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BLOOD TYPE AND BLOOD DONATION BEHAVIORS: AN EMPIRICAL TEST OF PURE ALTRUISM THEORY

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Blood Type and Blood Donation Behaviors:

An Empirical Test of Pure Altruism Theory

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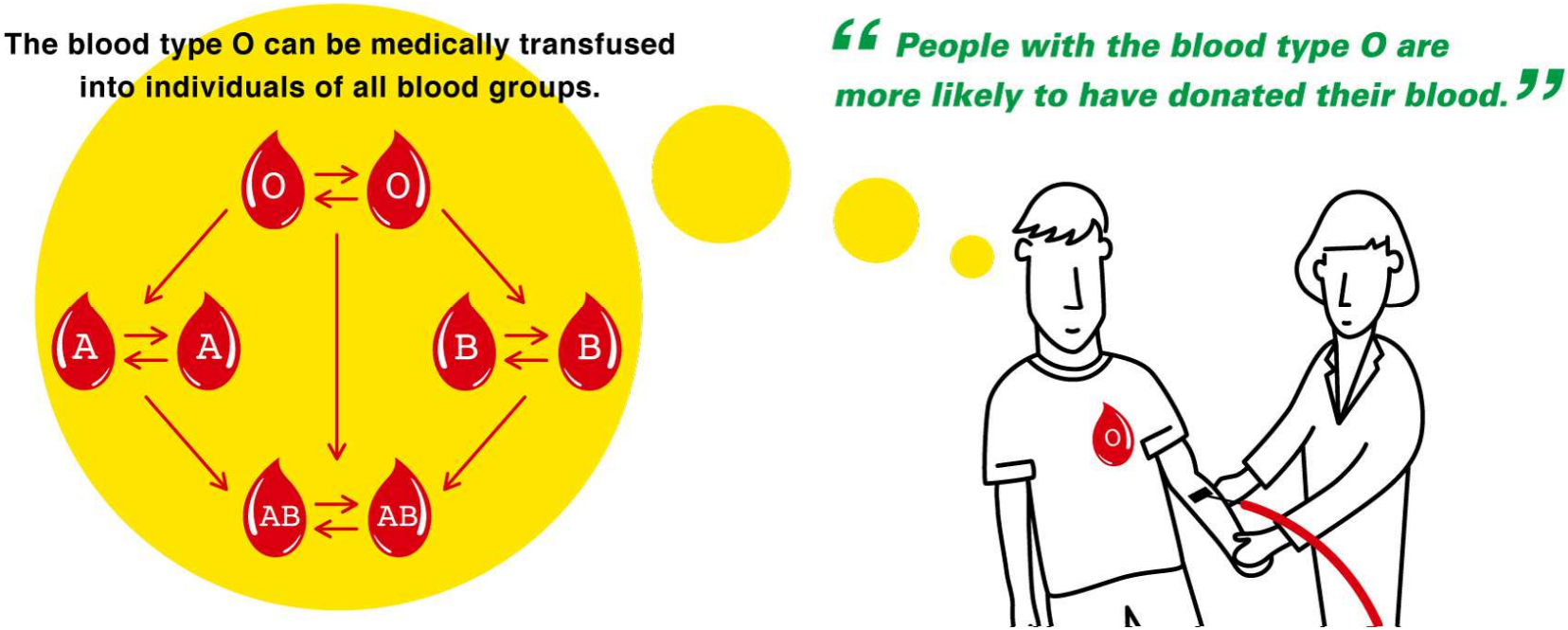
Abstract

We examined whether the knowledge that your private donation has a large number of potential recipients causes you to give more or less. We found that the people with blood type O are more likely to have donated blood than those with the other blood types, by using a Japan's nationally representative survey. This association was found to be stronger in a subsample of individuals who knew and believed that blood type O can be medically transfused into individuals of all blood groups. However, we found that blood type O does not have any significant relationship with the other altruistic behaviors (registration for bone-marrow donation, intention to donate organs, and the making of monetary donations) and altruistic characteristics (altruism, trust, reciprocity, and cooperativeness). After further analyses, we confirmed that the wider number of potential recipients of blood type O donations promote the blood-donation behaviors of the people with this blood type.

Keywords: *ABO blood group, blood donation, group size, public good, pure altruism, behavioral economics*

JEL Classification Codes**:** I10, D64, C30

Graphical Abstract



Introduction

Pure altruism is well known in economics as one major driver of providing several forms of public good: charitable giving, volunteering, and blood donations[1]. Andreoni has defined that an individual with pure altruism increases their personal utility when the utility level of others rises[2,3,4].[a] For example, in blood donations, when a certain amount of blood is transfused to a person who needs it, the recipient of the blood becomes pleased. In this situation, a purely altruistic individual feels happier as a result of the recipient's pleasure. An interesting point here is that a rise in their purely altruistic utility does not depend on who gives the blood to the recipient. They simply feel happy, not only when they, themselves, donate enough of their blood to a recipient to improve his/her health, but when they know that the other blood donors also donate as well.

If your privately-provided public good has a large number of potential recipients, how does it influence your behavior of providing the public good? Imagine that a natural disaster has occurred and that you are planning to donate one box of crayons to a child in

[a] Andreoni writes the utility function of a purely altruistic individual in the following way: $u_i(\pi_i, \pi_o)$, where π_i is the payoff of the individual and π_o is that of the other individual. Since the function includes not only the individual's payoff but also the other's payoff, their utility is affirmatively correlated with the other's payoff.

the affected area. In this case, the number of people who have the possibility to receive the box of crayons, the potential recipients, is the total number of children in the area. On the other hand, if you decide to make a monetary donation, the number of potential recipients increases, because such a monetary donation can be delivered not only to children but to adults. Thus, different forms of public goods have different numbers of potential recipients.

Does the knowledge that your private donation has a large number of potential recipients cause you to give more or less? This study considers this question, seeking to determine the answer by empirically examining how blood type affects blood-donation behaviors. The range of blood transfusion recipients differs widely across blood type, and this unique feature facilitates a natural experiment for our investigation.

[Insert Figure 1 here]

More precisely, blood type O can be medically transfused to individuals of all blood groups (Figure 1). This is mentioned in the guidelines of the Ministry of Health, Labor and Welfare in Japan[5].[b] In contrast, individuals with the blood types A or B can

[b] In “Guidelines on Implementation of Transfusion Therapy”, the Ministry of Health, Labor and Welfare mentions the following: when there is no time to clarify the blood type of a patient due to hemorrhagic shock, when there is no determination reagent for blood type at emergency, or when it is difficult to clarify

provide transfusions for those with the same blood type or the blood type AB. Also, individuals with the blood type AB can provide transfusions only for those with the same blood type.

We can regard these four types of blood as a local public good, the benefit of which is limited to a particular area or population[6]. A suitable analogy to this is a city library, to which only city residents have access. However, again, the range of blood transfusion recipients differs widely across blood type. Blood type O represents a local public good with the broadest range of blood transfusion recipients than the four blood types.

Blood type O's unique usability naturally means that it has a much larger number of potential recipients than the other blood types. As an example, using 100 Japanese people, the number of potential recipients of blood types A, O, B, and AB are respectively 50, 100, 30, and 10 people, because the distribution of blood groups across Japan is approximately A: O: B: AB = 4: 3: 2: 1[7].

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the blood type for to any other reasons, a red O type blood concentrate for which a cross-matching test has not been conducted can be used.

Here we assume for our investigation that the probability of people requiring a blood transfusion (e.g., the likelihood of their encountering an accident) is identical for each individual and that the quantity of transfused blood is also identical for each individual, on average. Furthermore, we assume that people recognize potential recipients of their blood as members of the same group and that they experience their personal utility gain from these members' happiness if they have purely altruistic motivation.

Under these assumptions, widening the range of blood transfusion recipients means increasing the number of group members who require a blood transfusion; thereby increasing the total quantity of transfused blood and, as a consequence, increasing the social surplus.[c]

Andreoni theorized how behaviors concerning the provision of a public good are influenced by the increase in social surplus due to the increase in the number of people (n) receiving the benefits of the public good[8]. First, a positive (income) effect occurs: as the number of recipients (n) increases, the provided good generates more social benefits, and people become more likely to provide the public good. Second, a negative (crowding

[c] We rewrote the basic utility function of a purely altruistic individual in the following way: $u_i(\pi_i, n\pi_o)$, where n is the number of group members. The purely altruistic utility gain changes, as its number n changes.

out) effect occurs: as the number of donors also increases, the same social benefit can be attained at a lower cost, and people become less likely to provide the public good. Although Andreoni showed in a laboratory experiment that the income effect exceeds the crowding out effect[8], in the case of blood donation behaviors, identifying which effect dominates depends on empirical analysis.

This study's purposes are as follows: (1) we investigated the differences in blood-donation behaviors between the people with blood type O and those with the other blood types; and (2) if we were able to identify a different pattern of blood donation behavior from the people with blood type O, we investigated whether the cause of such behavior was due to the fact that blood type O is a public good with a larger number of potential recipients than the other blood types.

The existing literature empirically has indicated the possibility that stimulating non-altruistic motivation promotes an individual's blood donation behavior[9,10,11]. However, these results have not demonstrated the non-existence of a blood donation behavior caused by purely altruistic motivation. Also, if some proportions of purely altruistic blood donors were provided with a non-altruistic incentive, it could impede their

blood donation behavior[12]. Taking these results into account, it is essential to directly test whether pure altruism motivates an individual's blood donation behavior.

Methods

Data Description

To conduct our investigation, we used a dataset from a nationally representative survey conducted in Japan, which is called the Preference Parameters Study of Osaka University (PPSOU)[13]. To the best of our knowledge, this is the only survey which included information concerning both of the Japanese respondents' blood type and blood donation behavior. The PPSOU survey is a panel survey, which has been conducted annually since 2003. Also, this survey is based on the concepts of behavioral economics, and the survey purpose is to identify the validity of the conventional economics assumptions that people are rational and seek to maximize their utility. Consequently, this survey collects unique information, including respondents' preference parameters and psychological personalities and attributes, in addition to their basic socio-economic characteristics. The

PPSOU dataset have been used for several empirical research in behavioral economics[14,15].

In the first wave in 2003, a nationally representative sample of individuals aged 20 to 69 was obtained by using two-stage stratified random sampling. In the current study, specifically, we have focused on 1,311 responses provided by the PPSOU survey in 2017, which for the first time included the questions to identify the respondents' blood type and blood donation behavior.[d] The data that supports the findings of this study is available from Institute of Social and Economic Research at Osaka University upon reasonable request.[e]

Using a Japanese sample for this analysis provides some essential advantages. First, our Japanese sample, including both blood donors and non-blood donors, generally knew their own blood type (over 99.0%); this is not the case in many other countries.

Second, it is well known in Japan that blood type O can be medically transfused into individuals of all blood groups; in fact, 74.0% of our sample knew and believed this

[d] Although the survey has sometimes added a new sample in order to keep it nationally representative, the concern remains that the 2017 sample deviates from that. When later introducing the descriptive statistics, we assessed whether our sample was significantly different from a Japan's official statistics or not.
[e] Contact information is here, http://www.iser.osaka-u.ac.jp/survey_data/eng_application.html

fact. However, we heard from some Japanese medical practitioners that it is actually rare that blood type O is transfused into individuals of the other blood types. That is, only the knowledge is shared by ordinary Japanese people. This feature rather helps us to exploit a pure impact of possessing blood type O and the knowledge relating to this blood type on blood donation behaviors. If blood type O was frequently transfused into individuals with the other blood types, this blood type would have been more in demand, and its high demand would have affected the blood-donation behaviors of the people with this blood type. However, in our case, we can ignore the concern.

Third, the distribution of Japanese people's blood groups is well-dispersed. If almost all members of the sample had a single particular blood type, we would not have been able to investigate our research question. Again, according to the Japanese Red Cross Tokyo Metropolitan Blood Center, the distribution of blood groups across Japan (approximate value) is A: O: B: AB = 4: 3: 2: 1[7], and the distribution of blood groups in our sample is 39.0% for blood type A, 30.4% for O, 21.1% for B, and 9.6% for AB. Thus, the distribution of blood groups in our sample is consistent with that across Japan.

Fourth, we were able to ignore any possible effects caused by people with Rh negative blood, because the proportion of Japanese people with Rh negative blood is quite small, approximately 0.5%. This feature allowed us to focus on a simple relationship diagram, where individuals with blood type O Rh positive are able to provide transfusions for those with Rh positive in all blood groups. Rh negative blood is another kind of universal blood, which can be transfused into individuals with Rh positive blood. If the proportion of people with RH negative blood were larger in Japan, the relationship diagram relating blood transfusion subjects would have been more complicated, and the predicted effect of blood type O would also have been more complicated.

Additionally, using the PPSOU dataset enabled us to directly investigate (and reject) the possibility that other mechanisms could explain our results. One major concern is that preferences and psychological characteristics may differ across blood groups, which would cause different patterns of blood-donation behaviors. For example, people with blood type O are likely to donate their blood, possibly because they have more altruistic personalities when compared to people with the other blood types. Several psychological studies have already rejected the validity of this concern for samples from

several countries, including Japan[16,17,18,19]; however, some people in Japan might still believe that blood-type determines preferences and psychological characteristics in this regard, and holding such a belief might unconsciously characterize the preferences and psychological characteristics of such individuals.

By using the PPSOU dataset, we were able to address the above concern directly. The PPSOU survey collects information relating to respondents' preference parameters and psychological personalities and attributes, including altruism. In our analysis, we investigated the effect of blood types on blood-donation behavior after controlling for such characteristics, and at the same time we checked whether these characteristics differ across blood groups.

Furthermore, we sought to reconfirm the advantages of using the PPSOU dataset by comparing it with a dataset used in a related study. To the best of our knowledge, only one empirical study by Wildman and Hollingsworth[20] analyzed the relationship between blood type and blood donation behaviors, using the blood donation dataset of the Australian Red Cross. As a main finding, the authors reported that Australian blood donors with type O had a lower frequency of blood donations.

We recognize that their study is entirely novel in being the first to investigate how possessing blood type O affected blood-donation behavior. Nevertheless, it is worthwhile to readdress this question with our PPSOU data, from the other viewpoints in addition to the viewpoint that the association between blood type and blood-donation behaviors can differ across countries. First, Wildman and Hollingsworth's dataset does not include information concerning preference parameters and psychological attributes and, therefore, it is difficult to examine other potential reasons for their results directly. For example, the authors suggested in their interpretations that non-altruistic motivation drove Australians' blood-donation behaviors. However, as Andreoni describes[8], a similar result can be observed when the negative crowding out effect surpasses the positive income effect, and if so, pure altruism shaped the Australians' blood-donation behaviors. Second, their sample contains only blood donors, which might generate a sample-selection problem. If our expected mechanism is verified, people with both blood type O and relatively low levels of altruism may still donate their blood. Furthermore, in this case, the altruistic level would also be low in blood donors with type O, and if psychological attributes, such

as altruism, are not controlled, the blood type O dummy variable might be a proxy variable of the lower altruistic level.

Our Japanese survey respondents consisted of both blood donors and non-blood donors. In addition, the survey collected information concerning respondents' behavioral economics preferences and psychological attributes. These features enabled us to avoid a potential sample-selection problem and to test whether pure altruism and a large number of potential recipients motivate an individual's blood donation behavior, after dealing empirically with the possibility that other explanations may also be valid.

Empirical Strategy

Variables and model specifications

We used a simple model specification for analysis, as shown in equation (1):

$$Blood\ donation_i = \alpha + Blood\ type_i'\beta + z'_i\gamma + u_i \quad (1)$$

where α represents a constant term, and u represents an error term.

The dependent variable, $Blood\ donation$, explains respondent i's blood-donation behavior. More precisely, we employed the following two dependent variables: the first represents respondents who have donated blood at least once within the past few years, and the second represented those who had donated blood once or more within the past year. Since these two variables are binary, we used logistic regression for the estimation. In addition, we applied to the estimation a sampling weight and robust standard errors clustered at the prefecture level.

The main independent variable, $Blood\ type$, expressed respondent i's blood type. These were dummy variables; for example, the dummy-coded variable of blood type O was coded as a "1" if a respondent i's blood type is O and was coded as a "0" for the other blood types. This dummy-coding was done for each of the blood types. Here, note that

respondents cannot select their blood type in a biological sense, and $Blood\ type$ are exogenous variables. Therefore, we can determine the starting point of the effect from blood types to blood donation behaviors, when simply using a cross-sectional dataset and a logistic regression model.[f]

As for covariates, we added z to the model. We used these to control the effects of socio-economic status, health status, and preferences and psychological characteristics. In the next subsection labeled "descriptive statistics," we discuss the information in more detail.

Our analysis procedure was as follows: First, we performed equation (1) with a full sample, clarifying the relationship between blood types and blood-donation behaviors. If a different pattern of blood-donation behaviors was found for people with blood type O, we then investigated whether such a result is generated because blood type O is a public good with a wider population of potential recipients than the other blood types. For this latter analysis, we performed equation (1) by using subsamples. Here the full

[f] In the countries where many people do not know their own blood type, people may donate blood in order to know their own blood type. In such a case, $Blood\ type$ are not exogenous. However, in Japan, most of people, including both blood donors and non-blood donors, know their own blood type. In fact, over 99.0 % of our Japanese sample do so. Therefore, in our case, $Blood\ type$ are enough exogenous.

sample was divided into two groups: one group containing those who knew and believed that blood type O could be medically transfused into individuals of all blood groups, and another group containing individuals who did not. We then investigated whether the estimated parameter of blood type O was statistically significant from zero in the former group but not the latter. If so, it would have directly supported that people with blood type O donate their blood differently as a result of the large number of potential recipients.

Descriptive statistics

[Insert Table 1 here]

Table 1 shows descriptive statistics regarding our sample's blood-donation behaviors, blood types, and covariates. From this table, it can be seen that 11.7% of our sample have donated blood at least once within the past few years and that 5.5% have done so once or more within the past year. According to the website of the Japanese Red Cross, 5.6% of the Japanese population donated blood in 2016[21], which is a similar percentage to that shown in our sample. Also, as we have already mentioned in Section 2, the distribution of blood type across Japan is consistent with that in our sample.

In addition, Table 1 introduces the sample's variables in regard to socio-economic status, health status, and preferences and psychological characteristics. Here, note that the lowest age in our sample is 27 years old, which is due to the fact that the PPSOU is a panel survey, meaning that it has surveyed the same respondents since the first wave in 2003. Therefore, our sample does not include any members of the general population's 16–26 age group, who can legally donate blood. However, this feature would not impede our analysis of blood donation behaviors, because the rate of blood donation among younger generations is showing a declining trend and, at present, people in their forties are the primary blood donors. In addition, the oldest age in our sample is 70 years old. Since 69 years old is the oldest age at which people in Japan can donate blood, our sample includes those who were 69 years old or younger the year before our survey, 2016. As a consequence, we advanced 1,311 responses from the 2017 PPSOU survey to the analysis phase. See Supplementary information for more details of questions and variables in particular of health status, preferences, and psychological characteristics.

Results

Basic Results

[Insert Table 2 here]

This section considers the relationships between blood type and blood-donation behaviors. Table 2 shows the basic results of our performance of equation (1) using the full sample. In all the columns (1) to (4), the estimated parameter of the blood type O dummy variable was positive and statistically significant, which indicates that people with blood type O were more likely to have donated blood at least once within the past few years than were people with the other blood types. In particular, column (4) shows that they were especially more likely to have done so than people with blood type A, whose blood donation behaviors were similar to those of people with blood types B or AB. These findings are consistent with one prediction of Andreoni's theory[8]; in these cases, the positive income effect overcomes the negative crowding-out effect.

These results remained stable also when using another dependent variable, which represents respondents who have donated blood once or more within the past year. In

addition, we checked that estimations using the probit regression model and the linear probability model produced similar results.

Interestingly, column (8) shows that the people with blood type AB were more likely to have donated blood once or more within the past year than were people with blood type A. Although this finding might be confusing at first glance, it also can be interpreted by considering Andreoni's theory[8], which indicates that, in the case of a decrease in the number of potential recipients, the income effect becomes negative and the opposite effect to crowding out occurs. Therefore, it is possible that since the opposite effect prevailed over the negative income effect, the people with blood type AB were more likely to have donated blood. When the group size is small, donors might think that they are among a few who are able to help such a small number of the recipients, and thus they might be eager to donate their blood to the recipients. However, since this tendency is not observed in column (4), it does not seem to be robust.

Thus, we found that the people with blood type O donated their blood differently than did people with the other blood types, as we expected. Following our analysis

procedure, the second step was to investigate whether they did so because blood type O is a public good with a wider population of potential recipients than the other blood types.

[Insert Table 3 here]

Table 3 shows the results of performing equation (1) with the subsamples. The results reveal that the blood type O dummy variable had a statistically and significantly positive impact on blood-donation behaviors only for the subsample of individuals who knew and believed that blood type O can be medically transfused into individuals of all blood groups (columns (1) to (4)). In contrast, columns (5) to (8) show dissimilar results when we used the other subsample, who did not know or believe this statement. What is important here is that, when using the smaller size sample in the former case than in the full sample analysis case, the coefficient size of the blood type O dummy variable and its statistical significance were indifferent from those in the full sample analysis case.[g] The findings more directly support that the people with blood type O were likely to have donated their blood because of the large number of potential recipients.

[g] Of course, we cannot completely deny the possibility that the latter results were influenced by their further small sample size.

Here, we discuss the validity of the step 2 in our analysis procedure. The step 2 supposed that being blood type O is correlated with possessing the knowledge relating to this blood type and that the covariates' coefficients are different between two subsample groups. Therefore, we did not use the full sample to estimate the equation (1), to which the cross-term of the blood type O dummy variable and the knowledge variable was added. In fact, we found that there was a weak positive correlation between the blood type O dummy variable and the knowledge variable. This means that the people with blood type O were more likely to have the knowledge relating to this blood type. This intuitively understandable finding does not impede but rather supports our interpretation that the people with blood type O were likely to have donated blood because of the large number of potential recipients.

[Insert Figure 2 here]

Finally, we introduce in Figure 2 the marginal effects of the blood type O dummy variable in the selected model specifications. The likelihood to have donated blood within the past few years was around 5.0% higher in the people with blood type O than in people with the other blood types, when using the full sample and the subsample of individuals

who knew and believed that blood type O can be medically transfused into individuals of all blood groups. However, when using the other subsample, we cannot reject the null hypothesis that the marginal effect of the blood type O dummy variable is indifferent from zero.

Further Results

This section examined (and rejected) the other possible explanations for our results. In so doing, we further confirmed our interpretations of the results. First, we arrested the concern that the people with blood type O were more likely to donate their blood, possibly because they had more altruistic personalities. We wish to restate that our model specification included covariates related to preferences and psychological characteristics, including altruism, and considered their potential differences across blood groups: however, it is possible that these covariates failed to sufficiently control for the differences. If unobserved altruistic factors remained after controlling the covariates and if the blood type O dummy variable was a proxy one for the factors, the blood type O dummy variable

should have had a statistically and significantly positive effect not only on blood-donation behaviors but also on the other altruistic behaviors.

[Insert Table 4 here]

Table 4 presents results that negate the first concern. Rows (1) to (8) show that the blood type O dummy variable had no effect on any other altruistic behaviors, including registering for bone-marrow donation, organ-donation intention, and making monetary donations. In addition, after controlling for several socio-economic and health status variables, and the other psychological characteristics aside from the dependent variable, we did not find any statistically significant relationship between blood type O and any altruistic characteristics. These findings deny the validity of the explanation that the people with blood type O have naturally stronger altruistic tendencies.

Second, we addressed the concern that the people with blood type O were more likely to donate blood, possibly because they were healthier than people with other blood types. In fact, medical studies have reported that the risks of contracting diseases indeed differ between blood groups[22,23]. We again wish to state that our model specifications included, and controlled for, variables that captured the respondents' current health

conditions; however, these variables might have failed to represent differences in terms of congenital or chronic health conditions. Consequently, to address this concern, we performed equation (1) after excluding respondents who reported, “I have donated blood, but I have not donated within the past few years because of my health condition,” or “I want to donate my blood, but I cannot because of my health condition.” The results are shown in Table 5. As these results are robustly similar to those previously obtained, we can suppose that this second concern is not a significant factor.

[Insert Table 5 here]

The third concern is that the people with blood type O were more likely to donate blood, possibly because blood type O was more in demand than the other blood types. For example, blood-donor centers might frequently make requests that the people with blood type O donate blood. To consider a (possible) difference in demand in this regard, we controlled for information relating to the inventory ratio of stocks of each blood type in each respondents’ prefecture. If the inventory ratio of stocks of a particular blood type is low in a prefecture, it would be likely that the blood-donor centers in the area make requests that people with that blood type donate their blood. In 2012, the Ministry of

Health, Labor and Welfare in Japan published weekly reports concerning the inventory ratios of stocks of blood types for all prefectures[24]. Using this information, we created variables relating to the annual averages and standard deviations of these inventory ratios of stocks in each respondent's prefecture.[h]

[Insert Table 6 here]

Table 6 shows that blood type O's parameter remained positive and statistically significant even after controlling for the information concerning the inventory ratio of stocks for each blood group. Therefore, this third concern is not crucial.

The fourth concern is that the people with blood type O Rh-negative was more likely to donate blood, and this behavior consequently shaped our results. It is well known that the blood type O Rh-negative is quite rare in Japan, and, therefore, people with this blood type might think that provided donations of this blood type are also rare. This rarity could make them more likely to donate their blood to others within the same group. Consequently, this has the potential to negate our hypothesis.

[h] The Ministry of Health, Labor and Welfare in Japan published the report every week only in 2012. Thus, our analysis assumed that the annual averages and standard deviations of the inventory ratios of stocks of blood types are almost indifferent during the years from 2012 to 2016.

It is unlikely that the above concern is valid, although our survey did not capture whether a respondent had Rh positive or negative blood and we were not able to control its effect directly in our estimations. According to the Japanese Red Cross Tokyo Metropolitan Blood Center, only 0.15% of the Japanese population has O Rh-negative blood (a proportion of 1:670 people)[25]. Therefore, our blood type O sample included very few people with blood type O Rh-negative. Even if there were such individuals in the sample, their proportion is likely to have been extremely small (i.e. approximately up to 2 people in the sample), meaning they would not have greatly influenced our estimation results. As an illustration, we shall imagine that there existed 2 people with blood type O Rh-negative, and both have donated their blood. Even after excluding the two observations, the ratio of blood donors among the people with blood type O is 14.6%, which is almost indifferent from that in the full sample (15.1%).

Discussion

Using the data from a nationally representative survey conducted in Japan, the Preference Parameters Study of Osaka University, we found that the people with blood type O are

more likely to have donated blood at least once within the past one or more years than those with other blood types. This association was strongly observed in a subsample containing individuals who knew and believed that blood type O can be medically transfused into all blood groups. However, we did not find any further significant relationship between blood type O and other altruistic behaviors, including registration for bone-marrow donation, intention to donate organs, and the making of monetary donations. Moreover, we did not find any relationship between blood type O and altruistic personality and characteristics, including altruism, trust, reciprocity, and cooperativeness. In so doing, we arrested the concern that the people with blood type O were more likely to donate their blood, possibly because they had more altruistic personalities. After additional analyses, we were able to confirm that the wider number of potential recipients of blood type O donations promotes the blood-donation behaviors of people with this blood type.

Our findings are consistent with one prediction of Andreoni's theory[8]. In the case of blood donation, when the number of potential recipients increases, a positive income effect prevails over a negative crowding out effect. Our study adds to the existing

literature unique field evidence concerning the relationship between group size and public goods provision. Furthermore, our findings can aid charities' fundraising or volunteer-recruiting activities; if such nonprofit organizations announce that a large number of people require a multitude of new donors or volunteers, it is likely that the numbers of donors and volunteers will increase.

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Author Contributions

S.S., H. K., and F. O. designed the research. S.S. and Y. F. analyzed the data and wrote the paper. All authors discussed the results, edited the manuscript, and approved the current draft of the paper.

Competing Interests

The authors declare no competing financial interests.

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FIGURES

Figure 1. Difference in the number of transfusion subjects for each blood group.

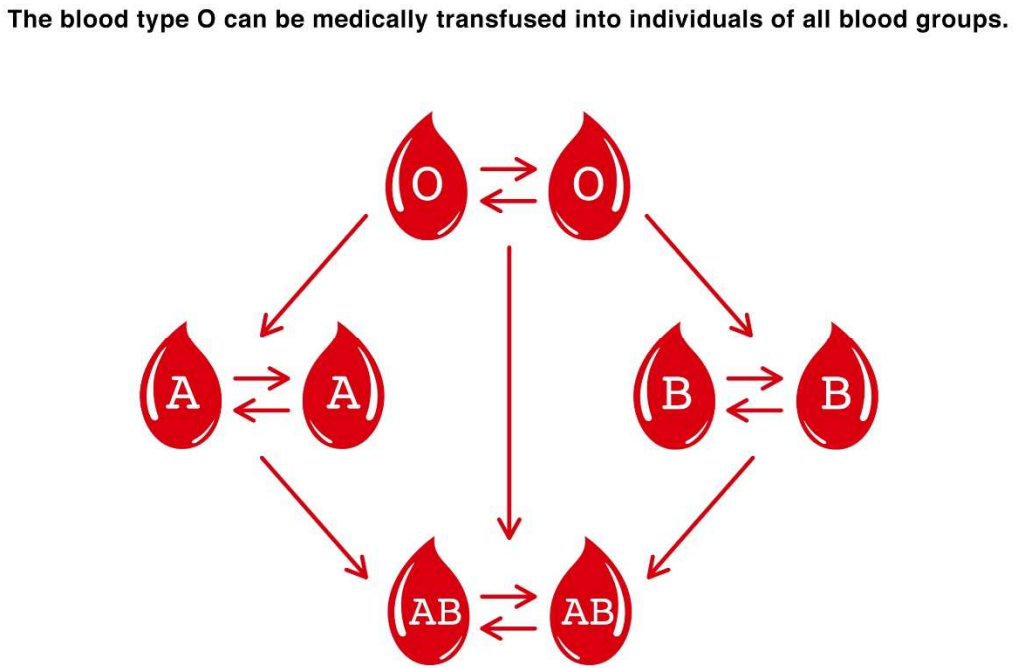
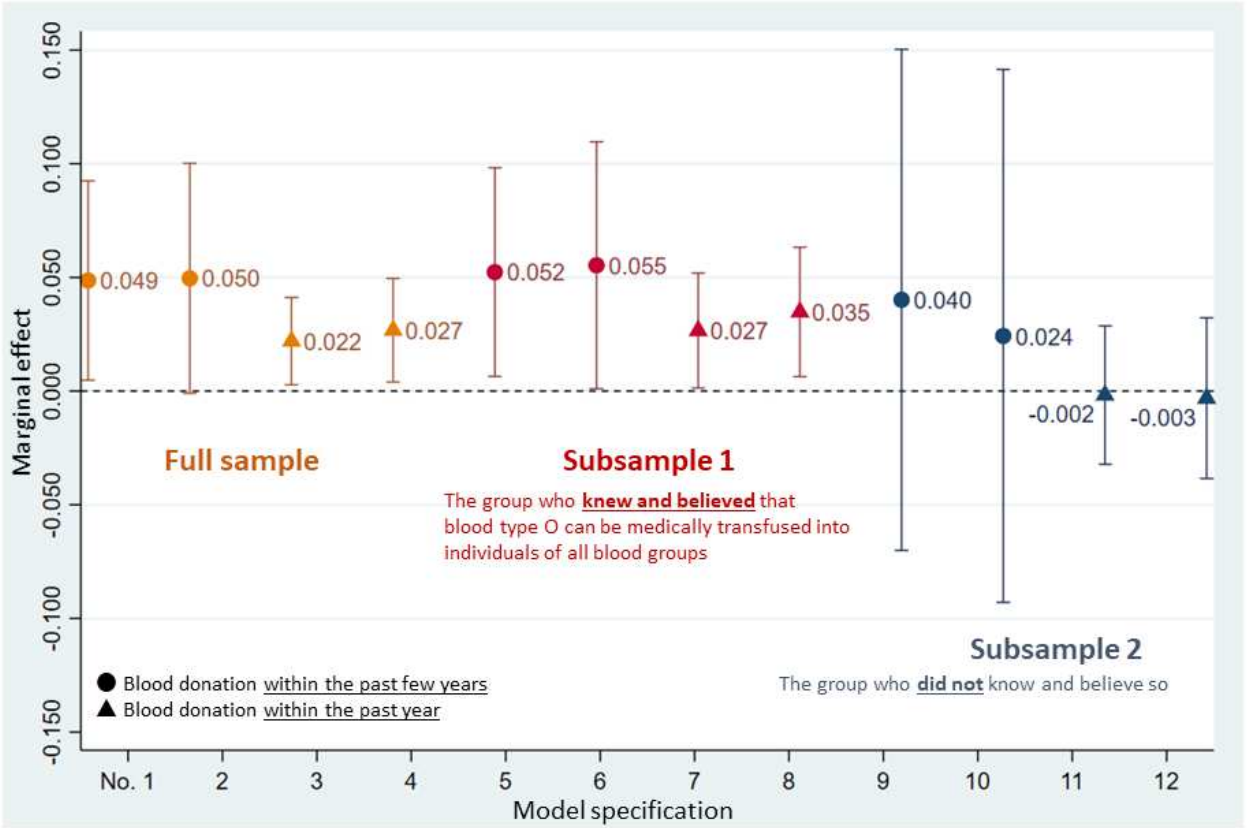


Figure 2. Marginal effect of blood type O dummy variable (with 95% CI).



Notes: The specifications with an uneven number include blood type O dummy variable, while those with an even number include not only blood type O dummy variable but also blood type B and AB dummy variables. Also, all the specifications include covariates of socio-economic status, health status, and preferences and psychological attributes.

TABLES

Table 1. Descriptive statistics.

Number of observations = 1,311 **Variables name**	**Mean**	**S.D.**	**Min**	**Max**
1. Blood-donation behaviors				
Have donated blood at least once within the past few years (dummy)	0.117	0.321	0	1
Have donated blood once or more within the past year (dummy)	0.055	0.228	0	1
2. Blood type				
Blood type A (dummy)	0.390	0.488	0	1
Blood type O (dummy)	0.304	0.460	0	1
Blood type B (dummy)	0.211	0.408	0	1
Blood type AB (dummy)	0.096	0.295	0	1
3. Socio-economic status				
Age	54.062	10.155	27	70
Female (dummy)	0.533	0.499	0	1
Spouse (dummy)	0.806	0.395	0	1
Household income levels (10,000 yen)	641.571	397.895	50	2,100
Educational years	13.298	2.039	9	21
4. Health status				
Body Mass Index (BMI)	22.864	3.379	13.333	44.983
Subjective health status	3.326	0.920	1	5
Mental illness	2.620	0.838	1	5
5. Preferences and psychological characteristics				
Behavioral economics preferences (1): Time discounting factor	0.883	0.225	-1.837	1.126
Behavioral economics preferences (2): Absolute risk aversion	0.00002	0.00006	-0.00040	0.00013
Psychological index (1): General trust	3.208	0.718	1	5
Psychological index (2): Altruism	3.792	0.659	1	5
Psychological index (3): Positive reciprocity	3.737	0.526	1	5
Psychological index (4): Negative reciprocity	2.286	0.787	1	5
Psychological index (5): Conformity	2.906	0.870	1	5
Psychological index (6): Social norm	4.339	0.950	1	5
Psychological index (7): Religious beliefs	1.661	1.031	1	5
Psychological index (8): Belief in fortune-telling based on blood-types	2.794	0.968	1	5
Big 5 personality traits (1): Extraversion	8.146	2.485	2	14
Big 5 personality traits (2): Agreeableness	10.081	1.775	3	14
Big 5 personality traits (3): Conscientiousness	8.116	2.090	2	14
Big 5 personality traits (4): Neuroticism	7.847	2.036	2	14
Big 5 personality traits (5): Openness to experience	7.792	2.112	2	14

Note: See Appendix for more details of questions and variables in particular of health status, preferences, and psychological characteristics.

Table 2. Basic results (1).

Logistic regression (coefficient)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	I have donated blood at least once within the past few years				I have donated blood once or more within the past year			
Blood type:								
Blood type O	0.397**	0.398*	0.497**	0.507**	0.400*	0.397	0.468**	0.573**
	(0.201)	(0.208)	(0.217)	(0.253)	(0.237)	(0.248)	(0.223)	(0.264)
Blood type B				-0.043				-0.075
				(0.298)				(0.467)
Blood type AB				0.143				0.707**
				(0.250)				(0.296)
Covariates:								
Socio-economic status	×	×	×	×	×	×	×	×
Health status		×	×	×		×	×	×
Preferences and psychological attributes			×	×			×	×
Number of observations	1,311							

Note: *** $p < 0.001$, ** $p < 0.05$, and * $p < 0.1$. The baseline in columns (1)-(3) and (5)-(7) is blood type A, B, or AB. The baseline in columns (4) and (8) is blood type A. When evaluating the marginal effect, the likelihood to have donated blood within the past few years was 4.0% (5.0%) higher in the people with blood type O than in people with the other blood types (in particular, the people with blood type A).

Table 3. Basic results (2).

Logistic regression (coefficient)		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable:	I have donated blood at least once within the past few years		I have donated blood once or more within the past year		I have donated blood at least once within the past few years		I have donated blood once or more within the past year	
Blood type:									
Blood type O		0.576**	0.609**	0.584*	0.767**	0.401	0.243	-0.042	-0.074
		(0.267)	(0.309)	(0.314)	(0.360)	(0.544)	(0.589)	(0.366)	(0.427)
Blood type B			0.021		0.138		-0.321		-0.394
			(0.379)		(0.457)		(0.382)		(0.686)
Blood type AB			0.189		0.867*		-0.270		0.285
			(0.373)		(0.458)		(0.499)		(0.917)
Subsample:		1. The group who **knew and believed** that blood type O can be medically transfused into individuals of all blood groups				2. The group who **did not know or believe** that blood type O can be medically transfused into individuals of all blood groups			
Number of observations		970				341			

Note: *** p < 0.001, ** p < 0.05, and * p < 0.1. The baseline in columns (1)(3)(5)(7) is blood type A, B, or AB. The baseline in columns (2)(4)(6)(8) is blood type A. All the model specifications include covariates of socio-economic status, health status, and preferences and psychological attributes.

Table 4. Further results (1).

Number of observations = 1,311		**Independent variable:** Blood type O
Dependent variable: Other altruistic behaviors		
(1)	I have registered as a bone-marrow donor.	-0.149
		(0.424)
(2)	I have registered as a bone-marrow donor, or	0.106
	I want to register as a bone-marrow donor, but I have not yet.	(0.220)
(3)	I have registered as a bone-marrow donor,	-0.018
	I want to register as a bone-marrow donor, but I have not yet, or	(0.148)
	I want to register as a bone-marrow donor, but I cannot register because of my age or health	
(4)	I have signed an organ-donation consent form.	-0.356
		(0.221)
(5)	I have signed an organ-donation consent form, or	-0.050
	I have a will, but I have not signed it yet.	(0.203)
(6)	Entire monetary donations for the past year	-5,135.761
		(4,702.118)
(7)	Monetary donations to disaster aid	-162.781
		(468.406)
(8)	Monetary donations to religious groups	-8,245.690
		(8,418.801)
Dependent variable: Altruistic characteristics		
(9)	Altruism	-0.066
		(0.043)
(10)	Trust	-0.044
		(0.065)
(11)	Positive reciprocity	0.041
		(0.033)
(12)	Cooperativeness (a Big 5 personality trait)	-0.011
		(0.124)

Notes: *** $p < 0.001$, ** $p < 0.05$, and * $p < 0.1$. Since the dependent variables in rows (1) to (5) are binary, we estimate these equations, using logistic regression. For the experience of monetary donations in rows (6) to (8), the original question items are as follows: "not making a donation", "1 yen ~ 5,000 yen", ..., "500,000 yen ~ 1,000,000 yen", "1,000,000 yen or more". Therefore, when the dependent variable is experience of monetary donation, we estimate these equations, using interval regression. The altruistic characteristics in rows (9) to (12) are ordinal variables whose values are 5, 4, 3, 2, and 1. Therefore, we regard them as continuous variables and estimate these equations.

Table 5. Further results (2).

Logistic regression (coefficient)		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable:	I have donated blood at least once within the past few years		I have donated blood once or more within the past year		I have donated blood at least once within the past few years		I have donated blood once or more within the past year	
Blood type:									
Blood type O		0.499**	0.495**	0.454**	0.530**	0.483**	0.475*	0.419*	0.507**
		(0.208)	(0.242)	(0.225)	(0.268)	(0.217)	(0.251)	(0.222)	(0.258)
Blood type B			-0.104		-0.158		-0.096		-0.125
			(0.289)		(0.460)		(0.278)		(0.450)
Blood type AB			0.175		0.724**		0.133		0.721**
			(0.269)		(0.315)		(0.266)		(0.321)
Excluded respondents:		We excluded the respondents who answered: "I have donated blood before, but I have not donated within the past few years because of my health."				We excluded the respondents who answered: "I have donated blood before, but I have not donated within the past few years because of my health," or "I want to donate blood, but I cannot because of my health."			
Number of observations		1,077				930			

Note: *** p < 0.001, ** p < 0.05, and * p < 0.1. The baseline in columns (1)(3)(5)(7) is blood type A, B, or AB. The baseline in columns (2)(4)(6)(8) is blood type A. All the model specifications include covariates of socio-economic status, health status, and preferences and psychological attributes.

Table 6. Further results (3).

Logistic regression (coefficient)	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	I have donated blood at least once within the past few years			I have donated blood once or more within the past year		
Blood type:						
Blood type O	0.474**	0.487**	0.471*	0.462*	0.453*	0.587**
	(0.213)	(0.205)	(0.243)	(0.237)	(0.241)	(0.271)
Blood type B			-0.088			0.034
			(0.291)			(0.479)
Blood type AB			0.063			0.681**
			(0.244)			(0.282)
Additional covariates:						
Annual average of the inventory ratio of stocks of blood groups for each respondent's prefecture	×	×	×	×	×	×
Annual standard deviation of the inventory ratio of stocks of blood groups in each respondent's prefecture		×	×		×	×
Number of observations	1,311					

Note: *** p < 0.001, ** p < 0.05, and * p < 0.1. All the model specifications include covariates of socio-economic status, health status, and preferences and psychological attributes. The baseline in columns (1)(2)(4)(5) is blood type A, B, or AB. The baseline in columns (3)(6) is blood type A.

Supplementary information: Questions and variables

The following are survey questions for capturing respondent's health status, preferences, and psychological characteristics. We add explanations for how we created the variables from the answers (if necessary).

1. Health status

a) *BMI:* What is your height and weight?

Height: _____centimeters, Weight: _____kilograms

Note: We calculated out the indicator of BMI, using the following equation:

$$\text{BMI} = \text{Weight in kilograms} \div (\text{Height in meters})^2$$

b) *Subjective health status:* How would you describe your current health status: Is it excellent, very good, good, fair, or poor?

1. Excellent
2. Very good
3. Good
4. Fair
5. Poor

c) *Mental illness:* How true for you is each of the following statements? Answer for each on a scale from 1 to 5, where “1” means “it is particularly true for you” and “5” means “it doesn't hold true at all for you.”

- I have been feeling stressed lately
- I have been feeling depressed lately
- I haven’t been sleeping well lately
- I have been feeling lonely lately

Note: First, we reconstructed the answers on the opposite scale from 1 to 5, where “1” means “it doesn't hold true at all for you” and “5” means “it is particularly true for you.” Second, we calculated out the indicator of mental illness, by summing up the answers for the fours statements and dividing the value by 4.

2. Preferences

a) *Time discounting factor:* Suppose that you are to receive money from someone. You can either choose to receive the money today, or 7 days from today, but the amounts will be different. Compare the amounts and dates below in Option “A” and Option “B,” and indicate which option you prefer for each of the nine choices.

Option A	or	Option B	Which ONE do you prefer?	
Receive today		Receive 7 days from today	Option A	Option B
JPY 3,005		JPY 3,014	A	B
JPY 3,003		JPY 3,297	A	B
JPY 3,008		JPY 3,037	A	B
JPY 3,000		JPY 3,000	A	B
JPY 3,005		JPY 5,951	A	B
JPY 3,009		JPY 3,068	A	B
JPY 3,001		JPY 3,119	A	B
JPY 3,002		JPY 2,996	A	B
JPY 3,008		JPY 3,011	A	B

Notes: As similarly in previous studies[1], we asked the respondents to choose between two options, “A” and “B.” For example, we asked them to choose between “A”—receiving today JPY 3,005, and “B”—receiving in 7days JPY 5,951. From each situation, we obtained response data, which revealed the switching point, where each respondent switched his or her choice from option “A” to “B.” At the switching point, the today’s option is equivalent to the delayed option.

We calculate out time discounting factor using the following way. We first take the average of the two monetary amounts for Option A at the point of switching from Option B to Option A. Second, we divide the numerator by the average of the two monetary amounts for Option B at the switching point.

b) *Absolute risk aversion:* Suppose that there is a "speed lottery" with a 50% chance of winning JPY 100,000 (USD 1,000). If you win, you receive a prize right away. If you lose, you receive nothing. How much would you spend to buy a ticket for this lottery? Choose Option "A" if you would buy the ticket at that price, or choose Option "B" if you would not.

Price of the "speed lottery" ticket	Which ONE do you prefer?	
	Option A (buy the "speed lottery" ticket)	Option B (DO NOT buy the "speed lottery" ticket)
JPY 10	**A**	**B**
JPY 2,000	**A**	**B**
JPY 4,000	**A**	**B**
JPY 8,000	**A**	**B**
JPY 15,000	**A**	**B**
JPY 25,000	**A**	**B**
JPY 35,000	**A**	**B**
JPY 45,000	**A**	**B**
JPY 50,000	**A**	**B**

Notes: we use answers for a hypothetical question related to a speed lottery and measure a respondent's risk tolerance from absolutely risk neutral to absolutely risk averse. This approach to elicit risk aversion using a hypothetical lottery is also taken by previous studies[2,3,4].

Specifically, this question asks respondents about their willingness to pay (π_1) for a hypothetical lottery with a 50 percent chance of winning JPY 100,000 (USD 1,000) or nothing otherwise. Since the expected value of the lottery is JPY 50,000

(USD 500), we interpret this to mean that a respondent whose π_1 is lower than the expected value is more risk averse. We calculate the indicator of absolute risk aversion using the following equation:

$$\text{Absolute Risk Aversion} = \frac{50{,}000 - \pi_1}{0.5(0.5 \times 100{,}000^2 - 2 \times 0.5 \times 100{,}000 \times \pi_1 + \pi_1^2)}$$

3. Psychological characteristics

a) *Altruism, trust, and belief in fortune-telling based on blood-types:* To what extent do you agree with each of the following statements? Answer on a scale from 1 to 5, where "1" means "you agree completely" and "5" means "you disagree completely." Of course, you may choose any number in between.

- *Altruism:* I feel happy when I do a good deed that I think benefits others (such as picking up trash in a park)
- *Trust:* In general, most people are trustworthy
- *Belief in fortune-telling based on blood-types:* A person's blood type indicates their character

Note: For our analysis, we reconstructed the answers on the opposite scale from 1 to 5, where "1" means "you disagree completely" and "5" means "you agree completely."

b) *Reciprocity, conformity, social norm, and religious beliefs:* How true for you is each of the following statements? Answer for each on a scale from 1 to 5, where “1” means “it is particularly true for you” and “5” means “it doesn't hold true at all for you.”

- *Positive reciprocity 1:* If someone does me a favor, I am prepared to return it
- *Positive reciprocity 2:* I go out of my way to help somebody who has been kind to me before
- *Positive reciprocity 3:* I am ready to undergo personal costs to help somebody who helped me before
- *Negative reciprocity 1:* If somebody offends me, I will offend him/her back
- *Negative reciprocity 2:* If somebody puts me in a difficult position, I will do the same to him/her
- *Negative reciprocity 3:* If I suffer a serious wrong, I will take revenge as soon as possible, no matter what the cost
- *Conformity:* Behaving similarly to people around me makes me feel comfortable
- *Social norm:* I never cut into a line of people
- *Religious beliefs:* I am deeply religious

Note: We reconstructed the answers on the opposite scale from 1 to 5, where “1” means “it doesn't hold true at all for you” and “5” means “it is particularly true for

you." In addition, we respectively calculated out the indicator of positive or negative reciprocity, by summing up the answers for the three statements and dividing the value by 3.

c) *Big 5 personality traits:* Please circle ONE applicable number next to each statement to indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

I see myself as;	Disagree Strongly	Disagree Moderately	Disagree A Little	Neither Agree Nor Disagree	Agree A Little	Agree Moderately	Agree Strongly
A: Extraverted, enthusiastic	1	2	3	4	5	6	7
B: Critical, quarrelsome	1	2	3	4	5	6	7
C: Dependable, self-disciplined	1	2	3	4	5	6	7
D: Anxious, easiliy upset	1	2	3	4	5	6	7
E: Open to new experiences, complex	1	2	3	4	5	6	7
F: Reserved, quiet	1	2	3	4	5	6	7
G: Sympathetic, warm	1	2	3	4	5	6	7
H: Disorganized, careless	1	2	3	4	5	6	7
I: Calm, emotionally stable	1	2	3	4	5	6	7
J: Conventional, uncreative	1	2	3	4	5	6	7

Notes: The Big 5 personality traits are a unifying framework comprising five basic characteristics: *extroversion, agreeableness, conscientiousness, emotional stability, and openness to experiences*. The 2017 PPSOU survey included the questions of Ten Item Personality Inventory (TIPI), which was developed by Gosling, Rentfrow, and Swan[5], and was translated into Japanese by Oshio, Abe, and Cutrone[6].

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