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Effects of Pathogen-Avoidance Tendency on Infection-Prevention Behaviors and Exclusionary Attitudes toward Foreigners: A Longitudinal Study of the COVID-19 Outbreak in Japan[1]

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Abstract: This study investigated the changes in public behaviors and attitudes following the spread of COVID-19 in Japan. Using a longitudinal approach that analyzes the movement of an unpredictable and real infection threat to explain and predict human behavior during the pandemic—a novel approach in behavioral immune system research—a panel survey was conducted on Japanese citizens. The results of the survey, conducted in late January, mid-February, and early March 2020, indicated that the influence of the interaction between the changes in situational infection threat and individual differences in pathogen-avoidance tendency on infection-prevention behaviors and exclusionary attitudes toward foreigners was not significant. Moreover, frequent contact with foreigners had a mitigating effect on exclusionary attitudes. The study thus provided a valuable contribution to the application of behavioral immune-system responses to problems associated with infection threats. Moreover, consideration of the aspects of adaptive reaction and social learning allowed us to observe the process of adaptive strategies in novel environments under conditions of high ecological validity and to accurately understand the psychological response to infectious disease outbreaks.

Key words: COVID-19, behavioral immune system, pathogen avoidance, exclusionary attitudes, infection-prevention behaviors.

In January 2020, the COVID-19 outbreak began in Wuhan, Hubei Province, China. Seemingly overnight, the number of infected and fatal cases reported worldwide grew exponentially. The seriousness of the outbreak became evident when the World Health Organization (WHO) declared a Public Health Emergency of International Concern on January 31, 2020 (January 30, UTC). With the situation changing rapidly and mixed information emanating from around the world, questions arose, one of them being, "What attitudinal changes and behavioral choices do humans make to avoid sudden infection?" This study thus focused on the

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preventive behaviors related to COVID-19 infection and on the exclusionary attitudes among the Japanese people toward foreigners, examining the changes in these responses associated with the spread of the coronavirus in Japan. In addition, the effects of individual differences in pathogen-avoidance tendency were examined, which refers to the degree of aversive responses to situations that carry a relatively high likelihood of pathogen transmission, and the frequency of daily contact with foreigners.

This study aimed to record the behavioral and psychological states of people in Japan during the 40 days preceding the WHO's declaration of the COVID-19 pandemic on March 11, 2020. For this purpose, the survey was conducted on the Japanese people during the early stages of the spread of COVID-19 when they experienced rapid and unpredictable real-world changes. The data collected in Japan, where the infection initially spread widely (cf. WHO, 2020), will provide valuable insights for countries anticipating significant social changes.

Behavioral Immune System Research into Modern Human Experiences regarding the COVID-19 Outbreak

How do people behave when they are at an increased risk of exposure to pathogens, such as COVID-19, for which there are no known cures or preventive vaccines? Historically, infections caused by deadly pathogens and parasites have severely threatened human survival (see Diamond, 1999). In response, humans have developed a psychological system known as the *behavioral immune system*, which is "a suite of psychological mechanisms that (a) detect cues connoting the presence of infectious pathogens in the immediate environment; (b) trigger disease-relevant emotional and cognitive responses; and thus (c) facilitate behavioral avoidance of pathogen infection" (Schaller & Park, 2011). As such, it is considerably more effective to prevent the risk of infection by following good food hygiene, isolating an infectious patient, and avoiding dirty objects than by relying on biological immune systems (Haidt, 2012).

Extant literature on pathogen and infection-avoidance mechanisms, including behavioral immune-system research, may be a valuable source of information that can explain and predict human behavior during the pandemic (Ackerman, Tybur, & Blackwell, 2021; Makhanova & Shepherd, 2020). The application of the behavioral immune system to problems associated with real pandemics can lead to a more accurate understanding of the psychological response to infectious disease outbreaks. However, prior research has primarily examined only hypothetical pathogen threats. Few studies have focused on pathogen avoidance in the context of a real threat (Makhanova & Shepherd, 2020), and even if they have, the focus has been on a single data point, so it is "premature" to conclude anything (Ackerman et al., 2021). Thus, what we need is an approach that uses the movement of a real, unpredictable threat, not a hypothetical one. The threat increased with the spread of infection in the case of COVID-19. When or how is the behavioral immune response to a real pandemic evoked? Does behavior change incrementally, or is the impact trivial and short-lived? These questions cannot be explained by previous studies that used short-term stimuli. Therefore, this study proposed a longitudinal approach in a real-world situation.

Changes in Infection-Prevention Behaviors and Pathogen-Avoidance Tendency

This study examined the effect of the COVID-19 outbreak and spread in Japan on the behavioral immune system response. Much of the research on the behavioral immune system has experimentally manipulated short-term stimuli with an intense threat of infection to activate this system (e.g., Faulkner, Schaller, Park, & Duncan, 2004; Miller & Maner, 2012). However, to the best of our knowledge, there is no research that reflects a situation in which the threat intensity increases gradually. In addition, no framework currently explains the change of behavior in the face of such a situation. Ackerman, Hill, and Murray (2018) noted that

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in stronger disease-threat manipulations, behavioral immune responses may be evoked in the majority of individuals regardless of dispositional factors, whereas in weaker manipulations, responses may be dependent on individual differences. Keeping this in mind, this study investigated whether behavioral immune responses were less likely to be evoked in the early stages of COVID-19 when the perception of infection threat was weak, but these responses increased gradually as the COVID-19 infection spread and the threat perception became stronger.

This study assumed individual differences in pathogen-avoidance tendency as a variable that influenced the changes in the totality of preventive behaviors following the outbreak and spread of COVID-19. Previous studies have shown that individuals prone to aversion to physical and mental contaminations, including infection from pathogens, tend to adopt preventive actions and avoidance behaviors (Deacon & Olatunji, 2007; Rozin, Haidt, McCauley, Dunlop, & Ashmora, 1999). In addition, individuals who have heightened chronic concerns about disease display a disease over-perception bias: a tendency to overperceive the presence of a target in the environment displaying heuristic disease cues (Miller & Maner, 2012); furthermore, they are more likely to activate their behavioral immune responses to disease avoidance (Ackerman et al., 2018; Tybur, Frankenhuis, & Pollet, 2014). However, these studies focused on behaviors under normal circumstances (i.e., a low perception of the infection threat).

In contrast, we focused on the relationship between the increase in the totality of preventive behaviors against the outbreak or spread of the COVID-19 infection and the individual differences in pathogen-avoidance tendency. According to previous studies (Ackerman et al., 2018; Miller & Maner, 2012; Tybur et al., 2014), individuals who show a strong pathogen-avoidance tendency are inclined to respond to even a weak infection threat. This study presumed that their behavioral immune responses to various pathogen cues are already active under normal circumstances. In other words, because they are more likely to avoid infection on a routine basis, they show a small change in preventive behaviors in emergency situations, such as a severe infection outbreak. Conversely, this study presumed that individuals who show a weak pathogen-avoidance tendency may be inclined to respond only to a strong infection threat, and their behavioral immune responses are unlikely to be active under normal circumstances. Because they do not engage in preventive behaviors under normal circumstances, they show major changes in such behaviors during an emergency: the infection-prevention behaviors of people who have a strong pathogen-avoidance tendency are not affected by the spread of the COVID-19 infection (H1a); the infection-prevention behaviors of people who have a weak pathogen-avoidance tendency increase with the spread of the COVID-19 infection (H1b).

Changes in Exclusionary Attitudes and Pathogen-Avoidance Tendency

Behavioral immune responses, in addition to preventive behaviors, can lead to exclusionary attitudes; i.e., avoiding people from other communities that have (or are thought to have) more infected members or, more broadly, out-group members as a whole. Because the behavioral immune system drives pathogen avoidance through cue-based inferences, it often results in two errors: (a) false-positive errors, which presume the presence of pathogens despite their absence, and (b) false-negative errors, which presume the absence of pathogens despite their presence. Of the two, the latter is more grave since it can lead to the spread of infection, but the former is extremely common, having evolved to "minimize the likelihood of (potentially fatal) false-negative errors" (Schaller & Park, 2011).

In the case of false-positive errors, people often assume that others are infected when they are not and are especially likely to associate the presence of pathogens with strangers whose dispositions are different from theirs (e.g., foreigners). There is some biological basis for this presumption: coming into contact with outgroup members from different ecosystems may increase the chance of infection from novel

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pathogens for which in-group members have not yet developed immunity (Diamond, 1999). Out-group members are perceived to be more likely to break the norms of the in-group community, including those related to infection prevention. This leads to the perception that the risk of infection to in-group members is increased due to the violation of norms by out-group members (Faulkner et al., 2004; Karinen, Molho, Kupfer, & Tybur, 2019).

Previous studies have shown a high level of distrust and discrimination against foreigners, especially those who are unfamiliar (e.g., Duncan, Schaller, & Park, 2009; Faulkner et al., 2004; Navarette, Fessler, & Eng, 2007). It has also been shown that presenting images of threats, such as plagues and infections, reduces participants' positive attitudes toward unfamiliar foreigners (Faulkner et al., 2004). Furthermore, a study of pregnant women found that ethnocentrism and in-group attraction are highest during the first trimester of pregnancy, when they are more susceptible to infection, because physical immune responses are compromised (Navarette et al., 2007). In other words, responses that can lead to the exclusion of out-group members may be pronounced under an infection threat. Not surprisingly, in a situation in which a high COVID-19 infection risk has activated people's behavioral immune systems, the prevalence of false-positive errors has led to the widespread adoption of exclusionary attitudes toward foreigners. Therefore, as is the case with preventive behaviors, an increased situational infection threat, such as the spread of COVID-19, will lead to stronger exclusionary attitudes.

Similar to the case of preventive behaviors, this study assumed individual differences in pathogen-avoidance tendency to be a variable that influenced the changes in exclusionary attitudes with the spread of COVID-19. In a previous study examining the individual differences related to pathogen-avoidance tendency, individuals who perceived the threat of diseases to be high, or had heightened recognition of their vulnerability to diseases, were more likely to exhibit negative attitudes toward foreigners when facing a high risk of infection (Faulkner et al., 2004). This study examined the relationship between the changes in exclusionary attitudes following the outbreak and the spread of the COVID-19 infection and the individual differences in pathogen-avoidance tendency. Based on previous studies (Ackerman et al., 2018; Miller & Maner, 2012; Tybur et al., 2014), we presumed that individuals who have a strong pathogen-avoidance tendency are inclined to have exclusionary attitudes even under normal circumstances, thus showing only small changes in their behavioral immune responses (i.e., exclusionary attitudes) in the face of a sudden threat, such as an infection outbreak. In contrast, individuals who show weak pathogen-avoidance tendency are more likely to display significant behavioral immune responses in the face of a sudden threat, thus showing major changes in attitudes: people who show a strong pathogen-avoidance tendency do not change their exclusionary attitudes toward foreigners, even with the spread of the COVID-19 infection (H2a). People who show a weak pathogen-avoidance tendency develop stronger exclusionary attitudes toward foreigners as the COVID-19 infection spreads (H2b).

Many behavioral immune system studies have examined the effects of the threat of infection for social outcome variables. Some of those studies shed light on the interaction between situational threats and individual differences in responding to infection threats, while others reveal only the main effects; moreover, the outcome variables in each study vary and are inconsistent. In addition, no model or explanatory framework currently explains when (or why) these effects are exhibited. It is a question that has been considered important as the research field matures, but has yet to obtain a satisfactory answer (Ackerman et al., 2018; Tybur et al., 2014). The hypotheses of this study provide insights into these interactions, which this field needs to accumulate.

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Exclusionary Attitudes and Frequency of Daily Contact with Foreigners

The combination of pathogen threat and attitudes toward unfamiliar people may have evolved through an interaction between evolved disease-avoidance responses and social-learning mechanisms that have operated in conjunction with historical experience, cultural transmission, and social context (Navarette et al., 2007). Although Kusche and Barker (2019) argue that behavioral immune system research should consider broader sociocultural contexts to understand attitudes toward immigrants and ethnic out-groups, no studies have actually incorporated this suggestion thus far. As a result, there may be discrepancies between the behavioral immune system theory and predictions and explanations of the psychological response to modern infectious diseases (cf. Ackerman et al., 2021). Therefore, this study examined whether social learning of the acceptance of unfamiliar people influences disease-avoidance responses, thereby revealing variable aspects of evolved behavioral immune responses. Faulkner et al. (2004) showed that when images related to plagues and infections were presented, participants exhibited lower acceptance of immigrants from unfamiliar countries compared to immigrants from familiar countries. Importantly, this indicates that familiarity is associated with exclusionary attitudes. Furthermore, it has been shown that multicultural experience and knowledge reduce stereotypes about and prejudices against out-groups (Tadmor, Hong, Chao, Wiruchnipawan, & Wang, 2012). This suggests that social learning that has been driven by daily familiarity or frequent contact with foreigners may influence changes in exclusionary attitudes, which led us to our third hypothesis: a high frequency of daily contact with foreigners mitigates exclusionary attitudes toward foreigners, even as the COVID-19 infection spreads (H3).

Method

This study examined changes in preventive behaviors and exclusionary attitudes of Japanese people, using a panel survey. Wave 1 was conducted from January 31 to February 1, 2020[3]; Wave 2 from February 18 to February 20, 2020[4]; and Wave 3 from March 4 to March 6, 2020.[5] To grasp the social psychological changes brought about by the spread of infection, we also measured items not directly related to the hypotheses mentioned above (see File S1 in Supporting Information).

Participants

The participants of this study were Japanese citizens aged 18 years or above who live in Japan and had registered with the crowdsourcing service Crowdworks Co., Ltd. We obtained their written consent to participate in this study. The first wave of the survey had 1,248 participants (424 men, average age of 37.03 years ± 9.53). Of these, 1,200 traceable respondents were asked to participate in the second wave of the survey, and valid responses were obtained from 1,076 respondents (371 men, average age of 37.79 years ± 9.43): a response rate of 89.7%. Valid respondents in the second wave were asked to participate in the third wave, and valid responses were obtained from 1,003 respondents (350 men, average age of 38.20 years ± 9.34): a response rate of 93.2%. We used the Directed Questions Scale (Miura & Kobayashi, 2019) to identify inattentive respondents, and cases where two consecutive questions were not answered correctly were excluded from the analysis.

First Wave of the Survey

Japan was in the warning phase for infection from COVID-19 at the end of January 2020, when the first wave of the survey was conducted. On January 27, the Ministry of Health, Labor, and Welfare recognized COVID-19 as a designated infectious disease: more than

[3]Questionnaire preview of the first-wave survey (in Japanese): https://bit.ly/38Wd8P8.
[4]Questionnaire preview of the second-wave survey (in Japanese): https://bit.ly/3deXslp.
[5]Questionnaire preview of the third-wave survey (in Japanese): http://u0u1.net/jcVU

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10 cases of infection in Japanese patients had been confirmed at the time.

Questionnaire Items. The degree of pathogen avoidance was measured by five items relevant to pathogen concerns, such as pollution and lack of cleanliness, based on the purity orientation/pollution avoidance scale (Kitamura & Matsuo, 2021) on a seven-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). These items assess the degree of aversive response in situations that connote a high general risk of infection. These are similar to the Germ Aversion sub-scale of the Perceived Vulnerability to Disease Scale (PVD) (Duncan et al., 2009), but are more reflective of Japanese cultural norms.

In this study, participants were presented with a list of preventive behaviors and asked to select those they were implementing. The total number (from 0 to 11) was used as an indicator of the degree to which they were engaging in preventive behavior because we considered that the number of preventive behaviors being taken best reflected the strength of the participants' preventive awareness at a given point in time. As the infection status changed, the implementation of individual preventive actions included in the list also changed (see Table S1 in Supporting Information), but we did not take this into consideration. The list included 11 items: five hygiene behaviors (hand washing, gargling, hand sanitizer use, mask use, and adequate sleep); five preventive behaviors to avoid contact with suspected pathogen cues (e.g., refraining from entering public places where there were many people and resisting sightseeing spots frequented by foreigners or the Chinese); and one another item (free description).[6] We asked the participants to indicate whether each behavior was present before and after the outbreak, and the total was calculated. The sum of the preventive behaviors implemented prior to the outbreak was measured retrospectively in Wave 1 and used as an index of normal times.

Two measures of exclusionary attitudes on a seven-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) were used; (a) four items on acceptance attitudes toward foreigners in general and the Chinese specifically; and (b) one item on ethnocentrism, based on Mifune and Yokota (2018, Study 3). The study examined attitudes to the Chinese, in particular, in addition to foreigners in general, because China is Japan's neighboring country, sends a larger number of visitors to Japan compared to other countries, and was also the center of the COVID-19 outbreak.

The frequency of daily contact with foreigners was measured on a three-point scale: 1 (*not at all*), 2 (*a little*), and 3 (*a lot*). When participants answered *a little* or *a lot* to that question, we asked how many foreign and Chinese acquaintances and friends they had.

We considered the following items related to the COVID-19 outbreak as extraneous variables to be included in a model when testing the hypotheses: (a) the degree of interest in COVID-19 on a seven-point scale ranging from 1 (*not at all interested*) to 7 (*strongly interested*); and (b) four items of risk perception (cf. Komori, Miura, Matsumura, Hiraishi, & Maeda, 2019; Slovic, 1987) on the two dimensions of "dreadful" and "unknown" on a seven-point scale, ranging from 1 (*do not feel at all*) to 7 (*strongly feel*).

Further, we measured four items related to impressions of foreigners in general – Chinese people, Americans, and Japanese people (the choices were *irritating*, *frightening*, *reliable*, and *interesting*) – on a seven-point scale ranging from 1 (*not at all*) to 7 (*very much*), based on Mifune and Yokota (2018, Study 2). We also gathered demographic data from the participants (i.e., age, sex, and prefecture where they lived).

Second Wave of the Survey

The COVID-19 situation in Japan worsened drastically after the first wave of the survey. The first deaths due to COVID-19 in Japan were announced on February 13, and new cases

[6]Although the list included two COVID-19 information-seeking behaviors, they were excluded from the analysis because it was difficult to compare them before and after the outbreak.

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of infection were confirmed throughout the country. In addition, the number of cases in which the infection route was unclear began to increase, and new cases on the cruise ship *Diamond Princess* were reported daily. The number of infected people worldwide had also increased significantly. In response to the rapid spread of COVID-19, many large-scale events entailing sizeable crowds were canceled throughout Japan. By February 16, the Japanese government had recognized the situation as being the early stage of what would be a widespread domestic outbreak—the stage immediately before an outbreak—and on the following day, the government established guidelines relating to the COVID-19 infection to address the imminent pandemic.

Questionnaire Items. In addition to the same items used in the first wave (we removed the items concerning whether the participants had shown preventive behaviors before the outbreak, their frequency of daily contact with foreigners, perceptions of the "AIDS" risk, and demographic variables), we added several items not directly related to the hypotheses testing: (a) an estimation of the probability of the COVID-19 infection to be rated from 0 to 100 (%) and its likely source of infection (free description); (b) the degree to which participants used various means to collect COVID-19-related information on a seven-point scale, from 1 (*not at all*) to 7 (*very much*); (c) perceptions of the "influenza" risk on a seven-point scale; and (d) impressions of "close friends" and "people you see when you go out" (i.e., unfamiliar people) on a seven-point scale.

Third Wave of the Survey

The number of infected people in Japan increased further after the second wave. On February 23, the government announced that the country was in a "transitional phase" of infection spread. Although the government did not come up with an aggressive policy, the Infectious Disease Control Headquarters began implementing formal measures on February 25, which caused dramatic changes in the lives of people living in Japan.

Questionnaire Items. In addition to the same items used in the second wave, we added several items not directly related to the hypotheses testing: (a) the presence or absence of infected individuals in the participants' immediate vicinity, and if present, their relationship with the individual(s) (multiple choice); (b) speculations on the likely infection route (multiple choice); (c) attitudes toward the new government policies on a seven-point scale ranging from 1 (*very disadvantageous*) to 7 (*very advantageous*), and six items on their impact on the participants' lives (postponement of events, changes in work style, closure of business, shutting of schools, access to medical services, and availability of daily necessities) on a six-point scale from -3 (*very negative impact*) to 3 (*very positive impact*), and 0 (*no impact*). Those who experienced any other impact were asked to provide a free description; (d) political ideology on a scale from 0 (*liberal*) to 10 (*conservative*) and *Don't know*; and (e) the objective level of scientific knowledge measured with five quiz-type questions (virus test, anti-virus, gene, physics, and paleontology), with participants asked to select one of three options (*True*, *False*, and *Don't know*). The number of correct answers (from 0 to 5) was used as a measure of scientific knowledge.

Results

First, we investigated whether there were any notable differences between the first wave (original sample) and the third wave (final sample). For this purpose, we examined the standardized mean difference of the main variables (age, pathogen avoidance, preventive behaviors [pre-outbreak and wave 1], acceptance attitudes toward foreigners in general and the Chinese, and ethnocentrism) for the final and dropped samples. If the standard deviation (*SD*) was greater than 0.25, we decided to treat it as an imbalance (cf., Ho, Imai, King, & Stuart, 2007). The results showed that there was an age imbalance (0.64 *SD*) as there was a large number of dropouts among younger people. There was no imbalance found for the other

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main variables ($SDs < 0.23$). These results indicated that there was not much difference in the main variables important for hypotheses testing, and the final sample was almost representative.

The outcome variables were preventive behaviors and exclusionary attitudes. For the former, the sum of preventive behaviors implemented was counted and analyzed as an indicator of the behavioral immune response to infection threat (the extent to which individuals were trying to avoid infection). Figures S1 and S2 in Supporting Information show the time-series plot at each time point and the histogram for preventive behaviors implemented in each wave. For exclusionary attitudes, the following three indicators were analyzed: acceptance attitudes toward foreigners in general, acceptance attitudes toward the Chinese, and ethnocentrism. Figures S3 (foreigners in general), S4 (the Chinese), and S5 (ethnocentrism) in the Supporting Information show the scatter plot of each attitude and the pathogen-avoidance tendency. Table S1 in Supporting Information shows the basic statistics for all items, including main items related to the hypotheses testing and extra items not directly related to the hypotheses testing.

Infection-Prevention Behaviors

First, to examine whether the threat of the COVID-19 spread affected individual differences in the pathogen-avoidance tendency, a one-way (wave points: Wave 1 vs. Wave 2 vs. Wave 3; within subjects) factorial analysis of variance was conducted. The degrees of freedom were adjusted using Greenhouse-Geisser's epsilon for violation in the sphericity test. The results showed that the main effect of the wave points on the pathogen-avoidance tendency was significant, but the effect size was very small (F (1.95, 1951.52) = 10.09, $p <$ .01, $\eta^2 = .001$). Therefore, we used the score of the pathogen-avoidance tendency in Wave 1 as an individual difference variable in the subsequent tests.

To test the hypotheses related to the effects of the interaction between a change in preventive behaviors and pathogen-avoidance tendency (H1a and H1b), we used a generalized linear mixed model where a Poisson distribution was assumed because the total numbers of preventive behaviors were discrete values (see Table S2 in Supporting Information). The main fixed effects in this model were pathogen-avoidance tendency (in the first wave), time points (Pre-outbreak, Wave 1, Wave 2, and Wave 3), which were dummy variables, and the interaction between them. All the variables were centralized. The other fixed effects that were extraneous variables in this model were the interest in and risk perception ("dreadful" and "unknown") of COVID-19, sex (0 = female), and age. Participants were assumed to have a consistent response tendency and were included in the model as a random effect.

First, we provide an overview of the results concerning each time point to examine the effect of the COVID-19 spread on preventive behaviors implemented. The result of the "vs. Pre-outbreak" model showed that the least number of preventive behaviors was implemented at normal times (see the middle row of Table S2). The result of the "vs. Wave 1" model showed that fewer preventive behaviors were implemented at every other time point than in the first wave. The result of the "vs. Wave 2" model showed that significantly more behaviors were implemented in the first and third waves than the second wave. In summary, the total number of preventive behaviors did not linearly increase in response to the COVID-19 spread.

Next, the main effect of pathogen-avoidance tendency was significant in all models; that is, people who had a stronger pathogen-avoidance tendency showed more preventive behaviors. However, we observed no interaction effects between the time points and pathogen-avoidance tendency in any of the models (see the bottom row of Table S2); thus, H1a and H1b were not supported.

In addition, the main effects of extraneous variables, which were interest in COVID-19, risk perception ("dreadful"), and sex, were significant. Participants who had higher interest in or felt dreadful because of COVID-19, or who were women, tended to engage in more

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preventive behaviors (see the top row of Table S2).[7]

To test the results of previous studies, which posit that people with a strong pathogen-avoidance tendency adopt more preventive behaviors under normal circumstances, the preventive behaviors in Pre-outbreak as the only dependent variable was used. We analyzed a generalized linear model in which a Poisson distribution was assumed (see Table S3 in Supporting Information). The pathogen-avoidance tendency (in the first wave) was the independent variable, while sex, age, and the interest in and risk perception of COVID-19 were extraneous variables. The results showed that the main effect of the pathogen-avoidance tendency was significant.

Exclusionary Attitudes

To test the hypotheses related to the three dependent variables of exclusionary attitudes (H2 and H3), a linear mixed model was used (Table 1; see Table S4 in Supporting Information for more details). The main fixed effects in this model were pathogen-avoidance tendency, the frequency of daily contact with foreigners, wave points (Wave 1, Wave 2, and Wave 3), which were the dummy variables, the interaction between pathogen-avoidance tendency and time points, and the interaction between the frequency of daily contact with foreigners and the wave points. All the variables were centralized. The other fixed effects and random effects were the same as in the testing of H1a and H1b.

First, we provide an overview of the results related to acceptance attitudes toward foreigners in general. The result of each wave point model showed that the second wave was not different from the first wave, and participants' attitudes became more exclusionary in the third wave than in the first and second waves. Thus, there was a significant decrease in acceptance attitudes toward foreigners in general at the third wave point.

The main effects of the pathogen-avoidance tendency and frequency of daily contact with foreigners were significant in all models. That is, people who had a strong pathogen-avoidance tendency showed lower acceptance attitudes toward foreigners, and people with a high frequency of daily contact with foreigners showed high acceptance attitudes. We did not observe any significant interaction effects. The main effects of the extraneous variables, which were the two dimensions of the risk perception ("dreadful" and "unknown") and age, were significant; thus, those with a higher perception of dread or who were older in age tended to show low acceptance attitudes, and those with a higher perception of the "unknown" dimension showed higher acceptance attitudes.

Next, we provide an overview of acceptance attitudes toward the Chinese. The main effect of the wave points was not significant in any of the wave point models. Thus, we did not observe a significant change in the acceptance attitudes toward the Chinese at any wave point. It is noteworthy that the average score of attitudes toward the Chinese was much more exclusionary than that toward foreigners in the first wave (foreigners: mean = 4.62; Chinese: mean = 3.64).

The main effect of the pathogen-avoidance tendency was significant in all models; that is, people who had a strong pathogen-avoidance tendency showed lower acceptance attitudes toward the Chinese. In contrast, the frequency of daily contact with foreigners was not significant. We did not observe any significant interaction effects. The main effect of interest in COVID-19 as an extraneous variable was significant; thus, those with a higher interest in COVID-19 tended to have low acceptance attitudes toward the Chinese.

Finally, we provide an overview of the results on ethnocentrism. The result of each wave point model showed that the second wave was not different from the first and third waves, and

[7]H1 was tested by focusing on only the five hygiene behaviors (hand washing, gargling, hand-sanitizer use, mask use, and adequate sleep). The results indicated that although the effect of risk perception disappeared, the overall trend of the effects was similar to that of all preventive behaviors. The mean difference between time points was also similar: Pre-outbreak < Wave 2 < Wave 3 < Wave 1 (see Table S5 in Supporting Information).

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Table 1 General Linear Mixed Model of Exclusionary Attitudes

	Acceptance attitudes					
	Foreigners in general		Chinese		Ethnocentrism	
	vs. Wave1 *B* (*SE*)	vs. Wave2 *B* (*SE*)	vs. Wave1 *B* (*SE*)	vs. Wave2 *B* (*SE*)	vs. Wave1 *B* (*SE*)	vs. Wave2 *B* (*SE*)
(Intercept)	5.18 (0.22)***	5.18 (0.22)***	4.43 (0.25)***	4.43 (0.25)***	2.19 (0.24)***	2.19 (0.24)***
Sex (Female = 0, Male = 1)	-0.12 (0.08)	-0.12 (0.08)	0.18 (0.10)†	0.18 (0.10)†	0.39 (0.09)***	0.39 (0.09)***
Age	-0.02 (0.00)***	-0.02 (0.00)***	-0.01 (0.00)	-0.01 (0.00)	0.01 (0.00)	0.01 (0.00)
Interest in COVID-19	-0.01 (0.02)	-0.01 (0.02)	-0.07 (0.02)**	-0.07 (0.02)**	0.01 (0.02)	0.01 (0.02)
Dreadful	-0.05 (0.02)*	-0.05 (0.02)*	-0.04 (0.02)†	-0.04 (0.02)†	0.03 (0.02)	0.03 (0.02)
Unknown	0.06 (0.02)**	0.06 (0.02)**	0.01 (0.02)	0.01 (0.02)	0.00 (0.02)	0.00 (0.02)
Pathogen-Avoidance Tendency	-0.17 (0.03)***	-0.17 (0.03)***	-0.17 (0.04)***	-0.17 (0.04)***	0.26 (0.04)***	0.26 (0.04)***
Frequency of Contact with Foreigners	0.17 (0.07)**	0.17 (0.07)**	0.14 (0.08)†	0.14 (0.08)†	-0.18 (0.07)*	-0.18 (0.07)*
Wave1	-	0.03 (0.03)	-	0.02 (0.03)	-	-0.04 (0.03)
Wave2	-0.03 (0.03)	-	-0.02 (0.03)	-	0.04 (0.03)	-
Wave3	-0.16 (0.03)***	-0.13 (0.03)***	-0.03 (0.03)	-0.01 (0.03)	0.09 (0.03)*	0.05 (0.03)
	Interaction between Pathogen-Avoidance Tendency and Each Wave					
Wave1	-	0.01 (0.02)	-	0.04 (0.03)	-	-0.01 (0.03)
Wave2	-0.01 (0.02)	-	-0.04 (0.03)	-	0.01 (0.03)	-
Wave3	-0.04 (0.03)	-0.02 (0.03)	-0.02 (0.03)	0.02 (0.03)	0.05 (0.03)†	0.04 (0.03)
	Interaction between Frequency of Contact with Foreigners and Each Wave					
Wave1	-	-0.03 (0.05)	-	-0.04 (0.05)	-	-0.01 (0.05)
Wave2	0.03 (0.05)	-	0.04 (0.05)	-	0.01 (0.05)	-
Wave3	0.04 (0.05)	0.01 (0.05)	0.11 (0.06)†	0.06 (0.06)	0.03 (0.06)	0.02 (0.06)

*** $p < .001$; ** $p < .01$; * $p < .05$; † $p < .10$

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participants' attitudes became more exclusionary in the third wave than in the first wave.

The main effects of the pathogen-avoidance tendency and frequency of daily contact with foreigners were significant in all models. People who had a strong pathogen-avoidance tendency were more ethnocentric, and people with a high frequency of daily contact with foreigners were less ethnocentric. However, we did not observe any significant interaction effects. The main effect of sex as an extraneous variable was significant; thus, men tended to show a higher degree of ethnocentrism.

In summary, H2 related to a change in exclusionary attitudes was not supported because there was no interaction effect between the tendency and the wave points in any of the models. On the other hand, H3 was partially supported, except with respect to the attitude toward the Chinese. In all the waves, people with a high frequency of daily contact with foreigners were less exclusionary toward foreigners in general and less ethnocentric. In addition, the results indicate that changes in the exclusionary attitudes toward foreigners in general and ethnocentrism grew with the third wave. However, such a tendency was not observed for the attitude toward the Chinese. We observed that exclusionary attitudes toward the Chinese were already markedly high in the first wave of the survey. People who had a strong pathogen-avoidance tendency also had strong exclusionary attitudes toward foreigners and the Chinese.

Discussion

This study focused on preventive behaviors against COVID-19 and exclusionary attitudes toward foreigners based on the behavioral immune system response, examining the changes in behaviors and attitudes associated with the outbreak and spread of COVID-19 in Japan, where the infection spread widely, early on. We hypothesized how the interaction between the changes in situational infection threat and individual differences in pathogen-avoidance tendency influence infection behaviors and exclusionary attitudes. In addition, the mitigating effect of daily frequent contact with foreigners on exclusionary attitudes was assumed.

Based on the results of the analyses, H1a, H1b, H2a, and H2b were not supported. Our results showed that an interaction between the changes in the situational infection threat of the COVID-19 spread and individual differences in pathogen-avoidance tendency did not have a significant effect on either preventive behaviors nor exclusionary attitudes. Ackerman et al. (2018) and Tybur et al. (2014) speculated on the causes of inconsistent interaction effects in previous studies based on the differences between studies:

(a) Disease threat-manipulation differences. There are no standard experimental manipulations for behavioral immune system research, and the approach varies between studies. Stronger disease threat manipulations (situation) may evoke behavioral immune responses in the majority of people regardless of individual differences. In this study, the pathogen-avoidance tendency was already high among all participants in the first wave (mean = 4.85). This is likely due to stronger disease-threat manipulations (situation) from the COVID-19 outbreak.

(b) Differences in the outcome variables. The main effects of situational disease cues may be observed for relatively malleable variables (e.g., social categorization of novel faces: Makhanova, Miller, & Maner, 2015), and the interactive effects may emerge for nonephemeral variables (e.g., future sexual variety: Hill, Prokosch, & DelPriore, 2015). Paradoxically, in this study, infection-prevention behavior and exclusionary attitudes toward foreigners may fall into the pattern of malleable variables. However, while behavioral immune system research has clarified the effects on various outcome variables over the past two decades, the accumulation of knowledge on each variable (including both infection-prevention behavior and exclusionary attitudes) has been insufficient. Therefore, conclusions regarding whether the results of this study fit into any pattern may be premature.

(c) Sample differences. Participants may have differentially calibrated sensitivities to disease

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cues based upon the levels of disease threat within their actual ecologies or cultures. However, in this study, only Japanese participants were examined, and an ecological comparison may be important to test this possibility.

(d) Statistical issues. This may be due to an underpowered sample size design for detecting interactions or a Type I error in testing for interactions. In this study, the sample size was determined arbitrarily because there was insufficient information to allow for sample size planning. In addition, the estimated values of exclusionary attitudes at each wave point were relatively small. These statistical issues should also be considered in this study. These factors may have influenced the results of this study. Although our method differs in that the situational threats were assumed in a real social situation rather than via experimental manipulations, the lack of interaction between the situational threat and individual differences in the present study presents evident motivation to solve problems faced by this field.

On the other hand, we observed a mitigating effect: the higher the frequency of daily contact with foreigners, the weaker the exclusionary attitudes toward them. This shows that H3 was partially supported, except with respect to the attitude toward the Chinese, which is consistent with the findings of previous studies (Faulkner et al., 2004; Tadmor et al., 2012). According to our results, social learning influences evolutionary responses, which suggests that research should consider the social context of a person's direct interaction with a foreigner.

Contribution to Behavioral Immune System Research

This study contributes to the development of behavioral immune system research in several ways. First, we have proposed an approach that focuses on a change or transition in a stimulus in the form of an infection threat. Examining evolutionary and socio-psychological changes in the state of a continuous and strongly activated behavioral immune system during situations such as an outbreak of an unknown virus is novel in this research field (cf, Ackerman et al., 2021; Makhanova & Shepherd, 2020). The longitudinal approach, which considered rapid changes through the early stages of real-world infection spread, allowed us to observe the process of adaptive strategies in novel environments under conditions of high ecological validity. The behavioral immune system theory itself was derived from the historical background of repeated conflict and coexistence with pathogens. Recent experiences regarding the COVID-19 outbreak can elucidate when and how the behavioral immune system responds. This finding will contribute to the expansion and reconstruction of the theory.

Second, we provided evidence of the interaction between situational threats and individual differences in threats, representing an area where empirical research is still insufficient (cf. Ackerman et al., 2018; Tybur et al., 2014). By examining the interactions, we sought to identify the differences in the adaptive strategies of when to perceive an infection threat and how to respond to such a threat based on individual differences in infection avoidance tendencies. However, we found no interactions because COVID-19 represented an uncontrollable and potent infection threat "manipulation." The results of this study can offer a new experimental paradigm that uses a controllable, incrementally changing threat manipulation to derive a more accurate understanding of the psychological response to infectious disease outbreaks. This examination would also provide insights on the intensity of the threat stimulus problem in behavioral immune system research.

Limitations and Future Directions

This study has several limitations because it was conducted in the unprecedented situation of a sudden, intense outbreak and spread of an infection. First, as mentioned above, the exact strength of the infection threat in the first wave, which we assumed to be a relatively weak stage, was unknown and may have already been sufficient to activate the behavioral immune system. Concerns about the infection among the Japanese people were likely to have increased significantly even by the time of the first wave of the survey, and we had no reliable data on their pre-outbreak attitudes that could be used as a control. Thus, this study did not perform a

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rigorous pre-outbreak comparison, making it difficult to determine whether the findings actually reflect the behavioral immune responses to the COVID-19 outbreak. In Wave 1, participants may have underreported the measures of preventive behaviors for the pre-outbreak period and overreported them for the first wave period because they were measured simultaneously to enable comparison. In addition, the exclusionary attitudes toward the Chinese people had been high since the first wave, which was the early stage of the COVID-19 spread. A reason for this trend may be that, from the outset, China was perceived as a threat as it was the source of the COVID-19 outbreak. Another reason may be that Japanese attitudes toward the Chinese have become increasingly negative in recent years (cf., Cabinet Administration Office Government of Japan, 2014); therefore, it is possible that these results only showed the original attitudes toward the Chinese and foreigners, in general, due to the influence of everyday others and the media. In the future, we hope to resolve this limitation by obtaining relevant data from previous studies or tracking data after the COVID-19 outbreak.

Second, this study did not report exploratory investigations on measures that were not involved in hypotheses testing. Documenting people's social behaviors and attitudes in detail amid a disease outbreak according to the change in the circumstances was also an important purpose of this survey; however, we focused on hypotheses-testing in this study. An exploratory analysis will be carried out in the future as we would maintain the panel samples analyzed in this study and collect data continuously.

Finally, given the low dropout rate of the panel and the requirement to answer the same questions repeatedly within a short span of time, it is possible that social desirability and demand characteristics influenced the responses. In the future, we would like to explore this matter by conducting surveys with new participants, in parallel with the current panel survey.

It should be noted that our study has been dealing with a real event in which dramatic changes have occurred rapidly and are ongoing. In early March 2020, the WHO's declaration of a pandemic sent a clear message to the Japanese people that anyone from anywhere might be carrying COVID-19 pathogens. It is difficult to conclude that all of the reported exclusionary behaviors and attitudes were irrational or had excessive false-positive errors. Since COVID-19 has spread rapidly throughout the world, there is an urgent need for international comparisons of the behavioral and psychological states of the affected populations. It is unlikely that our findings describe phenomena unique to Japan. The results of this research, which assumed the widespread activation of the evolutionary psychological infection-defense system, may help clarify people's responses to this global pandemic. We hope that the large-scale accumulation of COVID-19 research will contribute to addressing recommendations for interventions to promote rational infection-prevention behavior and resolving social problems, such as the exclusionary attitudes toward foreigners noted in this study, not only in Japan, but globally.

Declaration of Interest

The authors have no conflicts of interest to declare.

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Supporting information

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Figures S1–S5. Supplementary Figures of Results.

File S1. Questionnaire in Each Wave of Survey (in English).

Tables S1–S5. Supplementary Tables of Results.

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