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Behavioral immune system linked to responses to the threat of COVID-19

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ABSTRACT

People possess psychological processes that help them avoid pathogens, which is particularly important when novel infectious diseases (e.g., COVID-19) spread through the population. Across two studies we examined whether trait pathogen avoidance (operationalized as perceived vulnerability to disease; PVD) was linked with responses to COVID-19 and preventative behaviors. In Study 1, PVD was positively associated with stronger reactions to the threat of COVID-19, including increased anxiety, perceptions that people should alter their typical behavior, as well as reported importance of engaging in proactive and social distancing behaviors. In Study 2, PVD was again associated with increased anxiety, as well as more vigilant behavior when grocery shopping, fewer trips to the store, and fewer face-to-face interactions. These associations remained significant when controlling for the Big-5 personality traits. Although the two subscales of PVD (germ aversion and perceived infectability) were often parallel predictors, several differences between the subscales emerged. Germ aversion may be more associated with behaviors whereas perceived infectability with vigilance.

1. Introduction

The motivation to avoid pathogens underpins myriad aspects of people's psychology (Ackerman et al., 2018). Although people encounter pathogens daily, pathogens threat is accentuated by situations such as the flu season, or as was happening at the time of data collection: the COVID-19 pandemic. To slow down the propagation of novel infectious diseases like COVID-19, it is crucial to engage in preventative behaviors such as social distancing and strict hygiene practices, and earlier engagement is better. Yet, many disparage these recommendations at the critical, early stages because signs of illness are not evident in their immediate environment. Therefore, understanding factors that predict perceptions of pandemic threat and importance of preventative behaviors is imperative. One such factor may be people's trait pathogen avoidance.

People possess various affective, cognitive, and behavioral processes—often collectively termed the "behavioral immune system"—that help them navigate their environments in ways that reduce the risk of pathogen contagion (Schaller & Park, 2011). To the extent that some people are more chronically attuned to the potential threat of pathogens than others, research has demonstrated that there are individual differences in people's trait levels of pathogen avoidance (Duncan et al., 2009; Tybur et al., 2009). These individual differences have been proposed to stem from genetic, developmental, and sociocultural factors (Olatunji et al., 2019; Rozin et al., 2008; Sherlock et al., 2016;), as well as one's history of illness in childhood (Makhanova et al., 2020). Furthermore, situations that connote increased pathogen threat heighten pathogen avoidance processes (Schaller et al., 2015), perhaps particularly for those with higher trait pathogen avoidance (Ackerman et al., 2018). Thus, trait pathogen avoidance may predict stronger early responses to the COVID-19 pandemic.

Prior research, however, has primarily examined hypothetical pathogen threats. Only one study to our knowledge focused on pathogen avoidance in the context of an actual threat. Beall et al. (2016) linked the Ebola pandemic to downstream processes of pathogen avoidance—more conservative voting patterns (c.f. Tiokhin & Hruschka, 2017; Schaller et al., 2017). Other researchers, however, may have also noticed increased pathogen avoidance in their data (e.g., Prokosch et al., 2019). Nevertheless, no prior research has linked trait pathogen avoidance to people's psychological reactions to and behaviors during a pandemic.

Capitalizing on current events occurring at the time of data collection, the present research provides a critical test of the theory that trait pathogen avoidance attunes people to increasing pathogen threat. In Study 1, we surveyed a large, primarily American sample at the beginning of the COVID-19 pandemic and examined whether trait pathogen avoidance was associated with perceptions of the severity of the evolving threat, the importance of engaging in preventative behaviors,

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and selection of media information. We focused on proactive rather than reactive pathogen avoidance processes (see Ackerman et al., 2018), because at this time most people were not exposed to others who were sick with COVID-19. We predicted that trait pathogen avoidance—assessed using the Perceived Vulnerability to Disease questionnaire (PVD; Duncan et al., 2009)—would be positively associated with perceptions of and reactions to COVID-19. We conducted Study 2 a few weeks later to examine how trait pathogen avoidance was linked to people's behavior during social distancing efforts. Moreover, we isolated effects of trait pathogen avoidance by assessing and controlling for conscientiousness, neuroticism, extraversion, agreeableness, and openness to experiences. Although past research has demonstrated a link between pathogen avoidance and preventative health behaviors (Gruijters et al., 2016), that study examined people's reactions to hypothetical situations. Here, we report people's psychological responses to an actual threat.

2. Study 1

2.1. Method

2.1.1. Participants

Participants were recruited online through social media platforms (e.g., Facebook, Reddit) to participate in a 15-minute study with the opportunity to win one of ten Amazon gift cards valued at $50; 1674 people participated. Data were excluded from 12 participants who were under 18. See Table 1 for demographic information (n = 1662). For analyses, we excluded 69 participants. Sixty-six incorrectly answered a catch question ("Please select strongly disagree as the answer to this statement"); 18 people who left this question blank were not excluded. Three additional people told us not to use their data. Thus, our final sample consisted of 1593 people. Most participants were located in the United States (n = 1195).

We conducted a sensitivity analysis using G*Power for our main models: multiple regressions with two predictors. These analyses indicated that we had 80% power to detect effect sizes larger than r = 0.07.

2.1.2. Time of data collection

The bulk of data collection occurred from March 10, 2020 until March 12, 2020 (88.2%), 114 people completed the survey on March 13, 2020, and an additional 5% of participants completing the study up until March 19, 2020. For reference, these are the number of confirmed cases in the United States on these dates (CDC, 2020): March 10–937, March 11–1215, March 12–1629, and March 13–1896. On March 11, the World Health Organization declared COVID-19 a pandemic. Overall, data were collected before official quarantines had begun in the United States, but there were mounting concerns about the virus and the potential for future quarantines.

Table 1
Descriptive statistics for Study 1.

Measures	*M* (*SD*)	Frequency
Age	29.91 (10.95)	
Political Orientation (US only)	3.30 (2.24)	
Religiosity	3.25 (2.88)	
Gender		
Women		1035
Men		547
Transgender		31
Other		27
Did not wish to report		3
Race/ethnicity		
White or Caucasian		1353
Asian or Pacific Islander		110
Black or African American		25
Native American		26
Multiracial		41
Other		30
Hispanic or Latinx		77
Did not wish to report		17

2.1.3. Procedure and materials

On the first page of the online survey, participants were given study information and provided informed consent. Then, participants completed 8 blocks of questions presented in random order. The study was approved by the [University of Arkansas] IRB. All materials and data for both studies are available on the Open Science Framework (https://osf.io/ja86s/: https://osf.io/ja86s/?view_only=43c2a30e67ea4672b459db687fa3dc63). All data analyses conducted are reported in this manuscript.

2.1.3.1. Demographics. In addition to age, gender, and race/ethnicity, participants reported their religious beliefs (10-point scale from 1 *Not religious at all* to 10 *Very religious*) and political orientation (10-point scale from 1 *Very liberal* to 10 *Very conservative*). We only examined political orientation for the U.S. subsample.

2.1.3.2. Individual differences in pathogen avoidance. We assessed individual differences in pathogen avoidance using the PVD questionnaire (Duncan et al., 2009), which includes two subscales: germ aversion (GA) and perceived infectability (PI). GA reflects people's affective and behavioral responses to potential pathogens (8 items; α = 0.74; e.g., "I don't like to write with a pencil someone else has obviously chewed on"). PI reflects people's general perception about their susceptibility to disease (7 items; α = 0.92; e.g., "If an illness is going around, I will get it"). Participants rated their agreement with each statement using a 7-point scale (1 = *Strongly Disagree*, 7 = *Strongly Agree*). The scale was originally developed using a large sample of undergraduate students from Canada and the Netherlands (Duncan et al., 2009), and has since then been used in studies of young adults in other countries such as Spain (Díaz, Soriano, & Beleña, 2016), Czech Republic (Prokop & Kubiatko, 2014), and Iran (Ahmadzadeh et al., 2013). Thus, it was suitable for the present research on an international (albeit primarily American) sample.

To ensure that we were assessing trait levels of pathogen avoidance, participants were told to think about how they act typically, not necessarily how they would act right now and to think about how they would have answered these items 6 months ago. Although the reliabilities of the two subscales were similar to those reported in past research, we nevertheless conducted a confirmatory factor analysis (CFA) in MPlus to examine how well the data fit the two-factor structure hypothesized. The two-factor solution, $\chi^2(89)$ = 973.40, fit the data better than the one-factor solution, χ^2 (90) = 2731.13, $\Delta\chi^2(1)$ = 1757.73, p < .001. The two-factor solution fit the data reasonably well; see supplemental materials for fit indices for both models as well as the factor loadings. Thus, our findings are consistent with prior factor analyses suggesting that GA and PI are independent factors (Diaz et al., 2016). Indeed, GA (M = 4.16, SD = 1.10) and PI (M = 3.48, SD = 1.32) were only modestly correlated (r = 0.19, p < .001). Consistent with the theoretical perspective suggesting the subscales assess different aspects of trait pathogen avoidance (Duncan et al., 2009), research has demonstrated that GA and PI tend to predict different behaviors (e.g., Makhanova et al., 2019; Young et al., 2011) although this distinction has not yet been fully clarified. Consequently, we predicted that PVD would be positively associated with responses to COVID-19, but we did not have strong predictions about whether GA or PI would be associated with the dependent measures (except for choices of media articles, the hypotheses for which are clarified below).

2.1.3.3. Perceptions of threat. Participants responded to a question asking how the COVID-19 outbreak compares to the seasonal flu using a 7-point scale (1 = *It is much less of a problem*; 7 = *It is much*

more of a problem). Most participants reported that COVID-19 was more serious than the seasonal flu, $M = 5.40$, $SD = 1.34$, $t(1588) = 41.82$, $p < .001$.

2.1.3.4. Perceptions of need to alter behavior. Participants responded to a question asking how necessary it is for them to alter their typical daily behavior to combat the spread of COVID-19 using a 7-point scale (1 = *Not at all necessary*; 7 = *Extremely necessary*). On average, people were slightly above the midpoint ($M = 4.47$, $SD = 1.85$).

2.1.3.5. Overall anxiety. Participants rated their overall, general anxiety about COVID-19 using a slider to select a number between 0 and 100. On average, people were a little less anxious than the midpoint ($M = 45.33$, $SD = 25.43$).

2.1.3.6. Importance of preventative behaviors. Participants reported whether certain preventative behaviors were important for lowering their risk of becoming sick with the virus. Twelve behaviors were presented randomly. Participants responded how important did they think it was to (1) wash their hands for 20+ seconds, (2) clean their phone and other objects they touched often, (3) avoid touching their face, (4) have enough food in their house for a 14-day self-quarantine, (5) have enough disinfecting cleaning products, (6) avoid shaking hands with people, (7) wear a face mask when they were in public, (8) avoid international airplane travel, (9) avoid domestic airplane travel, (10) avoid going on cruises, (11) avoid large gatherings, and (12) getting enough sleep at night. Participants responded using a 7-point scale (1 = *Not important at all*; 7 = *Extremely important*). On average, people rated the importance of engaging in these behaviors somewhat higher than the midpoint ($M = 5.05$, $SD = 1.02$).

An exploratory factor analysis suggested that there may be two factors (Factor One: items 1, 2, 3, 5, 12; Factor Two: items 4, 6, 7, 8, 9, 10, 11) that were somewhat correlated ($r = 0.42$). We performed a CFA using participants ($n = 1555$) with no missing data for the behaviors, GA, PI, and SPA using MPlus. The two-factor solution, $\chi^2(53) = 609.77$, fit the data better than the one-factor solution, $\chi^2(54) = 1295.85$, $\Delta\chi^2(1) = 686.08$, $p < .001$. We will refer to Factor One as "proactive behaviors" and Factor Two as "social distancing behaviors."

2.1.3.7. Reported preventative behaviors. Participants were also asked an open-ended question about their actual behavior. Most participants ($n = 1339$) provided a valid answer. Responses were coded for whether the following behaviors were mentioned: hand washing, concern with touching (face, objects, people), cleaning objects and surfaces, social distancing (broadly construed), stocking up on food, wearing gloves or masks, and other (e.g., eating well, exercising, taking supplements, cancelling travel). For analyses, we considered the total number of categories mentioned ($M = 2.31$, $SD = 1.22$, range: 0 to 6). Additionally, because some participants wrote longer, more detailed responses than others, we analyzed the number of characters in each response as a proxy for level of engagement with the question ($M = 200.00$, $SD = 199.45$, range: 4 to 2000). We used this dependent measure for exploratory analyses.

2.1.3.8. Importance of staying home when sick. Participants responded how important it was to avoid going out in public if they were sick (even if they thought it was just a cold) using a 7-point scale (1 = *Not important at all*; 7 = *Extremely important*). On average, people rated the importance of this behavior somewhat higher than the midpoint ($M = 5.79$, $SD = 1.43$).

2.1.3.9. Article choices. We asked participants to make two choices regarding online media content they would prefer to read. One question asked participants to choose between seeing a list focused on how to avoid coming into contact with COVID-19 pathogens versus a list focused on how to protect your health during the COVID-19 outbreak. The majority of participants (75.4%, $n = 1201$) said they would prefer the second list. We hypothesized that GA may predict selecting the first list, whereas PI may predict selecting the second list.

Participants were also asked to choose which full article they would prefer to read: "COVID-19 isn't as deadly as we think" or "COVID-19 spread is reaching a new level." Most participants (58.4%, $n = 928$) selected the first article. We hypothesized that PI may predict selecting the second, more threatening article. We did not have any predictions for GA.

2.1.3.10. Situational pathogen avoidance scale. For exploratory analyses, participants completed a scale that assesses situational activation of pathogen avoidance processes. Scale details and results are reported in supplemental materials.

2.2. Results

2.2.1. Descriptive analyses

We first report the descriptive associations between demographic variables and GA and PI, as well as their responses to the threat of COVID-19. For brevity, we will use the phrase "responses to the threat of COVID-19" for situations in which a variable predicts all 6 dependent measures: perceptions that COVID-19 is a bigger problem than the seasonal flu, perceptions that people need to change their behavior to combat the spread of COVID-19, overall anxiety about COVID-19, importance of both factors of protective behaviors, and the importance of staying home when sick. Correlations are reported in Table 2.

Although age was not associated with GA, and was unexpectedly negatively associated with PI, older participants reported stronger responses to the threat of COVID-19 than younger participants. Similar to past research (e.g., Duncan et al., 2009; Haidt et al., 1994; Tybur et al.,

Table 2
Correlations between demographics and key variables.

Variable	2	3	4	5	6	7	8	9	10	11	12
1. Age	0.09***	0.10**	0.18***	0.03	−0.07**	0.07*	0.14***	0.14***	0.19***	0.18***	0.15***
2. Gender (male = 0, female = 1)		−0.13***	0.08**	0.10***	0.10***	−0.06*	0.05†	0.12***	0.26***	0.12***	0.09***
3. Political orientation			0.54***	0.14***	−0.12***	−0.23***	−0.15***	−0.16***	−0.05	−0.11***	−0.10**
4. Religious beliefs				0.14***	−0.02	−0.13***	−0.02	0.03	0.11***	0.01	0.01
5. Germ aversion					0.19***	0.03	0.15***	0.26***	0.37***	0.32***	0.20***
6. Perceived infectability						0.12***	0.11***	0.19***	0.10***	0.14***	0.02
7. Problem relative to flu							0.55***	0.45***	0.20***	0.47***	0.27***
8. Need to change behavior								0.56***	0.43***	0.60***	0.39***
9. Overall anxiety									0.38***	0.54***	0.31***
10. Behaviors Factor 1										0.56***	0.42***
11. Behaviors Factor 2											0.50***
11. Importance of staying home when sick											

Note. *** p < .001, ** p < .01, * p < .05, † p < .100.

2011), women reported higher levels of GA and PI than men. Furthermore, women generally reported stronger responses to the threat of COVID-19. This is particularly interesting given that the current medical data suggest that men are more likely to experience complications and die compared to women (Sun et al., 2020).

Being more religious was associated with higher GA, but there was no link between religiosity and PI. Religiosity was positively associated with engaging in proactive behaviors (e.g., washing hands and avoiding touching one's face) but not social distancing behaviors (e.g., avoiding travel and large gatherings). People who were less religious were more likely to report that COVID-19 was more problematic than the seasonal flu compared to people who were more religious. In the U.S. subsample, being more politically conservative was associated with higher GA and *lower* PI, as well as weaker responses to the threat of COVID-19 (except proactive behaviors such as washing hands).

We also examined how the announcement by the World Health Organization labeling COVID-19 a pandemic affected people's psychological responses. A portion of participants (n = 444) completed the survey on March 10, 2020—the day before the announcement. There was no difference in GA between participants who completed the survey before compared to after the announcement, $t(1585) = 0.23$, $p = .819$. PI scores were, unexpectedly, lower for participants who completed the survey after the announcement, $t(1585) = 2.09$, $p = .037$. Consistent with the notion that the announcement would increase the threat people perceived, participants who completed the survey after the announcement reported stronger responses to the threat of COVID-19. In supplemental materials we report full statistics for these analyses; we also report how GA, PI, and responses to the threat of COVID-19 differed for participants who were (or were not) immunocompromised and who had (or did not have) confirmed COVID-19 cases in their city.

2.2.2. Primary analyses

Results for our primary analyses using multiple regression are reported in Table 3.[1] GA was positively associated with people thinking that they needed to change their daily behavior to combat the spread of COVID-19, people's general anxiety about COVID-19, the extent to which people rated engaging in protective behaviors as important to them (both factors), and the extent to which people reported that it is important to avoid going out in public if they are sick (even if they thought it was just a cold). However, GA was not associated with perceiving that COVID-19 is a bigger problem than the seasonal flu.

PI, on the other hand, was positively associated with perceptions that COVID-19 is a bigger problem than the seasonal flu. Likewise, PI predicted people thinking that they needed to change their daily behavior to combat the spread of COVID-19 and people's general anxiety about COVID-19. That is, for these two analyses, both GA and PI were independent, significant predictors. Unlike the association with GA, PI was only associated with the second factor of preventative behaviors (social distancing) but not the first factor (proactive behaviors). PI was also not linked to the extent to which people reported that it is important to avoid going out in public if they were sick.

In ancillary analyses, all of the reported significant associations between GA, PI, and the dependent measures continued to be significant controlling for gender, age, and a binary variable coding whether the WHO has labeled COVID-19 a pandemic. Moreover, none of the results were moderated by whether participants were from the US or other parts of the world.

We also conducted two logistic regression analyses to examine the types of news articles people would choose to read. Given two options ("COVID-19 isn't as deadly as we think" and "COVID-19 spread is reaching a new level"), PI positively predicted people's likelihood of selecting the second article, $b = 0.12$, $SE = 0.04$, $p = .003$, $OR = 1.13$, 95% CI [1.04, 1.22]. GA did not predict article choice, $b = -0.64$, $SE = 0.22$, $p = .548$, $OR = 0.97$, 95% CI [0.89, 1.07]. Next, participants were asked to choose between two lists they could see ("How to avoid coming into contact with COVID-19 pathogens" and "How to protect your health during the COVID-19 outbreak"). For this question, PI did not predict article choice, $b = 0.04$, $SE = 0.05$, $p = .335$, OR = 1.05, 95% CI [0.96, 1.14]. GA, on the other hand, was associated with selecting the first article that focused on avoidance, $b = -0.12$, $SE = 0.06$, $p = .026$, $OR = 0.89$, 95% CI [0.80, 0.99]. Thus, our predictions regarding article choice were only partially supported.

We followed up the primary analyses to correct for multiple hypothesis testing using the Benjamini-Hochberg procedure with a false discovery rate set to 5% (Benjamini & Hochberg, 1995); all of the associations reported as significant above remained significant when using the correction procedure.

Table 3
Results of the primary regression analyses in Study 1.

Models	*b* (*SE*)	t	df	p	95% CI	r
How problematic is COVID-19 relative to the seasonal flu?						
GA	0.01 (0.03)	0.27	1582	.843	[−0.06, 0.07]	0.01
PI	0.12 (0.03)	4.54	1582	< .001	[0.07, 0.17]	0.11
How necessary is it to change your daily behavior?						
GA	0.22 (0.04)	5.16	1583	< .001	[0.14, 0.30]	0.13
PI	0.11 (0.04)	3.18	1583	.002	[0.04, 0.18]	0.08
General anxiety about COVID-19						
GA	5.32 (0.57)	9.29	1547	< .001	[4.20, 6.44]	0.23
PI	2.79 (0.48)	5.84	1547	< .001	[1.86, 3.73]	0.14
Importance of protective behaviors (Factor 1: proactive behaviors)						
GA	0.35 (0.02)	15.35	1584	< .001	[0.30, 0.39]	0.36
PI	0.03 (0.02)	1.36	1584	.176	[−0.01, 0.06]	0.03
Importance of protective behaviors (Factor 2: social distancing behaviors)						
GA	0.34 (0.03)	12.54	1584	< .001	[0.28, 0.39]	0.30
PI	0.08 (0.02)	3.48	1584	.001	[0.03, 0.12]	0.08
Importance of avoiding going out in public if sick (even if with a cold)						
GA	0.27 (0.04)	8.12	1580	< .001	[0.20, 0.33]	0.20
PI	−0.02 (0.03)	−0.73	1580	.383	[−0.08, 0.03]	−0.02

2.2.3. Exploratory analyses

We explored whether people's free response data were associated with GA and PI. First, we regressed the total number of coded categories for each participant onto GA and PI. The total number of coded categories were not associated with either GA, $b = 0.01$, $SE = 0.03$, $t(1329) = 0.27$, $p = .788$, or PI, $b = 0.01$, $SE = 0.03$, $t(1329) = 0.43$, $p = .665$. Next, we regressed the total number of characters in the free response onto GA and PI. In this model, GA was significantly associated with the number of characters, $b = 15.57$, $SE = 5.05$, $t(1330) = 3.08$, $p = .002$, 95% CI [5.66, 25.47], *semi-partial* $r = 0.08$, but there was no association with PI, $b = 2.73$, $SE = 4.24$, $t(1330) = 0.64$, $p = .520$. Thus, our data suggest participants with higher GA levels engaged with the question more than those with lower GA levels. This measure may be capturing a greater list of behaviors that participants higher (versus lower) in GA wrote. The total coded categories measure was limited: people received a point for mentioning a topic but the coding scheme did not account for lists (i.e., someone could get a 1 for saying "I am trying not to touch my face" and someone could get a 1 for saying "I am trying not to touch my face, I am avoiding shaking hands, and I am only touching public objects with a paper towel").

2.3. Discussion

At the start of the pandemic, trait pathogen avoidance was

[1] Analyses using structural equation modeling of the two latent factors of protective behaviors are reported in supplemental materials. The same pattern of results emerged using both approaches.

associated with stronger reactions to the threat of COVID-19, including higher overall anxiety about COVID-19, greater perceptions that people needed to alter their typical behavior, and greater rated importance of engaging in proactive and social distancing behaviors. Although both GA and PI were associated with responses to COVID-19 some differences emerged: GA demonstrated stronger links to behaviors whereas PI demonstrated stronger links to increased vigilance. One limitation, however, was our focus on hypothetical behaviors. Thus, in Study 2 we used more concrete dependent measures.

3. Study 2

In Study 2 we examined associations between people's trait pathogen avoidance and behavior during social distancing efforts. We assessed whether GA and PI are linked to people's behaviors when grocery shopping, whether these behaviors were more vigilant than their typical behaviors, and the number of times in the last 7 days they went out to the store or talked to people face-to-face. Furthermore, we isolated effects of trait pathogen avoidance by measuring and controlling for the Big 5 personality traits.

3.1. Method

3.1.1. Participants

Participants were recruited online through social media platforms to participate in a 15-min study with the opportunity to win one of five Amazon gift cards valued at $50; 1308 people completed the study. Data were excluded from 12 participants who were under 18. We additionally excluded 59 participants from analyses. Fifty-eight incorrectly answered the same catch question as in Study 1 and one participant told us not to use their data on the last page of the survey. Demographic information for the final sample (n = 1237) is reported in Table 4. Most participants were located in the United States (n = 882, 71%).

We conducted a sensitivity analysis using G*Power for our main models: multiple regressions with two predictors. These analyses indicated that we had 80% power to detect effect sizes larger than r = 0.08.

3.1.2. Procedure and materials

Data collection occurred from April 7, 2020 until April 16, 2020. On the first page of the online survey, participants were given study information and provided informed consent. Then, participants completed 6 blocks of questions presented in random order.[2]

Table 4
Descriptive statistics for Study 2.

Measures	*M* (*SD*)	Frequency
Age	30.55 (8.79)	
Political orientation (US only)	3.06 (1.85)	
Religiosity	2.81 (2.44)	
Gender		
Women		868
Men		327
Transgender		7
Nonbinary		27
Other		3
Did not wish to report		4
Race/ethnicity		
White or Caucasian		1010
Asian or Pacific Islander		137
Black or African American		19
Native American		16
Multiracial		25
Other		22
Hispanic or Latinx		90
Did not wish to report		10

3.1.2.1. Demographics. As in Study 1, participants reported their religious beliefs and U.S. participants reported their political orientation on 10-point scales.

3.1.2.2. Individual differences in pathogen avoidance. As in Study 1, participants completed the PVD questionnaire (Duncan et al., 2009). In this sample, GA (M = 4.18, SD = 1.22; α = 0.78) and PI (M = 3.69, SD = 1.40; α = 0.93) were modestly correlated (r = 0.25, p < .001). Again, we did not have strong predictions about whether GA or PI would predict these dependent measures. We replaced one item on the original questionnaire ("I avoid using public telephones because of the risk that I may catch something from the previous user") because we received open-ended feedback from participants in Study 1 that it was confusing because the behavior is not applicable. The new item was: "I avoid touching door handles in public because of the risk that I may catch something from previous people." Because of this change, conducted a CFA to verify that the two-factor solution was still appropriate. The two-factor solution, $\chi^2(89) = 963.79$, fit the data better than the one-factor solution, $\chi^2(90) = 2653.05$, $\Delta\chi^2(1) = 1689.26$, p < .001. The two-factor solution fit the data reasonably well; see supplemental materials for fit indices for both models as well as the factor loadings.

3.1.2.3. Big Five personality assessment. Participants completed a 50-item scale to measure their trait levels of agreeableness, conscientiousness, extraversion, neuroticism, and openness to experiences (Goldberg, 1999). Each personality factor was assessed by 10 items (α's ranged from 0.78 to 0.92).

3.1.2.4. Anxiety. As in Study 1, we asked participants to report their anxiety. This time, however, we asked about their anxiety about COVID-19 as well as their anxiety about social distancing. Participants answered using a slider from 0 to 100. Participants reported anxiety levels around the midpoint for both questions (disease: M = 55.91, SD = 25.39; social distancing: M = 45.93, SD = 29.72; r = 0.43, p < .001).

3.1.2.5. Vigilant behaviors at the grocery store. Participants were asked to imagine themselves at the grocery store at this moment and imagine how likely they would be to engage in seven behaviors: (1) avoid touching more items than necessary (select the first item you touch), (2) bag your own groceries/go through self-checkout rather than going to the cashier, (3) wait to go down an aisle until there were no/few customers, (4) wear a face mask, (5) wear gloves, (6), avoid buying foods that aren't prepackaged (e.g., fresh produce), and (7) bring your own hand sanitizer or wipes to use while at the store. Participants responded using a 7-point scale (1 = *Extremely unlikely*; 7 = *Extremely likely*). We created a composite of these behaviors (α = 0.64). Although the reliability of this composite was not ideal, removing any one item did not increase the reliability so we decided to retain all items.

Participants were also asked to consider how their behavior would be different from their typical behavior: "Taking into account your usual behavior at the grocery store, how much more careful would you be right now when it comes to avoiding germs?" Participants responded using a 7-point scale (1 = *Much less careful than usual*; 7 = *Much more careful than usual*). On average, all participants reported that they would be much more careful than usual (M = 6.41, SD = 0.90), one sample $t(1233) = 94.25$, p < .001. We predicted that PVD scores would be positively associated with being more vigilant than usual; we

[2] One additional block assessed sleep disturbances and was for a separate research hypothesis.

hypothesized that PI may be significantly associated with behaving differently whereas GA may not be.

3.1.2.6. Behaviors in the last 7 days. Participants were asked to respond how often they engaged in four different behaviors in the last 7 days: (1) "how many times have you left the house to go to a store (grocery store, pharmacy, home improvement store, etc.)," (2) "how many times have you picked up food from a restaurant or had food delivered to you," (3) "how many times have you left the house to go for a walk outdoors," and (4) "how many times have you had a face-to-face conversation (even if 6ft apart) with someone who does not live with you." For the last item, we elaborated that a friend or family member would be a relevant example but a cashier or a coworker (if still going to work) would not be a relevant example. We also assessed whether participants had a dog and used the binary variable as a covariate for analyses focusing on the number of days participants went for a walk. Participants answered on a 9-point scale (1 = *zero*, 9 = *eight or more*) and responses for each question ranged from 1 to 9. On average, participants reported the following frequency of behaviors in the last 7 days: going to the store on two days (M = 2.38, SD = 1.42), ordering food on two days (M = 2.20, SD = 1.49), going for walks on four days (M = 4.05, SD = 2.76), and talking to people face to face on two days (M = 2.45, SD = 2.04).

3.1.2.7. Exploratory analyses. Participants reported how likely they were to engage in various behaviors tomorrow and how many toilet paper rolls they had at their house. Details about these measures and results are reported in supplemental materials.

3.1.3. Analytic strategy

Our primary analyses are multiple regression models in which the dependent measure is regressed onto both GA and PI simultaneously. We also conducted ancillary analyses where we included a number of covariates: agreeableness, conscientiousness, extraversion, neuroticism, openness to experience, whether participants were living in the United States (0 = not in United States; 1 = in United States), and whether participants were under stay at home order (0 = no stay at home order or unsure, n = 225; 1 = under stay at home order, n = 1010). In text, we mention if the associations with PI and GA were different between the primary and ancillary analyses; see supplemental materials for full results from the ancillary analyses.

3.2. Results

The results of the primary analyses are reported in Table 5. GA and PI were associated with anxiety about COVID-19. In terms of anxiety about social distancing, only GA was associated with anxiety about social distancing. Both GA and PI were positively associated with more vigilant behaviors at the grocery store; however, only PI was associated with people saying that they would be more vigilant at the grocery store than they are typically. These associations remained significant in the ancillary analyses.

In terms of behaviors in the past 7 days, PI was negatively associated with the number of times participants went to the store and went for a walk. GA was not associated with either behaviors. However, GA was negatively associated with the number of face-to-face interactions in the past 7 days whereas there was no association between face-to-face interactions and PI. Neither GA nor PI were associated with ordering food at restaurants.

Table 5
Results of the primary regression analyses in Study 2.

Models	*b* (*SE*)	t	df	p	95% CI	r
How would you rate your anxiety about the illness (COVID-19) itself?						
GA	2.69 (0.60)	4.50	1211	< .001	[1.52, 3.86]	0.13
PI	3.16 (0.53)	6.01	1211	< .001	[2.13, 4.19]	0.17
How would you rate your anxiety about social distancing?						
GA	2.15 (0.74)	2.89	1141	.004	[0.69, 3.61]	0.09
PI	0.84 (0.66)	1.28	1141	.201	[−0.45, 2.13]	0.04
Vigilant behavior in grocery store (composite)						
GA	0.22 (0.03)	8.67	1231	< .001	[0.17, 0.27]	0.24
PI	0.09 (0.02)	4.03	1231	< .001	[0.05, 0.13]	0.11
Relatively more vigilant than usual						
GA	0.01 (0.02)	0.42	1229	.672	[−0.03, 0.05]	0.01
PI	0.08 (0.02)	4.03	1229	< .001	[0.04, 0.11]	0.11
Going to the store in the last 7 days						
GA	−0.05 (0.03)	−1.58	1231	.114	[−0.12, 0.01]	−0.05
PI	−0.08 (0.03)	−2.80	1231	.005	[−0.14, −0.03]	−0.08
Ordering food in the last 7 days						
GA	−0.003 (0.04)	−0.07	1231	.942	[−0.07, 0.07]	−0.002
PI	−0.01 (0.03)	−0.44	1231	.660	[−0.08, 0.05]	−0.01
Going for a walk in the last 7 days[a]						
GA	−0.12 (0.06)	−1.84	1229	.067	[−0.25, 0.01]	−0.05
PI	−0.15 (0.06)	−2.69	1229	.007	[−0.26, −0.04]	−0.07
Talking to someone face-to-face in the last 7 days						
GA	−0.14 (0.05)	−2.79	1230	.005	[−0.23, −0.04]	−0.08
PI	−0.04 (0.04)	−0.92	1230	.360	[−0.12, 0.05]	−0.03

Note. Bolded associations are significant when controlling for multiple hypothesis testing using the Benjamini-Hochberg procedure.
[a] Analyses control for whether participant owns a dog.

4. General discussion

Across two studies, trait pathogen avoidance was linked to stronger reactions to a real pathogen threat and greater proclivity to engage in preventative behaviors that both protect the individual from contagion and help slow the spread of the virus. Study 1 documented people's responses during the initial stages of the pandemic. Trait pathogen avoidance predicted people taking COVID-19 more seriously: PVD was positively associated with increased anxiety, perceptions that COVID-19 was more serious than the seasonal flu, and how important people thought engaging in preventative behaviors was for limiting virus propagation. Study 2 documented people's behavior several weeks later when most people were under stay-at-home orders. Trait pathogen avoidance predicted greater compliance with social distancing efforts: PVD was positively associated with vigilant behavior at the grocery store, number of times people left the house to go to the store or for walks, and the number of face-to-face interactions people reported having in the last 7 days. The associations between PVD and social distancing behaviors emerged when controlling for conscientiousness, extraversion, and neuroticism, highlighting the importance of individual differences specific to pathogen avoidance.

These data are consistent with prior research suggesting that people's pathogen avoidance psychology reacts to actual disease threats (Beall et al., 2016). Critically, findings extend the pathogen avoidance literature by demonstrating a link between trait pathogen avoidance and individuals' perceptions of a real-world threat, as well as the importance of engaging in hygiene and social distancing practices necessary to combat the contraction and spread of the disease.

Furthermore, our findings are consistent with recent evidence suggesting that GA and PI are associated with differential behavioral outcomes (e.g., Makhanova et al., 2019; Young et al., 2011). Indeed, although GA and PI often demonstrated parallel associations, at times differences between subscales emerged. In Study 1, GA was associated with perceptions of the importance of proactive protective behaviors and staying home if one is sick, as well as greater preference for information about how to avoid germs (rather than protecting their health). In Study 2, GA was associated with fewer face-to-face interactions during social distancing and greater anxiety about social distancing. Taken together, GA seems to be more strongly associated with behaviors than PI. On the other hand, in Study 1, PI was associated with

perceptions that COVID-19 was a greater threat than the seasonal flu and the desire to read an article that talked about the increasing risk of COVID-19 (rather than an article downplaying the risk). In Study 2, PI was associated with a greater change from typical in vigilant behavior at the grocery store and fewer trips outside of the house (to either the store or to walk outside). Taken together, PI seems to be more strongly associated with increased monitoring and vigilance than GA. Notably, both PI and GA were associated with responses to the threat of COVID-19 even though people were not reacting to an actual, visibly sick person in their environment. Findings are thus consistent with the notion that pathogen avoidance promotes proactive strategies aimed at mitigating pathogen transmission (Ackerman et al., 2018).

4.1. Limitations and future directions

It is important to acknowledge several limitations of the present research. First, although we recruited online using platforms that have wide dissemination capabilities, our participants tended to be relatively young, primarily American, primarily female, mostly White, and largely liberal in their political orientations.[3] Thus, we did not have the range to fully examine how different cultural and demographic variables may have affected people's responses to the threat of COVID-19, and how those factors may influence trait pathogen avoidance. Future research would benefit from increasing sociodemographic diversity of samples in order to examine such associations more systematically.

We found that people's trait levels of pathogen avoidance, both germ aversion and perceived infectability, predicted responses to the threat of COVID-19 and social distancing behaviors. However, it remains largely unknown what shapes people's trait pathogen avoidance levels. Research suggests that various factors may be important: past history of illness (Makhanova et al., 2020), cultural and developmental factors (Rozin et al., 2008), as well as genetic factors (Olatunji et al., 2019; Sherlock et al., 2016). Importantly these factors may be different for men and women. For example, Sherlock et al. (2016) studied female twin pairs and found that approximately 50% of the variation in disgust sensitivity is due to genetic components. However, a recent study that examined both female and male twin pairs, suggests that disgust sensitivity may not have genetic components for men (Olatunji et al., 2019). Considering women tend to have higher overall levels of disgust sensitivity than men (Duncan et al., 2009; Haidt et al., 1994; Tybur et al., 2011), it is important to examine whether other factors that shape people's trait pathogen avoidance may be moderated by sex or gender. Overall, because trait pathogen avoidance predicts important outcomes for social behavior during a pandemic, it is important to understand the determinants of variance in this trait.

Social behavior during a pandemic may also be perceived and enacted differently by men and women. In our samples, women tended to take COVID-19 and social distancing more seriously than men. Meanwhile, medical research demonstrates that men are more likely to experience worse consequences of getting sick with COVID-19 (Sun et al., 2020). It is thus important to understand what factors may influence men's and women's diverging perceptions of important social distancing behaviors. Some factors may be biological, stemming from greater evolutionary pressures to avoid pathogens faced by women compared to men. Over the evolutionary past, women spent a large proportion of their lives taking care of children, and maternal illness or mortality was of tremendous cost for offspring survival (Campbell, 2013). Alternatively, some of the factors may be due to sociocultural norms reflecting femininity and masculinity (Courtenay, 2000). Men may see observable social distancing behaviors as less masculine, because often masculinity is associated with taking risks rather than being cautious. Masculinity norms tend to promote unhealthy behaviors across many domains (Courtenay, 2000). Although in exploratory analyses of Study 2 we did not find that the associations between dependent measures and perceived vulnerability to disease were moderated by sex,[4] it is nonetheless important for future research to disentangle how evolutionary and sociocultural pressures may affect men's and women's health risk behaviors.

Another factor that may affect both trait pathogen avoidance and health behaviors is life history strategy. Research using Life History Theory has demonstrated that early childhood environments affect the ways that people allocate their time and energy between goals relevant to reproduction, survival, and somatic development (Belsky et al., 1991; Del Giudice et al., 2016; Ellis et al., 2009). Specifically, harsh and unpredictable early environments tend to promote a “fast” life history strategy associated with the allocation of greater resources toward earlier reproduction, and thereby the allocation of fewer resources toward long-term somatic development. More plentiful and predictable early environments on the other hand tend to promote a “slow” life history strategy associated with delayed reproduction and the allocation of greater resources toward somatic development. Recently several theoretical arguments have outlined ways in which early environments may affect pathogen avoidance behaviors (Ackerman et al., 2018; Hill et al., 2016). Moreover, research informed by life history theory has demonstrated that situations connoting increased pathogen threat promote less risk-taking (Prokosch et al., 2019). To the extent that life history strategy may sensitize people to pathogen threats and affect their responses to those threats, people from harsh and unpredictable early environments may respond differently to pathogen threats that people from plentiful and predictable environments. We did not assess any markers of life history strategy so we are unable to answer these questions with the present data. Thus, it would be imperative for future research to examine how early environments may sensitize people to the threat of potential pathogens and how life history strategies may affect people's social distancing behaviors during situations of acute pathogen threat like the COVID-19 pandemic.

Finally, the link between trait pathogen avoidance and stronger reactions to the threat of COVID-19 has broad implications, which were not directly assessed in the present studies. Pathogen avoidance is linked to many social behaviors including decision-making, morality, and prejudice (Ackerman et al., 2018). Therefore, the upregulation of pathogen avoidance processes described in these data may correspond to problematic downstream behaviors that emerged during the beginning of the COVID-19 pandemic, such as toilet paper hoarding[5] and negative social behavior toward people of Asian descent. Thus, the downstream effects of the reported associations are likely widespread beyond individuals' self-isolation.

4.2. Conclusion

Across two studies, trait pathogen avoidance was associated with taking the threat of COVID-19 more seriously and with greater engagement in social distancing. Thus, the findings buttress theories of pathogen avoidance by illustrating that trait pathogen avoidance predicts reactions to the real, looming threat of a pandemic. Given that trait pathogen avoidance was associated with greater vigilance toward a rather invisible threat (because most participants did not know anyone diagnosed with COVID-19 and transmission can occur from asymptomatic social partners), the findings additionally highlight the proactive rather than reactive processes of trait pathogen avoidance.

[3] We did measure other demographic information that were not analyzed for or reported in the present manuscript. The study codebooks and data are publicly available on OSF (https://osf.io/ja86s/).

[4] One exception was for the grocery behavior composite. Both the link between GA and behaviors as well as between PI and behaviors were significantly moderated by sex. However, simple slopes were significant for both men and women.

[5] Exploratory analyses reported in supplemental materials.

The findings further suggest that it is important to consider separately the two factors of trait perceived vulnerability to disease—germ aversion and perceived infectability—because whereas germ aversion was linked to more behavioral outcomes, perceived infectability tended to be more associated with increased vigilance for pathogen threats. Although many self-protective behaviors associated with pathogen avoidance have negative societal ramifications, these findings underscore an important prosocial outcome: pathogen avoidance promoted more serious responses to COVID-19 which could facilitate societal measures to flatten the curve of the disease.

CRediT authorship contribution statement

Anastasia Makhanova: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft.**Melissa A. Shepherd:**Methodology, Writing - review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2020.110221.

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