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Changes in risk perception and protective behavior during the first week of the COVID-19 pandemic in the United States

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Abstract

By mid-March 2020, the COVID-19 pandemic spread to over 100 countries and all 50 states in the US. Government efforts to minimize the spread of disease emphasized behavioral interventions, including raising awareness of the disease and encouraging protective behaviors such as social distancing and hand washing, and seeking medical attention if experiencing symptoms. However, it is unclear to what extent individuals are aware of the risks associated with the disease, how they are altering their behavior, factors which could influence the spread of the virus to vulnerable populations. We characterized risk perception and engagement in preventative measures in 1591 United States based individuals over the first week of the pandemic (March 11th-16th 2020) and examined the extent to which protective behaviors are predicted by individuals' perception of risk. Over 5 days, subjects demonstrated growing awareness of the risk posed by the virus, and largely reported engaging in protective behaviors with increasing frequency. However, they underestimated their personal risk of infection relative to the average person in the country. We found that engagement in social distancing and handwashing was most strongly predicted by the perceived likelihood of personally being infected, rather than likelihood of transmission or severity of potential transmitted infections. However, substantial variability emerged among individuals, and using data-driven methods we found a subgroup of subjects who are largely disengaged, unaware, and not practicing protective behaviors. Our results have implications for our understanding of how risk perception and protective behaviors can facilitate early interventions during large-scale pandemics.

Introduction

The genesis of the novel coronavirus epidemic (spread of COVID-19 disease) has been tied to the Hubei province of China and rapidly progressed to the level of a global pandemic, with multiple countries across the globe reporting exponentially increasing numbers of cases (1). The first case in the US was reported in January 14 2020 (2), followed by government interventions in travel restrictions. On March 11, however, COVID-19 officially become an global pandemic (3) and the introduction of a series of governmental decisions to restrict social and economic behavior began. By March 17, all 50 states reported at least one person with the virus (2). Like most developed countries, a major focus of the US has been minimizing transmission of the virus in order to flatten the epidemic peak and lessen the impact on healthcare services (4,5), enabling the most severe cases to be treated successfully and reduce overall mortality. The success of these measures is particularly critical in the case of COVID-19 due to its high transmissibility, even in the absence of symptoms (6,7), severity (4), and mortality rate, particular among older individuals (5). However, these protective measures rely largely on rapid changes in population behavior, which are dependent on individuals' ability to perceive risks associated with the virus and adapt their behavior accordingly (8).

Given the importance of human psychological and behavioral factors in managing pandemics, it is crucial to assess psychological and behavioral responses to the situation and determine how perceived risk is linked to engagement in protective behaviors (9). There is limited evidence on reactions to prior pandemics in the early stages when preventative measures are most necessary (9). While some studies have emphasized the role of risk perception, predominantly the personal effects of the disease (in terms of likelihood and severity if infection for the individual), on preventative behaviors, these often take place either in anticipation of an outbreak or long after its emergence (9). In addition, lab-based research has suggested that increased perceived effects of disease spread on others may increase engagement in social distancing (10). The few studies that have surveyed individuals during the early stages of a pandemic have also suggested that perceived personal risk of infection and health effects are linked to engagement in protective behaviors (11). However, it is also well established that individuals typically tend to underestimate their likelihood of experiencing adverse life events (such as cancer) relative to the average person, an effect known as optimism bias (12). Together, it is apparent that perceived risk is likely to affect individuals' behavior during a pandemic, but that individuals are often poor at perceiving risk. However, it is unknown how perceived risk relates to protective behaviors in the early stages of a pandemic on the scale of COVID-19. Additionally, we are unaware of any data of this kind for the current COVID-19 pandemic; given COVID-19's ongoing rampant nature, this data may have global value to the medical community, government leaders, and society more broadly.

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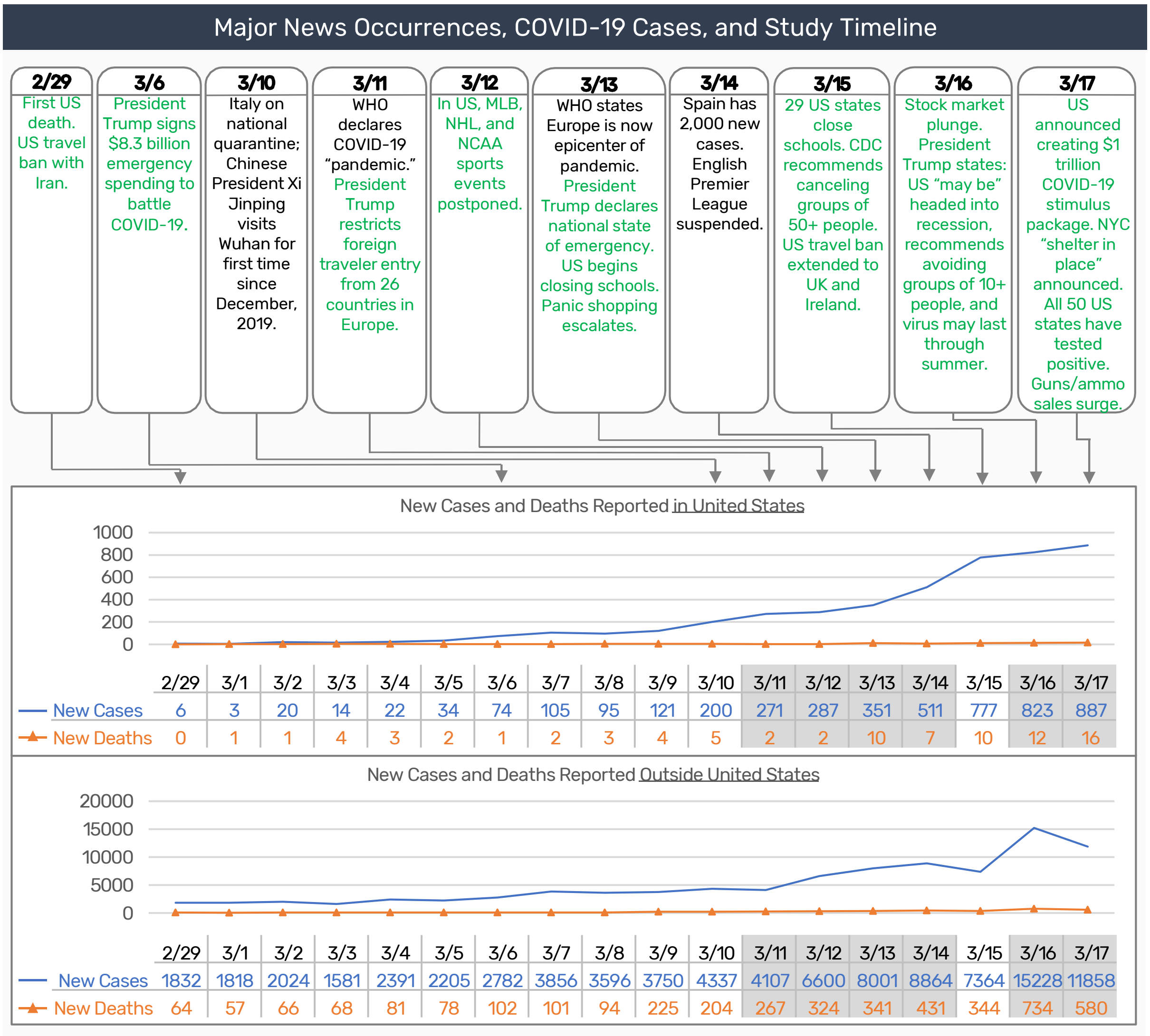

Figure 1. Timeline of events early in the United States COVID-19 pandemic. Days of current study data acquisition shown in gray. News events in green are most relevant for United States. COVID-19 data acquired from European Centre for Disease Prevention and Control. Major news events retrieved from National Broadcasting Company (NBC) News, Columbia Broadcasting System (CBS) News, and Cable News Network (CNN).

Results

We conducted an online survey of 1591 individuals in the USA during the early stages of the country's outbreak in March 2020, asking about their perceptions of risk and behavioral responses to the pandemic (see Figure 2 for demographic information). Subjects were recruited through Prolific (13) between 3/11/20, the day when the WHO declared COVID-19 a pandemic, and 3/16/20. The study was approved by the Institutional Review Board (IRB) at California Institute of Technology. We focused on how perceived risk from the virus and propensity to engage in protective behaviors developed as the pandemic progressed. We also sought to quantify the extent to which engagement in protective behaviors was dependent on perceived risk. 375 subjects of the 495 who participated on the first day were followed up after 5 days to provide a picture of within-person changes in perceptions and behaviors. We also replicated cross-sectional results in a subset of our data to ensure robustness.

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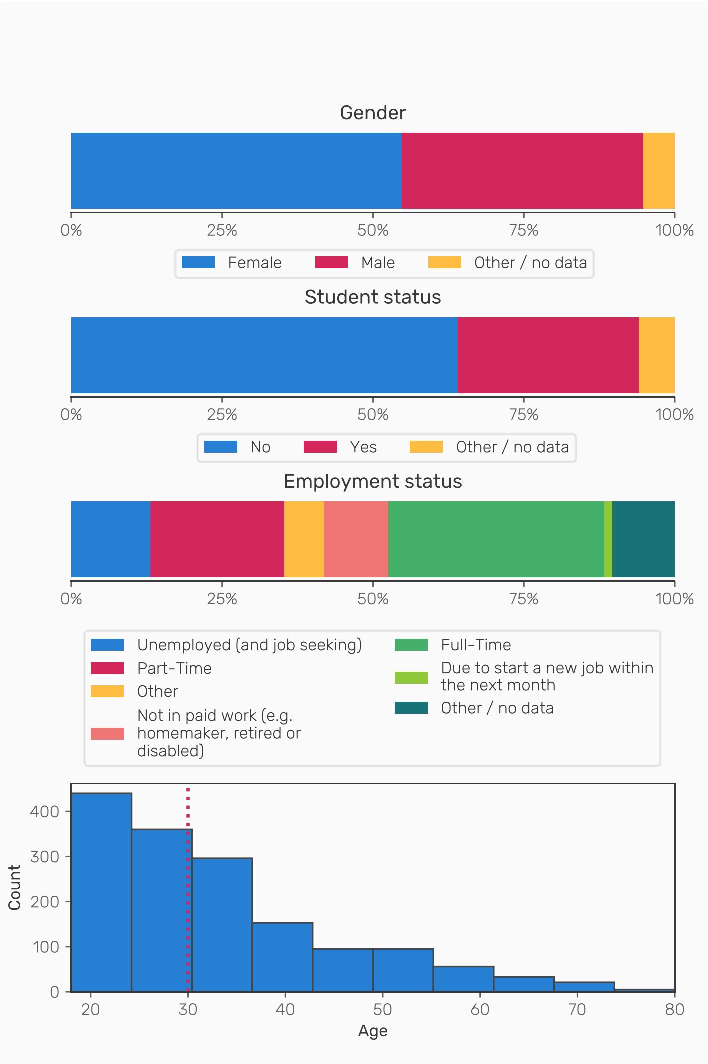

Figure 2. Demographics of survey respondents. The red dotted line on the lower panel represents the median age (30 years).

Perceptions of risk from COVID-19

While at the time of submission it remains unclear exactly how widespread the pandemic will be, current estimates suggest that up to 80% of the population may contract the disease (4). We sought to characterize perceptions of infection likelihood and severity, for both the study participants themselves and others. All responses were recorded on a visual analogue scale coded between 0 and 100. We also examined changes in behavior over time by sampling independent groups of subjects over five days and retesting subjects who participated on the first day after a five-day period. Despite being a short

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period of time, multiple significant political events occurred during this time period, including travel bans and restrictions on public gatherings (Figure 1).

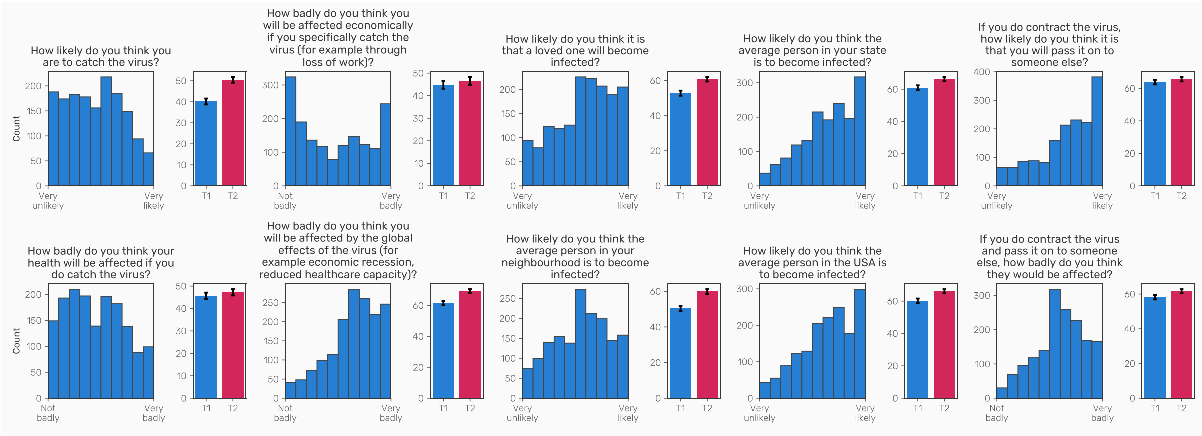

Figure 3. Distributions of responses to items regarding risk perception (n=1591). All responses were recorded on a visual analogue scale ranging from 0 to 100. Bar plots indicate mean responses to these items over the two timepoints where a subgroup of subjects was retested (n=375).

As shown in Figure 3, subjects assessed their risk of being infected as relatively high (mean = 43.06, SD = 26.62). Additionally, they reported perceiving the disease as being a threat to their health (mean = 44.70, SD=26.93). They also indicated that they would be personally affected economically, such as through loss of work (mean = 45.68, SD = 34.35), and that they would be affected by the global economic consequences, such as through economic recession and effects on healthcare provision (mean = 64.38, SD = 24.02), although responses to this question were not unimodally distributed..

Subjects were also aware of the potential for contagion, indicating that if they became infected, they would be likely to pass it to someone else (mean = 66.18, SD = 27.39, Figure 3). As with perceptions of infection likelihood, subjects believed that if they did infect another person, they would be worse affected than themselves, both in terms of health and of economic effects (mean difference = 14.82, SD difference = 26.67). Linear regression indicated that the difference between perceived effects on another person and reported personal health risk was partially dependent on age ($t(1550) = -8.33$, $p < .001$), suggesting that this may be explained, in part, by the relatively young age of the participants (median age=30 years) and knowledge of the worse health effects in older individuals. However, the intercept in this model remained positive and significant (β=29.68, $p < .001$), indicating the presence of such a bias even after accounting for age.

Perceived likelihood of infection however differed according to who participants were rating ($F(3, 4737) = 579.00$, $p < .001$, $\eta_p^2 = 0.27$), with participants rating the average person in the US to have the highest risk of infection, but themselves to have the lowest risk, in line with work on optimism bias (12) (Figure 4C). Perceived likelihood of infection differed across samples tested on different days, demonstrating a higher rate over time ($F(6, 1579) = 6.48$, $p < .001$, $\eta_p^2 = 0.024$, Figure 4C). An increase in perceived likelihood was found within-subjects in a subsample followed up after 5 days ($F(1, 374) = 69.19$, $p < .001$, $\eta_p^2 = 0.16$, Figure 4D). There was an interaction between time and subject of rating ($F(3, 1122) = 7.56$, $p < .001$, $\eta_p^2 = 0.02$), representing the greatest changes in risk perception for the self, however this was weak and likely influenced by ceiling effects.

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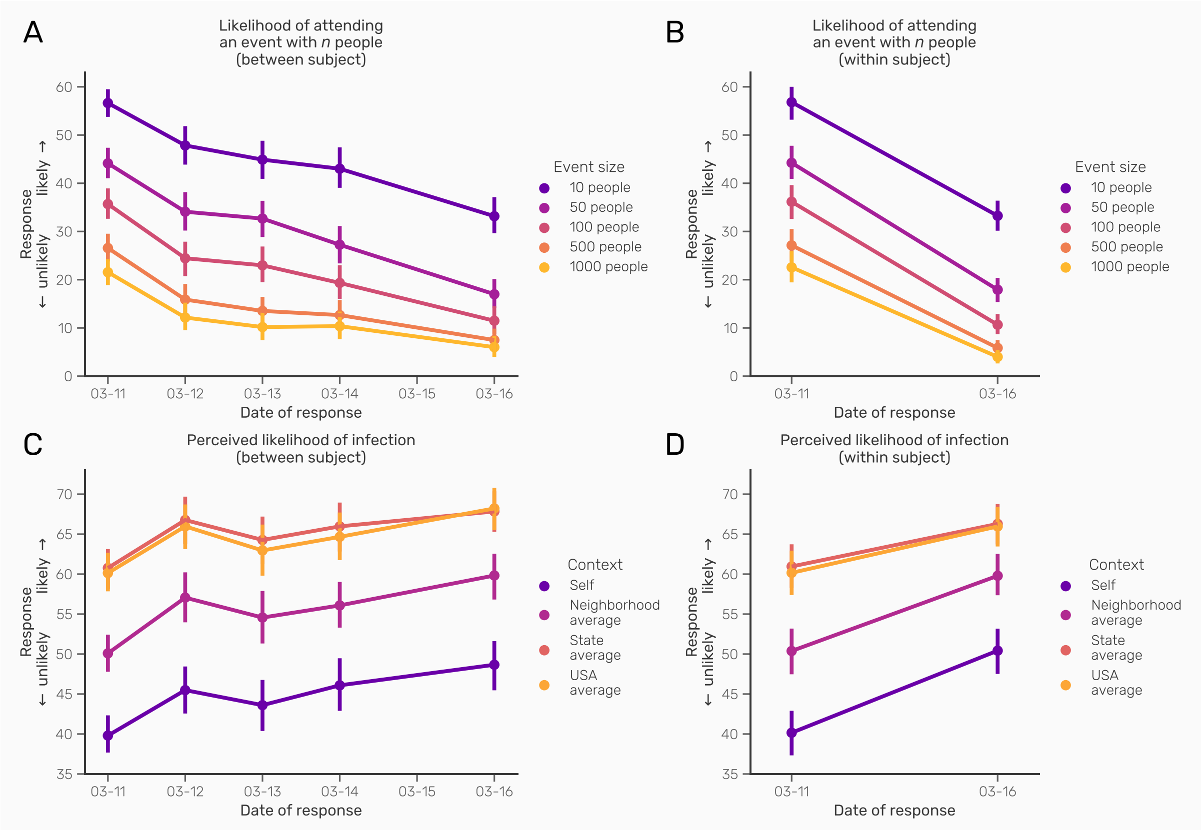

Figure 4. Changes in protective behaviors and risk perception over time. A) Reported likelihood of attending events with a given number of other people in separate samples tested on 5 days in the early stages of the outbreak in the United States. B) Reported likelihood of attending events of different sizes in a subset of subjects followed up 5 days after initially completing the survey. C) Perceived likelihood of becoming infected for participants themselves and average people at different geographic scales in separate samples tested over 5 days. D) Perceived likelihoods of infection in a subset of subjects followed up after 5 days.

Engagement in protective behaviors

We next assessed the extent to which subjects reported engaging in protective behaviors, such as social distancing and hand washing, in addition to superficially helpful behaviors such as buying more food and water. On average, subjects indicated that they were engaging in such behaviors more than usual, although response distributions included peaks at the extremes (Figure 5). Five out of six protective behaviours had a peak for *not* engaging in the protective behaviour more than normal, and three out of six had a peak for engaging in the protective behaviour more than normal. In particular, subjects reported washing their hands more than normal (median = 77, IQR = 38) and staying home more than normal (median = 62, IQR = 69), representing high engagement with sanitization and social distancing measures. In subjects who completed the survey a second time point 5 days after first completion (3/11/2020), responses had changed for both hand-washing (Wilcoxon $W(375) = 25027.5$, $p < .001$) and social distancing ($W(375) = 12269$, $p < .001$) to reflect increased engagement in these behaviors.

We also asked people how likely they would be to attend events with varying numbers of people (10 to 1000) to assess how they were adapting their behavior according to transmission risk. As expected, we observed a main effect of group size ($F(4, 6316) = 1311.68$, $p < .001$, $\eta_p^2 = 0.45$, Figure 4A), whereby individuals were less likely to attend an event with more people. We also saw markedly lower likelihood ratings over time in separate samples collected across multiple days ($F(6, 1579) = 22.84$, $p < .001$, $\eta_p^2 = 0.08$, Figure 4A). Congruently, a decrease over time emerged in our within-subject analysis ($F(1, 374) = 279.02$, $p < .001$, $\eta_p^2 = 0.43$, Figure 4B), providing evidence that individuals reported dramatically changing their intended behavior within the space of only a few days. Notably, this occurred before and

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after the CDC's recommendation of avoiding gatherings of 50+ people (3/15/20) and on the same day of President Trump's announcement to avoid gatherings of 10+ people (3/16/20).

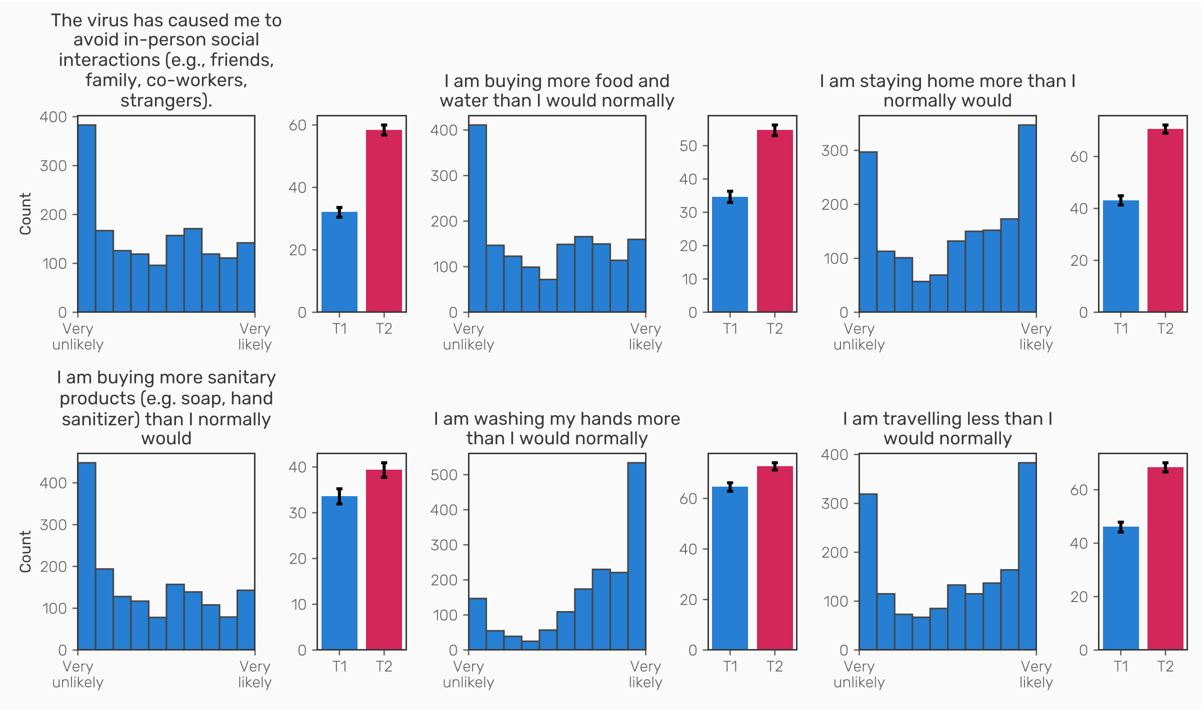

Figure 5. Distributions of responses to items regarding behavior (n=1591). All responses were recorded on a visual analogue scale ranging from 0 to 100. Bar plots indicate mean responses to these items over the two timepoints where a subgroup of subjects was retested (n=375).

Influence of risk perception on protective behaviors

We next investigated the extent to which risk perception was predictive of engagement in protective behaviors. We used multiple linear regression to assess the extent to which of our 10 items assessing risk perception (shown in Figure 6) were associated with engagement in two primary protective behaviors, hand washing and social distancing (assessed through asking subjects whether they were staying home more than normal), controlling for age. We performed this analysis in a subset consisting of 75% of participants and repeated it in the remaining 25% to ensure reproducibility of our results. Results reported here are from the larger dataset but were consistent across both subsets (Figure 6). All data were scaled to zero mean and unit variance prior to analysis to allow comparability of regression coefficients.

The clearest effect common to both behaviors was a significant effect of perceived *likelihood* of personally becoming infected (hand washing β = 0.17, p < .001, social distancing β = 0.20, p < .001, Figure 6), while perceived *severity* of illness was not a significant predictor (hand washing β = -0.03, p = .37, social distancing β = 0.002, p = .95, Figure 6). Perceived impact from global consequences (e.g. economic recession, healthcare overcapacity) also significantly predicted engagement in both behaviors to a lesser extent (β=0.08, p = .01, social distancing β=0.14, p < .001, Figure 6). Notably, likelihood of passing the virus on to others and perceived negative effects for another individual who contracted the virus did not significantly predict behavior (Figure 6). Age did not have a significant effect in either dataset.

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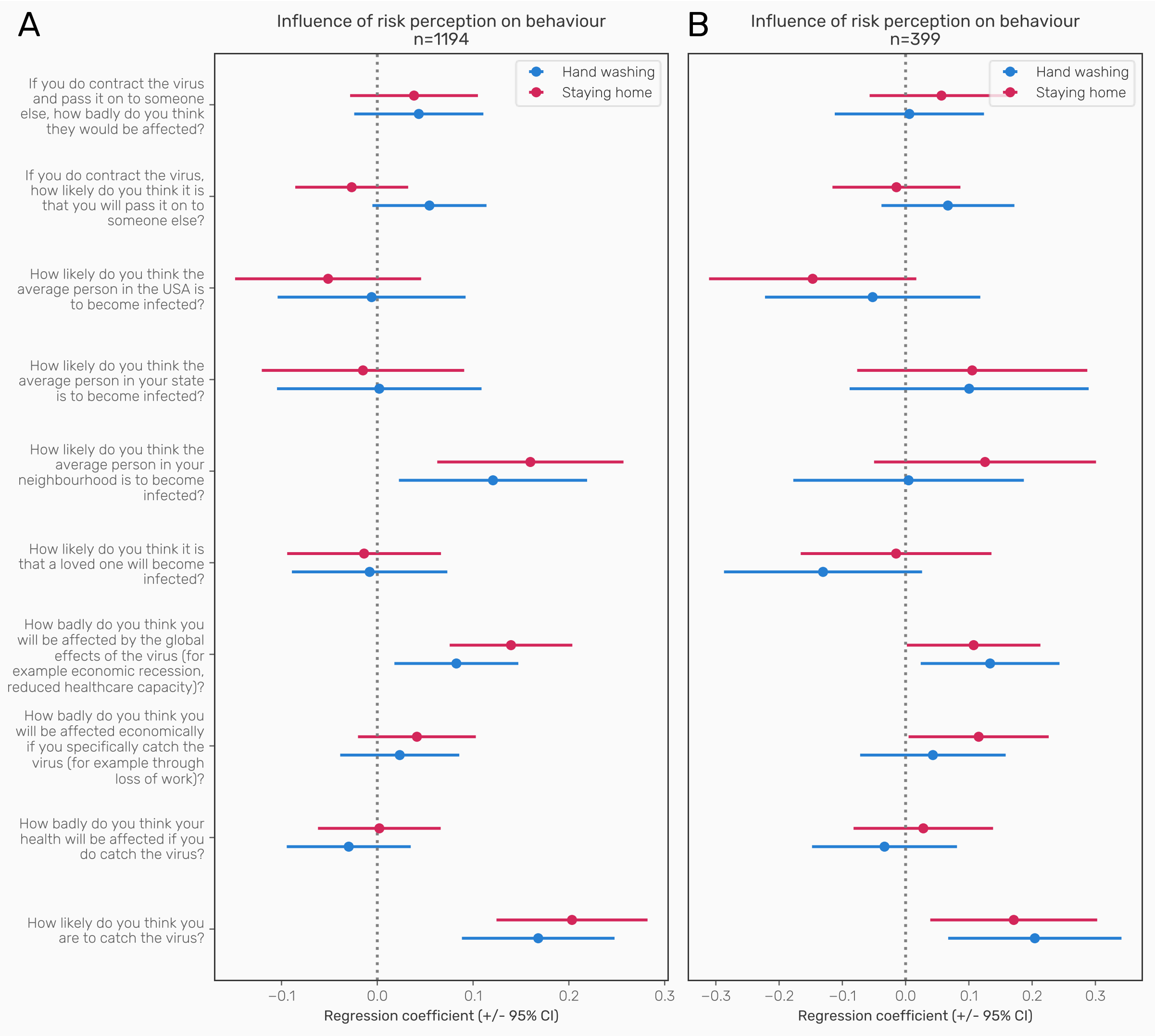

Figure 6. Results of linear regression predicting engagement in hand washing and social distancing (represented by responses to an item regarding staying home) from measures of risk perception, with validation in a subsample of 25% of subjects. A represents the discovery dataset and B represents results from the validation dataset.

Identification of subgroups demonstrating low engagement in protective behavior

The distributions shown in Figure 5 clearly indicate that the pattern of responses to questions on protective behaviors was not Gaussian, and was not consistently unimodal, suggesting that there are likely to be subgroups of individuals responding to the outbreak in qualitatively different ways. To explore this further, we used a Bayesian Guassian mixture model (GMM) to decompose the distribution of responses to four primary questions (avoiding social interaction, hand-washing, staying home, and travelling less) into latent components. The Bayesian GMM approach assigns weights to these components and we rejected any with a weight below 0.01 as these had a negligible contribution to the model, leaving 16 components as the final solution (Figure 7B). Based on the mean response scores of the components, two components (components 4 and 6) were characterised by high and very low reported engagement with the four protective behaviours respectively (Figure 7A). Others indicated that there were clusters of individuals selectively engaging in certain protective behaviours but not others (components 3, 10, and 16 for example).

The model allowed us to assign a probability of each subject being described by each component, which we used to select individuals most likely to belong to the low or high engagement cluster. Having labelled individuals according to their behaviour, we then assessed Z-scored responses to other items to examine how these individuals compared to the group average in terms of percevied risk, information seeking, and personal effects of the pandemic (Figure 7C). This revealed a broad pattern of below average perceived risk for both themselves (mean Z = -0.68) and others (mean Z = -0.38), perceived likelihood of transmission (mean Z = -0.28), low engagement with information sources (mean Z = -0.89), and low perceived personal effects (mean Z = -0.66), while the opposite pattern was observed in the high engagement group. Significant differences from the group average are shown in Figure 3C. Together, this indicates that there exists a subgroup in the population who are generally disengaged in terms of information seeking, feel unaffected by the situation, and perceive the risk of COVID-19 as being low for themselves and others, and who do not engage in protective behaviours.

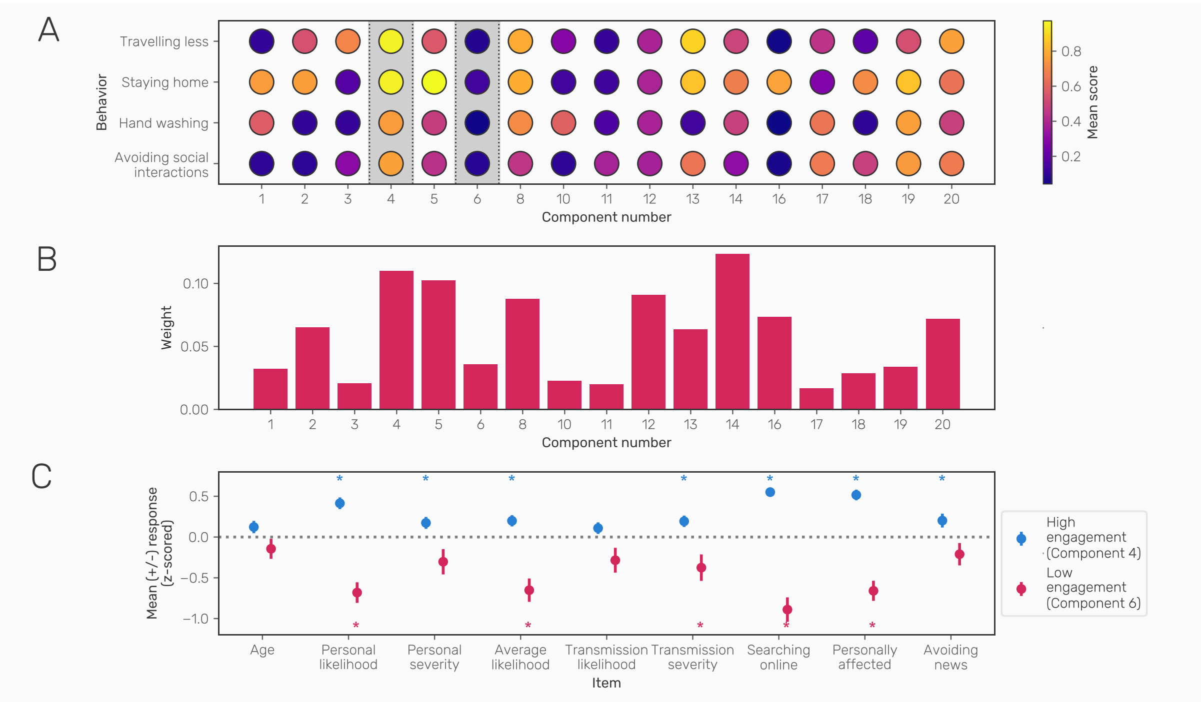

Figure 6. Results of Bayesian Gaussian Mixture Model (GMM) decomposing response distributions for protective behavior items into clusters. A) Mean scores for each component in the GMM model on the four items used to generate clusters. B) Weights of retained components. Four components were rejected due to having negligible weights (< .01). C) Z-scored responses on other questionnaire items for the low engagement and high engagement clusters, demonstrating how they compare to the average individual. Asterisks represent significant differences from the group average (one sample t-test on the Z scores versus zero, FDR corrected for 18 comparisons).

Discussion

Understanding how psychological factors influence behavior in severe, global pandemics such as that COVID-19 is key to facilitating disease minimization strategies. Our analyses indicate that although most individuals are aware of the risk caused by the pandemic to some extent, they typically underestimate their personal risk relative to that of others, an example of optimism bias (12). In turn, higher perceived personal risk predicts engagement in protective behaviors such as hand washing and social distancing, as shown in studies of prior pandemics (9). Notably, we identified and characterized a non-negligible subset of subjects reporting little to no engagement in protective behaviors, who rated overall likelihood of infection as low and reported being generally disengaged in information seeking and being personally unaffected. Overall, the presence a subgroup is concerning given the threat posed by COVID-19 and the beneficial effects of widespread behavioural changes.

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One explanation for our results is the optimism bias (12). This bias is associated with the belief that we are less likely to acquire a disease than others, and has been shown across a variety of diseases including lung cancer (14). Indeed, those who show the optimism bias are less likely to be vaccinated against disease (15). Recent evidence suggests that this may also be the case for COVID-19 and could result in a failure to engage in behaviors that contribute to the spread this highly contagious disease. Our results extend on these findings by showing that behavior changes over the first week of the COVID-19 pandemic such that as individuals perceive an increase in personal risk they increasingly engage in risk-prevention behaviors. Notably, we observed rapid increases in risk perception over a 5-day period, indicating that public health messages spread through government and the media can be effective in raising awareness of the risk. This effect was strongest for perceptions of subjects' own risk, diminishing the optimism bias. The speed at which perceptions changed is such that this could have a meaningful effect in terms of reducing disease transmission.

Our results point to candidate targets for intervention in public information campaigns during pandemics on this scale. Clear communication of risk could aid the development of accurate risk perception, in turn facilitating engagement in protective behaviors. It would be particularly important to target the subset of individuals who remain disengaged and are not themselves seeking information on the pandemic. This suggests the need to expand outreach methods to individuals who do not seek information themselves (e.g., emergency alerts on phones). Furthermore, such disengagement should be considered in epidemiological models used to forecast the effects of behavioral interventions on disease spread. Additionally, education on the beneficial effects of such behaviors for others may improve engagement, particularly in those at low perceived personal risk; it is possible that links between protective behavior and perceived personal risk minimization are merely easier to appreciate.

There are limitations to our work that should be considered. First, the median age (30 years) of our sample is relatively young. However, many of our results do not appear to be highly dependent on age, for example age was not a significant predictor of hand-washing or social distancing. In addition, young people are typically the primary target of efforts to encourage social distancing, having on average larger social networks (16) and therefore a higher likelihood of engaging in social contact. This is particularly important in the context of COVID-19, where there is evidence that the spread of the virus has been facilitated by the movement of young people with limited to no symptoms (5,6). Second, our data only reflects views of those in the United States and may not be applicable to other cultures. It will be important to characterize psychological and behavioral responses across the globe during pandemics in order to recommend and implement the most optimal strategies for effecting behavioural change, which often are culturally specific.

Adaptation of behavior will be fundamental to the management of a pandemic on the scale of COVID-19. Our results provide insights into key psychological and behavioral states during a crucial time in the developing situation.

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