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Can probability neglect bias promote social distancing during the COVID-19 pandemic?

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ARTICLE INFO

Keywords:
Probability neglect bias
Life-space mobility
COVID-19

ABSTRACT

The effectiveness of a stay-at-home order depends on the speed of behavioral changes that are triggered by risk perception. Probability neglect bias, one of the cognitive biases, may lead people to engage in social distancing. However, there is no empirical evidence of the relationship between probability neglect bias and social distancing. This study aims to examine the relationship between individual differences in susceptibility to probability neglect bias and the level of social distancing practice during the early stages of the COVID-19 outbreak in Japan. The level of engagement in social distancing was defined as the narrowing of life-space mobility. We conducted a web-based questionnaire survey among 1000 adults living in central Tokyo, Japan, at the beginning of the pandemic outbreak. Our results show that people had a strong fear of infection in the early pandemic stages. Approximately 60% of our subjects were influenced by probability neglect bias. People susceptible to probability neglect bias engaged in social distancing more intensely than those who were not susceptible after the state of emergency was lifted.

1. Introduction

Since the outbreak of COVID-19 (SARS-CoV-2) in early 2020, governments have adopted policies focused on minimizing the spread of infection and mitigating its impact on medical services (Lewnard \& Lo, 2020). A stay-at-home order is one of the representative recommendations to prevent the spread of disease. This policy aims to force people to physically distance themselves from others because COVID-19 is highly contagious even without symptoms (Lai, Shih, Ko, Tang, \& Hsueh, 2020). The effectiveness of this type of order depends on citizens’ ability to perceive risks associated with the virus and trigger rapid behavioral changes (Wise, Zbozinek, Michelin, Hagan, \& Mobbs, 2020; Xu \& Peng, 2015). A great deal of research in behavioral psychology and economics has shown that cognitive biases compromise the accuracy of risk perception (e.g., Peters \& Slovic, 2000; Slovic \& Peters, 2006). Therefore, cognitive biases in risk perception also potentially affect decision-making during COVID-19 (Mohamed, Moulin, \& Schöth, 2021). This knowledge may be helpful when considering behavioral changes to curb this global pandemic.

Recent studies indicate that two cognitive biases may affect people’s attitude toward engagement in protective behavior: the first is “exponential growth bias,” and the second is “probability neglect bias.” Exponential growth bias (EGB) is the tendency of people to underestimate the compounding of exponential growth (Levy \& Tasoff, 2016). According to various epidemiological studies, the number of new COVID-19 cases would grow exponentially without any preventive measures (Roser, Ritchie, Ortiz-Ospina, \& Hasell, 2021).
Therefore, we compared the participants’ knowledge revealed by our research may be helpful for governments or politicians who aim to control traffic flow during a pandemic to cognitive biases. Second, individual characteristics can encourage behavioral change for the entire population of a country. The probability neglect bias caused by probability neglect bias by comparing life-space mobility. The main findings of our study are that the people who tend to be affected by probability neglect bias by comparing life-space mobility. We considered that individual differences in susceptibility to probability neglect bias might fill a gap between the theoretical explanation of people’s behavior using probability neglect bias and the findings from macroeconomic data. Suter et al. (2016) observed individual differences in strategic choices under two situations: one situation that arouses strong emotion and the other that does not. According to Suter et al. (2016), only approximately 30% of participants made decisions that relied on probability neglect bias in the situation that aroused strong emotion. The others maintained the decision strategy employed in the situation that did not arouse strong emotion.

Therefore, even if minority groups who suffered from probability neglect bias rapidly changed their behavior to follow the WHO guidelines, the behavioral data of groups who changed their behavior slowly occupy a significant part of the macroeconomic data. The current study investigates the relationship between individual differences in susceptibility to probability neglect bias and the level of social distancing practice during the early stages of the outbreak in Japan, when a noncoercive lockdown was implemented. We collected data in Japan because Japan was a rare country where the government imposed noncoercive lockdowns. That is, in Japan, practicing social distancing by decreasing mobility relied on each Japanese citizen’s decision-making despite being under a state of emergency.

First, we measured affect strength when people imagined COVID-19 infection because strong emotion is necessary for probability neglect bias. Past studies note that fear is the central affect in relation to COVID-19 (Pakpour & Griffiths, 2020; Van Bavel et al., 2020). Therefore, we compared the participants’ level of fear between two scenarios that hypothesized infection with COVID-19 and losing money, which is frequently used in risk assessment experiments. Then, we sorted the subjects into two groups based on their susceptibility to probability neglect bias. We followed the sorting method developed by Suter et al. (2016).

In this method, people’s tendency to be affected by probability neglect bias was measured with a choice set that measured their likelihood of avoiding the severe side effects of medicine. The results of Suter et al. (2016) show that the choice of two treatments with significant side effects arouses strong emotion and triggers probability neglect bias. Finally, we measured people’s level of engagement in social distancing using part of the Life-Space Assessment (LSA) questionnaire (Baker, Bodner, & Allman, 2003). During the pandemic, the Japanese government recommended that citizens avoid all nonessential and nonurgent outings and decrease travel as much as possible. From the announcements of the Japanese government, we defined the level of engagement in social distancing as the narrowing of life-space mobility.

In the results, we investigate the relationship between the level of engagement in social distancing and people’s tendency to be affected by probability neglect bias by comparing life-space mobility. The main findings of our study are that the people who tend to be affected by probability neglect bias have more limited life-space mobility only after the state of emergency is lifted than people who do not. During the state of emergency, we could not observe any characteristics of people that predicted their engagement in social distancing. In the discussion, we consider why we could not observe people’s behavioral differences during the state of emergency. Additionally, in our data, the percentage of people who tended to be affected by probability neglect bias was more significant than that in research in Switzerland (Suter et al., 2016). The success of the stay-at-home order depending on voluntary cooperation in Japan might be because the majority of people were affected by probability neglect bias.

Our results indicate two main points. First, individuals’ behavioral changes during the pandemic were closely related to sensitivity to cognitive biases. Second, individual characteristics can encourage behavioral change for the entire population of a country. The knowledge revealed by our research may be helpful for governments or politicians who aim to control traffic flow during a pandemic outbreak.

2. Method

2.1. Participants

We recruited participants through a web-based survey service company (Rakuten Insight, Inc., Tokyo, Japan). Of the sample of 1254 Japanese people who completed the survey, we rejected responses from 160 men and 94 women because the responses were
deemed insincere. This left a sample of 1000 community-dwelling adults living in the urban core of Tokyo (Chiyoda, Chuo, Minato, Shinjuku, Shibuya, Bunkyo, Taito, Toshima, Sumida, and Koto wards) with stratified sampling by sex and age group (25–34, 35–44, 45–54, 55–64, and ≥65 years). The participants received a fixed reward of ¥50 (approximately $0.5) as points in Rakuten’s loyalty program (https://point.rakuten.co.jp/) for completing the survey.

2.2. Measurements

2.2.1. Measurement of life-space mobility

To measure participants’ life-space activity outside of the home, we used part of the Life-Space Assessment (LSA) questionnaire (Baker et al., 2003) translated into Japanese (Harada et al., 2010). The LSA is a self-reported assessment that was developed to assess the size of the spatial area used by older adults (bedroom, other rooms, outside home, neighborhood, town, and beyond town) and their need for assistance. There is empirical evidence that self-reported life-space measures show good agreement with more objective measures derived from GPS data (Fillekes, Röcke, Katana, & Weibel, 2019). The LSA provides a score measuring the distance and frequency of going out in a week and the need for assistance. The score is calculated by the spatial area (bedroom = 0, other rooms = 1, outside home = 2, neighborhood = 3, town = 4, and beyond town = 5), the frequency of mobility (never = 0, less than once a week = 1, 1–3 times a week = 2, 4–6 times a week = 3, and daily = 4) and assistance needed (from another person and/or by use of equipment) for each life-space level. The score ranges from life space limited to the bedroom (LSA = 0) to daily travel out of town without equipment or assistance (LSA = 120) and follows a normal distribution. We used the three sections of the LSA covering individual life-space mobility outside of home (neighborhood, town, and beyond town). The score therefore ranged from life space limited to inside the home (LSA = 0) to daily travel out of town (LSA = 48).

We asked participants about their life-space mobility during a week in three periods: p0 was before the outbreak of infection (last year), p1 was during Japan’s state of emergency (April and May 2020), and p2 was after the state of emergency was lifted (June to the time of the survey).

The LSA questionnaire consisted of two types of questions depending on the purposes of activities: 1) activity status without limiting the purpose (“overall activity”) and 2) activity limited only to leisure activities (“leisure activity”). For the questions about overall activity, the participants were asked to describe the frequency of all kinds of outings by recalling a typical week in each period. Similarly, for questions about leisure activity, the participants were asked to describe the frequency of nonessential outings by recalling an average week in each period. For an overview of the full LSA, see Appendix A.

2.2.2. Susceptibility to probability neglect bias

To sort individuals based on their degree of susceptibility to probability neglect bias, we followed the strategic classification method of Suter et al. (2016). The participants first indicated their willingness-to-pay (WTP) in Japanese yen for therapeutic medication for COVID-19. Next, the participants were presented with a two-outcome risky decision task. The items of the two-outcome risky decision task were the same as the items used by Suter et al. (2016). The choice items in this task consisted of two kinds of therapeutic medications. At the beginning of the two-outcome risky decision task, the participants were asked to imagine that they were suffering from an (unspecified) illness and needed to take medication for one week. Then, the participants chose between two therapeutic medications that led to a particular side effect with some probability (e.g., medication A: fatigue with a probability of 15%; medication B: memory loss with a probability of 0.5%). The participants were presented with a set of 44 decision problems and options.

According to the method of Suter et al. (2016), each participant’s choices were accounted for by two different strategic decision mechanisms: 1) a model assuming that individuals behave as although they maximize the product of probability and value of the result (named “CPT”) and 2) a model assuming that individuals process only outcome information, which is an equivalent idea with probability neglect heuristics (named “minimax”). We show the details of the classification method below.

We first converted the participants’ WTP in Japanese yen to Swiss francs (110.4 yen/CHF). According to the value function of cumulative prospect theory (Tversky & Kahneman, 1992), the subjective value of each option in the two-outcome risky decision task is determined as

\[ V(A) = \sum_{i=1}^{n} v(x_i)w(p_i), \]

where \( v(x_i) \) is the subjective value of outcome \( x_i \) and \( w(p_i) \) is the probability-weighting function, which are defined according to the following value functions:

\[ v(x) = \begin{cases} x^n, & \text{if } x \geq 0 \\ -(−x)^n, & \text{if } x < 0 \end{cases} \]

\[ w(p,0) = \frac{\delta p^r}{\delta p^r + (1-p)^r}. \]

\[ \delta = 0.64, r = 2.25. \]
The parameter $\alpha$ reflects the sensitivity to outcome variation and is assumed to be in the range $[0, 1]$, and the parameter $\gamma$ reflects the sensitivity to probability variation and is assumed to be in the range $[0, 1]$. Parameter $\delta$ is interpreted as the measure of risk aversion.

To predict the choice probability $p(A, B)$ of $A$ over $B$, we used the softmax choice rule:

$$p(A, B) = \frac{e^{\phi v(A)}}{e^{\phi v(A)} + e^{\phi v(B)}},$$

where $\phi$ is a choice sensitivity parameter in the valuations $v(A)$ and $v(B)$, which are computed according to CPT. The minimax rule was also calculated using the same choice rule used for CPT. However, because the minimax model supposes that people rely on only the outcome, the value function was defined as the same as the subjective value of outcomes, $V(A) = v(A)$ and $V(B) = v(b)$, respectively.

We quantified the deviation between the predicted and observed choices using the likelihood measure $G^2$, where a smaller $G^2$ shows a better fit:

$$G^2 = -2 \sum_{i=1}^{N} \ln(f_i(y|\theta)).$$

where $f_i(y|\theta)$ is the probability for which CPT and $N$ refer to the total number of choices. We calculated the two models’ $G^2$ separately for individuals. The participants were first sorted into two groups (CPT group or minimax group) depending on their two models’ $G^2$. Participants were sorted into the group that indicated the smaller model’s $G^2$.

Finally, we calculated the Bayesian information criterion (BIC; Schwarz, 1978) for each participant’s choice to evaluate the model flexibility:

$$\text{BIC}_M = G^2_M + K_M G^2_M \times \ln(N).$$

When the BIC exceeded the baseline, which was predicted from a random choice (probability of 0.5), the participants were grouped as “unclassified.” Finally, the participants were sorted into three groups.

### 2.2.3. Measuring fear of infection and losing money

To compare the strength of affect between being infected with COVID-19 and losing money, we asked the participants to state their level of fear when they faced the two hypothetical situations. In the first part, the participants were asked to imagine that they were infected with the COVID-19 virus. In the second hypothetical situation, they were asked to imagine that they had lost a bet and would lose a specified amount of money. The monetary amount used in the second situation was the WTP for therapeutic medication for COVID-19. In each part, the participants indicated how strongly they would experience each fear by selecting the appropriate value from 1 (not at all) to 7 (very strongly).
2.3. Design and procedure

To observe individuals’ activity in a situation where the risk of infection was high but there were no legal restrictions, we conducted the survey when the number of new infections was high but there was no state of emergency (from August 17 to September 4, 2020). We started the survey after a week of the highest daily record of reported COVID-19 cases in Japan. The Japanese government did not declare a state of emergency during this period, but the daily number of confirmed cases during our survey period was at least as high as during Japan’s first state of emergency (Fig. 1). Our survey was part of a multipurpose survey to observe behavior changes during the COVID-19 pandemic.

The participants first completed the questionnaire measuring susceptibility to probability neglect bias. They subsequently completed the questionnaire of the affective evaluation task and LSA. The LSA questionnaire asked participants to retroactively state their mobility for each pair of purposes of activity (overall activity and leisure activity, respectively) during three periods (p0: before the outbreak of infection, p1: during Japan’s state of emergency, and p2: after the state of emergency was lifted). Finally, the participants provided sociodemographic information. The order of items within each task and questionnaire were randomized to avoid an order effect.

3. Results

To investigate the relationship between the degree of susceptibility to probability neglect bias and the individual’s level of engagement in social distancing, we analyzed the data using STATA 17. The significant level was set at \( p \leq 0.05 \).

Past studies have shown the relationship between demographic factors (age and gender) and protective behaviors. Therefore, we analyzed the effect level by age and gender in addition to the two types of strategic decision-making on the level of social distancing practice.

Before our analysis, we sorted the participants into two groups depending on whether they were over or under 65 years old. In Japan, it is well known that one of the essential factors that triggers aggravation is age, and people over 65 years old are exposed to a higher risk of aggravation than others. This shared knowledge among Japanese people might make a difference in the practice of social distancing. Therefore, we divided our participants by age over and under 65 years old. Next, we sorted the participants into two groups depending on their tendency toward strategic decision-making. The detailed sorting method is shown in the Methods section, “Susceptibility to probability neglect bias.”

We first analyzed whether COVID-19 triggered people’s strong affect. Then, we compared the reported level of fear between two hypothetical situations (being infected with COVID-19 and losing money). We next analyzed the effect of strategic decision-making, gender, and age on the self-reported level of fear and subjective risk of infection. Likewise, we analyzed the effect of the types of strategic decision-making, gender, and age on the level of engagement in social distancing. Because our data did not follow a normal
distribution, we employed a nonparametric test in our analysis.

3.1. Participants

In terms of employment, 14% of participants reported being unemployed or retired, 8% were in part-time employment, 53% were in full-time employment, 16% were self-employed, and 16% reported not being in paid work (e.g., being a homemaker). A total of 8% of the sample indicated that they were currently students. When asked for the highest level of education they had achieved, 16% had completed high school, 53% had a bachelor’s degree, 9% had a master’s degree, and 2% held a Ph.D. or higher. When asked for their income and asset situation, nearly half reported income above the average household income in Japan, and nearly two-thirds reported having assets worth less than $300,000. Demographic information is shown in Table 1.

3.2. Two different strategic decision mechanisms

In total, there were 610 participants in the minimax group (N_{men} = 309, M_{age} = 49.44, SD_{age} = 14.47) and 198 in the CPT group (N_{men} = 98, M_{age} = 49.97, SD_{age} = 14.40). The remainder of the participants (N_{men} = 93, N_{women} = 92, M_{age} = 50.82, SD_{age} = 14.31) were unclassified. A chi-square goodness of fit test showed that the ratio of gender and age was equal between the minimax and CPT groups. Table 2 shows the average parameters for each group and the result of the Wilcoxon rank-sum test. In Fig. 2, the red line shows the probability weighting function drawn with the average parameters of participants in the minimax group, and the blue line shows the average parameters of participants in the CPT group. The probability weighting function of minimax is a good representation of the characteristics of so-called probability neglect heuristics, where people disregard a small probability under conditions of uncertainty (Sunstein & Zeckhauser, 2011). The average parameter estimates for cumulative prospect theory (CPT) and minimax were obtained for the choice tasks, and the results of significance testing were used for the difference in estimates.

3.3. Self-reported level of fear

We asked the participants about their level of fear when they faced two different hypothetical scenarios: in the first scenario, participants were asked to imagine being infected with coronavirus; in the second scenario, participants were asked to imagine losing money equivalent to their WTP for the coronavirus vaccine. The participants reported their level of fear for each scenario from 1 (not at
To determine in which scenarios participants reported stronger fear, we compared the fear scores between the two scenarios. On average, the fear score increased in the coronavirus infection scenario (Mdn = 5) more than in the monetary loss scenario (Mdn = 3). A Wilcoxon matched-pairs signed-rank test indicated that this difference was statistically significant, T = 436967, z = 22.047, p < .001. This result indicates that perceptive risk related to the infection arouses stronger fear than the risks in other domains (monetary loss).

To determine the factors that affected the level of fear of infection, we compared the fear score by gender, age, and two different strategic decision mechanisms (CPT and minimax). Women reported stronger fear (Mdn = 6) than men (Mdn = 5) when they faced the hypothetical scenario of infection with coronavirus. A Mann-Whitney test indicated that this difference was statistically significant, U (N_{women} = 500, N_{men} = 500) = 20854167, z = -7.856, p < .001. Although participants over 65 years old and under 65 reported the same levels of fear (Mdn = 6), a Mann-Whitney test indicated a significant difference, U (N_{over65} = 200, N_{under65} = 800) = 13346667, z = -2.956, p = .003. We next compared the level of reported fear between two different strategic decision mechanisms. Our data showed no significant difference in the fear of infection level between the CPT and minimax groups.

3.4. Subjective risk of infection

Participants reported their subjective risk of infection when they left home using a numeric scale rating from 0% (not at all likely) to 100% (very likely). In total, 444 participants answered this question. Eighty percent of participants (354 participants) reported their subjective risk of infection to be <1. The mean reported subjective risk was 8.18 (SD = 23.33), and the median was 1. The distribution of our data was strongly skewed to the right, and it was neither symmetric nor normal.

To determine the factors that affected the level of subjective risk of infection, we compared the reported scale rating by gender, age, and two different strategic decision mechanisms (CPT and minimax). Our results showed that only age affected the subjective risk of infection: participants over 65 years old showed a higher subjective infection risk than participants under 65 years old (P = 0.003 by Fisher’s exact test). Other factors (gender and two different strategic decision mechanisms) did not affect the subjective risk of infection.

3.5. Life-space mobility

We next investigated the factors that predicted the level of social distancing practice (gender, age, two different types of strategic decision-making, level of fear and subjective risk of infection). We show the distribution of LSA in three periods for the two purposes. Our LSA data exhibited nonnormal distributions (Fig. 3). LSA score of all periods appears to have the same variabilities. LSA score of p0 and p2 are skewed to the left and the score in p1 is skewed to the right. LSA score of p1 appears to have lower center than those of p0 and p2 for both activities. LSA score in the overall activity appears to have higher center than those in the leisure activity.
Friedman’s test showed that there was a significant difference between LSA scores before the pandemic (p0), during the state of emergency (p1), and after the state of emergency was lifted (p3), \( \chi^2_F(2) = 8.16, p < .000 \) for overall activity and \( \chi^2_F(2) = 8.43, p < .000 \) for leisure activity. Post hoc tests using a Wilcoxon signed-rank test with a Bonferroni-adjusted test were conducted for overall activity, and there were significant differences in the LSA score among the three different periods: the postpandemic LSA and the LSA of the period during the state of emergency (p < .000), the postpandemic LSA and the LSA after the state of emergency was lifted (p < .000), and the LSA of the period during the state of emergency and the LSA after the state of emergency was lifted (p < .000). Likewise, for leisure activity, there were significant differences in the LSA scores among the three different periods: the postpandemic LSA and the LSA of the period during the state of emergency (p < .000), the postpandemic LSA and the LSA after the state of emergency was lifted (p < .000), and the LSA of the period during the state of emergency and the LSA after the state of emergency was lifted (p < .000). These results indicate that Japanese people followed the noncoercive lockdown (mild lockdown) and decreased their activity. Furthermore, Japanese people voluntarily maintained social distancing after the state of emergency was lifted.

Next, we investigated the factors that affected the participants’ LSA. Our results showed that only the two different strategic decision-making strategies affected it: there was a significant difference in the LSA score of leisure activity between the CPT group and the minimax group in the period after the state of emergency was lifted (p = 0.05 by one-sided Fisher’s exact test). In our results, any other factors (gender, age, level of reported fear, and subjective risk of infection) did not explain the variance in the LSA score (Fig. 4). This result indicates that people who tended to be affected by probability neglect biases maintained social distancing even after the state of emergency was lifted.
4. Discussion

Understanding the relationship between cognitive biases and citizens’ engagement in protective behavior may be key to managing disease minimization strategies, especially at the beginning of global pandemics such as COVID-19.

Our results indicate that the Japanese people dramatically decreased their mobility during the state of emergency even though the stay-at-home order was not obligatory and there was no fine for its violation. Furthermore, the Japanese people maintained social distancing after the state of emergency was lifted. Surprisingly, in our data, the characteristics and factors that were tied to engaging in protective behaviors in past studies, such as gender (e.g., Jones & Salathé, 2009; Leung et al., 2005), age (e.g., Jones & Salathé, 2009; Barr et al., 2008), the subjective risk of infection (Parady, Taniguchi, & Takami, 2020), and the level of fear (Yıldırım, Geçer, & Akgül, 2021), did not contribute to social distancing. The only factor that promoted the practice of social distancing was the decision-making tendency: people who tended to be affected by probability neglect bias maintained smaller life-space mobility than others after the state of emergency was lifted.

For Japanese people, the cause of the decrease in their life-space mobility without a forced order may be peer pressure. Previous studies show that peer pressure influences various decisions and behaviors, such as purchasing, drinking, and sexual intercourse. According to social psychology, peer pressure occurs to eliminate conflict among within-group members. Previous studies suggest that Japanese and Asian people (even if they migrated to Western countries some years before) prefer to avoid unnecessary interpersonal friction with their immediate in-group members (Heine & Lehman, 1997; Sakai & Andow, 1980). When they experience cognitive

Table B
Choice set of 44 decision problems.

| No. | Lottery A | Probability | Outcome | Lottery B | Probability | Outcome |
|-----|-----------|-------------|---------|-----------|-------------|---------|
| 1   | 0.5       | Depression  | 0.97    | Dizziness |             |         |
| 2   | 0.98      | Dizziness   | 0.35    | Memory loss|             |         |
| 3   | 0.98      | Dizziness   | 0.55    | Memory loss|             |         |
| 4   | 0.5       | Insomnia    | 0.98    | Trembling |             |         |
| 5   | 0.98      | Trembling   | 0.7     | Insomnia  |             |         |
| 6   | 0.45      | Speech disorder | 0.98     | Insomnia  |             |         |
| 7   | 0.56      | Speech disorder | 0.98     | Insomnia  |             |         |
| 8   | 0.93      | Fatigue     | 0.6     | Fever     |             |         |
| 9   | 0.96      | Insomnia    | 0.5     | Hallucinations |         |         |
| 10  | 0.71      | Hallucinations | 0.96    | Insomnia  |             |         |
| 11  | 0.19      | Memory loss | 0.98    | Fever     |             |         |
| 12  | 0.94      | Trembling   | 0.05    | Speech disorder |         |         |
| 13  | 0.99      | Trembling   | 0.25    | Speech disorder |         |         |
| 14  | 0.98      | Fever       | 0.26    | Speech disorder |         |         |
| 15  | 0.55      | Trembling   | 0.97    | Fatigue   |             |         |
| 16  | 0.65      | Trembling   | 0.98    | Flatulence |             |         |
| 17  | 0.63      | Diarrhea    | 0.97    | Fatigue   |             |         |
| 18  | 0.94      | Itching     | 0.52    | Dizziness |             |         |
| 19  | 0.3       | Hallucinations | 0.98     | Diarrhea  |             |         |
| 20  | 0.98      | Flatulence  | 0.15    | Hallucinations |         |         |
| 21  | 0.6       | Itching     | 0.97    | Fatigue   |             |         |
| 22  | 0.81      | Memory loss | 0.98    | Depression |             |         |
| 23  | 0.006     | Trembling   | 0.09    | Flatulence |             |         |
| 24  | 0.005     | Fever       | 0.1     | Fatigue   |             |         |
| 25  | 0.03      | Insomnia    | 0.001   | Depression |             |         |
| 26  | 0.02      | Fatigue     | 0.001   | Diarrhea  |             |         |
| 27  | 0.01      | Itching     | 0.001   | Dizziness |             |         |
| 28  | 0.003     | Hallucinations | 0.04    | Speech disorder |         |         |
| 29  | 0.89      | Fatigue     | 0.01    | Depression |             |         |
| 30  | 0.04      | Itching     | 0.003   | Dizziness |             |         |
| 31  | 0.91      | Diarrhea    | 0.03    | Hallucinations |         |         |
| 32  | 0.045     | Fatigue     | 0.006   | Itching   |             |         |
| 33  | 0.003     | Speech disorder | 0.02    | Insomnia  |             |         |
| 34  | 0.79      | Fever       | 0.015   | Memory loss|             |         |
| 35  | 0.003     | Insomnia    | 0.095   | Trembling |             |         |
| 36  | 0.006     | Memory loss | 0.65    | Dizziness |             |         |
| 37  | 0.38      | Dizziness   | 0.003   | Depression |             |         |
| 38  | 0.003     | Trembling   | 0.04    | Fatigue   |             |         |
| 39  | 0.003     | Memory loss | 0.24    | Depression |             |         |
| 40  | 0.035     | Fatigue     | 0.001   | Dizziness |             |         |
| 41  | 0.008     | Insomnia    | 0.28    | Fatigue   |             |         |
| 42  | 0.99      | Fatigue     | 0.7     | Insomnia  |             |         |
| 43  | 0.33      | Diarrhea    | 0.82    | Flatulence |             |         |
| 44  | 0.6       | Itching     | 0.5     | Trembling |             |         |

Referred to Suter et al. (2016).
dissonance caused by not living up to their cultural ideals, they change their attitudes to reduce cognitive dissonance (Hoshino-Browne et al., 2005). At the beginning of the COVID-19 pandemic, most Japanese people may therefore have obeyed the government’s request to reduce interpersonal friction.

If Japanese people were performing social distancing due to peer pressure rather than the fear of being infected with COVID-19, this could explain the difference from previous studies. However, no evidence of a link between peer pressure and social distancing practice in Japan was found in this study. Therefore, demonstrating this link will be a challenge for future research.

According to our data, the Japanese people voluntarily maintained social distancing after the state of emergency was lifted. Our analysis showed the characteristics of the Japanese population, which may explain the high rate of engagement in voluntary social distancing after the state of emergency was lifted. First, our results showed that the participants who were easily affected by probability neglect bias tended to maintain social distancing even without requests from the Japanese government. Second, the subjects who tended to be affected by probability neglect bias accounted for 60% of our participants. This proportion is almost double that found by Suter et al. (2016), who employed the Swiss as participants in their experiments. This result may be related to a genetics study showing that Japanese individuals have stronger anxiety-related personality traits than Caucasians (Murakami et al., 1999).

Furthermore, our results indicated an association between ethnicity and behavior during a pandemic. Rubin, Amlot, Page, and Wessely (2009) found that non-White ethnic participants were more likely than White participants to adopt avoidant behaviors. If the ratio of people who are easily affected by probability neglect bias is different among ethnic groups, the behavioral tendency of people in the country might depend on the characteristics of the majority ethnic group. Showing evidence of a relationship between ethnicity and behavior changes during a pandemic is an issue for future research.

Our investigation showed empirical evidence of the existence of probability neglect bias during the pandemic. However, there are limitations to our current methods. First, our data consist of self-enumeration data. Research based on questionnaires is one of the most affordable ways to gather quantitative data. However, a previous study noted that self-enumeration data may be biased toward ideal behavior (Mito, Shimamoto, Yashima, & Kwon, 2017). Therefore, if subjects feel that self-isolation is suitable behavior during the pandemic, our LSA data might report smaller scores than their real mobility. Future research designs may benefit from digital mapping technology, such as the Global Positioning System, which can provide people’s mobility more precisely than self-report questionnaires.

Second, our data only reflect the views of people in Japan and may not be applicable to other countries or cultures. In particular, the percentage of people who tend to easily be affected by probability neglect bias may differ depending on the culture or race. To recommend optimal strategies for managing the behavioral changes of citizens, it will be important to analyze the links between the native characteristics of citizens and their engagement in personal protective behaviors. It also was not possible to investigate the changes in attitudes about COVID-19 over time. The declarations of a state of emergency and noncoercive lockdown have been issued many times over these two years. Therefore, people may become accustomed to the situation changing between declaring and lifting a state of emergency. As a result, there is a possibility that the noncoercive lockdowns that were repeated several times had fewer impacts on people’s behavioral changes than the first time.

Additionally, some of the participants were not sorted into either the CPT group or the minimax group. This result indicates that our method might not capture fuzzy decision-making or may teeter between minimax and CPT. Therefore, developing effective strategies for improving the method to assess individual sensitivity to probability neglect bias should be required for future work.

5. Conclusion

The current investigation showed that probability neglect bias reduces people’s mobility during pandemics. In Japan, the percentage of people who tend to be affected by probability neglect bias is much higher than in Switzerland. On average, our results showed that the Japanese population maintained social distancing during the pandemic. People might have avoided unnecessary outings due to pressure from within-group members or society.

Understanding how people react to risks may help identify ways to encourage behavioral changes during a pandemic outbreak. Similarly, identifying the factors associated with social distancing among the general public may help politicians or communicators concoct compelling public messages.

However, our data consist of self-reported data, which may be biased. Therefore, in future studies, the mobile data of individuals should be collected using GPS data. Additionally, to contribute to the practical management method of behavioral changes at the beginning of the pandemic, our data should be expanded to other regions and communities with different cultures.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was funded by Toyota Central R&D Laboratories. The authors thank Hiroyuki Sakai for advising in the survey method and the data analysis, Shintaro Kawabata and Hiromi Komine (Survey Research Center Co., Ltd.) for supporting the online survey.
Appendix A. Details of survey tasks and questionnaires

A.1. Measurement of life-space mobility

Participants were asked to answer the questionnaire of LSA (Table A) to measure their typical activity level during each period. The questionnaire of LSA consisted of 18 items (three periods × two purposes × three-level of life-spaces).

A.2. Tasks for susceptibility to probability neglect

- Willingness to pay for therapeutic medication for COVID-19

Imagine that you were infected with COVID-19. If there is a therapeutic medication that completely cures a COVID-19, how much can you pay for that medication? Please tell us your maximum willingness to pay for the therapeutic medication of COVID-19.

- Choice tasks between two therapeutic medications

Imagine that you were infected with COVID-19. You need to take medicine to treat the illness, but the medication has side effects. The possible side effect of each medicine is depression, dizziness, insomnia, trembling, speech disorder, fatigue, hallucinations, memory loss, fever, diarrhea, itching, and flatulence. We will present you with two therapeutic medications whose side effects and probability of occurrence are known. Would you please choose a therapeutic medication that you want to use from the presented two options? (see Table B).

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