Black Americans do not reflect lower rates of racially motivated vaccine hesitancy. Instead, these lower rates reflect a higher proportion of Blacks among groups with vaccine hesitancy – lower income and lower educated individuals. To reduce racial disparities in vaccination rates, it will be necessary to address vaccine hesitancy more broadly in disadvantaged populations.

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Table 1. Sample descriptive statistics

	Population	**Sample Mean (N=387)**
Sex		
Male	49.2%	191 (49.4%)
Female	50.8%	196 (50.6%)
Age (years)* **		
Under 30	22.9%	82 (21.2%)
31 - 40	17.1%	69 (17.8%)
41 - 50	15.8%	113 (29.2%)
51 - 60	16.7%	48 (12.4%)
Over 60	27.5%	75 (19.4%)
Race**		
White	76.3%	294 (76.0%)
Black	13.4%	37 (9.6%)
Asian	5.9%	22 (5.7%)
Mixed	2.8%	18 (4.7%)
Other	1.6%	10 (2.6%)
Prefer not to say / missing[a]	--	6 (1.6%)
Income (USD)		
Less than $20K	13.1%	56 (14.5%)
$20K - $40K	15.9%	72 (18.6%)
$40K - $75K	24.6%	89 (23.0%)
More than $75K	46.4%	155 (40.1%)
Prefer not to say / missing[a]	--	15 (3.9%)
Education***		
None[a]	0.3%	0 (0%)
Less than high school	10.3%	4 (1.0%)
High school graduate / GED	28.3%	137 (35.4%)
Associate's degree	9.8%	71 (18.3%)
Bachelor's degree	21.3%	114 (29.5%)
Professional / graduate degree	12.0%	61 (15.8%)

Smoking Status**		
Not a smoker	86%	309 (79.8%)
Current smoker	14%	78 (20.2%)
Health Status		
No chronic health conditions		252 (65.1%)
Chronic health conditions		135 (34.9%)
Risk-taking Behavior		
I don't take more risks than others		138 (35.7%)
I take more risks than others		249 (64.3%)
Physical Health Pre-COVID		
Excellent		61 (15.8%)
Very Good		133 (34.4%)
Good		131 (33.9%)
Fair		53 (13.7%)
Poor		9 (2.3%)

Table 2: Predicted Vaccine Uptake

Vaccine Uptake	No Vaccine	Wait for free vaccine	Pay for Immediate Access
LCA all data	10.6%	59.9%	29.5%
By race			
White	11.8%	59.2%	28.9%
Black	7.6%	62.6%	29.8%
Asian	7.6%	62.4%	30.0%
Mixed	7.5%	62.4%	30.1%
Other	12.0%	58.6%	29.4%*

Table 3: Socio-Demographic Make-Up of Individual Classes

	Latent Class Difference from Sample Mean (Posterior Estimation)		
	Class 1: Anxious	**Class 2: Evaluative**	**Class 3: Cost-conscious**
No Vaccine	1.2%	51.5%	4.1%
Wait for free vaccine	36.8%	36.2%	89.3%
Pay for Immediate Access	61.8%	12.3%	6.6%
Sex			
Male	--	--	--
Female	-4%	-7%	6%
Age (years)***			
Under 30	26%	-2%	-20%
31 - 40	-29%	-18%	30%
41 - 50	-6%	18%	-2%
51 - 60	3%	7%	-5%
Over 60	5%	-13%	1%
Race**			
White	0%	7%	-2%
Black	8%	-2%	-5%
Asian	-10%	-42%	24%
Mixed	-10%	-8%	11%
Other	1%	-33%	11%
Prefer not to say / missing[a]	41%	-97%	3%
Income (USD)			
Less than $20K	13%	21%	-18%
$20K - $40K	40%	-31%	-21%
$40K - $75K	-19%	-21%	23%
More than $75K	-14%	17%	5%

Prefer not to say / missing[a]	--	--	--
Education* **			
None[a]	--	--	--
Less than high school	-96%	193%	5%
High school graduate / GED	14%	-11%	-7%
Associate's degree	2%	4%	-3%
Bachelor's degree	-1%	-10%	5%
Professional / graduate degree	-26%	25%	11%
Smoking Status**			
Not a smoker	--	--	--
Current smoker	4%	-14%	2%
Drinking Status			
Not a drinker	--	--	--
Current drinker	-24%	11%	16%
Health Status			
No chronic health conditions	--	--	--
Chronic health conditions	2%	-34%	11%
Risk-taking Behavior			
I don't take more risks than others	--	--	--
I take more risks than others	3%	-9%	1%
Physical Health Pre-COVID			
Excellent	-17%	61%	-9%
Very Good	4%	24%	-12%

Good	0%	-33%	12%
Fair	12%	-54%	10%
Poor	-6%	26%	-4%

Table 4. Latent Class Nested Logit Models with interactions

Model description	**LC-NL, 3 classes, with interaction**		
Number of individuals	387		
Number of observations	2322		
Estimated parameters	51		
Log Likelihood	-2968.62		
Parameter	**Class 1**	**Class 2**	**Class 3**
ASC: Position	0.127** (0.047)	0.028 (0.048)	0.054 (0.042)
ASC: Free Option	0.894 (0.83)	-1.217** (0.533)	0.245 (0.437)
ASC: Paid Option	2.148** (0.821)	-1.79** (0.603)	-1.675*** (0.489)
ASC: No Vaccine	--		
Risk of Infection	-0.023 (0.039)	-0.013 (0.039)	-0.161*** (0.037)
Risk of Illness	-0.071*** (0.02)	-0.044* (0.025)	-0.077*** (0.02)
Unknown Protection Duration	--	0.097 (0.206)	--
Protection Duration	0.017*** (0.004)	0.001 (0.004)	0.022*** (0.004)
Mild Side Effects	0.013 (0.019)	-0.026 (0.02)	--
Severe Side Effects	-15.751 (10.367)	-29.487* (16.156)	-35.872*** (10.756)
Wait Time (months)	-0.006 (0.012)	-0.026** (0.013)	-0.013* (0.008)
Fee (USD)	-0.003*** (0.001)	-0.002* (0.001)	-0.003** (0.001)
Population Coverage (%)	0.028 (0.026)	0.008 (0.005)	0.021 (0.013)
Lambda: Vaccination Nest	--	0.502** (0.195)	--
Exempt Status from Travel Restrictions * No Recent Travel	--	--	--
Exempt Status from Travel Restrictions * Recent Travel	-1.273 (1.138)	-0.027 (0.34)	0.294 (1.182)

delta	--	-0.723*** (0.186)	0.295* (0.165)
Fee * Non-White Status	--	-0.908** (0.753)	1.785 (0.934)
Risk of Illness * 60 < Age	--	1.299 (0.47)	0.932 (0.384)
Risk of Illness * Non-White Status	--	1.498 (0.735)	0.954 (0.486)
Severe Side Effects * Non-White Status	--	0.129 (0.57)	0.032 (0.695)
Wait Time * Non-White Status	--	-1.047** (0.802)	4.057 (3.277)
Lambda: Fee * Income	-0.127* (0.072)		
Fee * No Reported Income	1.727 (0.816)		

Figure 1: Reasons for getting vaccinated, by race