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Vaccine hesitancy and monetary incentives

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Vaccine hesitancy is a significant barrier to reaching herd immunity and exiting the Covid-19 pandemic. This study examines the potential effectiveness of monetary incentives in conjunction with informational treatments about vaccine efficacy, lack of side effects, and zero costs. We elicit monetary valuations (both positive and negative) for the coronavirus vaccine by conducting an online randomized experiment on a representative sample of 2461 individuals across the US. The study elicits vaccination uptake, then participants' valuations (willingness to pay (WTP) or the willingness to accept (WTA)) for the vaccine based upon the stated choice of participants to accept or reject the vaccine. We find that a $1000 incentive increases vaccination uptake up to 86.9%. We identify two distinct segments among the vaccine hesitants—"Reluctants" and "Unwillings". Reluctants can be persuaded to vaccinate for some level of monetary incentive, whereas Unwillings indicate that no amount of monetary incentive will persuade them to vaccinate. The Unwillings are more likely to (a) think that the disease is insufficiently severe, (b) have less faith in the public health system, (c) be older, compared to the Reluctants.

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Introduction

Herd immunity is necessary for the world to exit the coronavirus pandemic, which occurs when enough people in the population develop antibodies to the virus such that it cannot spread further (Fine et al., 2011). Deploying safe and effective vaccines is the best strategy to achieve herd immunity and flatten new infections and mortality (Kissler et al., 2020; Piraveenan et al., 2021). Epidemiologists' best assessments are that a herd immunity threshold (HIT) of 75 to 90% of the population needs to be vaccinated for Covid-19 (Anderson et al., 2020); however, there is a significant gap between the current uptake and the threshold needed due to vaccine hesitancy (Lazarus et al., 2020). Recent polls indicate an improvement from those done early in the pandemic, but still show that only two thirds of the U.S. population are willing to take the vaccine (Malik et al., 2020; Lazarus et al., 2020). Even among front-line workers who are most at risk of catching the virus, significant vaccine
Q1 −Q6 hesitancy is observed (Shalby, 2020).

This gap is cause for concern for numerous reasons: (i) new variants of the virus, which may be more infectious and deadly, circulate amongst people that are unvaccinated, prolonging the pandemic (Davies et al., 2021), (ii) due to heterogeneity in vaccination rates across geographic regions, the average uptake needs to be substantially higher than the HIT. The need for higher uptake is further amplified by heterogeneity in the immune response to vaccination across different sub-populations (based on age, obesity and the prevalence of metabolic related disease) within geographic regions (Markovic et al., 2021). Even by achieving the HIT within a geographic area, there are likely to be substantial pockets of vulnerable groups further allowing the virus to mutate (iii) to date, vaccination plans in most countries do not include the vaccination of children who make up a significant fraction 15% of the population (in 2019, 14.6% of the US population was <12 years old). The unvaccinated population of children is a potential segment where the virus may continue to spread. (iv) finally, the effectiveness of the approved vaccines is not 100%. The vaccines with the highest efficacy are 95% and many of the approved vaccines (Johnson & Johnson and AstraZeneca) have efficacy of ~70%. Assuming a value of 80% HIT, the vaccination rate would have to be 84.3% if the entire population took the most efficacious vaccine. However, if 65% of the administered vaccines are Pfizer and the remainder are Johnson and Johnson, a vaccination rate of 93% is needed to reach the HIT. The gap between the intention to vaccinate and the vaccinations required to reach the HIT is large. Effective strategies are needed to increase the rate of vaccination quickly. The alternative is a never-ending pandemic fueled by the appearance of variants, which may be more contagious than the original virus.

We identify individuals who are unwilling to take the vaccine initially, and examine possible mechanisms to overcome vaccine hesitancy. First, we examine the importance of information about the vaccine cost, efficacy, and the lack of side effects in countering vaccine hesitancy. Second, we elicit the monetary willingness to accept the coronavirus vaccine (WTA) among those who answer "no" to the uptake question. We find that the high efficacy and the no side effects informational conditions increase uptake modestly (from 70 to 75%), whereas the free condition does not have a significant effect.

Using our WTA elicitation, we show that monetary incentives can significantly increase vaccine uptake. Figure 1 summarizes the rate of vaccine uptake by condition. The figure first shows the percentage increase (vs. the control condition) delivered by the informational treatment and then shows the additional increase that can be obtained with monetary incentives. For example, with a $500 incentive, vaccine uptake can be increased by between 11.5 to 16.2% from the level delivered by the informational treatment. Moreover, with a $1000 incentive, uptake can be increased to 85.6% (average across all four conditions). A $1000 incentive has been proposed in policies put forth by some members of the US congress and former US presidential candidates (Delaney, 2020).

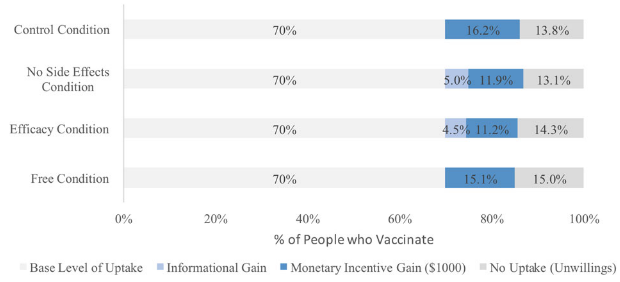

Fig. 1 Vaccine uptake gain by condition (informational and monetary).

Existing research proposes strategies to increase uptake for the influenza vaccines; these include both informational and monetary strategies. Researchers find that no strategy consistently solves the problem (Betsch et al., 2015; Horne et al., 2015). Specifically, for Covid-19, recent research shows that certain information strategies can increase uptake modestly, but not enough to reach the HIT (Moehring et al., 2021; Wilf-Miron et al., 2021). Thus, a contribution of this study is to investigate how monetary incentives can possibly increase overall vaccination rates when used in conjunction with an assortment of relevant informational treatments designed to persuade vaccine hesitant people to vaccinate.

The standard economic argument is that incentives should increase vaccine demand yet there exist arguments against the use of monetary incentives to increase demand (Largent and Miller, 2021). The value of a monetary incentive may be negated (or even reversed) if people infer that offer of money for a vaccine is a signal of low quality. Alternatively, monetary incentives may crowd out altruistic motives for vaccination (Nyhan and Reifler, 2015; Lacetera and Macis, 2010). Thus, an important empirical question is whether monetary incentives are likely to improve vaccination outcomes for Covid-19.

We conducted a randomized controlled experiment involving a national survey of online participants in December 2020. For the study, we contacted a total sample of 2500 participants and of these, 2461 completed surveys. The study consisted of three informational treatment arms and a control group. Similar to theoretical accounts of vaccine uptake (for example, Piraveenan et al., 2021), our analysis is based on a utility model (Supplementary Appendix A) that incorporates the important factors that might cause an individual to decide against vaccination: (i) the probabilities assigned to side effects, (ii) the efficacy of the vaccine, and (iii) the cost of getting vaccinated (costs may be both monetary and non-monetary, such as time spent). The treatments in this study test the saliency of these factors. Subjects in the study are randomly assigned into the control condition "*Will you get the coronavirus vaccine when it becomes available?*" or one of the three informational treatments conditions of free, high efficacy and no side effects *"If coronavirus vaccines are provided for free (are shown to have high efficacy; are shown to have little to no side effects;), will you get one when it becomes available?"*

Vaccine uptake is a binary outcome (everyone in the population will either get vaccinated or they will not), thus the initial uptake question had a forced response of yes or no. From the subjects who say "yes" to being vaccinated, we elicit their willingness to pay (WTP). From the subjects who say "no" (vaccine "Hesitants"), we elicit their willingness to accept (WTA); that is, the monetary incentive needed to induce vaccine uptake. This

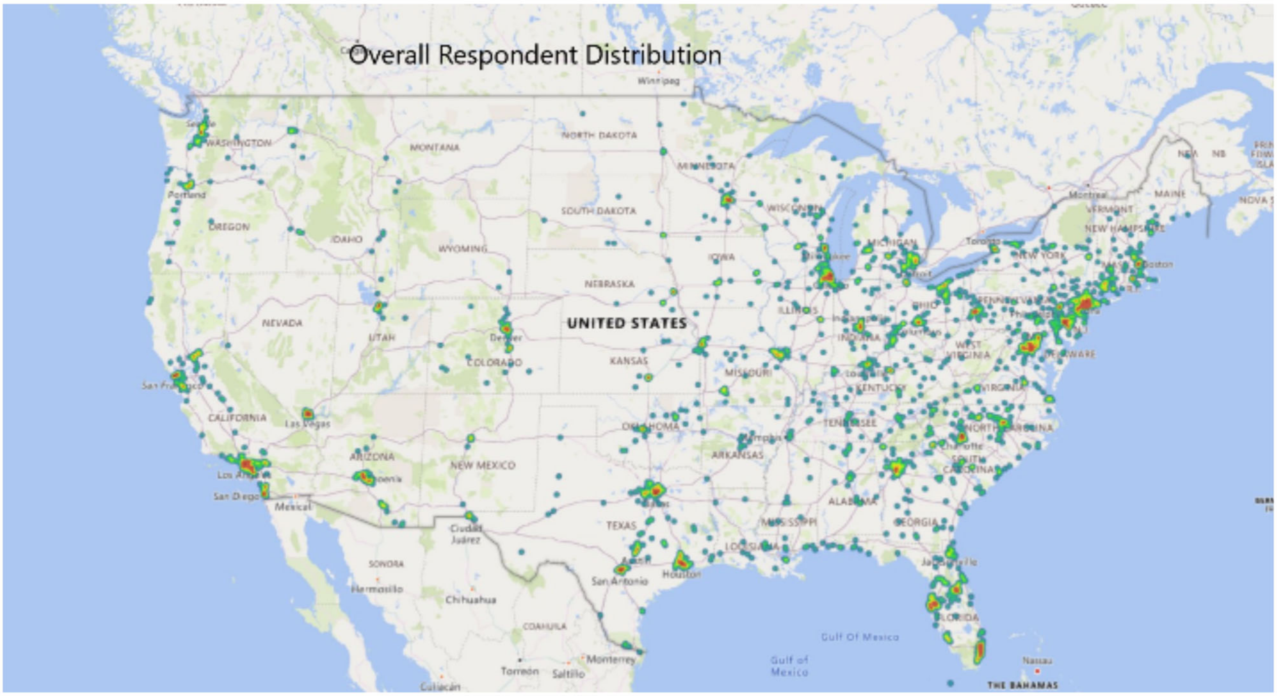

Fig. 2 Location of respondents.

allows us to obtain estimates of the percentage of the population that would accept vaccination for different levels of the monetary incentive. It also enables us to uncover possible segmentation based on the differences in the willingness to accept. Finally, the study presented participants with a series of questions designed to collect information to explain their vaccination decisions and health behaviors regarding Covid-19. The questions were comprised of statements designed to predict vaccine hesitancy validated in previous research (Betsch et al., 2018), health behaviors specific to Covid-19 as described by the CDC, and a set of standard demographic questions.

We find that the high efficacy and the no side effects informational conditions increase uptake by five percentage points (from 70 to 75%, significant at $p < 0.05$), whereas the free condition does not have a significant effect. This suggests that adopting a purely informational approach of making the efficacy and no side effects salient will be insufficient to reach the HIT. Consequently, we analyze the dollar level of Willingness to Accept (WTA) for the hesitants who said no to the vaccine to understand how it may improve potential uptake.

The analysis of the WTA estimates provides strong evidence for two distinct segments within the vaccine hesitant population. Roughly half of the vaccine hesitants who say "no" to the initial uptake question are categorized as the "Unwillings". These individuals report that "no amount of money will incentivize them to take the vaccine." The remaining half of the vaccine hesitants in our sample are labeled as the "Reluctants". This group has indicated a willingness to take the vaccine conditional on monetary incentives (up to $1000). Our analysis shows that the Unwillings are more likely to (a) think that the disease is insufficiently severe to require vaccination, (b) have less faith in the value of a public health system, and (c) be older in age compared to the Reluctants.

The study shows that a $500 incentive can increase the proportion of those willing to be vaccinated to ~80%, and with a $1000 incentive, the proportion vaccinated can be as high as 86.9% (in the no side effect condition). Current estimates suggest that this might be sufficient to get the population of the USA to the herd immunity threshold.

Methods

We conducted a randomized experiment using Amazon's Mechanical Turk with a control and three treatments arms to (a) test the saliency of information about the efficacy, side effects and cost for the coronavirus vaccine and (b) assess the WTP for respondents who want vaccination and the WTA for respondents who are hesitant about vaccination.

The respondents were paid $0.50 for completing a 4-min study. The data was collected from a final sample of 2461 respondents in the United States during last week of November and first week of December 2020.

We recruited respondents in order to have 150 "No" responses in each condition. The rationale for this number is to have sufficient power to conduct within treatment analysis. Based on previous studies, we expected 30% of respondents to say "No", which led to a minimum target of 500 respondents in each treatment. Adding 25% as safety factor, we set a minimum target of 2500 respondents. Of our sample, six respondents did not complete the study, and another 33 did not complete the attention check properly. This left 2461 in the final sample.

In Fig. 2, we provide a heat location map to show the location and concentration of all respondents. The respondents are geographically diverse and closely follow the population concentrations of the US.

Figure 3 goes one step further and shows the relative distribution of respondents who are positive to getting vaccinated (orange dots) vs. negative to getting vaccinated (blue dots). The figure suggests that the relative fraction of people who refuse vaccination might be higher in rural vs. urban areas.

The M-Turk sample is diverse from a socioeconomic and racial perspective (Tables 1 and 2). Detailed analysis shows that it is marginally different from the general population: the sample is somewhat wealthier and less representative of Hispanics and African Americans than their proportion in the general population.

Study design. In the experiment, we aim to learn how information about the cost, efficacy, and side effects impact the reported

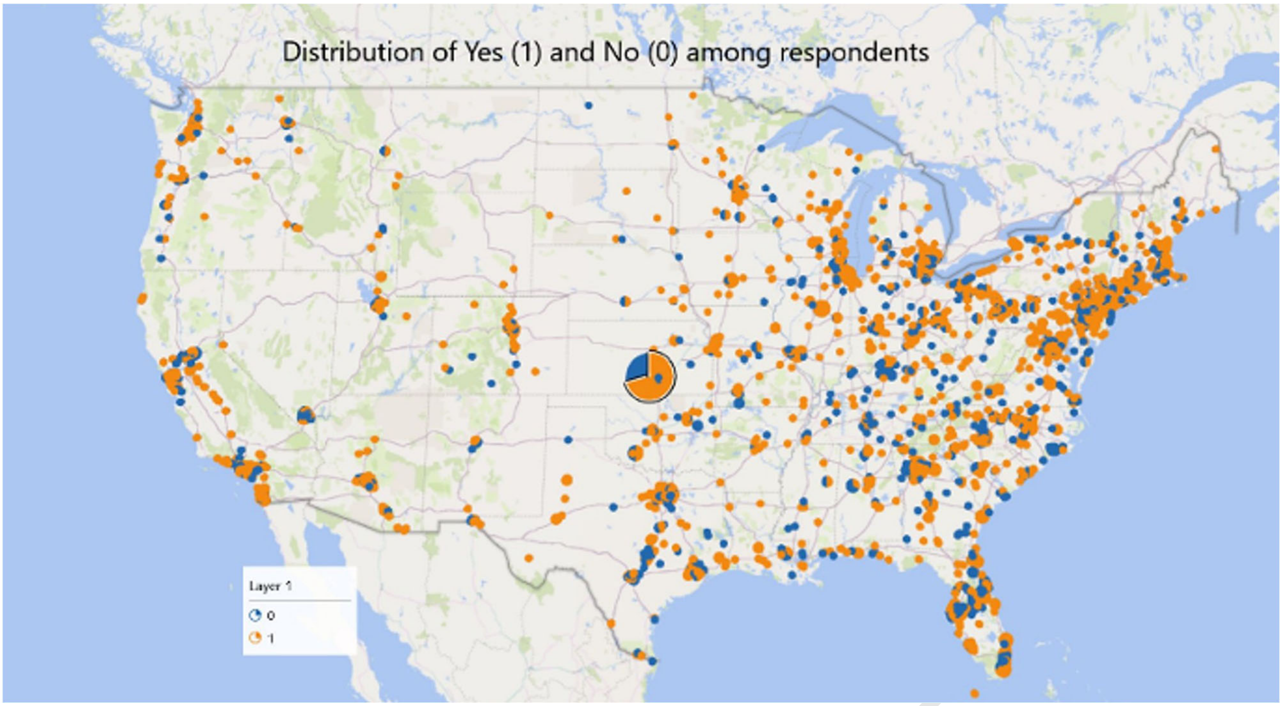

Fig. 3 Location of Yes/No among respondents.

Table 1 Socioeconomic status of US population vs. our sample.

Income bracket	General US population	Our sample
0–20 K	34.94	18.7
20–50K	35.29	32.7
50–100 K	20.62	36.2
>100 K	9.15	12.4

Table 2 Racial diversity of US population vs. our sample.

Racial classification	General US population	Our sample
Indigenous or Native American -	1.3	0.2
East Asian	4.35	4.6
Pacific Islander	0.2	0.2
Black or African American	13.4	8.8
White or Caucasian	60.1	75.4
Hispanic or Latino/a/x	16.5	5.6
South Asian	1.85	1.9
Other (incl. mixed race)	2.3	2.9
Prefer not to say	–	0.4

uptake of the vaccine. We ask, “Will you get the coronavirus vaccine when it becomes available?”

For example, in the free condition, we ask:

> “If coronavirus vaccines were provided for free, would you get one when it becomes available?” and so on with the efficacy treatment and the no side effects treatment.

We then elicit WTP for “Yes’s” and WTA for “No’s” with the following questions respectively.

> Suppose a coronavirus vaccine were available to the public. How much would you pay for the vaccine (in dollars)? Please select the maximum you would be willing to pay.

> Suppose a coronavirus vaccine were available to the public. How much would the government have to incentivize you to receive the vaccine (in dollars)? For example, this could be offered as a rebate off of next year’s taxes. Please select the smallest amount you would be willing to accept. (Select “None” if no amount of money would incentivize you to take the vaccine)

For both questions, we allowed amounts from zero to 1000 to be selected.

We then ask a series of statements that have been previously validated. These 12 statements are presented to the respondents who then assess their agreement with the statements on a seven-point Likert scale from Strongly Disagree to Strongly Agree.

Six questions are directly from a previously validated study on vaccine hesitancy (e.g., “I am completely confident that vaccines are safe.” (Betsch et al., 2018) along with three statements about health behaviors (e.g., “In the last 6 months I have been putting distance between myself and people who do not live with me”) (CDC) and three statements about institutional trust (e.g., “How strongly do you agree or disagree with the following statement: That public health institutions can be trusted?”) (OECD, 2019)

Results

For each informational arm, we first present responses to the vaccine uptake question with a forced binary response. Figure 4 is bar chart that shows the fraction of respondents who would choose to be vaccinated by informational treatment.

Only the no side effects and the efficacy condition significantly increase uptake ($p < 0.05$).

The Efficacy and No Side Effects conditions are significantly higher compared to control ($p < 0.05$). However, no increase in uptake for the Free condition (the uptake is 68.3%) was observed. A potential explanation for the absence of an increase in uptake is that the free condition may heighten worries about the vaccine’s safety as a basis for choosing to be vaccinated. This is implied in the classification analysis of Acceptants/Hesitants for each condition based on the measured explanatory variables provided in Table 3.

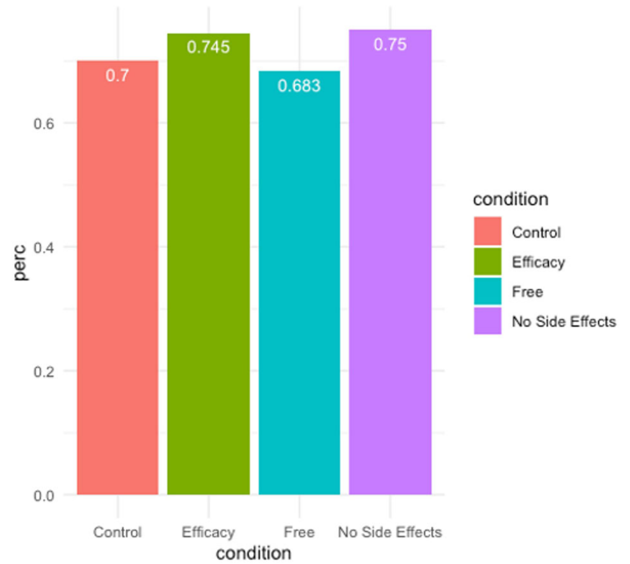

Fig. 4 Percent in each condition who say "yes".

As explained in the previous section, subjects were presented a series of statements regarding vaccine acceptance and different levels of trust associated with the process of vaccination after the elicitation of WTA/WTP. The variables associated with "Government Trust" and "Vaccines [in general] are effective at preventing disease spread" were significant predictors of uptake in the free condition but not in the remaining three conditions. The data shows that emphasizing that a vaccine is provided for free" has no significant effect on vaccine uptake. This is important because offering a service for free is thought to be effective for achieving compliance. For each informational treatment, Table 4 shows the average WTA by quartile and the fraction of respondents who indicate that "No amount of money will incentivize me to take the vaccine". Surprisingly, the free condition led to more people selecting "No amount of money will incentivize me to take the vaccine" (at a significance of $p < 0.10$).

As for demographics, age is a significant predictor of vaccine uptake in the control and free conditions, yet it is insignificant in the high efficacy and no side effects treatment conditions. This is consistent with the vaccine uptake model of Supplementary Appendix A because of a positive correlation between the utility of vaccination and age. In the control and free conditions, older people are more likely to choose to vaccinate due to a higher benefit. However, in the high efficacy and no side effects treatments the effect of age disappears because the information provided seems to assuage the concerns of the younger respondents.

Table 3 Classification model of all participants into hesitants and acceptants.

	Dependent variable:			
	Control	Free	Efficacy	No side effects
	(1)	(2)	(3)	(4)
Vaccines are safe	0.257*** (0.092)	0.693*** (0.109)	0.551*** (0.104)	0.337*** (0.095)
Vaccines prevent disease	0.102 (0.136)	0.272** (0.138)	0.014 (0.138)	0.180 (0.132)
Public health is good	0.218* (0.121)	0.212* (0.125)	0.111 (0.118)	0.317*** (0.119)
Diseases aren't severe enough	−0.337*** (0.088)	−0.104 (0.107)	−0.224** (0.097)	−0.206** (0.096)
Everyday stresses prevent vaccination	0.304*** (0.098)	0.063 (0.112)	0.097 (0.106)	0.258** (0.100)
Cleaning hands	−0.235 (0.149)	−0.263 (0.163)	−0.259 (0.162)	−0.126 (0.135)
Socially distanced	0.014 (0.126)	0.406*** (0.138)	0.010 (0.136)	−0.054 (0.128)
Mask wearing	0.061 (0.148)	−0.232 (0.164)	−0.073 (0.156)	−0.061 (0.166)
Vaccination protects society	0.649*** (0.119)	0.495*** (0.116)	0.478*** (0.106)	0.539*** (0.099)
Healthcare trust	−0.081 (0.142)	−0.036 (0.158)	0.230* (0.132)	0.269* (0.143)
Government trust	0.108 (0.107)	0.280** (0.120)	0.043 (0.121)	−0.071 (0.109)
Public health trust	0.265* (0.148)	0.014 (0.162)	0.236 (0.144)	−0.155 (0.155)
Age	0.033*** (0.011)	0.042*** (0.013)	0.011 (0.013)	0.018 (0.011)
Income	0.009 (0.139)	0.083 (0.171)	0.001 (0.162)	0.043 (0.148)
Politics	−0.219*** (0.085)	−0.177* (0.097)	−0.198* (0.103)	−0.251*** (0.090)
Constant	−1.762*** (0.641)	−2.329*** (0.782)	0.250 (0.757)	−0.737 (0.652)
Observations	637	603	589	632
Log likelihood	−201.259	−151.489	−152.284	−186.293
Akaike Inf. Crit.	438.518	338.978	340.567	408.587

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 4 WTA and NA's in each condition for hesitants.

	Control condition	Free condition	Efficacy condition	No side effects condition
1st Quartile	50	198.500***	201***	101**
Mean	440.748	584.769***	608.379***	544.987***
3rd Quartile	1000	1000	1000	1000
NA's (no amount of money would incentivize them to vaccinate)	88/637 = 13.8%	100/603 = 16.6%*	84/589 = 14.3%	83/632 = 13.1%

*, **, *** significantly different from control with 90%, 95%, 99% confidence, respectively.

Political ideology is found to be a significant predictor of vaccine uptake in all conditions and the effect is strong, consistent with previous literature. The more conservative a respondent, the more likely it is that he/she refuses the vaccine.

The informational effects tested in our initial question are relatively consistent with previous research regarding the challenge of changing vaccine hesitant attitudes (Horne et al., 2015).

As a basis to understand the added potential of monetary incentives, we elicit and examine WTA estimates for all vaccine hesitant participants (participants who said No to the first uptake question). These participants also had the opportunity to indicate that no amount of money could incentivize them to vaccinate (see Table 4). The mean WTA for the participants who refused vaccination for each of the three treatments was larger than the control (free and efficacy at $p < 0.05$ and no side effects at $p < 0.10$). We collected WTP estimates for those who said Yes and these are provided in the Supplementary Appendix B for completeness.

Figure 5 shows the probability density function for WTA for each of the four informational treatments (the area under each curve of the four curves is 1). From 0 to 300 dollars, the control condition PDF curve is higher than the curves for all three informational treatments; this explains why the average WTA for the first quartile is significantly lower in the control condition (Table 4).

Figure 5 suggests that a small but significant fraction of Hesitants are moved away from the 0 to 300 dollar range by the informational treatments. For the high efficacy and no side effects treatments, this fraction of Hesitants appears to move across uptake threshold due to perceived changes in the effectiveness and safety of the vaccine, respectively. However, in the free condition, the fraction of Hesitants seems to have moved in the opposite direction. Recall that the vaccine acceptance rate of 68.3% in the free condition was not an increase compared to the vaccine acceptance rate of 70% in the control condition. We observe a different effect because the average WTA for the first quartile and the average WTA for the sample increase significantly compared to the control condition. The pdf for the free condition exhibits a bump at WTA = 500 (in the middle of the graph). It seems that respondents who had a WTA in the 0 to 300 range may have moved to a higher WTA as a result of the treatment. The free condition seems to cause people who have a natural distrust of government to say No (since the vaccine is offered for free, they become skeptical). This might also explain the increase in the fraction of NA's "No amount is sufficient for me to get vaccinated" for the free condition. This is unexpected because our utility model suggests that a free vaccine should deliver higher utility to respondents (Supplementary Appendix A). Yet it seems do the opposite by signaling signal low efficacy or poor safety for the vaccine.

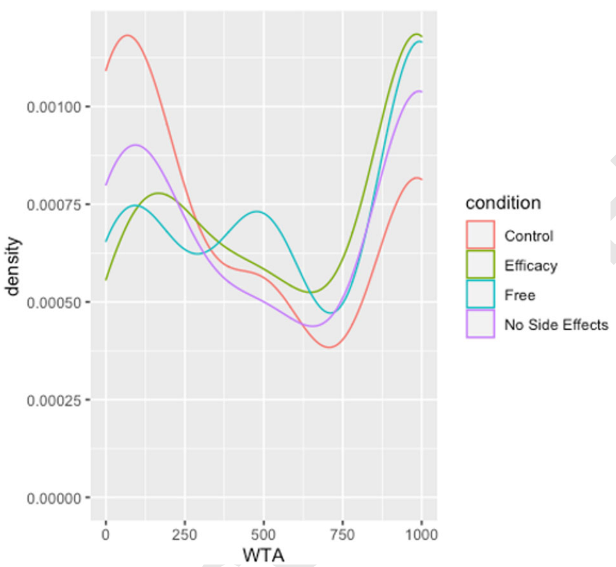

Fig. 5 WTA in each condition for reluctants.

Our findings provide support for the use of monetary incentives to increase vaccine uptake. In contrast to Loewenstein and Cryder (2020) and Largent and Miller (2021), monetary incentives motivate respondents across all conditions to vaccinate and do not seem to exacerbate concerns about the perceived efficacy or gravity of side effects.

In order to account for a possible hypothetical bias of the WTP and WTA provided by respondents, each respondent was asked to provide their level of certainty for the estimated WTP or WTA s/he provides (Champ et al., 2009; Ready et al., 2010). This allows us to analyze whether those who have greater confidence in the WTP and WTA had different valuations of the vaccine. We did not find evidence of a statistical difference based on the level of certainty of the elicited WTAs and WTPs (see Supplementary Appendix C). Thus, we have confidence that the reported WTAs is a legitimate reflection of actual WTA despite the study being based on hypothetical stated valuations.[1]

The responses to the monetary incentive question are suggestive of the existence of distinct segments amongst vaccine hesitant respondents. Across all conditions, we find that 355 out of 690 "No" respondents (51.45%) indicated that they would not vaccinate for any amount. We call this group of respondents the Unwillings (respondents who are unwilling to be vaccinated). The remaining 48.55% of vaccine Hesitants provided monetary estimates of the WTA for them to vaccinate and we label this group Reluctants. Understanding segmentation amongst the vaccine Hesitants has crucial implications for the efficient targeting and prioritization of resources to promote vaccine uptake. Accordingly, we address the issue of segmentation in more detail in the next section.

Table 5 summarizes the fraction of subjects willing to vaccinate by informational conditional and for two levels of monetary incentive ($500 and $1000). With an incentive of $1000, the proportion of respondents willing to be vaccinated increased to 86.22% in the control condition. This effect of 16.2% is

Table 5 Informational and monetary uptake gains by condition.

	Control condition	Free condition	Efficacy condition	No side effects condition
Base level of uptake	70%	70%	70%	70%
Informational gain	n/a	−1.7%	+4.5%**	+5.0%**
Monetary incentive gain ($500)	80.2***	76.1***	78.9***	80.9***
Monetary incentive gain ($1000)	16.2***	15.1***	11.2***	11.9***
Combined uptake informational & monetary incentive of $1000	86.2%***	83.4%***	85.7%***	86.9%***

*, **, ** significant with 90%, 95%, 99% confidence, respectively.

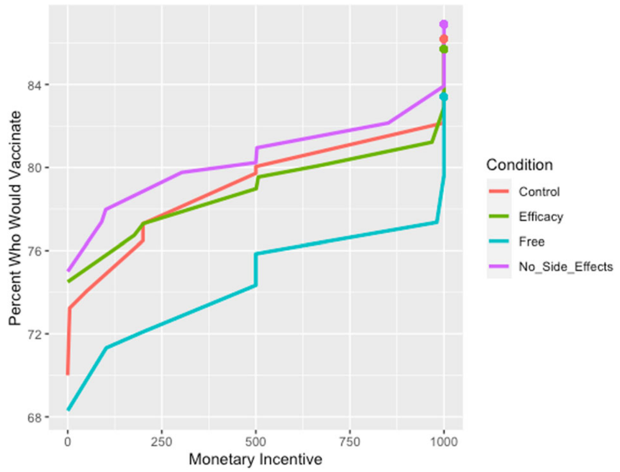

Fig. 6 Percent accepting vaccination as a function of the informational condition and the monetary incentive.

significantly higher than the information treatments, which show a maximum increase of 15.1% (in the free condition).

Table 5 underlines the futility of directing incentives or informational treatments to the Unwillings (~13% of the population). However, with targeted marketing and carefully crafted incentives, 86.9% of the population can be vaccinated.

Our methodology provides an estimate of the WTA for each Reluctant in all four conditions. In Fig. 6, we use these estimates to a construct a cumulative estimate of the fraction of the population that would accept vaccination for each of the four informational conditions and a specific level of monetary incentive. The percentages on the vertical axis obtain by summing the fraction of respondents who say yes (with no monetary incentive) and the fraction of vaccine hesitant respondents who indicate at WTA that is equal to or less than the incentive on the horizontal axis.

Figure 6 illustrates the positive effect of increasing the monetary incentive across all four conditions. The figure also shows that the best performance across the full range of monetary incentives in terms of *the percentage accepting vaccination* is the no side effects informational treatment.

Segmentation. To assess segmentation of the vaccine hesitant population, we analyze our data using two distinct methods. The first is a method of direct classification and the second is a method of indirect classification. As discussed earlier, direct classification sorts vaccine hesitant individuals by their having checked (or not) the box that indicates that no amount of money would be sufficient for me to accept vaccination. Then based on this response, we analyze the nature of the two segments to see if there are observed respondent characteristics that are associated with whether a respondent is unwilling to vaccinate for any amount or "open" to vaccination for a monetary payment.

Second, the indirect classification method entails analyzing the demographic and respondent specific behavioral questions utilizing a *k*-means Cluster analysis to determine whether a natural segmentation scheme emerges from the data. Based on this classification, we then assess the accuracy of the indirect classification method as a basis for predicting whether a respondent is unwilling to vaccinate for any amount or "open" to vaccination for a monetary payment.

It is important to note that identification of clusters is informational-condition specific because the informational treatments themselves affect the composition of the vaccine hesitant population. In particular, a fraction of respondents who are

Table 6 Classification model of hesitants into reluctants and unwillings.

	Dependent variable: Willing to be incentivized to vaccinate
Vaccines are safe	0.123* (0.064)
Vaccines prevent disease	−0.064 (0.071)
Public Health is good	0.181** (0.071)
Diseases aren't severe enough	−0.109* (0.059)
Everyday stresses prevent vaccination	0.212*** (0.057)
Cleaning hands	−0.069 (0.075)
Socially distanced	−0.059 (0.064)
Mask wearing	0.108 (0.070)
Vaccination protects society	−0.077 (0.060)
Healthcare trust	−0.026 (0.097)
Government trust	−0.058 (0.078)
Public Health trust	0.043 (0.099)
Age	−0.013* (0.008)
Income	−0.235** (0.095)
Politics	0.035 (0.057)
Gender_1	0.312* (0.187)
P_contract_covid	0.002 (0.003)
Certainty_P_contract_covid	−0.0003 (0.003)
P_vax_efficacy	0.006 (0.005)
Certainty_P_vax_efficacy	−0.001 (0.004)
P_vax_safety	0.009** (0.005)
Certainty_P_vax_safety	−0.006 (0.004)
Constant	1.251** (0.607)
Observations	690
Log likelihood	−419.448
Akaike Inf. Crit.	898.895

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

vaccine reluctant may accept vaccination based on the information to which they are exposed. Accordingly, the clusters that emerge from each informational condition must be interpreted with caution, yet the clusters that emerge from the control condition are the most accurate representation of the vaccine hesitant population.

First, we analyze the segments generated by direct classification to see if demographic and/or attitudinal variables can be used to predict whether a Hesitant belong to the Unwilling segment or the Reluctant (335 out of 590 Hesitants in the sample are Unwillings).

Here, we estimate a classification model on the respondents who said No to the initial uptake question (with the Reluctants coded as 1 and the Unwillings coded as 0) on all the measured explanatory variables and the results are presented in Table 6. The estimation shows that any of the behavioral health variables of cleaning hands, mask wearing, and socially distancing are not significant in predicting whether one will be Unwilling or a Reluctant. Conversely, "vaccines are safe" and "trust in public health" are significant predictors.

Respondents (among Hesitants) who think the disease is not severe are more likely to select "No amount of money will incentivize me to vaccinate". Interestingly, income is a *negative* predictor of being willing to take a monetary incentive to vaccinate, holding all else equal. An unwillingness to vaccinate for any amount seems to follow from a belief that Covid-19 is not serious. Thus, conceiving a viable strategy to move this stubborn group to accepting vaccinations is challenging.

The most encouraging result is perhaps that "Everyday stresses make me not able to vaccinate" is significant. While beyond the scope of this study, it appears that convenience initiatives (for example, bringing on-site vaccination services to places of work) could increase the fraction of the population willing to vaccinate. Some corporations such as (Target, Trader Joes, etc.) are already offering such conveniences and monetary incentives to their employees (Kohll, 2021).

Second, we present segmentation that obtains through indirect classification. Indirect classification entails analyzing demographic and behavioral data for the respondents to see whether the pattern of the responses is indicative of distinct clusters. The clusters can be used as a basis to predict the respondents' willingness to accept vaccination for monetary payment.

The selection of variables we employ are chosen such that (a) the privacy of individuals is not violated and (b) the behaviors are objective (such that replicability of the clustering is possible with a different sample) and reveal the preferences of the individual more accurately than answers to questions about trust, which are potentially time variant. The demographic variables used are age and gender (ethnicity, income, religion, political leaning are avoided for reasons of privacy). The behavioral questions used relate to three pandemic-related behaviors (I wore masks, I socially distanced, I washed hands frequently).

The approach we employ is *k*-means cluster analysis (MacQueen, 1967). This approach entails selecting the optimal number of segments by analyzing the reduction of the within-cluster sum of squared errors for each question (the elbow method) and the average silhouette width (this assesses the fit of each individual in the data set to its assigned cluster relative to the average of other clusters). We focus on and present the control condition however, the elbow plots and silhouette analysis figures for the three informational treatments reinforce the findings based on the control condition.

The reduction of the within-cluster sum of squared errors shown in Fig. 7 provides clear guidance on the optimal number of clusters. The drop is largest when we increase the number of clusters from 1 to 2 and the figure shows a distinct elbow at 2 clusters.

In addition, the silhouette analysis provided in Fig. 8 is unequivocal. It shows that the optimal number of clusters is 2 and little is gained by adding additional clusters.

Accordingly, we present the results for the 2-cluster solution for the control condition of 191 respondents of which 88 chose NA (no amount of monetary incentive will persuade me to vaccinate). As explained earlier, the control condition is the best representation of the pre-existing segmentation that exists among the vaccine hesitant population. In Table 7, we summarize the key statistics related to WTA and the number of respondents choosing NA.

We find that the first cluster has a larger number of individuals who claim that they will not vaccinate for any monetary incentive (NA), thus the first cluster closely reflects the characteristics of the Unwillings identified through direct classification. The purity measure for classification of the Unwillings achieved with the 2-cluster solution is 0.56, a substantial increase compared to the purity measure achieved with naïve classification of 0.47. The second cluster is similar to the Reluctants identified through direct classification: it contains a much smaller number of NA's and the reported WTA is lower.

In Table 8, we provide the Key Statistics for the clusters that emerge from the 3 informational treatments. We see a similar split in the NA's in each condition.

As noted earlier, the statistics are affected by the informational treatments because respondents with low WTA are affected the message used to promote vaccination in each treatment (the average WTA increases across all 3 informational treatments). The respondents with low WTA are found to a) decide upon vaccination in which case, they are not part of the vaccine hesitant population or b) increase their WTA (as is observed in the "Free" informational treatment).

Despite the clusters being significantly affected by the informational treatments, two observations emerge from all four conditions. First, the data are best explained by a cluster analysis with two segments and second, one cluster that emerges is characterized by a high number of NAs compared to the other segment. In sum, we find that the indirect classification of respondents provides strong support for the conclusion obtained through a direct classification of respondents. Our analysis suggests that the vaccine hesitant population be treated as two

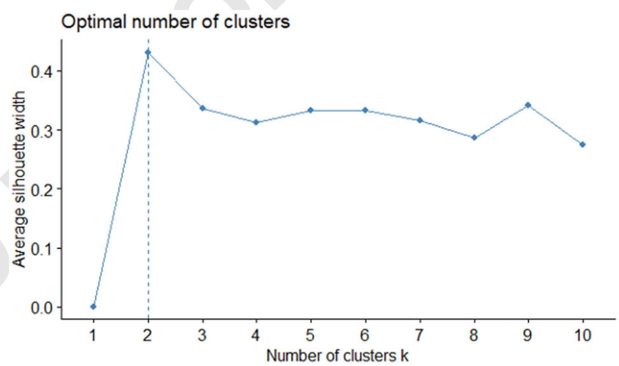

Fig. 8 Average silhouette width.

Table 7 Control condition clusters—key statistics.

Cluster/statistic	Median WTA	Mean WTA	SD WTA	NA's
1	496.0	463.4	407.2	71
2	111.0	283.8	362.5	17

Table 8 Three informational treatment clusters—key statistics.

Cluster/statistic	Median WTA	Mean WTA	SD WTA	NA's
Free condition—100 unwillings				
1	507.0	601.7	384.9	69
2	500.0	537.6	411.7	31
Efficiency condition—84 unwillings				
1	692.0	608.2	377.6	68
2	505.0	609.2	386.5	16
No side effect condition—83 unwillings				
1	500.0	509.9	405.8	61
2	730.5	619.5	378.5	22

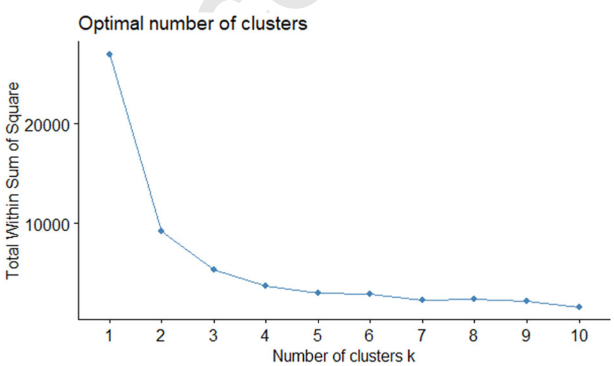

Fig. 7 Sum of squared errors (elbow analysis).

distinct segments; one of which is "highly" responsive to monetary incentives in the 0-to-1000-dollar range and a second, which is relatively unresponsive to monetary incentives.

Overall reasons for vaccine hesitancy and a possible solution. For all Hesitants (participants who said No), we also asked why they would not vaccinate. Figure 7 shows the number of participants who agreed with the various explanations that were provided in the survey. A majority of participants have concerns about the side effects of the vaccine and do not trust the public health system.

In order to explore a "soft" regulatory approach to persuade vaccine Hesitants to be vaccinated, we measured the respondents' level of agreement with the following sentence. "I would get vaccinated if that allowed me to attend events with large crowds again (sporting events and concerts)." This idea is analogous to requiring a vaccine passport to access public and mass transportation in planes, trains, and buses. Figure 8 shows the number of respondents by the level of agreement with the sentence in question. The results suggest that restricting sporting events and concerts to people who can prove they were Q8 vaccinated may be too "soft" and would have limited effect (Figs. 9–11).

Discussion

Using a nationally representative survey, we document uptake given informational designs and elicit WTA estimates for Covid-19 vaccine Hesitants. We find that informational treatments increase uptake by at most 5%, while incentives can increase uptake by 16.2% (for a $1000 level incentive) to an estimated uptake of ~86%, which significantly improve the likelihood of moving the US population towards the herd immunity.

The use of incentives has been proposed both by academics as well as some US politicians (Litan, 2020). Our study provides empirical support for the use of incentives for coronavirus vaccines. The cost of the pandemic continuing far outweighs the cost to implement the incentive scheme described in this study (Cutler and Summers, 2020). While there has been some debate on whether incentives for public health can signal low quality (Loewenstein and Cryder, 2020) we show that almost 50% of Hesitants will accept a monetary incentive to vaccinate for the coronavirus.

Some discussion of how governments should pay for this cost of incentivization is warranted. This is challenging as in most countries the government wishes to provide the vaccine at no cost. Recently, some members of the US congress and social scientists have proposed paying citizens $1000 to get vaccinated. At present, this could cost as much as $300 billion dollars if those already vaccinated qualify to receive the incentive. However, a selective screening mechanism that focuses on geographic areas with high levels of vaccine hesitancy would cost significantly less and has the potential to move the country much closer to herd immunity. The targeting suggested by our analysis is designed to focus limited resources on individuals where the impact is maximized and follows the prescriptions made by Piraveenan et al. (2021). In addition, the benefit of targeting is amplified when people with like-minded attitudes towards vaccination are socially connected (Chen and Perc, 2014).

It is clear that exiting the coronavirus pandemic is at the forefront of almost everyone's mind including policy makers. Even with a highly efficacious vaccine, there is substantial vaccine hesitancy that stands in the way of populations around the globe achieving herd immunity. That is why we propose a multi-pronged approach of information campaigns to those whose

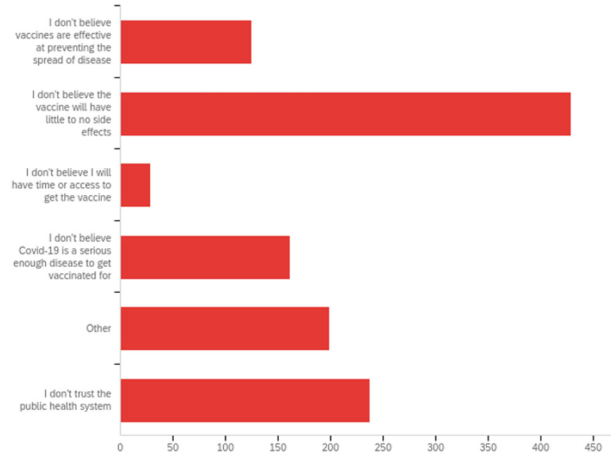

Fig. 9 Reported reasons for not wanting to be vaccinated.

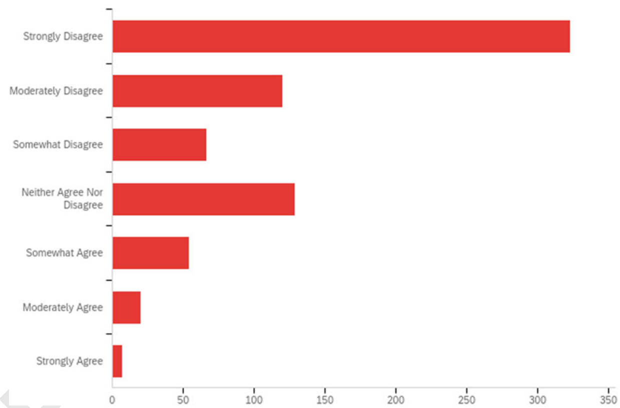

Fig. 10 Hesitants agreeing to vaccinate in order to attend events with large crowds.

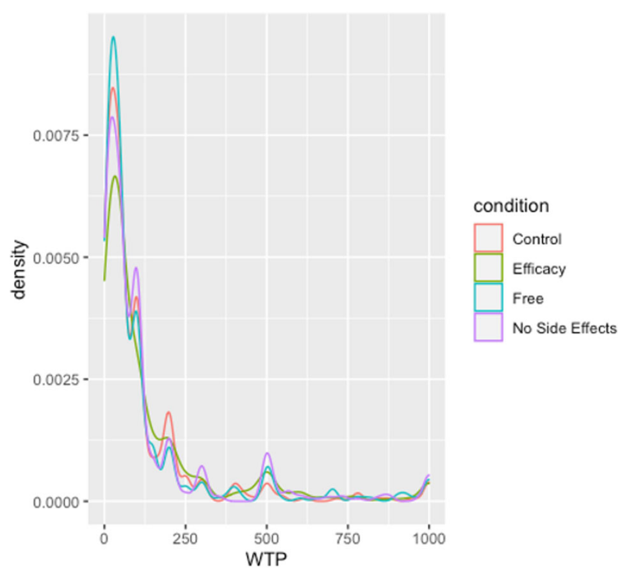

Fig. 11 WTP distribution (in Supplementary Appendix).

beliefs are biased about the vaccine, and monetary incentives to those who have high hassle or time costs for vaccination.

This study is the first to measure valuations for the coronavirus vaccine, both positive and negative. We identify the existence of a segment of Hesitants that we term the "Unwillings". It may be impossible to convince members of this segment to vaccinate with persuasive approaches that encompass information and monetary incentives. Unwillings make up about half of the Hesitants, or about 15% of the participants in our study. However, the target of herd immunity would be in closer focus were strategies adopted that persuade Reluctants to vaccinate.

A limitation of our analysis is that we restrict our attention to incentives that reward public cooperation to increase vaccination ("carrot" strategies as opposed to "stick" strategies). Punishment strategies, while often less costly (Chen and Perc, 2014), may face human rights and legal challenges depending on the country.

Data availability

Data from the paper and replication code is available at at https://doi.org/10.7910/DVN/HBL6TH.

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Note

1 We also assess the degree to which the M-Turk sample is representative of the overall US population. As we show in the Methods section, our sample is geographically and racially diverse and only marginally different from the general population.

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Competing interests

The authors declare no competing interests.

Ethical approval

REB of the University of Toronto approved the study under RIS Protocol 39979. The data were collected with a survey conducted through Amazon's Mechanical Turk under University of Toronto IRB protocol number 00039979. The design was a randomized control trial of three different descriptions to announce the availability of the vaccine and a control.

Informed consent

Informed consent was collected from all participants in this study. All participants agreed to the following terms: You are invited to take part in a research study conducted by Professor David Soberman and Ph.D Student Vivek Nandur from the Rotman School of Management, University of Toronto as you are an adult consumer over 18. The purpose of the study is to better understand choices and behaviors in regard to various medical treatments and health behaviors. If you participate, you will be asked to provide some demographic information as well as some of your preferences regarding health treatments. You will be asked to read some information, respond to a variety of questions, and make some choices. There are no wrong answers; we are simply interested in your personal preferences and behaviors. Your participation in this study is entirely voluntary; you may refuse to participate. You are free to withdraw from the study at any time without penalty. Withdrawal prior to completion will result in a loss of financial compensation. You will receive $0.50 for participating in this study. The total duration of this study is ~4–7 min. Participation presents minimal to no risks. Data generated during this study will remain anonymous and confidential, and accessible only to personnel associated with the study. You will be asked to provide some basic demographic information about yourself, but none of this information will be used to personally identify you. Any identifying information will be collected separately from your responses and cannot be associated with your responses. The research results are intended for presentation in academic conferences and publication in scholarly journals, where no personal information will appear. Although we cannot guarantee any direct benefits to you as a result of your participation, you may gain an appreciation of social science research. The results gathered will contribute to scientific research understanding how individuals process and respond to various health behaviors and treatments. If you have any further questions, contact Vivek Nandur. By clicking the "I agree to participate" button, I acknowledge that I have read the consent form and I consent to participate in this study. I also certify that I am 18 years of age or older.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-022-01074-y.

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