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Longitudinal relationships between COVID-19 preventative behaviors and perceived vulnerability to disease

Leah D. Church [a,*], Nadia Bounoua [a], Samantha N. Rodriguez [b], Keith Bredemeier [c], Jeffrey M. Spielberg [a]

[a] University of Delaware, Department of Psychological and Brain Sciences, 108 Wolf Hall, Newark, DE 19176, USA
[b] University of New Mexico, Department of Psychology, 1 University of New Mexico, Albuquerque, NM 87131-0001, USA
[c] University of Pennsylvania, Perelman School of Medicine, 3535 Market St., Philadelphia, PA 19104, USA

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ABSTRACT

Engagement in infection-preventing behaviors (e.g., mask wearing) has become crucial in the context of the COVID-19 pandemic, and health-related anxiety may be an important determinant of individual compliance with recommended guidelines. However, little is known about transactional associations between health anxiety and preventative behaviors, particularly with respect to COVID-19. The present study aimed to longitudinally examine the links between preventative behaviors and both emotion-driven (*Germ Aversion*) and belief-based (*Perceived Infectability*) aspects of health anxiety during the COVID-19 pandemic. We hypothesized that greater health anxiety at Time 1 (early in the pandemic) would predict future compliance with preventative behaviors six months later. Two hundred and ninety-six adults (M/SD_{age}= 30.9/10.9 years, 42.2% female) completed two online assessments during the COVID-19 pandemic (Time 1 =June 2020; Time 2 =December 2020). Longitudinal cross-lagged analyses revealed that initial *Germ Aversion* predicted greater engagement in preventative behaviors at follow-up ($\beta = 0.16$; $p = <.001$), over and above initial engagement in such behaviors. Similarly, initial engagement in preventative behaviors predicted increases in *Germ Aversion* at follow-up ($\beta = .23$; $p = <.001$), over and above initial *Germ Aversion*. The present findings indicate that affect-driven aspects of health anxiety have a complex transactional relationship with engagement in behaviors aimed at curbing the spread of the COVID-19 pandemic. Clinical and public health implications are discussed.

1. Introduction

Previous research has identified several factors that impact the uptake of health preventative behaviors (Rubin, Amlot, Page, & Wessely, 2009; Taylor, 2019). For example, individuals with higher levels of health anxiety (e.g., beliefs about the likelihood of becoming ill, exaggerated worry about one's health; Asmundson, Abramowitz, Richter, & Whedon, 2010) are more likely to engage in behaviors that they believe will reduce their own vulnerability to disease and illness (Deacon & Maack, 2008; Taylor, 2019). Indeed, research shows that emotional appeals, such as campaigns that elicit fear, are strong motivators that promote engagement in prevention behaviors (Witte & Allen, 2000). This is consistent with negative reinforcement models of anxiety, in which engagement in these behaviors serves to mitigate anxiety and stress (Schaller, 2006). Therefore, higher health anxiety may lead to greater compliance with recommended prevention strategies in order to avoid the short-term distress caused by anticipation of aversive outcomes, although this may actually maintain longer-term stress. Consistent with theories of selective attention and threat overestimation, continued engagement in preventative behaviors may prompt heightened awareness of pathogen exposure/risk and subsequent health anxiety (Deacon & Maack, 2008). Moreover, perceptions of vulnerability to disease are a key component of health anxiety which may impact individual differences in preventative behavior engagement (De Coninck, d'Haenens, & Matthijs, 2020).

Studies conducted during previous epidemics (e.g., Swine flu, Ebola) found cross-sectional associations between health-related stress and anxiety and health preventative behaviors (Blakey, Reuman, Jacoby, & Abramowitz, 2015; Rubin et al., 2009; Wheaton, Abramowitz, Berman, Fabricant, & Olatunji, 2012). Yet, a major limitation of previous studies is the predominant use of cross-sectional designs, which prohibits elucidation of the temporal order of health anxiety and engagement in

* Correspondence to: Leah D. Church, University of Delaware, Department of Psychological and Brain Sciences, 108 Wolf Hall, Newark, DE 19716, USA.
E-mail address: lchurch@udel.edu (L.D. Church).

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prevention behaviors, along with potential transactional relationships between these factors over time. In other words, although we know that health anxiety is positively correlated with engagement in these behaviors, far less is known about whether each predicts the future occurrence of the other. Outside of an epidemic, one exception is a longitudinal study by Olatunji (2015) in which engagement in health behaviors related to subsequent increases in disgust propensity. However, the extent to which these longitudinal relationships exist in the context of global pandemic remains unknown. Furthermore, previous studies have not examined the *bidirectional* temporal effects of health anxiety and preventative behaviors, thus leaving the potential causal relationships between these factors unclear.

In late 2019/early 2020, a novel, highly contagious virus (SARS-CoV2) spread across the globe, leading the World Health Organization to declare the COVID-19 pandemic on March 11, 2020 (WHO, 2020). Global health organizations quickly began to encourage comprehensive health safety preventative behaviors, including wearing a mask and physically distancing from others in public, to mitigate COVID-19 infection and death rates (Centers for Disease Control and Prevention, 2021). Although recommended behavioral changes benefit both the individuals who engage in them and society at large, available data shows that historical rates of compliance with preventative behaviors vary widely (Clark, Davila, Regis, & Kraus, 2020; Taylor, 2019). Given that engagement in these preventative behaviors is crucial to the control and elimination of viral diseases like COVID-19, nonadherence remains a significant problem. Thus, identification of factors that may contribute to adherence is critically necessary to mitigate future illness and death.

The COVID-19 pandemic also represents a different context than past examinations of health anxiety. Higher levels of health anxiety may have become more normative, and the need for engagement in preventative behaviors is a vital tool to stop the spread of the pandemic. In other words, COVID-19 represents a novel context within which to understand dimensional relationships between health anxiety and preventative behaviors, and three extant studies have begun to probe these questions. For example, germ aversion during COVID-19 has been linked cross-sectionally with a greater likelihood to social distance and follow other recommended behavioral changes (Makhanova & Shepherd, 2020). As well, pre-pandemic disgust-proneness predicted increased COVID-related anxiety and engagement in preventative behaviors during the pandemic (Cox, Jessup, Luber, & Olatunji, 2020). Finally, pre-pandemic contamination fear has been found to predict increased engagement in preventative behaviors during the pandemic (Knowles & Olatunji, 2021). Taken together, these findings provide preliminary evidence for a significant relationship between health anxiety and preventative behaviors during the COVID-19 pandemic.

Although quite informative, a key weakness of these COVID-19 longitudinal studies is that the analytic strategies could not disentangle longitudinal prediction from cross-sectional relationships. For example, preventative behaviors at the first measurement point were not assessed and, therefore, could not be controlled for when testing whether pre-pandemic contamination fear predicts peri-pandemic preventative behaviors. This lack of baseline measurement is completely understandable, given that the first measurement point in these studies occurred before the pandemic, when preventative behaviors were less common and not a focus of research. In fact, the use of pre-pandemic data is a strength of this work. At the same time, the fact that pre-pandemic preventative behaviors could not be controlled for means that cross-sectional variance may be driving what appear to be longitudinal relationships. For example, *p re* -pandemic fear of contamination may be related to *peri*-pandemic preventative behaviors, because of the cross-sectional association between the two, not a temporal predictive relationship. Consequently, an important next step is to supplement this work by examining data collected at two time-points *during the pandemic*, which is necessary to disentangle these relationships. Potentially of greater import, this design allows us to examine how both factors unfold and influence each other over time (e.g., does engagement in preventative behavior impact *future* anxiety).

The goal of the present study was to examine longitudinal associations between perceived vulnerability to disease and preventative health behaviors across a six-month period during the early stages of the COVID-19 pandemic. We focused on perceived vulnerability to disease because it indexes personal beliefs about susceptibility to infectious diseases above and beyond more general health-relevant anxiety (Duncan, Schaller, & Park, 2009), and thus, may be particularly relevant to the COVID-19 context. Based on previous research (e.g., Knowles & Olatunji, 2021), we hypothesized that greater perceived vulnerability at Time 1 would predict *future* compliance with preventative behaviors, over and above Time 1 compliance. Given past work on the maintaining effect of preventative behaviors in anxiety pathology (Abramowitz & Moore, 2007), we also hypothesized that compliance with preventative behaviors at Time 1 would predict future increases in perceived vulnerability to disease.

2. Methods

2.1. Participants

Study data were collected and managed using REDCap (Research Electronic Data Capture) tools, a secure, web-based software platform, hosted at the University of Delaware (Harris et al., 2009; Harris et al., 2019). Initial data were collected from 544 adults recruited from an online crowdsourcing platform (Prolific Academic, https://www.prolific.co) in June 2020 amidst the COVID-19 pandemic. Individuals were eligible to participate if they were between the ages of 18 and 65, were fluent in English, and resided in a country wherein the government had recommended COVID-related preventative behaviors that were similar to those recommended in the US, so as to maintain some consistency across the sample in what preventative behaviors were relevant. This included Canada, the European Union, and Australia. Follow-up data were collected after a 6-month interval from 308 participants in December 2020. Individuals who completed the data collection at Time 1 in less than 20 min ($n = 22$) were excluded from follow-up due to concerns about validity of their responses. Of the 308 from whom follow-up data was collected, 12 (3.9%) were excluded for incomplete data on key study variables.

The final sample consisted of 296 adults (M/SD_{age}=30.9/10.9 years, 42.2% female). The sample was international and largely located in Europe ($n = 264$; 89.2%), with the remainder in the United States ($n = 20$; 6.8%) and other regions ($n = 12$; 4.1%). Approximately 43% of the sample was currently employed full-time, followed by: 18.2% unemployed (and job seeking), 15.1% employed part-time, 14.1% 'Other', 7.2% not in paid work (e.g., homemaker, retired, or disabled), and less than 1% due to start a new job within the next month.

3. Measures

3.1. Perceived vulnerability to disease (PVD)

The 15-item PVD questionnaire (Duncan et al., 2009) was used to assess individual differences in concerns about the transmission of infectious diseases. For each item, participants rated the extent to which they agreed or disagreed with each statement on a 7-point Likert scale from 1 ("*Strongly disagree*") to 7 ("*Strongly agree*"). The PVD is comprised of two subscales: (i) *Germ Aversion* (8 items), measuring emotional discomfort with disease (e.g., "*It really bothers me when people sneeze without covering their mouths.*") and (ii) *Perceived Infectibility* (7 items), measuring beliefs about the likelihood of sickness (e.g., "*If an illness is 'going around', I will get it.*"). Summed scores were calculated for each subscale.

3.2. COVID-19 preventative behaviors scale

A 12-item scale was created for the present study which measured the frequency of engagement in COVID-19 preventative behaviors (see Table 1 for items). At Time 1, participants were asked to report "*Which of the following changes to your behavior have you made since the COVID pandemic started*?" At the 6-month follow-up, participants were asked to report "*Which of the following changes to your behavior have you made in the last two months?*" These differences in instructions were employed to remove any direct overlap in behavior between reports (i.e., the 6-month follow-up would index behavior change that occurred since the initial data collection). For behaviors that were common before the pandemic (items 1–5 in Table 1), a Likert scale was used that ranged from 1 ("*Stopped completely*") to 5 ("*Increased a lot*"). For behaviors that were not common pre-pandemic (Table 1 items 6–12), the scale ranged from 1 ("*I never do this*") to 5 ("*I always do this*"). Mean scores were calculated for each timepoint (Cronbach's alpha Time 1 = .78; Cronbach's alpha Time 2 = .80). We conducted an exploratory factor analysis to ensure the scale was measuring a unitary construct. Results of the exploratory factor analysis of Time 1 data indicate a good single factor model fit to the data (CFI = .93, TLI = .91, RMSEA = .08).

3.3. Covariate measures

We administered the Anxious Arousal Subscale of the Mood and Anxiety Symptoms Questionnaire (MASQ-AA; Clark & Watson, 1991) to measure anxious arousal, the Intolerance of Uncertainty Scale (IUS; Carleton, Norton, & Asmundson, 2007) to index general aversion toward uncertainty of future events, the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) to assess general worry, the Social Phobia Inventory (SPIN; Connor et al., 2000) to index the severity of fear, avoidance, and physiological symptoms of social anxiety, and the Obsessive-Compulsive Inventory, Revised (OCI-R; Foa et al., 2002) to assess obsessive-compulsive thoughts and behaviors. Both the full OCI-R as well as a modified version were used in covariate analyses. The modified version removed hoarding items within the OCI-R in line with current conceptualizations of OCD and hoarding disorder as separate diagnoses (Abramowitz & Jacoby, 2014; Wootton et al., 2015).

4. Data analysis

Bivariate correlations between participant demographics and key study variables were conducted using SPSS v26 (IBM Corp, Released 2019). Cross-lagged structural equation modeling was conducted using MPlus v.1.7 (Muthen and Muthen, 1998-2017) to examine predictive relationships between PVD subscales (e.g., *Germ Aversion, Perceived Infectibility*) and COVID-19 health preventative behaviors (e.g., *Preventative Behaviors*). Separate models were examined for each of the PVD subscales. Autoregressive paths were included in the models, and the variables were allowed to covary within each timepoint. Standardized parameter estimates are depicted in Fig. 1 (sex and age covariates are not shown). Based on significant bivariate correlations with one or both PVD subscales, age and sex were used as covariates in all cross-lagged path models. To examine effect sizes, standardized betas may be interpreted similar to correlation coefficients wherein small = .2, medium = .5, and large = .8 (Cohen, 1988). Fig. 2.

To determine whether findings were specific to health anxiety, cross-lagged analyses were rerun with a series of additional covariates which indexed potentially confounding constructs (Time 1 values were used). Each of these covariates was tested in a separate cross-lagged model. Specifically, we examined broader cognitive (i.e., worry assessed via the PSWQ; Meyer et al., 1990) and physiological (i.e., anxious arousal assessed via the MASQ-AA; Clark & Watson, 1991) aspects of anxiety to ensure that findings were not driven by such broader tendencies. Relatedly, the early pandemic was fraught with uncertainty, both with regard to the virus itself (e.g., what precautions *may* be effective) and other aspects of life (e.g., employment and housing insecurity). Therefore, we tested whether intolerance of uncertainty (indexed via IUS; Carleton et al., 2007) accounted for the observed relationships. Given associations between health anxiety and certain presentations of Obsessive-Compulsive Disorder, we also tested whether obsessive-compulsive ideation (indexed via OCI-R; Foa et al., 2002) accounted for the observed relationships. Finally, given the social nature of many of the preventative behaviors (e.g., social distancing), social anxiety may have indirectly increased the incidence of such behaviors. Thus, we tested whether social anxiety (assessed via the SPIN; Connor et al., 2000) accounted for observed relationships.

Table 1
Covid preventative behaviors scale items.

1. Wash your hands
2. Being in crowds (reverse coded)
3. Disinfect your house
4. Use public transportation (reverse coded)
5. Leave the house for non-essential reasons (i.e. other than for groceries, medications) (reverse coded)
6. Wear a mask and/or gloves in public
7. Stay 6 + feet away from strangers in public (e.g., at a grocery store)
8. Wipe down groceries/removing food from packaging after purchasing
9. Ask for 'no contact' options (e.g., when getting food delivered)
10. Leave boxes from online purchases outside of your home for at least a few hours
11. Avoid touching eyes, nose, and mouth with unwashed hands
12. Sneeze and/or cough into elbow

5. Results

See Table 2 for means/standard deviations and bivariate correlations among study variables.

5.1. Cross-lagged path models

5.1.1. Germ aversion model

The total model accounted for 60.3% of the variance in *Germ Aversion* at Time 2% and 49.0% of the *Preventative Behaviors* at Time 2. Results revealed significant bidirectional relationships between *Germ Aversion* and *Preventative Behaviors*. Specifically, Time 1 *Germ Aversion* predicted a small increase in engagement in *Preventative Behaviors* at six-month follow-up ($\beta = .16$; $p = <.001$), over and above Time 1 *Preventative Behaviors*. Similarly, Time 1 *Preventative Behaviors* predicted a small increase in *Germ Aversion* at follow-up ($\beta = .23$; $p = <.001$), over and above *Germ Aversion* at Time 1. All findings remained significant (p's < .05) after covarying general worry, anxious arousal, social anxiety, intolerance of uncertainty, or obsessive-compulsive ideation, supporting the hypothesis that the effects are specific to health anxiety.

5.1.2. Perceived infectibility model

The total model accounted for 60.0% of the variance in *Perceived Infectibility* at Time 2% and 47.0% of the *Preventative Behaviors* at Time 2. No significant predictive relationships were found between *Perceived Infectibility* and *Preventative Behaviors* (p's > 0.2).

6. Discussion

Disparities in compliance with recommended health preventative behaviors pose a significant threat to public health, particularly in response to the ongoing COVID-19 pandemic. While previous research has identified a relationship between health-related anxiety and engagement in preventative behaviors, the transactional nature and directionality of the relationship between these factors has been unclear. We addressed these gaps in the literature by investigating transactional relationships *over time* between health anxiety and COVID-19 behavior guidelines.

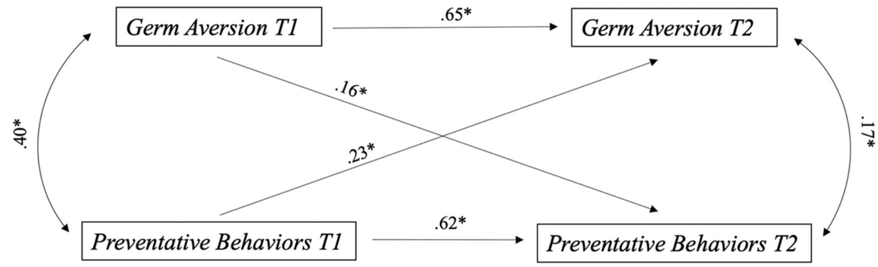

Fig. 1. Germ Aversion Standardized Cross-lagged Path Model. Note. * p < .01.

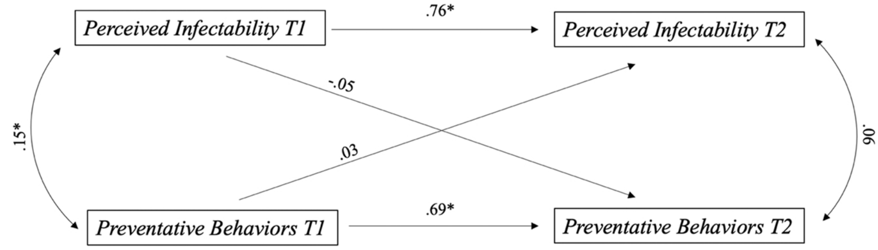

Fig. 2. Perceived Infectability Standardized Cross-lagged Path Model. Note. * p < .01.

Table 2
Correlations between demographics and key variables.

Variable	M/SD	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	30.9/10.9	.17**	-.24**	-.23**	-.13*	-.19**	-.23**	-.00	.12*	.03	-.07	.10	-.03
2. Sex (male = 0, female = 1)	42.2% female		-.07	.21**	.01	-.08	-.06	.10	-.02	.08	.11	.14*	.05
3. Anxious Arousal (MASQ-AA) T1	25.09/7.80			.39**	.35**	.37**	.54**	.25**	.09	.08	.23**	.04	.12*
4. General Worry (PSWQ) T1	50.25/14.94				.51**	.64**	.43**	.25**	.18**	.12*	.29*	.21**	.13*
5. Social Anxiety (SPIN) T1	26.29/13.91					.59**	.43**	.21**	.22**	.02	.24**	.16**	.01
6. Intolerance of Uncertainty (IUS) T1	34.53/8.87						.49**	.11	.26**	.10	.16**	.21**	.08
7. Obsessive-Compulsive (OCI-R) T1	18.09/11.87							.21**	.40**	.20**	.21**	.30**	.20**
8. Perceived Infectibility T1	23.65/8.32								.21**	.16**	.77**	.17**	.06
9. Germ Aversion T1	35.05/8.80									.39**	.20**	.73**	.39**
10. Preventative Behaviors T1	44.0/7.20										.15**	.49**	.68**
11. Perceived Infectability T2	23.49/8.46											.24**	.10
12. Germ Aversion T2	36.24/8.70												.49**
13. Preventative Behaviors T2	42.80/7.50												

Note.
** p < .01,
* p < .05

Across a six-month period of the COVID-19 pandemic, we found significant transactional relationships between *Preventative Behaviors* and *Germ Aversion*, a measure of health anxiety related to the affective responses to potential disease. As expected, Time 1 *Germ Aversion* predicted increases in *Preventative Behaviors* at six-month follow-up, above and beyond Time 1 behavioral compliance, suggesting that anxiety about potential disease drove an increase in behavior aimed at preventing this disease. Interestingly, Time 1 *Preventative Behaviors* also predicted higher *Germ Aversion* at six-month follow-up, over and above *Germ Aversion* at Time 1, suggesting these 'safety behaviors' exacerbate such anxiety. Although effect sizes of the significant model were relatively small (βs = .16–.23), these findings provide novel insight into specific, bidirectional processes in the context of an ongoing global pandemic. Importantly, these findings remained significant after controlling for more general anxiety constructs (e.g., intolerance of uncertainty, general worry), supporting the specificity of these findings. Taken together, these findings extend the literature by showing a predictive, transactional association between these processes as they unfold over time during a health pandemic.

Previous research shows that anxiety-based processes may impact the uptake of health preventative behaviors (Rubin et al., 2009; Taylor, 2019). Our findings are consistent with the Behavioral Immune System (Schaller & Park, 2011) and similar models, which posit that engagement in health preventative behaviors may provide short-term alleviation of health anxiety via negative reinforcement (e.g., avoidance). In particular, given that *Germ Aversion* reflects affective distress in response to potential or actual pathogen exposure, it appears that the *emotional reactivity* elicited by the threat of infectious disease is a key motivator of engagement in preventative behaviors.

An affective component that seems likely to be particularly relevant to this discussion is disgust, or the tendency to experience the emotion of disgust in response to a variety of stimuli (e.g., bodily fluids, disease). Notably, disgust has been strongly linked to *Germ Aversion*, whereas the association with *Perceived Infectibility* was much weaker (Duncan et al., 2009). Recent studies have found disgust propensity and sensitivity to be linked to COVID-specific anxiety and stress via individual differences in activation of the Behavioral Immune System (McKay, Yang, Elhai, & Asmundson, 2020; Paluszek et al., 2021). Although these studies provide greater insight into affective factors that promote Behavioral Immune System activation, the implications of this link (e.g., on preventative behaviors) have not been examined. Indeed, the relationships between *Germ Aversion*, disgust, and the Behavioral Immune System are of particular relevance to individual motivations to engage in preventative behaviors. Although the activation of the Behavioral

Immune System promotes engagement in behaviors aimed at reducing infection (Schaller & Park, 2011), the present study provides insight into distinct mechanisms that drive this engagement. Specifically, disgust may serve as the mechanism by which *Germ Aversion* promotes engagement in preventative behaviors. At the same time, it should be noted that there are important distinctions between *Germ Aversion* and disgust (Duncan et al., 2009), including that the measure of *Germ Aversion* used herein is specific to potential disease exposure, whereas disgust typically reflects a broader emotional response to an array of stimuli. Thus, the present study significantly adds to the current literature by identifying more *specific* factors (i.e., germ aversion) than general disgust that promote Behavioral Immune System activation and subsequent behavioral engagement.

In relation to the COVID-19 pandemic, recent work has shown that specific facets of health anxiety may be particularly associated with health preventative behaviors (Makhanova & Shepherd, 2020). We found that *Germ Aversion*, but not *Perceived Infectibility*, was associated with *Preventative Behaviors*, consistent with research showing that *Germ Aversion* and *Perceived Infectability* are distinct facets of perceived vulnerability to disease (Duncan et al., 2009). The current findings are also consistent with previous work by Clark et al. (2020) who found that *Perceived Infectability* was not a predictor of compliance with behavioral recommendations. Given that *Perceived Infectability*, which reflects *explicit beliefs* about vulnerability to infection, was not a significant predictor of future health behaviors, it appears that such 'cold' beliefs about health risk are not key drivers of prevention related behaviors, in contrast to the 'hot' affective processes indexed by *Germ Aversion*.

Interestingly, *Preventative Behaviors* at Time 1 also predicted increases in future *Germ Aversion,* consistent with previous work indicating that *Preventative Behaviors* are associated with increases in health anxiety over time (Deacon & Maack, 2008; Olatunji et al., 2011). Our findings are consistent with the idea that preventative behaviors serve as 'safety' behaviors that maintain anxiety, such that pathogen aversion is reinforced when individuals engage in safety behaviors and then do not contract an illness. In other words, preventative behaviors may have a short-term anxiolytic (e.g., affective) effect, which reinforces such behaviors, but does not actually reduce anxiety in the longer term. The fact that we found this relationship for *Germ Aversion*, but not *Perceived Infectibility*, is consistent with the idea that this reinforcement is affective in nature rather than a 'cognitive' mechanism based in beliefs. In particular, compliance with preventative behaviors may maintain or increase future levels of health anxiety due to greater attentional awareness and affective reactivity to continued pathogen exposure risk. Taken together, present findings provide greater insight into the maintenance of health-specific anxiety in response to engagement of health preventative behaviors.

As the first study to examine longitudinal associations between distinct facets of health anxiety and engagement in preventative behaviors, our findings have compelling implications for the advancement of public health strategies. Specifically, understanding factors that influence compliance with health preventative behaviors allows for the advancement of public health policies. Together, these findings suggest that public health guidelines with a greater focus on attitudes of pathogen aversion (e.g., emphasizing germ exposure) may encourage better rates of health behavior engagement. Furthermore, present study findings introduce the likelihood that engagement in health behaviors may also reinforce distinct anxiety-based processes over time.

Although preliminary, the findings of this study suggest that the relationship between specific forms of health anxiety and compliance with behavioral recommendations is transactional and complex. It is important to note that engagement in these behaviors is necessary to "stop the spread" of the COVID-virus. Indeed, some degree of health-specific worry and adherence to health preventative guidelines is adaptive to promote safety during a health crisis. The implications of the present work are complex, given that high levels of *Preventative Behaviors* are desirable, but this may also lead to/exacerbate anxiety pathology. Consequently, during periods in which virus prevention is not paramount, addressing the affective aspects of health anxiety may be a key intervention target.

6.1. *Strengths and limitations*

The present study has several conceptual and methodological strengths. Indeed, this is the first study to implement a longitudinal design in order to examine the transactional relationships between specific forms of health anxiety (e.g., *Germ Aversion*, *Perceived Infectability*) and health preventative behaviors (e.g., handwashing, social distancing). This longitudinal component significantly adds to the current literature by providing stronger support of potential causal theories about the relationships between these variables. Additionally, the cross-lagged analytic model enables for bidirectional relationships between variables across timepoints, allowing for interpretations of the transactional relationship between key study variables. It should be noted that, although longitudinal designs provide information of temporal order, they do not provide sufficient evidence for causality.

Several limitations must also be considered when making inferences based on the present findings. First, given that only self-report questionnaires were used, future research would benefit from the integration of additional data modalities (e.g., behavioral observation, experience sampling). For example, self-reported compliance with health preventative behaviors may not fully capture the incidence of such behaviors. Notably, no measure of current health status or objective susceptibility to disease was included in the current study, limiting our ability to determine the extent to which levels of health anxiety were out of proportion. Further, data regarding current employment workplace (e.g., in-office vs. remote) was not collected, which is unfortunate given that these data may have influenced the rates at which individuals engaged in certain preventative behaviors (e.g., using public transportation, social distancing). The use of an online crowdsourcing platform may reduce the generalizability of findings due to sampling biases. Although the use of such platforms allows for the collection of larger quantities of data and from a wider geographic array, the sample may not be representative of socioeconomically, ethnically, and racially diverse populations. Additionally, the lack of data on race or ethnicity further reduces generalizability of findings. This notable limitation prohibits our ability to test for potential group differences as well as evaluate the generalizability of findings. Future research is necessary to explore the potential differences among a variety of racial ethnic groups. However, it should be noted that the sampling strategy used herein can offer greater generalizability (e.g., across different nations) than typical strategies that are geographically limited. Given that both data collection periods occurred during the pandemic, we are not able to assess relationships with pre-pandemic levels of anxiety/behavior. At the same time, the preventative behaviors examined in the present study were relatively uncommon before the pandemic. Thus, the use of pre-pandemic data as a baseline would reduce our ability to examine the bidirectional relationships explored in the current study. Consequently, the optimal design would be to have both pre-pandemic measures of health anxiety, along with the two measurement points used in the present study. Therefore, the present study provides unique insights into the development and maintenance of health anxiety within the context of a global pandemic. Finally, although the use of a cross-lagged panel model design allows for elucidation of bidirectional effects, the use of only two waves of data means that the model is 'just identified', which limits our ability to evaluate model fit (Hamaker, Kuiper, & Grasman, 2015). Collection and examination of a third wave of data would significantly add to the ability to explicate underlying mechanism of the relationship between health anxiety and preventative behaviors.

6.2. *Conclusion and future directions*

In summary, the present study found a predictive, transactional relationship between the affective component of pathogen aversion and engagement in health preventative behaviors over a six-month period of the COVID-19 pandemic. The present study adds key insights to existing literature, given that these bidirectional relationships had not previously been explored longitudinally. An important next step is to examine the potential role of disgust as it relates to the relationship between distinct facets of health anxiety (e.g., germ aversion) and engagement in health preventative behaviors, particularly through individual differences in Behavioral Immune System activation. Additionally, future studies may seek to understand how adaptive levels of health anxiety that promote compliance with public health efforts may evolve into maladaptive levels of sustained threat, particularly if/when rates of COVID-19 have declined. Ultimately, these data suggest that the relationship between distinct anxiety-based processes and health preventative behaviors during a global pandemic is complex, and future research is needed to further understand mechanisms that may be driving these associations.

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Conflicts of interest

Jeffrey M. Spielberg has received research grants from the National Institute of General Medical Sciences. Leah D. Church has received research grants from The National Science Foundation. Keith Bredemeier has received research grants from the National Institute of Mental Health and the Patient-Centered Outcome Research Institute.

Data availability

The authors are unable or have chosen not to specify which data has been used.

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