12-2022

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Citation

COLARELLI, Stephen M., MIRANDO, Tyler J., HAN, Kyunghee, LI, Norman P., VESPI, Carter, KLEIN, Katherine A., & FALES, Charles P..(2022). Responses to COVID-19 threats: An evolutionary psychological analysis.. *Evolutionary Psychological Science,* , 1-11.
Available at: https://ink.library.smu.edu.sg/soss_research/3730

Evolutionary Psychological Science
https://doi.org/10.1007/s40806-022-00348-7

RESEARCH ARTICLE

Responses to COVID-19 Threats: an Evolutionary Psychological Analysis

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Received: 27 June 2022 / Revised: 8 November 2022 / Accepted: 8 November 2022

Abstract

Responses to COVID-19 public health interventions have been lukewarm. For example, only 64% of the US population has received at least two vaccinations. Because most public health interventions require people to behave in ways that are evolutionarily novel, evolutionary psychological theory and research on mismatch theory, the behavioral immune system, and individual differences can help us gain a better understanding of how people respond to public health information. Primary sources of threat information during the pandemic (particularly in early phases) were geographic differences in morbidity and mortality statistics. We argue that people are unlikely to respond to this type of evolutionarily novel information, particularly under conditions of high uncertainty. However, because individual differences affect threat perceptions, some individual differences will be associated with threat responses. We conducted two studies (during Phase 1 and 2 years later), using data from primarily public sources. We found that state-level COVID-19 morbidity and mortality rates had no relationship with mental health symptoms (an early indicator of how people were responding to the pandemic), suggesting that people—in general—were not attending to this type of information. This result is consistent with the evolutionary psychological explanation that statistical information is likely to have a weak effect on the behavioral immune system. We also found that individual differences (neuroticism, IQ, age, and political ideology) affected how people responded to COVID-19 threats, supporting a niche-picking explanation. We conclude with suggestions for future research and suggestions for improving interventions and promoting greater compliance.

Keywords COVID-19 · Mismatch · Decision-making · Individual differences · Behavioral immune system

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The number of deaths in the USA from the COVID-19 pandemic (over 1 million) has exceeded the US total from the Spanish influenza epidemic (Curley, 2021), which had been the deadliest pandemic in the US history (Barry, 2020).[1] Worldwide, over 6 million people have died from COVID-19. While there have been significant improvements in scientific and public understanding of the disease, progress with public health interventions remains disappointing (Ishak, 2022; Lewis, 2021; Nan et al., 2022). For example, despite the severity of the COVID-19 pandemic and the widespread availability of safe and effective vaccines (the best-known way to defeat the pandemic), only 64% of the US population was fully vaccinated at the beginning of 2022 (Center for Disease Control and Prevention, 2021). Throughout the world, only 59% of the population has been vaccinated

[1] Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the virus that causes COVID-19.

Published online: 15 December 2022

with at least two doses (Ritchie et al., 2020). These rates are much lower than for other serious infectious diseases—approximately 83% for polio, DPT, and measles (Muhoza et al., 2021). Although the COVID-19 pandemic will likely run its course, there will be other pandemics (Olshaker & Osterholm, 2017). Moreover, given the unprecedented scale of global travel, future pandemics have the potential to be as widespread and severe as the COVID-19 pandemic.

While much has been achieved, challenges remain for improving how public health information is presented and how people respond to it (Ash et al., 2022). Guided by theory and research in three areas of evolutionary psychology—mismatch, the behavioral immune system, and individual differences—we undertook the present study to gain a better understanding of how people respond to COVID-19 threat information under different conditions as well as to examine psychological mechanisms that influence those responses. Primary sources of COVID-19 threat information (particularly during Phase 1 of the pandemic) were morbidity and mortality statistics (by geography) as well as non-personalized media images. We argue that people are unlikely to respond to this type of evolutionarily novel information, particularly under conditions of high uncertainty. However, because individual differences affect threat perceptions, some individual differences will be associated with threat responses.

We examined people's responses to the pandemic in the USA at two points in time—during Phase 1 and 2 years later. In Study 1, we examined the relationship between variation in state-level COVID-19 threat information and mental health symptoms (as indications of concern about COVID threats), as well as the relationship between personality characteristics and mental health symptoms. In Study 2, conducted 2 years later, we used available (state-level) data to examine the effects of intelligence, age, and ideology on vaccination rates.

Timeline of the COVID-19 Pandemic

During the first phase of the pandemic in the USA (March–June 2020), connections among the virus (SARS-CoV-2), infection, symptoms, and morbidity were causally opaque (Koelle et al., 2022). It was initially unknown who was most susceptible to infection, what groups would suffer the worst effects, and when during the course of infection the virus was most transmittable (Slifka & Gao, 2020; World Health Organization, 2020). Messages about wearing masks varied from unnecessary to a good idea to essential (Eikenberry et al., 2020; Worby & Chang, 2020). What was known was that morbidity and mortality rates varied by geography (CDC COVID-19 Response Team, 2020). Public health interventions were limited to keeping the public informed of morbidity and mortality rates and imposing lockdowns to prevent the spread of the virus. Thus, many types of direct metrics (e.g., vaccination, masking, and social distancing rates) that could be used to assess people's threat responses were not available during Phase 1. A number of researchers argued that mental health symptoms were one of the few available indicators of how people were responding to the pandemic and to public health information—assuming that greater concern about or fear of the virus should manifest in greater emotional distress (Cullen et al., 2020; McGinty et al., 2020; Pfefferbaum & North, 2020).

Two years later, the situation was considerably different. Although most areas of the USA experienced spikes in morbidity and mortality, lockdowns had mostly ended. There was a better scientific understanding of the virus and disease. Studies found that children were least at risk (Pierce et al., 2022), the elderly were most vulnerable (Liu et al., 2020), the primary vectors were respiratory droplets and contact routes, and infected people were most likely to transmit the virus when they were pre-symptomatic (Johansson et al., 2021). The evidence was clearer that masking and social distancing helped to minimize the chances of infection. Most important, effective vaccines became widely available, which provided a direct metric for assessing how people were responding to COVID-19 threats.

COVID-19, Mismatch, and the Behavioral Immune System

A likely assumption underlying the reporting of morbidity and mortality rates during Phase 1 was that people would respond "rationally" (e.g., Cushman, 2020; Eiser et al., 2012) to this information.[2] That is, they would attend to the information, weigh the pros and cons of alternative courses of action, and behave according to threat levels. Where threat levels were high, people would behave more cautiously, be more concerned about health risks, and report greater levels of distress and anxiety. Conversely, where local threat levels were low, people would be less cautious, less concerned about becoming infected, and less anxious. Would this be the case?

An evolutionary psychological perspective would suggest the opposite: people, in general, would not respond differentially to statistical information, particularly under conditions of high uncertainty (Colarelli & Thompson, 2008; Moore, 1996). Over millennia, our behavioral immune system has been the primary way that people responded to infectious disease threats—by detecting

[2] Providing statistical information on food labels and menus, particularly the calorie content of food items, has been a common public health intervention to attempt to curb the worldwide epidemic of obesity. It has also been unsuccessful (Kiszko et al., 2014). Folwarczny et al. (2022) argue that evolutionary psychological-based interventions would be more effective.

and avoiding pathogens (Schaller & Duncan, 2007). It operates by triggering avoidance responses to animate and inanimate objects that—recurrently over our evolutionary history—had a high probability of carrying infectious pathogens. This system triggers an avoidance response through the emotion of disgust (Cepon-Robins et al., 2021; Oaten et al., 2009). Both animate and inanimate objects with obvious signs of carrying infectious pathogens trigger the disgust response. Examples include spoiled food, feces, cadavers, sick animals, and people with noticeable signs of illness (e.g., blemishes, pustules, vomiting, a runny nose, skin pallor, deformities). The disgust response is normally followed by avoidance. More proactive (cultural) responses can also develop, including adherence to social norms and rituals that help guard against infection (e.g., personal hygiene, food preparation customs). However, because the behavioral immune system evolved in ancestral environments that are quite different from modern environments (Li et al., 2018), it is unlikely that people—in general—will respond to evolutionarily novel information, such as pandemic statistics and commentaries about global trends.[3] However, as we discuss later, some individual differences are likely to influence how people respond to COVID-19 threat information.

One might counter that the media and social media were full of images related to the ravages of COVID-19—and that these images should activate the behavioral immune system. While there were abundant images of overworked health care workers, intensive care units overflowing with COVID-19 patients, spikey balls representing the virus, and even coffins, there have been—for a variety of reasons, including medical privacy laws—few images of identifiable victims in the throes of the disease (Lewis, 2020). Moreover, images of intensive care units filled with COVID-19 patients, ventilators, and so forth are evolutionarily novel. Graphic images of sick and suffering people would most likely activate the behavioral immune system (Schaller et al., 2010). This was the case during the polio epidemics of the mid-twentieth century, with widespread public health campaigns using images of crippled children (see Fig. 1) (Mayo Clinic Staff, 2022).[4] In addition, people infected with the coronavirus are initially asymptomatic, and early symptoms are not severe (resembling the common cold). By the time people were severely ill, many were out of view—isolated—at home or in a hospital. As a result, there were few inputs to activate the evolved behavioral immune system. Not surprisingly, it was people with direct experience with COVID-19—either experiencing symptoms themselves or having a friend or relative who was sick with COVID-19—that were most likely to

Note: History of Polio – GPEI polioaradication.org

Fig. 1 Typical images of victims of the polio epidemic and COVID-19 pandemic

[3] Several studies have found that people respond to statistical information about threats (disease, storms). Two studies found that they respond with over-perception bias (Makhanova et al., 2015; Miller & Maner, 2012). Another study (Bacon & Corr, 2020) found that perceived vulnerability to disease increased slightly after participants in an experiment read COVID-19 morbidity and mortality statistics. Because these were lab studies, it is likely that subjects' attention was specifically focused COVID-19 statistics, which is less probable in a natural setting. Thus, research in a variety of settings is important for understanding how people assess risk to natural threats (Eiser et al., 2012) and how the outcomes found in lab studies relate to avoidance emotions and behavior in natural settings.

[4] The polio epidemic was one of the most (if not the most) feared disease in the first half of the twentieth century. Unlike COVID-19, the symptoms of polio were obvious—paralysis and often death, primarily among infants and children (Baicus, 2012; Centers for Disease Control and Prevention (CDC), 2021). Prior to the vaccine and when the polio pandemic was at its worst (1948–1955), parents were extraordinarily cautious about letting their children go outside or to public gathering places (e.g., swimming pools), particularly in the summers, when the incidences of infection were highest (Mayo Clinic Staff, 2022).

suffer negative mental health symptoms (González-Sanguino et al., 2020).

We expand behavioral immune system research to investigate the role of evolutionarily novel stimuli associated with infectious diseases. Research on the behavioral immune system has traditionally examined how exposure to pathogenic stimuli—stimuli that, over evolutionary history, have recurrently been associated with infectious disease—creates a disgust response (or perceived vulnerability to disease), and how this in turn motivates avoidance behavior. We examine whether evolutionarily novel stimuli (specifically, variation in disease threat exposure statistics) creates differential vulnerability responses. We expect that the behavioral immune system may be less responsive to evolutionarily novel threat stimuli (Schaller et al., 2021).[5]

Individual Differences and Threat Information

In large measure, evolutionary psychology focuses on broad, species-level adaptations and behavior. For example, the behavioral immune system is a species-typical mechanism that evolved to detect infectious pathogens and motivate people to avoid them. Yet, individual differences inevitably create variation in species-typical responses, including how people respond to disease (and other) threat information. While it is important to understand how people in general respond to infectious disease threats, it is also critical to understand how individual differences affect responses. This helps in building public health policies that can be tailored to individuals who may respond outside of population norms. Recent research in evolutionary psychology provides useful frameworks for thinking about how individual differences influence threat responses.

Theories of niche picking, reactive heritability, and frequency-dependent selection suggest how individual differences in personality can evolve and be adaptive in different circumstances. Neuroticism continues to be widespread because people with this trait, over evolutionary history, were more likely to survive and reproduce by playing it safe. Given that hypervigilance to threat information can be an adaptive response for people with neurotic personalities, these individuals would be most likely to suffer depression, loneliness, or anxiety in the face of imminent danger, which in turn would trigger caution and isolating behavior. In contrast, other traits (e.g., extraversion, openness to experience) continue to be widespread because of the adaptive value of pursuing risky strategies. Ignoring threat information and carrying on normally may provide access to valuable opportunities, despite the risks (Nettle, 2006). Several studies conducted in the early phases of the pandemic, for example, found that neuroticism (Airaksinen et al., 2021) and perceived vulnerability to infection (Makhanova & Shepherd, 2020) stimulated protective responses. Thus, we expect that neuroticism would be associated with indices of emotional distress, while this is unlikely to be the case for other Big Five personality traits.

The savanna-IQ interaction hypothesis suggests how general intelligence evolved to allow individuals to overcome problems associated with a mismatch (Kanazawa, 2010). That is, differences in intelligence should affect how people assess and act upon evolutionarily novel information (to the extent that causal connections are not entirely opaque). Thus, as the relationship between vaccines and disease mitigation became clearer, we would expect a positive relationship between intelligence and vaccination rates. In addition, evolution designed a variety of psychological adaptations that can be switched on and off throughout the lifespan (Buss, 2009). One of which is that people become more risk averse as they age (Rolison et al., 2014). As people age, they become more frail and susceptible to injury and infection.[6] Thus, we would expect that older people would become more responsive to COVID-19 threats—to the extent that relatively clear and believable threat information was available.

Finally, beliefs and ideology are memes that, given sufficient time, can evolve into norms and cultural practices on which people differ (Campbell, 1975; Henrich, 2016). Through cultural evolution, beliefs can become protective. However, they can also be unreliable (or harmful) over the short-term (Henrich, 2016)—such as some beliefs about COVID-19 threats and responses to threats (Conway et al., 2021; van Holm et al., 2020). In particular, anti-science beliefs and associated norms have, in some cases, become more of a signal of in-group-out-group membership (Boykin et al., 2021) than helpful responses to minimize COVID-19 infection.

[5] People responded pretty much the same during the Spanish Flu pandemic on the early twentieth century as they did now—ignoring public health recommendations to social distance and wear masks (Barry, 2020).

[6] With children, of course, vaccinations are parents' decisions. We expect, though, that parents would follow a decision calculus based on the perceived threat of COVID-19 to their children's well-being. As the evidence became clear that young children were least susceptible to infection and least likely to become ill or die from Covid (Pierce et al., 2022), we would expect that children would be the group least likely to be vaccinated. During the polio epidemic children were the most susceptible demographic group, and they were most likely to be vaccinated (Mayo Clinic Staff, 2022).

Table 1 Sample size, mean (standard deviation) of loneliness, anxiety, and depression by state

State	*n*	Loneliness *M* (*SD*)	Anxiety *M* (*SD*)	Depression *M* (*SD*)
California	55	2.39 (0.88)	1.86 (0.72)	1.72 (0.79)
Florida	29	2.28 (0.87)	1.76 (0.64)	1.53 (0.65)
Georgia	19	2.39 (0.53)	1.75 (0.67)	1.43 (0.68)
Illinois	18	2.47 (0.91)	1.93 (0.80)	1.77 (0.73)
Michigan	10	2.20 (0.67)	1.77 (0.95)	1.39 (0.49)
New York	32	2.54 (0.85)	1.93 (0.71)	1.65 (0.81)
North Carolina	20	2.21 (1.06)	1.88 (0.93)	1.63 (0.80)
Ohio	17	2.65 (0.94)	1.81 (0.51)	1.67 (0.72)
Pennsylvania	16	2.65 (0.98)	2.09 (0.66)	1.78 (0.72)
Texas	40	2.40 (0.76)	1.72 (0.68)	1.63 (0.74)
Virginia	15	1.99 (0.70)	1.37 (0.46)	1.44 (0.67)
Washington	10	2.66 (0.45)	2.03 (0.64)	1.84 (0.78)
Wisconsin	10	2.76 (0.55)	1.98 (0.59)	1.86 (0.82)

Loneliness (1–5 scale), anxiety (1–4 scale), depression (1–4 scale)

Study 1

During Phase 1 of the pandemic, people were exposed to two primary types of threat information that are evolutionarily novel: statistical reports of morbidity and mortality rates across different geographic regions and non-personalized images related to the virus, its treatment, and its effects. In addition, by the time people presented with serious symptoms, they were often isolated. We would therefore expect that people, on average, would not respond to variations on COVID-19 threat levels during Phase 1. That is, people in areas with high rates of mortality and morbidity should exhibit similar levels of mental distress as those in areas with lower mortality and morbidity rates. However, personality traits affect how people respond to threat information. In particular, traits such as neuroticism are associated with a higher threat sensitivity level (Barlow et al., 2014) and should be strongly associated with emotional distress.

Method

In Study 1, 418 individuals (67% response rate) across the USA were recruited during the third week of May 2020 using Amazon's Mechanical Turk. However, only 291 participants representing 13 states (see Table 1) were included after removing states with less than 10 participants. The mean age of the sample was 37.76 years ($SD = 10.98$ years). Of the 291 participants, 54.0% were male, 45.7% were female, and 0.30% identified as other. The self-reported major racial/ethnic composition of the sample was 68.4% Caucasian, 18.2% Black, 10.0% Asian, 6.5% Hispanic/Latino, 3.4% Native American, 0.7% Middle Eastern, 0.7% Hawaiian, and 0.3% Other. Most of the participants were married (49.1%), while 27.5% were single, 16.5% were in a relationship/not married, 5.5% were divorced/separated, and 1.4% were widowed. Education categories for the sample were as follows: high school degree or equivalent (6.5%), some college but no degree (11.7%), associate degree (11.0%), bachelor's degree (52.9%), and graduate degree (17.9%).

We assessed state-level COVID-19 indicators with archival data from the COVID-19 Tracking Project at *The Atlantic* (The COVID-19 Tracking Project at *The Atlantic*, 2020). These data were gathered from state health websites across the nation. State-level infection and mortality rates were selected and divided by the population of each state. We also captured variations in length of government-imposed lockdowns between states using data from *USA* Today (2020). Data provided by *USA Today* were based on official reports of state-level lockdowns and aggregated by Safe Graph (a California-based firm).

For mental health indicators, we measured loneliness with *The Loneliness Scale* (De Jong Gierveld & Van Tilburg, 1999), an 11-item Likert-style questionnaire ($\alpha = 0.83$), depression severity with the 9-item *Patient Health Questionnaire* ($\alpha = 0.94$; Kroenke & Spitzer, 2002), and state-anxiety with the 5-item shortened version of *The State-Trait Inventory for Cognitive and Somatic Anxiety* ($\alpha = 0.88$; Marteau & Bekker, 1992). We measured the personality traits of neuroticism ($\alpha = 0.73$), extraversion ($\alpha = 0.79$), conscientiousness ($\alpha = 0.70$), openness ($\alpha = 0.79$), and agreeableness ($\alpha = 0.76$), with the Mini-IPIP (Donnellan et al., 2006).

Results and Discussion

Table 1 presents the means and standard deviations of mental health variables (loneliness, anxiety, and depression) for 13 states. The lowest and highest means across states for each mental health variable were as follows: 1.99 (Virginia) to Wisconsin (2.76) for loneliness, 1.37 (Virginia) to Pennsylvania (2.09) for anxiety, and 1.39 (Michigan) to Wisconsin (1.86) for depression. Table 2 presents correlations among state-level COVID-19 threats (number of days locked down, infection rate, and mortality rate) and mental health symptoms (loneliness, anxiety, and depression). The number of days locked down was not significantly related to any of the outcome variables ($r = -0.01$ to 0.03). The mental health symptoms were not significantly related to either infection ($r = 0.00$ to 0.06) or mortality rates ($r = -0.00$ to 0.07).

Figure 2 shows mean scores of loneliness, anxiety, and depression across 13 states. States are listed in an ascending order of days of lockdown. Georgia had the shortest lockdown length (27 days), whereas Michigan had the longest lockdown (73 days). We expected an upward monotonic trend if days of lockdown were positively related to loneliness. However, no linear pattern was observed, suggesting

Table 2 Correlations among state-level COVID-19 threats, mental health outcomes, and personality

		Loneliness	Anxiety	Depression
State-level indicators of COVID-19[a]	Number of days locked down	−.01	−.00	.03
	Infection rate	.06	.06	.00
	Mortality rate	.06	.07	−.00
Personality traits[b]	Neuroticism	.57	.59	.57
	Extraversion	−.18	−.15	−.12
	Openness	−.29	−.23	−.24
	Agreeableness	−.36	−.23	−.26
	Conscientiousness	−.41	−.39	−.42

[a] $n = 291$; $p > .05$ for all *rs*

[b] $n = 418$; $p < .05$ for all *rs*

that loneliness mean scores were not associated with the length of lockdowns. Similar results were found for infection and mortality rates. Although mean mental health outcome scores did not vary in a meaningful way across states, personality traits were associated with loneliness, depression, and anxiety (see Table 2) ($r = -0.42$ to 0.59, $p < 0.05$).

Our findings suggesting no association between threats of COVID-19 and mental health symptoms are similar to findings in other studies examining objective measures of COVID-19 threats and mental health (Nocentini et al., 2021). As we argued, people may not be attending to or believe implications of morbidity and mortality rates from COVID-19. However, our results also suggest that some people may be more sensitive to real or imagined health risks. We found that people low in emotional stability (i.e., high in neuroticism) reported greater negative mental health symptoms, while those with higher levels of extraversion, agreeableness, conscientiousness, and openness to experience reported greater levels of psychological well-being.

Study 2

In Study 2, we examined how intelligence, age, and political ideology affected threat responses (vaccination rates) to COVID-19 2 years after the initial outbreak. Although

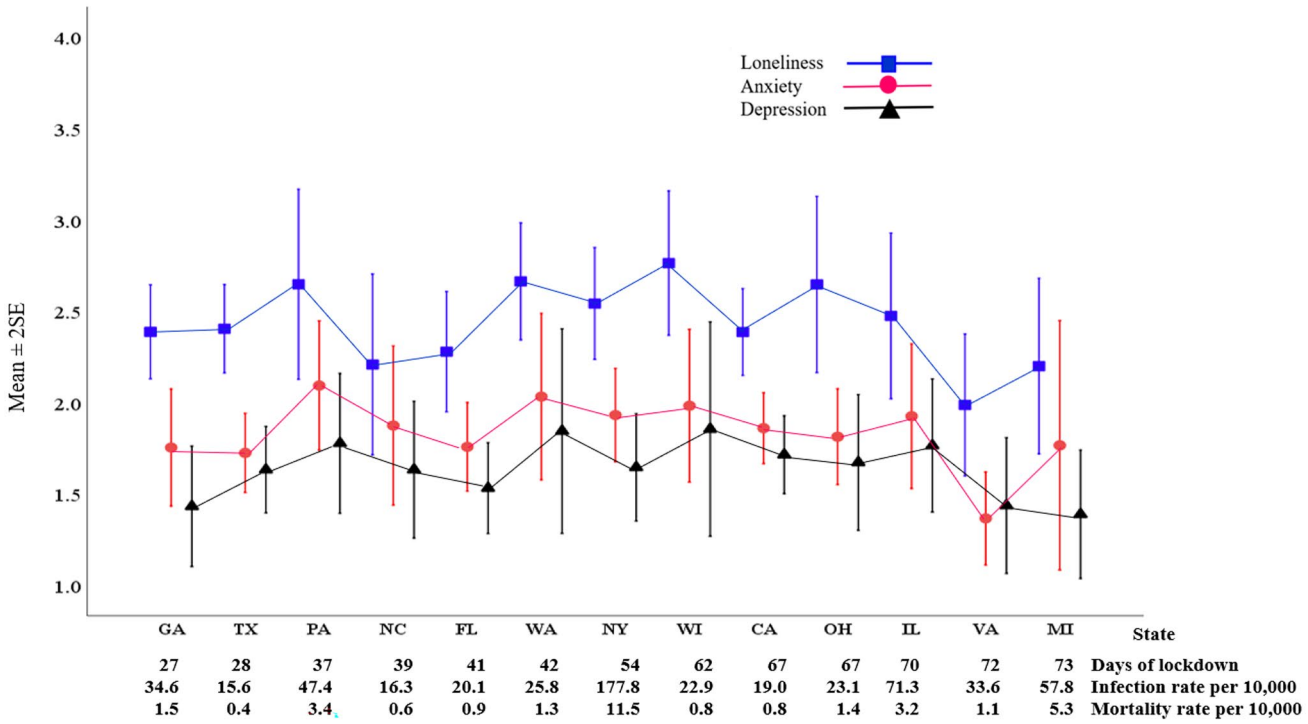

Fig. 2 Mean mental health outcome scores by days of lockdown, infection rate, and mortality rate

information about the virus remained evolutionarily novel (morbidity and mortality statistics, non-personalized images), causal connections were clearer, the nature of the virus was better understood, and vaccines were widely available. Thus, we expected that intelligence and age would be positively related to vaccination rates, whereas an ideology that was suspicious of experts and science would be negatively related.[7]

Method

Current total vaccination rates for each US state (as of February 6th, 2022) were gathered from the Mayo Clinic's website (Mayo Clinic, 2022). The Mayo Clinic is a nonprofit hospital system and academic medical center that provides esteemed, often publicly-accessible medical research. We collected vaccination rates by age group (ages 5–11, 12–17, 18–64, and 65 +) for each US state from the Mayo Clinic website, and the average vaccination rate for each age group was calculated.

We collected IQ data for each state from the World Population Review website (World Population Review, 2022). The World Population Review is an independent organization that seeks to provide normally inaccessible demographic data for public examination and use. For the data used in the present study, the World Population Review used a study conducted by the *Washington Post* that aggregated various measures of cognitive ability (IQ scores, SAT and ACT scores, and education level) into an overall IQ measure for each US state. Data pertaining to 2020 presidential election results were drawn from CNN's website (CNN, 2020), which tracked which states were won by Joe Biden or Donald Trump, as well as the percentage of the votes going to either of the two candidates for each state.

Results

The mean full vaccination rate for each age group across all the US states is shown in Table 3. Vaccination rates increased with age, with the youngest age group (5–11) showing the lowest percent vaccinated ($M = 21.89$, $SD = 9.60$) and the oldest age group (65 +) showing the largest percent vaccinated ($M = 94.08$, $SD = 4.65$). The 65 + age group also showed the least amount of variability in vaccination ($SD = 4.65$) of all the age groups.

The relationship between the total vaccination rates of the US states and each state's average IQ was tested, along with the relationship between states' total vaccination rates and the total percentage of each state's vote that went to Trump in the 2020 presidential election. There was a significant positive correlation between the percentage of the population fully vaccinated and average IQ across all states ($r = 0.35$, $p < 0.001$). There was also a significant and strong negative correlation between total vaccination rate and the percentage of the vote that went to Trump across all states ($r = -0.88$, $p < 0.001$).[8]

Table 3 Percent of the US population fully vaccinated by age group

Age group	*M*	*SD*
5–11	21.89	9.60
12–17	53.72	12.97
18–64	68.28	9.30
65 +	94.08	4.65
Total	59.71	27.81

Percentages were averaged across all the US states for each age group

These results also show that individual differences influence how people responded to COVID-19 pandemic information—in this case, even when vaccines and more information about the virus were available. Both intelligence and age correlated positively with vaccination rates, while political ideology (support for Donald Trump in the 2020 presidential election) correlated negatively with vaccination rates.

General Discussion

We found that state-level COVID-19 threat information (number of days locked down, infection rates, and mortality rates) had no relationship with mental health symptoms (loneliness, anxiety, and depression) during the early months of the pandemic. Mean scores of mental health variables did not vary in a meaningful way across states. Our finding of a lack of association between information about COVID-19 threat exposure and mental health is consistent with other studies examining objective measures of COVID-19 threats and mental health (Nocentini et al., 2021). These findings are consistent with evolutionary psychological explanations. The behavioral immune system is unlikely to be triggered by evolutionarily novel information, such as statistical information and non-personal images (Li et al., 2018).

[7] At the beginning of the pandemic, when causal connections were opaque and before effective vaccines were available, there was some evidence that the elderly were no more cautious than people of middle age (Daoust, 2020).

[8] For elderly group, vaccination % ranged from 83.20 (Arkansas) to 99.90 (VT, RI, Main, WA, NH, MN, DE, WI) in 50 states. The mean % vaccination for states that voted for Biden was 96.67 ($SD = 3.69$), and for Trump, it was 91.48 ($SD = 4.05$).

However, individual differences were associated with how people responded to COVID-19 threats. Even when causal information about the pandemic was vague (during Phase 1), neuroticism correlated strongly with negative mental health symptoms (loneliness, anxiety, and depression). All of the other traits correlated negatively with adverse mental health symptoms. While our data are cross sectional, these correlations suggest some impact of the pandemic: they are stronger than typical correlations among the Big Five and negative mental health outcomes prior to the pandemic (e.g., Bunevicius et al., 2008). Individual differences played an important role in how people responded to COVID-19 threats 2 years after the outbreak of the pandemic when causal connections were clearer and after vaccines were available. The elderly (65 +), who were most at risk from COVID-19, had considerably higher rates of being fully vaccinated (94%) than all other age groups. Aggregate state IQ levels correlated positively with aggregate vaccination rates. Thus, although the behavioral immune system is unlikely to respond to abstract information (such as infection and mortality statistics), perceived vulnerability and intelligence can, to some extent, counteract this.

Limitations

A limitation of Study 1 is that the mismatch implication—people not having evolved to respond to novel stimuli such as threat information—was supported by the absence rather than the presence of significant results. Moreover, the lack of correlations between COVID-19 threat indicators and mental health could be due to many unidentified factors. Thus, while we contribute to the literature by outlining a potentially strong explanation for a pressing, real-world phenomenon, we only provide indirect empirical support for the mismatch hypothesis. More rigorous tests—including experimental methods that manipulate different ways of conveying the virus (e.g., evolutionarily novel statistical reporting versus visual presentation of severe outcomes) are clearly needed to substantiate the hypotheses. Another promising route is to investigate moderators that may influence when the correlation between COVID-19 and mental health, as well as vaccination and other precautions, becomes significant.

Another possible limitation is the use of state-level data. It would have been preferable if threat level data in Study 1 were at a smaller unit of analysis (e.g., county). In Study 2, it would have been preferable if our data were at the individual level. However, certain types of individual data relevant to our research questions (e.g., matching individual vaccination status with IQ, who an individual voted for) would be restricted and possibly inaccurate. Nevertheless, we believe that our results are broadly indicative of the relationships we assessed. We recommend that more granular research should be conducted in future studies to delve further into these relationships.

Implications

Despite the mitigating influence of scientific literacy and education, the remediation of modern, global pandemics through public health interventions is and will remain difficult. Most public health interventions provide evolutionarily novel information and require people to behave in ways that are mismatched with evolved human perceptual and decision-making mechanisms. This includes understanding and accepting abstract scientific information, avoiding or staying distant from people who do not seem ill, staying at home when feeling fine, wearing face coverings, and getting injected with foreign substances. The greater the degree that a desired behavior is at odds with its adaptive value over millennia of human evolution, the more difficult it will be for an intervention to effectively encourage that behavior (Jones, 2001). For example, because frequent social interaction with friends and family has been adaptive to humans for millennia, people will be more resistant to public health interventions that restrict normal human interaction (lockdowns, social distancing, wearing facemasks) than to interventions that facilitate social interaction.

Our findings, combined with the above evolutionary logic, have four major implications for public policy. First, expecting broad voluntary compliance—especially during COVID-19-like pandemics—is unrealistic. For the majority of people, some mandatory regulations may be necessary to assure sufficient compliance, particularly during the early stages of an outbreak. This can occur through mandates from government or other institutions, such as employers. Typically, countries with stronger vaccine mandates and social pressure for vaccination have higher vaccination rates (Suliman et al., 2021). Interventions that link compliance with valued evolutionary-based rewards (such as status, access to status, or mating opportunities) are more likely to be successful. For example, making admission to workplaces, schools, and gathering places for singles contingent upon wearing masks or having proof of vaccination is likely to increase compliance.

Second, because people respond selectively to pandemic threats based on individual differences, communication strategies should be selectively tailored to specific groups. People who are most likely to be affected by a pandemic—the elderly in the case of COVID-19 and parents of young children in the case of polio—are more likely to use effortful appraisal—what Kahneman (2011) calls System 2 thinking and what others have referred to as systematic or central processing (Petty & Cacioppo, 1986). Thus, information and appeals to the most vulnerable groups should be designed to engage more elaborate processing, such as the presentation

of high-quality and accessible scientifically backed arguments. Groups that consider themselves to be less vulnerable—and thus are less motivated to carefully process information—may be persuaded by more superficial methods such as using attractive celebrity endorsements (Petty & Cacioppo, 1986).

Third, when populations are facing disease-based threats, public health information should be tailored so that it activates the behavioral immune system. With COVID-19, more work should be done on examining appropriate and believable imagery in public health communications. Such public health interventions were successful polio vaccination and anti-smoking campaigns. Unfortunately, this approach has been little used COVID-19 public health campaigns as well as with some mismatched-based lifestyle diseases (obesity, Type II diabetes) where it would clearly be appropriate.

Finally, it must be acknowledged that belief systems are difficult to change. If people believe that a vaccination is unsafe or that the negative effects of the disease are overstated, which is increasingly common due to media misinformation, it will be difficult to change those beliefs with a rational argument based on scientific evidence. People use reason to find justifications for their beliefs, which in turn enhance their reputations within specific groups—not to find the true state of affairs (Mercier & Sperber, 2017; Yong et al., 2021). Thus, to overcome opposition to public health policies, clearer explanations of their scientific basis are unlikely to be effective. A better strategy to get through to a skeptical public would be to use positive public health testimonials from high status individuals who are from those groups in which a majority of members are resistant to public health interventions. This would be a much more effective way of changing norms (Henrich, 2016).[9]

In summary, the COVID-19 pandemic has generated a less than desirable response in places where people are relatively free to choose that response. We have provided an explanation based on evolutionary psychological principles and obtained empirical results consistent with this explanation and inconsistent with a more commonly accepted explanation. More work is needed, but findings from a growing number of studies indicate that a consideration of how the modern world is mismatched to how we have evolved to think, feel, and behave can provide insights into the numerous problems that humans are now facing and why they are difficult to overcome.

[9] Among the most successful public strategies in the anti-smoking campaigns were using graphic images of the ravages of smoking and invoking peer pressure from high status role models (e.g., Farrelly et al., 2012; Hurd et al., 1980).

Author Contribution TJM, KAK, and CPF collected data for Study 1. CV collected data for Study2. KH conducted the statistical analyses. SMC and TJM wrote the initial drafts. SMC and NPL wrote the latter drafts. TJM and SMC initiated the study. KH, NPL, TJM, CV, and SMC edited later drafts.

Funding This research did not receive funding from public, commercial, or not-for-profit sectors.

Data availability Data are available from the first author upon request.

Declarations

Ethics approval Individual data were collected anonymously; all other data were from publically available archival sources. The study was therefore exempt from institutional review board approval (IRB#: 2020–173).

Consent to participate Informed consent was obtained from all individual participants.

Consent for publication All authors approved this submission.

Conflict of interest The authors declare no competing interests.

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