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Emotional Sensitivity to Probability as a Predictor of COVID-19 Vaccine Hesitancy and Prevention Behaviors

Heather P. Lacey* and Alexa N. Rivera
Department of Psychology, Bryant University

ABSTRACT. Any path out of the COVID-19 crisis will depend heavily on widespread vaccination, but substantial vaccine hesitancy and refusal stand in the way of reaching that goal. The pre-COVID literature on vaccine hesitancy points to several important factors, but important features of this pandemic may be uniquely contributing to hesitancy specifically for this vaccine. This pandemic has been characterized by unprecedented access to real-time risk statistics, such as positivity rates and case counts, and interpretations of those numbers may help account for individual differences in how people respond to the virus. In a survey of college students, we measured participants' intention to pursue the vaccine, their adherence to guidelines like masking and social distancing, and their worry about both the virus and the vaccine. We modeled these responses using a measure of emotional sensitivity to probability (ESP; the extent to which individuals calibrate their emotional responses to changes in risk probability) as well as 3 other individual difference measures for emotional reactivity to possibility (ERP), aversion to ambiguity in medicine (AAMed), and medical maximizing-minimizing (MMM). We found that ESP significantly predicted greater vaccine intention, $\beta = .29$, $p = .003$, and AAMed predicted less, $\beta = -.25$, $p = .008$. MMM predicted more frequent masking, $\beta = .21$, $p = .02$, social distancing, $\beta = .22$, $p = .01$, and avoidance of public places, $\beta = .25$, $p = .006$. ERP predicted worry about long-tern illness, $\beta = .29$, $p < .001$, hospitalization, $\beta = .25$, $p = .001$, and death, $\beta = .27$, $p < .001$, from COVID-19 but also predicted worry about side effects from the vaccine, $\beta = .22$, $p = .006$.

Keywords: risk perception, vaccine hesitancy, COVID-19, emotional sensitivity to probability

Since its emergence in late 2019, the COVID-19 pandemic has wreaked havoc across the globe. As of September 2021, over 4.5 million deaths have been attributed to COVID-19, over 650,000 of them in the United States, and many more people have experienced long-term health effects after recovering from the disease (Dong et al., 2020). In addition to the devastating health effects, economies have been disrupted, schooling has been upended, and families and friends have suffered long separations. Few aspects of daily life have not been affected by the pandemic. Yet, since its earliest days, dramatic individual differences have been observed in perceptions of COVID-19 risks and adherence to preventative behaviors, such as mask-wearing and social distancing (Wise et al., 2020). Some people experience significant worry and carefully adhere to guidelines, whereas others conclude that the risk is exaggerated and that the behavioral guidelines are unwarranted. Although politicization of the virus and its prevention certainly accounts for much of this variability (Barrios & Hochberg, 2020), cultural and psychological variables also contribute to perceptions and responses to the virus (Alqahtani et al., 2021; Dryhurst et al., 2020).

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*Faculty mentor

Through much of 2021, different interpretations have manifested in vaccine uptake. It has become clear that vaccines are a critical element of any path back from the COVID-19 crisis. Initially, scarcity of supply made it necessary to ration vaccines through age-stratified eligibility, but by late spring 2021, all age groups then authorized for the vaccine from the FDA (12 years and older) had been offered access across the United States. Yet, demand has dropped off, and it is unclear whether the United States will reach the goal of herd immunity, the point at which a sufficient portion of the population has developed immunity to prevent the virus from effectively spreading (Khadkhoda, 2021). Without herd immunity, we may continue feeling the effects of this pandemic for some time, with additional surges of positive cases and the virus persisting at endemic levels indefinitely (Anderson et al., 2020). Perhaps more concerning, the longer the virus lingers in the population, the greater its opportunity to mutate into variants that are more transmissible, more severe, or even vaccine resistant (Fontanet et al., 2021). For these reasons, public health guidance is focused on getting as many people vaccinated as possible, as quickly as possible. Overcoming vaccine hesitancy is critical not only for an individual's health, but for the health of the population.

The problem of vaccine hesitancy is not unique to COVID-19 (Harrison & Wu, 2020), and substantial literature predating this pandemic has focused on identifying factors related to vaccine hesitancy. Religion and political orientation have both been found to predict hesitancy (Rosen et al., 2017; Whitehead & Perry, 2020), and studies have shown mixed results regarding demographic variables, such as age, gender, race, and socioeconomic status. For example, within the United States, higher education and income has been found to predict parental hesitancy, refusal, or delay of childhood vaccines (Smith et al., 2016; Wei et al., 2009), but so has lower education and income (Crouch & Dickes, 2015; Kempe et al., 2020), suggesting a bimodal distribution. Many studies have found that Black and Hispanic patients are vaccinated for flu at lower rates than White patients (e.g., Lu et al., 2017; Quinn et al., 2017), but Smith et al. (2016) found that vaccine delay was more likely for non-Hispanic White mothers. In a 24-country review, Hornsey et al. (2018) found that demographic factors, such as gender, age, and education, were nonsignificant predictors, and that political orientation (conservativism vs. liberalism) was a significant predictor but accounted for less variance than psychological variables. The uncertainty around demographic predictors points to the importance of understanding the psychological processes involved with vaccine hesitancy. Understanding vaccine hesitancy is not just about who is making the decision; it is about how they make it.

In 2012 the World Health Organization's (WHO) Strategic Advisory Group of Experts (SAGE) on Immunization determined that mistrust of vaccines was a significant problem for immunization efforts around the globe and established a working group to study vaccine hesitancy. The SAGE working group identified three categories of factors influencing vaccine uptake (Dubé et al., 2015). Sometimes called the "Three Cs," this model describes issues related to complacency (degree of risk perception of disease), confidence (degree of trust in the safety of the vaccine), and convenience (barriers to vaccine access). However imperfectly, government agencies and private entities in the United States and elsewhere have done much to address convenience issues for COVID-19 vaccination, with the proliferation of vaccine clinics and the sponsorship of cost-free vaccines. However, the other two Cs, complacency and confidence, are more psychological than systemic, so addressing them requires persuasive communication strategies grounded in psychology.

The issue of confidence, or trust in vaccines and in the institutions that promote them, has been the focus of much research on vaccine hesitancy. Hornsey et al. (2018) focused on the upstream psychological underpinnings, or what they termed the "attitudinal roots" of antivaccination beliefs. They found that general endorsement of conspiratorial beliefs, reactance, disgust, and a hierarchical and individualistic cultural orientation were all significant predictors of vaccine attitudes. Others have identified trust as an important factor. Mistrust of government, healthcare professionals and systems, and pharmaceutical companies, often but not always grounded in conspiracy theories and fueled by websites and social media, is associated with reluctance or refusal to vaccinate (Kata, 2010; Lee et al. 2016; Mergler et al., 2013; Reuben et al., 2020; Salvador Casara et al., 2019; Wilson et al., 2020).

The issue of complacency, or the question of whether the diseases themselves are perceived as dangerous, has also been addressed in research relating risk perception to vaccine uptake (Cori et al., 2020). When people fail to recognize a vaccine-preventable disease as risky, they are unlikely to seek that vaccine, and vaccines have been so effective in eliminating or reducing infectious disease, they

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are perceived as less necessary now. Diseases that were once common and severely dreaded have become so rare and so unfamiliar that people no longer recognize their risk (Salmon et al., 2015). As they are encountered less frequently, they become less available in mind, and are judged as less risky (Lichtenstein et al., 1978; Tversky & Kahneman, 1973). Salmon and colleagues pointed to cognitive heuristics contributing to underestimation of disease risk and overestimation of vaccine risk, including the omission bias (the tendency to prefer risks that are brought on passively over those resulting from one's own actions; Ritov & Baron, 1990) and a naturalness bias (the tendency to view naturally occurring risks, such as disease, as less dangerous than manmade risks, such as vaccines; Dibonaventura & Chapman, 2019). Early studies on COVID-19 vaccine intention have shown that higher perceived risk of the virus is indeed associated with greater interest in the vaccine (Caserotti et al., 2021; Zeballos Rivas et al., 2021), and higher perceived risk of the vaccine is associated with less interest (Karlsson et al., 2021). Nevertheless, much of the literature on interventions has suggested that information-focused interventions have limited impact on vaccine uptake, which has been interpreted to mean that cognitive factors are not the problem. Hobson-West (2003) argued for moving beyond risk perception to understand vaccine hesitancy, pointing to emotional, spiritual, and other factors as more important determinants and argued that interventions that focus on cognition, correcting risk misperception or other informational goals, are misguided.

These social and emotional factors are no doubt critically important, but the characterization of risk perception as distinct from emotionality may miss a fundamental aspect of risk perception. By now, it is well understood in the risk perception and decision-making literature that affect plays an important, and perhaps primary role in risk perception, arguably dominating so-called "rational" processing of objective risk information (Loewenstein et al., 2001; Peters & Slovic, 2000; Slovic et al., 2004). Probabilities are often underutilized or misunderstood, but that does not imply that probabilities are not influential in risk perception. Recent evidence has suggested that the very emotions that guide risk perception are in turn influenced by objective risk probabilities (Lacey et al., 2021). Although people may experience some baseline emotional response to the mere possibility of a risk without regard to its probability, that emotional response may be updated in response to changes in probability, and individuals differ in the extent of that updating. In other words, thinking about what might happen engages an emotional response, and thinking about how likely it is to happen further guides that response. So even if people recognize the importance of emotion in vaccine decisions, that does not mean that probabilities are irrelevant or should be ignored.

The COVID-19 pandemic presents a number of new factors that may contribute to vaccine hesitancy, above and beyond the issues previously identified in the literature. First, the novelty of the virus and the rapidity with which vaccines were developed, tested, and authorized for emergency use may create concern about the thoroughness of the process and the quality of the science itself. Most vaccines in the standard vaccine schedule have been around for decades and distributed to generations. By contrast, the COVID-19 vaccine was released less than a year after initial detection of the virus itself, and two of the vaccines available in the United States, the Pfizer-BioNTech and Moderna vaccines, are based on the relatively new technology of mRNA technology. Although mRNA vaccines have actually been under development for three decades (Verbeke et al., 2019, 2021), that history has not been as obvious to the general public as its breakthrough status, which may be adding to the concerns many people feel about its efficacy and long-term safety.

Second, people are experiencing this pandemic in the era of social media and 24-hour news. One obvious outcome of this media environment is the proliferation of conspiracy theories and politicized messaging, which has affected perceptions of the disease itself and the vaccine (Romer & Jamieson, 2020). Another important aspect of this constant media access is the unprecedented access to the ongoing science, and particularly the statistics, associated with this disease. Never before has the public had so much access to real-time updates in a disease's case counts, positivity rates, hospitalization rates, and mortality rates. These numbers are routinely reported at the global, national, and local levels on dedicated online dashboards and news outlets. COVID-19 statistics are shared on social media in the form of news links, infographics, memes, and personal posts. Interpretation of these numbers has been complicated, not only by the selectivity and even falsification of statistics shared across social media, but also the inconsistency in statistical reporting from official sources (Galaitsi et al., 2021), affecting the credibility of the statistical reports. Nevertheless, these numbers are generally

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intended to inform about risk levels and help guide individual behavior as well as policy, so how people understand and interpret these numbers may help explain the varied responses to the pandemic.

Although the prevalence of these numbers is unique to this pandemic, people often receive probability information when making health decisions, such as the likelihood of experiencing a side effect from a new medication, the chances of a complication from surgery, or the odds of surviving cancer. Those probabilities should ideally be factored into decisions, but there is a great deal of variability in how well people understand these numbers and utilize them in health decisions (Cokely et al., 2012; Garcia-Retamero et al., 2015; Heilmann, 2020; Malloy-Wier et al., 2016; Reyna et al., 2009). Beyond comprehension of the numbers, there is substantial variability in the way this kind of risk information is incorporated into emotional processing (Lacey et al., 2021). For example, some people worry much more about a 1 in 10 risk than a 1 in 1,000,000 risk, whereas others barely distinguish between such rare and relatively common risks, worrying equally about both. This *emotional sensitivity to probability* (ESP) essentially measures the extent to which affective response to risk varies with probability, and that tendency has been found to predict how people respond to a number of hypothetical health and safety risks, including cancer, asbestos exposure, and prenatal alcohol consumption (Lacey et al., 2021). It seems likely that it would also play a role in emotional and decisional responses to both a disease and its vaccine for which statistics are so available and salient.

A recent study by Shih et al. (2021) suggested that probability information does indeed factor into perceptions of COVID-19 vaccines. Their study, conducted months before vaccines became available, measured anticipatory hesitancy for hypothetical vaccines with different risk profiles, varying both the hypothetical effectiveness probabilities and the hypothetical probabilities of vaccine side effects. Vaccine perceptions were sensitive to these probabilities and trade-offs; hesitancy was lowest when effectiveness was high and side effect risks were low and increased as effectiveness dropped and side effect risks increased. However, another study found that interest in the vaccine declined over a five-month period as case numbers were increasing (Fridman et al., 2021), and another found evidence of “psychological numbing” in a qualitative analysis of social media posts; as the numbers of cases increased, posts indicated less concern (Dyer & Kolic, 2020). None of these studies accounted for individual differences in sensitivity to probability, which might account for the apparent discrepancy in responses to disease statistics.

In this study, we explored the way these unique characteristics of this pandemic engage individual differences in the way people interpret and respond to statistical information and medical science and their impact on vaccine decisions, as well as other COVID-19 prevention behaviors, including masking and social distancing. We surveyed participants about intentions to seek the COVID-19 vaccine, the frequency of their other preventative behaviors, and their worry about the disease itself and about the vaccine. We modeled those responses using individual differences in ESP along with several other individual difference measures related to perceptions of uncertainty and attitudes toward medical science and treatment; specifically, we also measured emotional reactivity to possibility (ERP), which measures affective response to the possibility of some outcome when probability is fixed, aversion to ambiguity in medicine (AAMed), which measures degree of comfort with uncertainty or ambiguity in medical science or treatment, and medical maximizing-minimizing (MMM), which measures the tendency to utilize all available medical care or underutilize available care. We hypothesized that (a) participants who are more emotionally sensitive to changes in probability would show more concern about COVID-19, would be more likely to pursue vaccination, and would be more likely to engage in other preventive behaviors including social distancing and masking, (b) participants who feel more aversion to medical ambiguity would be less likely to pursue vaccination, (c) participants who generally seek all medical interventions would be more likely to pursue vaccination and would be more likely to adhere to medical guidance about masking and social distancing. Finally, we also predicted that (d) participants who are more emotionally reactive to possibility would worry more about both COVID-19 and its vaccine. As these are competing worries, we remained agnostic as to whether ERP would predict vaccine seeking or vaccine avoidance.

For this study, we focused on college students, an age group for which COVID-19 vaccine hesitancy is particularly salient. The dynamics of the disease have placed older adults at highest risk for death or serious health complications, so they have been given higher priority for vaccine eligibility, and large majorities of this age group have been fully vaccinated. The focus on age as a risk factor has arguably left many younger adults feeling less vulnerable to

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the disease and less motivated to vaccinate, and vaccine rates for young adults have lagged behind older adults, long after the vaccine became widely available to all adults (Kirzinger et al., 2021). It may be particularly important, then, to understand vaccine hesitancy among this age group.

Method

Participants

A convenience sample of participants were recruited from a small private university in the northeast United States through announcements in psychology and biology courses, and to athletic teams and student organizations. Participants had the opportunity to enter a drawing in which 1 in 10 received a $10 Amazon gift card. One hundred seventy-six participants initially logged in to the survey, and 159 completed it, for an attrition rate of 9.7%. Of those completed surveys, 144 were included in regression models and 15 were omitted from analysis for missing one or more items used to compute individual difference measures. Thirty-four percent of participants indicated that they were either fully or partially vaccinated at the time of their participation, and 66% had not received any vaccine doses. Only those who were not yet vaccinated were included in the regression model for vaccine intention.

Participants ranged in age from 18 to 24 (M = 20.46, SD = 1.18), with 55% identifying as women, 31% as men, <1% as nonbinary, and 14% who did not disclose their gender. Seventy-two percent identified as White, 6% identified as non-White Hispanic, 3% identified as Asian or Pacific Islander, and 2% identified as Black or African American. Sixteen percent did not specify their race or ethnicity.

Pandemic Context

This survey was conducted in April and early May 2021, more than a year into the pandemic. Vaccines had been authorized for use in the United States in late 2020, but at the start of the survey, most states in the region (New England) were not yet making vaccines available to participants in this age group. However, some of our participants were eligible due to health status or occupational status (e.g., working or interning in schools or healthcare settings). Although several states did fully open eligibility to that age group before the study was completed, vaccine appointments were still scarce through most of this period. Vaccine mandates were not in place at this time.

At the time of this study, student participants were required to wear masks in any indoor common spaces on campus, and there were capacity limits for common spaces. Hybrid instruction was in place, with students rotating between in-person and virtual instruction, to reduce classroom density. Weekly COVID-19 testing was also required for everyone on campus, as were daily self-attestations about symptoms. Contact tracing was also active on campus. The campus positivity rate was low (<1%) but quarantining was common, mostly due to contact tracing. Mask mandates and capacity limits were also in place for Rhode Island (the location of the campus) and surrounding states. Rhode Island lifted these requirements later in May 2021, after the completion of data collection. Positivity rate in the state was around 1 to 2%.

Survey

COVID-19 Questions

Participants first saw questions related to COVID-19. They were asked whether they had received the vaccine and those who indicated that they had not received any doses of any vaccine were asked to rate, "How likely are you to get the COVID vaccine once it is available to you?" using a 7-point rating scale (1 = *not at all likely*, 7 = *extremely likely*). All participants were then asked to rate their worry about several possible problems associated with COVID-19, including short-term illness, long-term illness, hospitalization, dying, spreading the disease to others, and being required to quarantine. Participants rated each of these on a 7-point rating scale (1 = *not at all worried*, 7 = *extremely worried*). Participants were also asked to rate the severity of COVID-19 on a 7-point scale (1 = *not at all severe*, 7 = *extremely severe*), and their worry about side effects from the COVID-19 vaccine, on a 7-point scale (1 = *not at all worried*, 7 = *extremely worried*). Next, they were asked to rate the frequency with which they used masks in four settings (outside with well-known others, inside with well-known others, outside with unfamiliar people, and inside with unfamiliar people) and the frequency with which they socially distanced, maintaining a space of six feet between themselves and others in the same four settings, each on a 5-point scale (1 = *never*, 2 = *sometimes*, 3 = *about half the time*, 4 = *most of the time*, 5 = *always*). Finally, participants used this same 5-point scale to rate the extent to which COVID-19 has affected their willingness to engage in various public activities, including indoor restaurant dining, working out at a gym, shopping in-person at stores, seeking routine medical care, and seeking emergency medical care.

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Individual Difference Measures
Participants completed the 14-item Possibility/Probability Questionnaire (PPQ; Lacey et al., 2021), which measures both ESP (i.e., the extent to which affective response to risk varies with changes in probability), and ERP (i.e., the baseline affective response to risk when probability is held fixed). The PPQ is unusual in that composite scores are computed by regressing affective responses on item probabilities for each participant and estimating each individual's slope (which serves as the ESP score) and intercept (which serves as the ERP score). Participants also completed the 6-item Ambiguity Aversion in Medicine Scale (Han et al., 2009), which measures discomfort with uncertainty or conflicting information about medical tests and treatments, and the 10-item Medical Maximizer-Minimizer Scale (Scherer et al., 2016) which measures the tendency to over- or under-utilize healthcare. The psychometric properties of these measure are detailed in their original citations.

Procedure
Approval was obtained from the Bryant University Internal Review Board (file #2021-0322e) prior to this study. Participants logged on to the online survey hosted on Qualtrics and read a brief description of the survey and were given the option to give consent and continue with the study. The survey presented the set of COVID-19 questions first. The three individual difference measures followed, and the order of these measures was randomized across participants. Finally, participants were asked to provide demographic information including age, gender, and ethnicity. At the end of the survey, participants were directed to follow a second link where they could enter themselves into the gift-card drawing.

Results

Analysis
All analyses were completed using R statistical software (R Core Team, 2019). Composite scores were computed by averaging across ratings for the score masking items (α = .71), the four social distancing items (α = .80), and the five items describing avoidance of public places (α = .86). For the six items describing worry about COVID-19 consequences, Chronbach's alpha was unacceptably low (α = .44), so we analyzed each item separately rather than analyzing a composite score. The lack of cohesion for these worry items suggests some independence among the varied concerns people have about COVID. Fear of serious or long-term illness may or may not be associated with fear of death, for example. And there may be individuals who do not feel personally vulnerable to the health effects of COVID-19 but are worried about spreading it to more vulnerable others or about quarantines and other barriers to normal life.

Each of these outcome measures, as well as the single-item responses for vaccine intention, worry about vaccine side-effects, and perceived severity of COVID-19 was modeled using linear regression, with the four individual difference measures (PPQ-ESP, PPQ-ERP, AAMed, and MMM) as predictors. All variables were standardized to have mean of 0 and variance of 1 before running regression models, placing the different variables onto the same scale, allowing for easier comparison of coefficient effect sizes. An alpha level of .05 was used for all significance tests.

Scoring of the PPQ followed the procedures detailed in Lacey et al. (2021). Chronbach's alpha was not previously reported for this measure, but here we found an alpha of .85. For the AAMed scale, Han et al. (2009) previously found acceptable reliability (α = .73), and in the current study, reliability was slightly lower (α = .68). Although this is considered to be at the high end of the range considered questionable, the scale has been widely used and replicated, so we included it in our analyses without any alterations to its standard scoring. Scherer et al. (2016) previously reported an alpha of .87 for the MMM scale, and we found an acceptable alpha of .79.

Vaccine Intention and Prevention Behaviors
Model coefficients for vaccine intention, masking average, social distancing average, and avoidance of public places are shown in Table 1. Consistent with our first hypothesis, PPQ-ESP was a significant predictor of vaccine intention (p = .003). The more people calibrate their emotional responses to changes in risk probability, the greater their intention to seek the COVID-19 vaccine. Although we hypothesized that PPQ-ESP would also predict greater adherence with each of the prevention behaviors that we measured, the relationship that we found for vaccine intention was not found for masking, social distancing, or willingness to attend public places (p > .10 in all cases).

We also found support for our second hypothesis, and the pattern of results for the AAMed predictor was similar to that of PPQ-ESP. Participants who are more intolerant of medical ambiguity indicated significantly less interest in receiving the COVID-19 vaccine (p = .008) but AAMed was

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unrelated to masking, distancing, or avoidance of public places ($p > .10$ in all cases).

Hypothesis 3 was also partially supported; people who tend to maximize their use of available medical care indicated significantly more frequent masking ($p = .10$), social distancing ($p = .02$), and avoidance of public places ($p = .006$). However, MMM had no significant relationship with vaccine intention ($p > .01$). This is the reverse of the pattern found for PPQ-ESP and AAMed, which were associated with vaccine intention but not with masking, social distancing, or avoiding public places.

For each our three hypotheses regarding preventative behaviors, we saw a split; the predictors in our model either predicted vaccine intention or social behaviors that limit viral exposure (i.e., masking, distancing, and avoiding public places). But none of our predictors predicted both, suggesting different motivations underlying these behaviors.

TABLE 1

Coefficient Estimates for Regression Models of COVID-19 Preventative Behaviors and Individual Difference Measures

Preventative Behavior	Predictors			
	PPQ-ESP	PPQ-ERP	AAMed	MMM
Vaccine intention	.29**	−.09	−.25**	.14
Masking	.05	.09	−.02	.22*
Social distancing	−.03	.14	.004	.21*
Avoiding public places	.04	.16*	−.05	.25**

Note. PPQ = Possibility/Probability Questionnaire. ESP = emotional sensitivity to probability. ERP = emotional reactivity to possibility. AAMed = aversion to ambiguity in medicine. MMM = medical maximizing-minimizing.
$^{*}p < .05$. $^{**}p < .01$.

TABLE 2

Coefficient Estimates for Regression Models of COVID-19 Perceptions and Individual Difference Measures

COVID-19 Perceptions	Predictors			
	PPQ-ESP	PPQ-ERP	AAMed	MMM
Short-term illness	.06	.12	.06	.18*
Long-term illness	.14†	.29***	−.08	.18*
Hospitalization	.09	.25**	−.10	.27**
Death	.002	.27***	−.16*	.23**
Spreading to Others	.22**	.12	−.12	.08
Quarantine	−.03	−.08	−.05	−.14
Vaccine side-effect worry	−.09	.22**	.31***	−.01
Perceived severity	.22**	.18*	−.11	.35***

Note. PPQ = Possibility/Probability Questionnaire. ESP = emotional sensitivity to probability. ERP = emotional reactivity to possibility. AAMed = aversion to ambiguity in medicine. MMM = medical maximizing-minimizing.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Worry

Table 2 shows model coefficients for each of the worry items, as well as perceived severity of COVID-19. We hypothesized that ERP should predict worry about adverse outcomes, both for COVID-19 itself and for its vaccine, and this hypothesis was generally supported, particularly for the most severe consequences of the virus. PPQ-ERP predicted significantly more worry about long-term illness ($p < .001$), hospitalization ($p = .001$), and death ($p < .001$) resulting from COVID-19, and also predicted significantly more worry about side-effects for the vaccine ($p = .006$). PPQ-ERP was also associated with significantly greater perceived severity of the virus ($p = .02$). PPQ-ERP was not a significant predictor of worry about short-term illness ($p = .14$), spreading the virus to others ($p = .13$), or quarantining ($p = .32$), although the trend approached significance for short-term illness and spreading the virus.

We also found that PPQ-ESP predicted significantly more worry about spreading the virus ($p = .006$) and higher perceived severity of the virus ($p = .005$) and was marginally associated with more worry about long-term illness ($p = .09$). AAMed was associated with significantly less worry about death from the virus ($p = .04$) and significantly more worry about vaccine side effects ($p = .005$). MMM predicted significantly more worry about short-term ($p = .04$) and long-term ($p = .03$) illness, hospitalization ($p = .002$) and death ($p = .005$) from the virus, and significantly higher perceived severity of the virus ($p < .001$).

Discussion

As is clear from the literature on vaccine hesitancy, the reasons for refusal or hesitation to receive the COVID-19 vaccine are varied, so interventions to increase vaccine uptake must be varied as well. For example, some may feel compelled by appeals to communal responsibility, whereas others may only harden their stance, interpreting these appeals as a threat to their decisional autonomy. Some may respond positively to endorsements from healthcare or government sources, whereas for others, this may trigger distrust. And for some, daily information about risk statistics may be compelling, whereas others may be indifferent to it. To approach the goal of herd immunity, it will be necessary to take varied strategies addressing these different motivations, so it is critically important to identify as many of these factors as possible.

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In this study, we added to this understanding by identifying two variables, ESP and aversion to medical ambiguity, that predict variability in intention to vaccinate. People who tend to draw on probability information to calibrate their emotional responses to risk, responding more strongly to high probability risks than low probability risks, indicated more interest in pursuing the vaccine. Those who are more distressed by ambiguity and uncertainty in medical care indicated less interest. Both constructs deal with how people deal emotionally with uncertainty and risk, much like the uncertainties everyone has faced during this pandemic. How does it spread? When will it end? What is the right way to stop it? Whose information can I trust? And perhaps most centrally, will it happen to me? How people answer these questions for themselves (whether those answers are objectively accurate or not) and how those answers make them feel (whether it is fearful, hopeful, or something else) helps to guide their decisions.

Interestingly, although both ESP and AAMed were associated with vaccine intention, neither was associated with other preventative behaviors, including the frequency of masking, social distancing, or avoidance of public places. But why not? After all, like vaccines, these behaviors are intended to mitigate the risk of contracting or spreading the COVID-19 virus. We speculate that the difference lies in the locus of the decision for vaccinating vs. other behaviors. At the time of this study in Spring 2021, masking and distancing were normative and even mandated. The student participants of this study were required to wear masks anywhere on campus beyond their own dorm rooms. Classrooms, dining halls, and other venues were arranged to maintain physical distance between people. The surrounding community had similar norms and rules in place, including mandated masking and limited capacity in restaurants and other public settings. Certainly, an individual could choose not to conform but that choice would be very visible, and in some cases, punishable. A study from early in the pandemic confirms that social norming was a strong predictor of preventative behaviors during the early lockdown period in Italy (Savadori & Lauriola, 2020). By contrast, there was no mandate for vaccines at the time of our study, and the shot is virtually invisible unless someone chooses to disclose it. The decision to vaccinate or not could be made much more privately and thus had more freedom to reflect the individual's interpretation of the risks and uncertainties involved and the feelings evoked by that interpretation.

This issue of mandates and norms highlights the importance of the temporal context of these findings. In May 2021, after completion of this study, the Centers for Disease Control (CDC) changed its guidelines, recommending masks only for unvaccinated individuals. Many states quickly followed suit, ending mask mandates as well as capacity limits. By the end of July, the CDC again changed its recommendation in response to the more contagious delta variant of the virus, recommending that both vaccinated and unvaccinated people should once again wear masks indoors or in crowded outdoor settings in areas where COVID-19 transmission is high. By that time, with mask rules already loosened, few states or municipalities reinstated mask mandates, and in some instances, states moved in the other direction, banning schools or other organizations from initiating their own masks mandates. As a result, mask use has become less ubiquitous, and as both mandates and norms have relaxed, the decision to wear a mask has more room to respond to personal interpretations of risk. We might expect that, under these circumstances, ESP and AAMed might predict masking behavior in the way that they predicted vaccines earlier.

Nevertheless, at the time of our data collection, we did find a different variable that predicted frequency of masking, social distancing, and avoidance of public places. Medical maximizers, those who are more likely to utilize medical care, more frequently engaged in those preventative behaviors. Medical maximizers are characterized by their willingness to accept medical guidance and engage in preventative care, so it follows that these individuals would be more willing to conform to these preventative measures that were unambiguously recommended by the medical community since early in the pandemic. What is less clear is why medical maximizing was unrelated to vaccine intention. We expected that these individuals would also be particularly motivated to take advantage of this important medical intervention, but they were no more or less likely to seek the vaccine than others. This question may warrant exploration in future research, though the specific circumstances of this pandemic at this moment in time may be difficult to recreate.

Although this study provided some important insights into decisions about individuals' decisions regarding COVID-19 prevention, it certainly has its limitations. First, because this was an opportunistic study timed to capture responses to a real-world event and relying on a convenience sample of students, the study was time-limited by the end of

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an academic year and by the changing landscape of vaccine availability at the time. This timing constrained our sample size, and we were unable to optimize statistical power. The monotonic positive relationship between power and significance implies that, when an effect is significant, it is adequately powered, so the significant effects found in this study were adequately powered. However, it is more difficult to interpret null effects, specifically the nonsignificant relationships of ESP and AAMed with masking, social distancing, and avoidance of public places, and the nonsignificant relationship between MMM and vaccination. We have offered speculative explanations for this pattern of results, but it is possible that these effects were simply underpowered.

Given the low power, it is useful to consider effect size, not just significance level. The relationships between ESP and masking, distancing, and avoidance of public places are all extremely small (these standardized beta coefficients reported in Table 1 translate to Cohen's f^2 values < .01 which is considered extremely low by conventional standards). By contrast, the significant relationship between ESP and vaccine intention was an order of magnitude higher ($f^2 = .09$), albeit still considered a medium-low effect size. The pattern with AAMed was similar, with near-zero effect sizes for masking, distancing, and avoiding public places ($f^2 = .01$ in each case), and a larger (but still small) effect size for vaccine intention ($f^2 = .07$). It is unlikely that a larger sample size would bring the near-zero effects above the threshold for significance, so it is arguably safe to accept the null hypothesis that these two variables do not predict masking, distancing, and avoidance behaviors. The relationship between MMM and vaccination decision is slightly higher, but the effect is still considered quite low (Cohen's $f^2 = .03$). A larger sample size might indeed provide more clarity about this relationship, although the effect size is small enough that even a significant result might have limited clinical relevance to the real-world problem of vaccine hesitancy.

A second limitation is that our convenience student sample was not representative of the general population, limiting generalizability. Our findings apply to a very specific population of college students. Although the student population is an important one, given the lower vaccination rates for this age group, these data may not generalize to other age groups or even to other young adults outside of the context of a similar residential college community. What is more, these were students at a small, private, disproportionately White university in New England, so even generalization to other college populations may be limited. Certainly, age, education, and other demographic variables are themselves important predictors of vaccination and other COVID-19 responses, but without a broader sample, we cannot determine whether these demographics interact with the individual difference variables tested here.

There may also be other important aspects of vaccine hesitancy that cannot be addressed with this student sample. For example, parents are the ones making vaccine decisions for children under the age of 18, and those decisions may not always follow the decisions people make for themselves. In the United States, the Pfizer-BioNTech vaccine was authorized for children over the age of 12 in May 2021, but uptake for this age group has stayed particularly low (Kirzinger et al., 2021), suggesting that many parents who accepted the vaccine for themselves are hesitant to seek it for their children. This may reflect the general risk aversion that is observed when people make decisions for others (Batteux et al., 2019; Klein & Ferrer, 2018; Polman & Wu, 2019), but that tendency may be moderated by the risks that parents perceive for this particular disease and vaccine. For a parent who perceives the disease as riskier than the vaccine, the most risk-averse choice would be to go ahead with vaccination. The factors identified in this study may play an important role in identifying how parents perceive the risk of the disease and the vaccine and should help explain vaccination decisions made on behalf of children. This is a question that could not be explored with our college student sample, most of whom do not yet have children. Another limitation of the study is that we did not request information about participants' parents' vaccination status, their attitudes about COVID-19, nor their education or other demographic characteristics. Although our college student participants are legally responsible for their own health decisions, they are very likely influenced by parental behavior and attitudes, and we did not explore those possible predictors.

Finally, it is important to recognize that attitudes are an imperfect predictor of behavior (Glasman & Albarracín, 2006), including attitudes about risk (Sheeran et al., 2014). Intention is a somewhat better predictor, but there is still a meaningful intention-behavior gap (Sheeran & Webb, 2016). This means that our measures of vaccination intention may not translate to actual jabs in arms in every case. There are a number of internal factors that affect the likelihood that intention results in action, such as the specificity of the goal (Locke & Latham, 2013), the locus of motivation (internal or

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external; Sheeran & Orbell, 1999), and relevance to personal identity (Sheeran & Orbell, 2000). But there is also evidence that behavioral "nudges" work (Dai et al., 2021), suggesting that the removal of external barriers and the active facilitation to action also can increase behavioral follow-through. Returning to one of the "Three Cs" (confidence, complacency, and convenience), it is important to continue efforts to make vaccines as convenient as possible to reduce the intention-behavior gap.

Despite these limitations, this study does contribute new insight into the varied responses we have seen during the COVID-19 crisis. As of the writing of this article (late summer, 2021), the second anniversary of this pandemic approaches. Although many hoped life would have returned to "normal" long before now, people are instead riding out yet another surge of cases and hospitalizations, driven by new variants combined with low vaccination rates, so there is continuing urgency to understand the concerns and motivations of those who hesitate or refuse to get vaccinated. And on a farther horizon, this may not be the last such crisis faced, as viruses continue to evolve or cross into people. Not only is rapid development of vaccines and treatments in the event of another pandemic needed, but also continuing preparations for the psychological motivations that interfere with effective deployment of those tools.

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Author Note. Heather P. Lacey https://orcid.org/0000-0003-2257-0170

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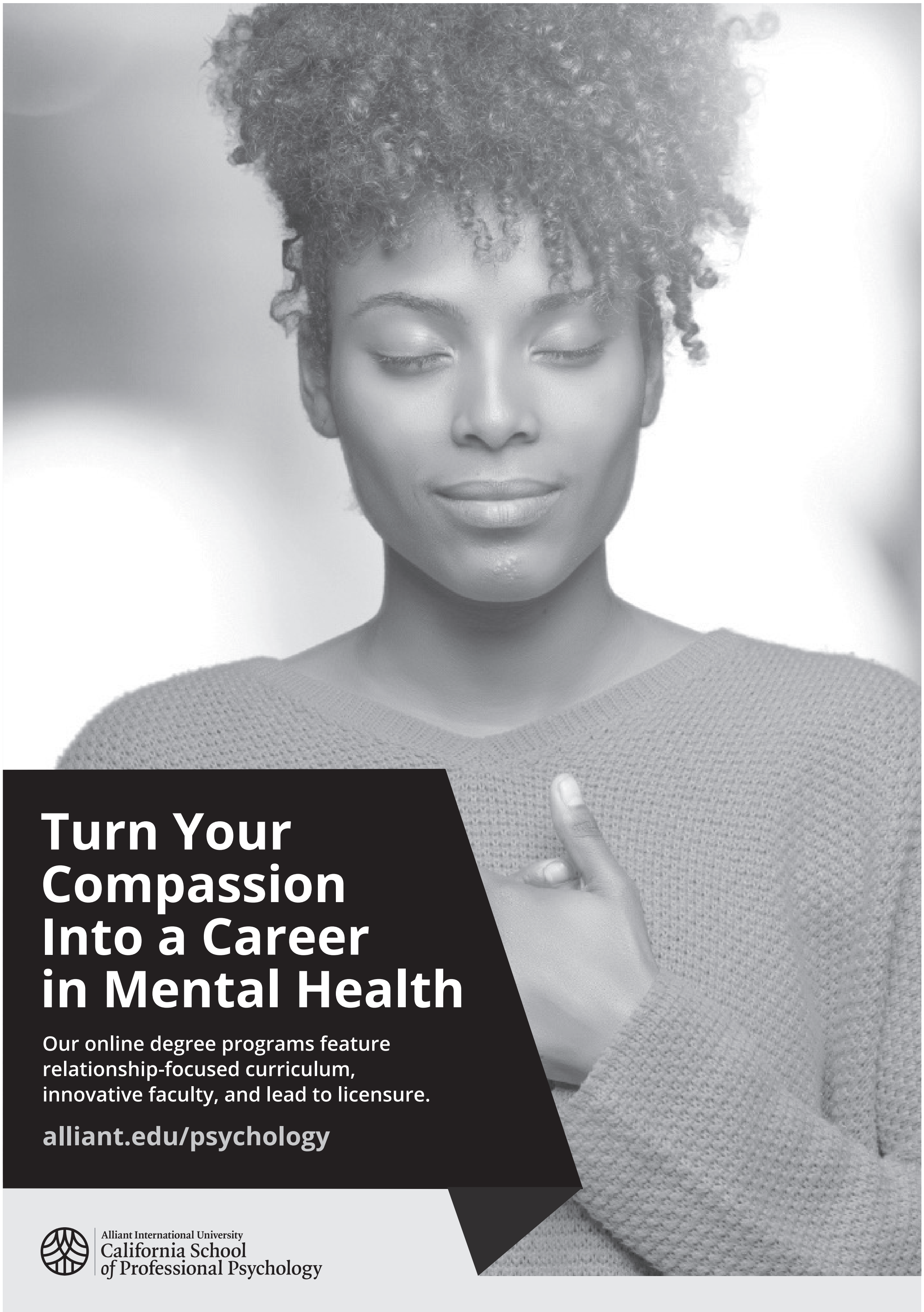
Correspondence regarding this article should be addressed to Heather P. Lacey, Department of Psychology, Bryant University, 1150 Douglas Pike, Smithfield, RI, 02864. Email: hlacey@bryant.edu



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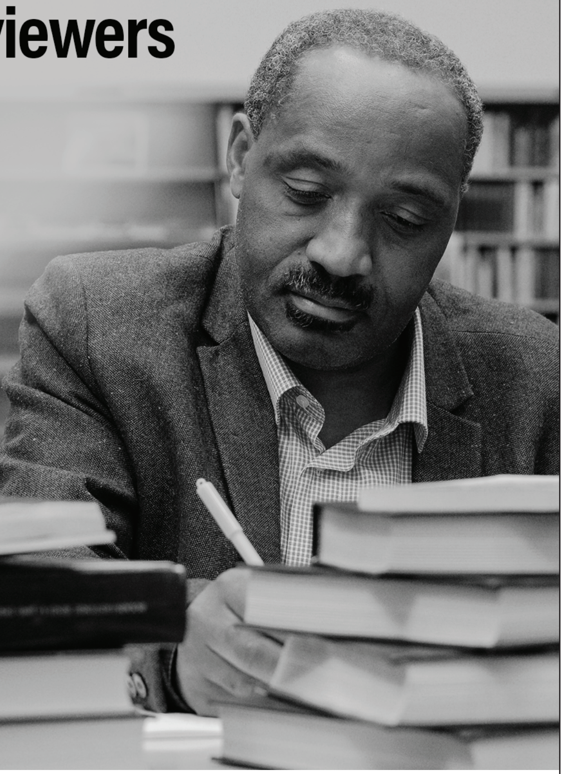

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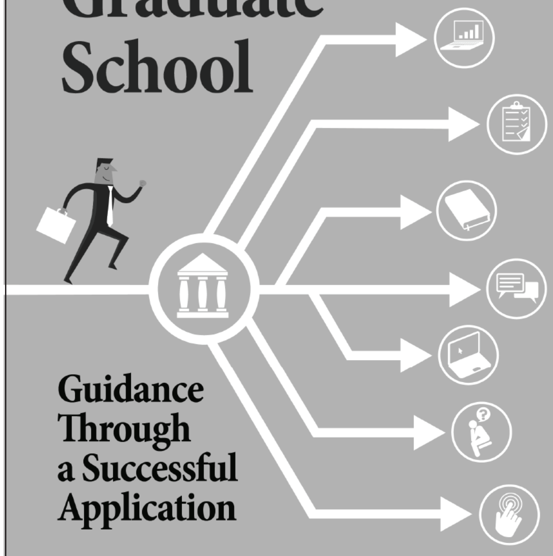

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