Adding Nudge-based Reminders to Monetary Incentives for Promoting Rubella Antibody Testing and Vaccination*

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Abstract

We study effects of combining financial incentives with nudges to promote rubella antibody testing and vaccination. In FY2019, the Japanese government began providing vouchers for free testing and vaccination to men aged 40–57 years. Vouchers were mailed to 40–46-year-old men in FY2019. While those aged 47–57 received vouchers in FY2020, they could obtain vouchers and receive testing and vaccination in FY2019 through applying. Focusing on this policy distinction, we conduct a late-FY2019 online field experiment with Japanese 40–57-year-old men. We randomly send nudge-based reminder messages recommending antibody testing and vaccination, and track self-reported behavior until the end of FY2019. One nudge-based reminder with an altruistic message on fetal harm through infection from men to pregnant women significantly promotes antibody testing and vaccination among those who have already received vouchers as a financial incentive. For those who must apply for vouchers, nudge-based reminders have no promoting effect.

JEL classification: D90, I12, I18

Keywords: Rubella; Vaccination; Antibody Test; Text Reminders; Free Vouchers.

1 Introduction

Vaccination is an essential countermeasure against infectious diseases, including COVID-19, seasonal influenza, and rubella. Vaccination enables individuals to voluntarily acquire antibodies and immunity. They can thus prevent the onset of infectious diseases and even infection itself.

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Vaccination has positive externalities and benefits for the vaccinated individuals, surrounding community, and society. For example, vaccination lowers the risk of developing an infectious disease or becoming severely ill. It also reduces the risk of the health-care delivery system becoming strained. Vaccination with infection-preventive effects, including the rubella vaccine, reduces the risk of infection for the vaccinated and the risk of spreading the infection. Vaccination can contribute to social stability during pandemics and the acquisition of herd immunity via these positive externalities.

However, economic theories suggest that vaccination rates may not reach the socially optimal level due to the positive externalities (Brito et al. 1991, Francis 1997, Stiglitz 2000). With the externalities, the marginal individual benefit of vaccination becomes lower than the marginal social benefit, and this feature discourages vaccination by those with selfish motives. Even if people are altruistic and gain utility from the social benefits of their vaccinations reducing the infection probability of others, they still have an incentive to free-ride on others' vaccinations and not receive the vaccines themselves, because the infection probability is lowered by the others' vaccinations. We find empirical studies reporting that others' increased vaccination rates reduce the likelihood of people being vaccinated (Hershey et al. 1994, Ibuka et al. 2014).

To overcome the challenge of vaccine coverage not achieving socially optimal levels, governments have used a variety of interventions, including monetary and non-monetary interventions (nudges in behavioral economics). Many countries subsidize COVID-19 vaccinations, making them free. Some local governments set subsidies above and beyond the amount required to make vaccination free, giving vaccinated people the right to join a lottery, and recent studies have confirmed the effectiveness of these measures (Barber & West 2022, Brehm et al. 2022). Nudge-based interventions include recommending a predetermined vaccination date, sending a reminder message, and changing message wording (Chapman et al. 2010, Sasaki et al. 2022, Yokum et al. 2018).[1]

This study explores the possibility of combining financial incentives with nudges in vaccination and antibody acquisition. Many previous studies estimated or compared these two as independent or substitutive. However, Richard Thaler and Cass Sunstein define nudges as "an aspect of choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler & Sunstein 2009, p.6). As mentioned, "without significantly altering economic incentives," nudges include devising wordings and expressions for existing financial incentives. They further explain that nudges adjust the salience of financial incentives so that the incentives have the expected effect.[2] In other words, nudges and financial incentives are complementary in their original definition.

Recently, more studies have examined the two combinations in non-vaccination contexts. For example, Burtch et al. (2018) found that combining a nudge emphasizing social norms with a financial incentive

[1] In the context of vaccines for seasonal influenza and COVID-19, some studies found that messages stimulating people's ownership, "A vaccine dose is reserved for you," promotes their vaccination uptake (Dai et al. 2021, Milkman et al. 2021).

[2] They mention "iNcentives," "Understand mappings," "Defaults," "Give feedback," "Expect error," and "Structure complex choices" as the six principles of "NUDGES" for creating a good choice architecture. The first principle, "iNcentives," explains the complementary relationship between financial incentives and nudges.

improves the length and quality of online market reviews more than either intervention alone. Thorndike et al. (2016) reported similar results regarding healthy food choices in a hospital cafeteria. Meanwhile, in the study of Kullgren et al. (2014), combining nudges and financial incentives does not increase outdoor exercise among older adults. Furthermore, Pellerano et al. (2017) reported that adding a financial incentive to a social norm nudge undermines the energy-saving effect of the nudge-based intervention alone.[3] We can expect relatively large facilitating effects in combining nudges and financial incentives, while in practice, the effects' direction and extent depend on contexts. Before applying the combinations to policies, we must confirm their effects empirically.

To the best of our knowledge, no study has focused on the combination of financial incentives and nudges in the context of vaccination. As previously stated, many previous studies have separately estimated the effects of financial incentives (Banerjee et al. 2010, Barber & West 2022, Barham & Maluccio 2009, Brehm et al. 2022) and nudges (Dai et al. 2021, Chapman et al. 2010, Milkman et al. 2021, Sasaki et al. 2022) as stand-alone measures. Although some studies focused on both, they compared the effects of the two interventions, examined which is larger, and seemed to regard the two as substitutive. For example, Bronchetti et al. (2015) conducted a randomized controlled trial with college students in Pennsylvania and found that a financial incentive increases their seasonal influenza vaccination rate. In this experiment, a peer-related nudge increases vaccine information exposure but does not increase vaccination rates. Campos-Mercade et al. (2021) reported that a €20 financial incentive increases vaccination rates by 4 percentage points (pp) in a Swedish field experiment and emphasized that some nudge-based interventions have little promotional effect.

We add new insights to the literature on the combination of financial incentives and nudges, by focusing on Japan's policy on rubella antibody testing and vaccination and conducting a nationwide online field experiment. We estimate the effect of providing nudge-based messages in each of the situation where people can easily obtain financial incentives and where they must incur additional transaction costs to obtain the incentives. In the former situation, financial incentives and nudges are more closely combined.

In Japan, men born between April 2, 1962, and April 1, 1979 (aged 40–57 years as of 2019) have historically been excluded from routine rubella immunization (see Section 2 for details). Consequently, men in this age group have lower antibody prevalence than their female counterparts. Therefore, Japan has yet to achieve herd immunity against rubella. Unlike flu and COVID-19 vaccinations, rubella vaccine-induced immunity is long-lasting, and people without antibodies must receive a single vaccination to achieve herd immunity against rubella. The Ministry of Health, Labor, and Welfare (MHLW) then initiated an additional measure for routine rubella vaccination in FY2019 by mailing vouchers covering the costs of the rubella antibody test (approximately 5,000 JPY, which is equal to 45 US dollars) and vaccination (approximately 10,000 JPY) to

[3]Besides field experimental studies, some laboratory experimental studies have also tested the effects of the combination; Chen et al. (2021) show that combining a financial incentive with an informational nudge induces cooperative behaviors in a prisoner's dilemma game among intrinsically motivated individuals.

men aged 40–57 years, to confirm whether they have an antibody and then encourage vaccination for those without it.[4]

Free vouchers were distributed progressively through local governments: vouchers were mailed to men aged 40–46 in FY2019 and those aged 47–57 years in FY2020. Men aged 47–57 years had to apply to their local government to receive the vouchers during FY2019. That is, in FY2019, men aged 40–46 years received the free vouchers as financial incentives by default, whereas men aged 47–57 years had to opt-in to receive the vouchers, incurring transaction costs.

We conducted an online field experiment in February–March 2020 (at the end of FY2019) with men aged 40–57 years living throughout Japan, including the aforementioned two age groups. In this study, we use a randomized controlled trial (RCT) and send reminders with nudge-based messages to encourage the uptake of antibody testing and vaccination. We ascertain their intentions to receive the test and vaccine, and their self-reported behaviors to receive them in a follow-up survey.

By focusing on the sample aged 40–46 years, we can capture the effects of providing additional reminders with nudged messages in one situation where they already obtained the vouchers as financial incentives. Meanwhile, we can capture the effects of providing reminders in another situation where they must incur transaction costs and opt-in to obtain financial incentives with the sample aged 47–57 years. In other words, this study focuses on the combination of nudges and the costs of acquiring financial incentives. The approach of reducing these costs by delivering vouchers to the target population is observed in a variety of policy issues. Therefore, exploring this realistic combination of financial incentives and nudges is important from a policy perspective.

In each of the group who obtain the financial incentive by default and the other group who needs to opt-in, our experiment randomly offers either of a control reminder message with no nudge and six nudge-based reminder messages. The main finding reveals that a reminder with an altruistic message is effective in promoting antibody testing and vaccination behaviors only in the former group. This altruistic message emphasizes the negative impact on newborns caused by infection from the men to pregnant women.

This study contributes to the literature exploring the conditions under which nudges work effectively. Evidence for the effectiveness of nudges has been mixed in recent years; according to a meta-analysis by DellaVigna & Linos (2022), nudges are not large in reality, and their effectiveness depends on various conditions, including topics and channels. This study focuses on the combination of financial incentives and nudges, which have often been treated as mutually substitutive measures, and demonstrates that nudges can be effective when given to a group that has already obtained financial incentives. This result is also consistent with the original definition of the two being complementary.

This research also contributes to acquiring global herd immunity against rubella; according to the World

[4] We assume 1 USD = 110 JPY.

Health Organization, 101 of 194 countries have not yet eliminated rubella, accounting for 52% (Zimmerman et al. 2022). Specifically, in the Eastern Mediterranean, South-East Asia, and Western Pacific regions, the proportion of countries that have not yet achieved herd immunity is high. As cross-border traffic increases toward the end of the COVID-19 pandemic, achieving herd immunity against rubella will become increasingly important for the remaining countries. Japan is extremely close to achieving herd immunity. The nudge-based strategy used in such a country to acquire that last mile will be useful for many other countries in the future.

The rest of this paper is structured as follows. Section 2 provides an overview of rubella in Japan. Section 3 describes the experimental design and Section 4 presents the results. Finally, Section 5 discuss results and concludes the paper.

2 Background of Rubella Vaccination in Japan

Rubella is a highly contagious disease spread through droplet transmission. The most common symptoms are fever and rashes, but the disease is rarely severe.[5] The most serious problem is that women infected with rubella during early pregnancy may have children with congenital rubella syndrome (CRS), which includes eye and ear defects. Because the spread of rubella tends to increase the CRS incidence, the Japanese government has designated rubella as a disease requiring immunization to prevent its spread. According to Kinoshita & Nishiura (2016), Japan can obtain herd immunity against rubella if the antibody prevalence exceeds 90% in all generations.[6]

However, due to low antibody prevalence among men in their 40s and 50s, Japan has not achieved herd immunity to rubella. Figure 1 plots the prevalence of rubella antibodies by age and gender from the National Institute of Infectious Diseases (NIID) "2018 Infectious Disease Epidemic Prediction Survey." The antibody prevalence among men aged 39–56 years (as of 2018) is approximately 81.5%, which is lower than that of women of the same generation (about 97.9%) and other generations because they have not received routine rubella vaccination and have not had less opportunity to infect naturally.[7] Thus, influx of virus of Southeast Asian origin caused rubella epidemic, mainly among males with relatively low antibody prevalence in 2013 and 2018 (National Institute of Infectious Diseases 2019).[8] As cross-border traffic is increasing, achieving

[5]According to the NIID, subclinical transmission of rubella (the state in which a person is infected but has no symptoms) occurs in approximately 15–30% of cases. Fever is observed in approximately 50% of patients. Adults may also experience transient arthritis (5–30%). Rarely, complications such as thrombocytopenic purpura (0.02–0.03%) and acute encephalitis (0.01–0.03%) may require hospitalization (https://www.niid.go.jp/niid/ja/kansennohanashi/430-rubella-intro.html. Japanese. Access date: September 22, 2023).

[6]According to Plans-Rubió (2012), antibody prevalence of 83% to 95% achieves herd immunity against rubella. Nishiura et al. (2015) found that the antibody prevalence for herd immunity is 83.6%.

[7]The prevalence of antibodies in men and women aged 57 and older is 91.1% and 89.3%, respectively. Despite not having received routine vaccination, men and women aged 57 and older grew up during a time when rubella was common and people are likely to have antibodies from natural infection. The antibody prevalence of men and women aged 38 years and younger is 91.3% and 94.0%, respectively. They have had at least one dose of rubella vaccine administered as part of routine immunization.

[8]In the 2018 epidemic, U.S. CDC advised pregnant women to travel to Japan (The Japan Times, October

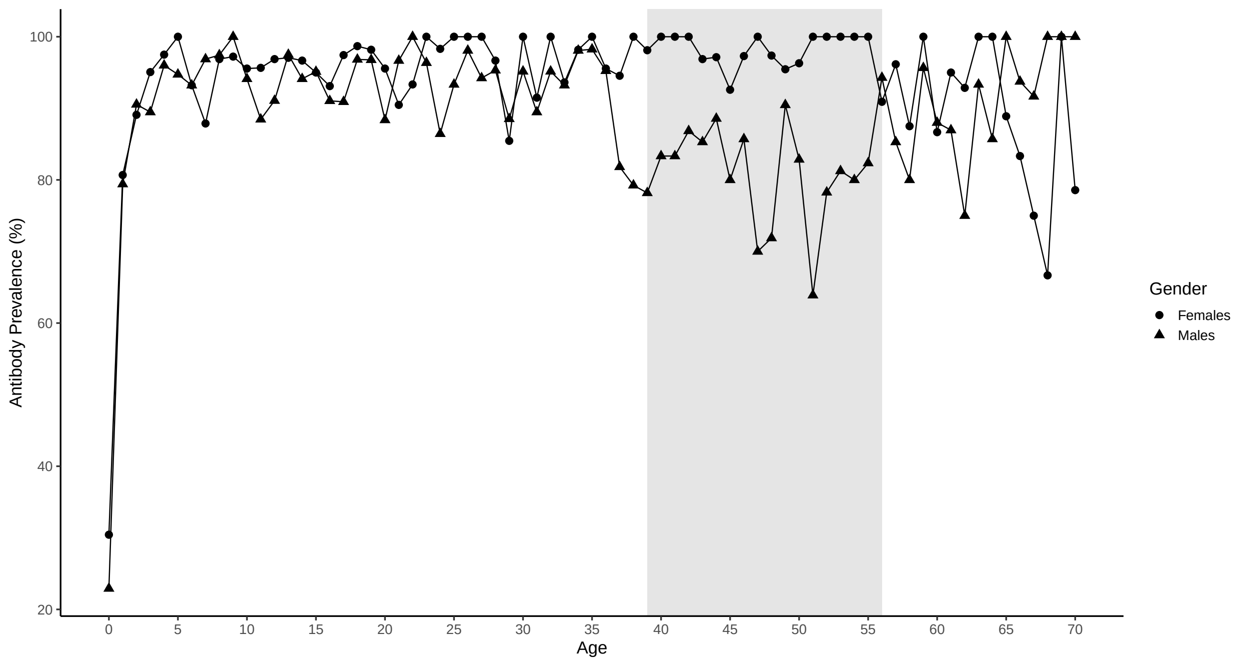

Figure 1: Percentage of Rubella Antibody Carriers at Each Age by Gender. Data: NIID "2018 National Epidemiological Surveillance of Vaccine-Preventable Diseases (NESVPD)."

herd immunity against rubella becomes increasingly important for Japan.[9]

To achieve herd immunity, Japan must raise the antibody prevalence among men in their 40s and 50s from 80% to 90%. To achieve this goal, MHLW has provided the rubella vaccine as an additional free routine immunization for men aged 40–57 years (as of 2019) between April 2019 and March 2022.[10] For efficient utilization of vaccination, eligible men must first get antibody testing. Men who have a negative test can then be vaccinated against rubella.

Following the Immunization Act, eligible men can receive free antibody testing and vaccinations. MHLW requested local governments to send free vouchers for a rubella antibody test and vaccine to eligible men over a three-year period. Concerning whether they automatically receive the voucher in FY2019, we can divide eligible men into the following two age groups:

1. 40–46 years old: they automatically received the free voucher in FY2019;
2. 47–57 years old: they automatically received the free voucher after FY2020 but had to apply to obtain it in FY2019.

24, 2018. https://www.japantimes.co.jp/news/2018/10/24/national/science-health/u-s-cdc-warns-pregnant-women-traveling-japan-amid-rubella-outbreak/. Access date: 2023/9/22).

[9]If transmission to pregnant women is the most important issue, one might think that vaccinating pregnant women would be the optimal strategy. However, Japan has already implemented measures for pregnant women in advance of the 2019 vaccination campaign. Pregnant women (average age 30) have received at least one vaccination. In addition, since 2014, pregnant women and women who want to become pregnant, including their partners, have been offered free antibody testing. However, during the 2013 and 2018 epidemics, some infants were affected by CRS. Therefore, to eradicate CRS, interventions for pregnant women alone are not sufficient; interventions to achieve hard immunity are needed.

[10]More precisely, eligible men were born between April 2, 1962, and April 1, 1979.

Thus, transaction costs for the monetary incentives in FY2019 differ between the two age groups. In particular, 40-to-46-year-old men have no transaction costs because they obtained monetary incentives by default in the form of free vouchers in FY2019 (*default incentive* group). However, 47-to-57-year-old men have high transaction costs such as travering cost to a city hall because they must contact their local government to obtain the free vouchers in FY2019 (*opt-in incentive* group).[11]

Although men aged 40–46 years automatically received monetary incentives, the uptake rate of antibody testing with vouchers remained as low as 18% as of January 2020.[12] Given adequate financial incentives, non-monetary interventions should be considered to increase antibody testing. Therefore, we developed reminders with nudge-based text reminders for those who were not tested and vaccinated. Using a nationwide online survey, we tested how well those reminders improve antibody testing and vaccination rates among default voucher recipients (and the effect on those who incur a transaction cost to obtain them).

3 Nationwide Online Survey Experiment

In collaboration with MHLW, we commissioned MyVoiceCome Co. Ltd. to conduct two nationwide online surveys at the end of FY2019. On February 15–17, 2020, we conducted the first survey (wave 1) of 4,200 Japanese men aged 40–59 years living throughout Japan. Wave 1 randomizes seven text reminders to test how they affect antibody testing and vaccination intentions. On March 17–25, 2020, we surveyed wave 1 respondents again for the second survey (wave 2). We received responses from 3,963 individuals (attrition rate = 5.64%).[13] Wave 2 aims to test how the randomly assigned text reminders in wave 1 affect the actual uptake of antibody testing and vaccination. We obtained prior approval from the IRB of the Graduate School of Economics, Osaka University (approval number: R020114) for conducting the RCT on the online survey.

3.1 Wave 1: Treatments and Outcome Variables on Intention

We randomly sent one of the text reminders in Table 1. The *MHLW (Control)* message is the control. Using this message, MHLW promotes antibody testing and rubella vaccination against rubella on its website (business-as-usual control). We developed six additional text reminders based on the MHLW (Control) message to explore what elements to use and how to emphasize them. Recent behavioral science research

[11] One local government has posted the application forms on its website. To obtain a vaccination ticket, eligible men must download the forms from the website, complete them, and either mail them to the local government or visit the city hall in person. The cost of obtaining the documents and traveling to the city hall seems to be significant.

[12] More than half of eligible men are 40–46 years old (6.46 million). They received the free vouchers from April 2019 to March 2020. According to interviews conducted by the MHLW, approximately 96% of local governments planned to send them by October 2019. The cumulative number of antibody tests using vouchers through January 2019 was 1.17 million. We calculate antibody testing uptake by dividing the cumulative number of antibody tests using vouchers up to January 2019 (1.17 million) by the population of 40-to-46-year-old men (6.46 million).

[13] The seven experimental arms have similar attrition rates. We linearly regress an attrition dummy on treatment group dummies. F-test for joint null hypothesis is statistically insignificant (F-value = 1.434; p-value = 0.197).

Table 1: List of Text Message Reminders

Message	Contents		Age (as of Apr 2019) 39	40–46	47–56	57–59	All
MHLW (Control)	Dear all men born between 1962 and 1979. Get rubella antibody testing and be vaccinated to protect yourself and the upcoming generation!	N	20	210	321	49	600
MHLW (Age)	Dear men in their 40s and 50s (all men born between 1962 and 1979). Get rubella antibody testing and be vaccinated to protect yourself and the upcoming generation!	N	23	205	309	63	600
Altruistic	Dear men in their 40s and 50s (all men born between 1962 and 1979). If you get a pregnant woman infected with rubella, she may give birth to a child with a serious disability. Get rubella antibody testing and be vaccinated!	N	24	214	296	66	600
Selfish	Dear men in their 40s and 50s (all men born between 1962 and 1979). Rubella infection in adult men may have serious complications such as encephalitis and thrombocytopenic purpura. Get rubella antibody testing and be vaccinated!	N	16	225	302	57	600
Social Comparison	Dear men in their 40s and 50s (all men born between 1962 and 1979). Compared to other generations, more than twice as many people in your generation can get rubella because one in five of you does not have rubella antibodies. Get rubella antibody testing and be vaccinated!	N	18	204	321	57	600
Deadline	Dear men in their 40s and 50s (all men born between 1962 and 1979). The voucher for a free rubella antibody test and vaccine is valid on March 31, 2020. Get rubella antibody testing and be vaccinated!	N	18	216	299	67	600
Convenient	Dear men in their 40s and 50s (all men born between 1962 and 1979). You can use your coupon for a rubella antibody test at a growing number of workplaces and government agencies, in addition to your usual health examinations. Get rubella antibody testing and be vaccinated!	N	19	213	307	61	600

has increasingly investigated the efficacy of multiple candidate messages (e.g., Dai et al. 2021, Milkman et al. 2021), similar to this study.

The six treated text reminders alter the MHLW (Control) message to (1) a simple age expression (first sentence) and (2) message content (following sentences). In addition to the precise target age for the additional rubella measures, the *MHLW (Age)* message includes the simple phrase "men in their 40s and 50s," which helps the reader understand if they are eligible for vaccination and pay attention to the message. The MHLW (Age) message only changed the age expression; the message's content is identical to the control. The other five messages both add simplified age expressions and change message content based on behavioral economics.

The *Altruistic* message describes how one's infection can harm others, particularly pregnant women and their children. As previously stated, vaccination has positive externalities. In the case of rubella, having antibodies through vaccination prevents infection in pregnant women, thus protecting their children. The Altruistic message is the inverse of this positive externality, emphasizing the negative externality of not being vaccinated. This message is intended to help altruistic readers imagine the negative externalities caused by the infection and change their behavior.[14]

The *Selfish* message and *Social Comparison* message aim to change behavior by increasing the importance of having rubella antibodies. The Selfish one describes in detail the damage caused by the infection to the individual, making it easier for the reader to imagine it. Meanwhile, the Social Comparison informs the reader that antibody prevalence is low and reminds them that they are susceptible to infection. This message can help people avoid underestimating the likelihood of infection and undervaluing vaccination.

The *Deadline* message and *Convenient* message describe detail system of the 2019 vaccination campaign. Deadline emphasizes that the FY2019 vouchers are valid until the end of March. This message aims to prevent people from postponing antibody testing and vaccination due to the present bias, which is one of behavioral economics' key findings. Meanwhile, Convenient states that some people can get antibody testing as part of a regular health examination and emphasizes its convenience. This message aims to reduce the subjective cost of antibody testing.

We employed stratified randomization. The survey firm divided respondents into four age groups (40–44, 45–49, 50–54, and 55–59) and equally assigned messages within each stratum. The sample size for each group is 1,050, with 150 for one experimental arm within each group. Thus, the sample size for one experimental group is 600.[15]

In wave 1, after viewing a randomly assigned message, participants expressed their intention to get antibody

[14] We define an altruistic person as someone who considers social benefits, including externalities.

[15] The ages shown in Table 1 are as of April 2019, calculated using the year and month of respondents' birth. Men aged 40–56 years as of April 2019 are eligible for the MHLW's additional measures. Those aged 40–46 years automatically receive coupons for the first year. We assume that those born in April have not yet reached their birthday. Also, some men aged 39 years as of April 2019 were 40 years old at the time of the survey.

testing and vaccinated on a 5-point Likert scale (5 = definitely yes; 1 = absolutely no). The question of willingness to take antibody testing is, “Are you willing to take an antibody test for rubella now?” Meanwhile, the intention to get vaccinated question asks, “If the antibody testing reveals that you have no antibodies, are you willing to get vaccinated?” We create a binary variable taking the value of 1 if the participant responds 4 or 5 for each question and use it as the outcome variable for intentions.

Note that, before reading a randomly assigned message, participants were asked about economic preferences such as altruistic preference, daily health behaviors, rubella knowledge, and the willingness to pay for the rubella vaccination. At the end of survey, they were asked about socio-economic status. We use these variables to perform regressions and balance checks and to explore mechanisms. See Table 5 in Appendix C for variables used in regression analysis and balance checks.

3.2 Wave 2: Outcome Variables on Behavior

Wave 2 investigates actual antibody testing and vaccination behavior since wave 1. We present exact questions and choices about antibody testing and vaccination in Appendix A. We create a binary variable taking 1 if the respondent has taken antibody testing since the end of wave 1.

To receive rubella vaccination through routine immunization, eligible men must first undergo antibody testing. However, they may have been vaccinated against rubella at their own expense without having their antibodies tested. To eliminate this possibility, we create a binary variable taking 1 if respondents have been tested and vaccinated since the end of wave 1. Then, we use it as the outcome variable on vaccination coverage.

Although self-reported behavioral measures may be subject to the experimenter demand effect and social desirability bias, the design and analysis of the current study addresses these biases in the following two ways. First, because this study is a randomized controlled trial and if these biases exist to the same extent in each group, they are not fatal to the identification of treatment effects. Second, even if these biases are heterogeneous across groups, our analysis directly controls for respondents’ psychological factors potentially associated with these biases (following social norm, accepting bad behavior in anonymous conditions) and then estimates treatment effects.

4 Results

4.1 Study Population

Our target population consists of men who did not have antibody testing or vaccinations. We exclude respondents who stated in wave 1 that they had already received either antibody testing or vaccination. In wave 2, we again asked respondents whether they had already received either testing or vaccination until wave 1 because they may check vaccination history after wave 1. Thus, when estimating the effect on behavior, we exclude respondents who stated in either wave that they had received either antibody testing or vaccination prior to wave 1.

Our aim is to estimate the effect of text reminders in situations where men received monetary incentives as vouchers by default and where they had to incur transaction costs to obtain them. To accomplish this, we create a subsample of men aged 40–46 years and another of men aged 47–56 years. Men in the former subsample automatically received the free vouchers (*default incentive* group). Meanwhile, men in the latter subsample received no incentives or required a costly procedure to get it (*opt-in incentive* group). Thus, in the *default incentive* group, monetary incentives and text message reminders are more closely combined than in the *opt-in incentive* group.

4.2 Effect of Text Reminders on Intentions

This subsection estimates the effect of text reminders on intentions. We find that individuals' observable characteristics are balanced across experimental arms in both *default incentive* and *opt-in incentive* group (See Table 6 and 7 in Appendix C). Thus, we first report the difference-in-mean test (t-test) for each group.

4.2.1 Difference-in-mean Test

We show the proportion of intention for antibody testing in each experimental arm for the *default incentive* group (Panel A) and the *opt-in incentive* group (Panel B) in Figure 2. The results show that, in the *default incentive* group only, the Altruistic message increases the intention for antibody testing by a statistically significant 14.3 pp compared to the MHLW (Control) message (35.1% in the Altrustic message group versus 20.8% in the MHLW (Control) message group). On the other hand, in the *opt-in incentive* group, the Altruistic message increased intention by 5.3 pp, which is not statistically significant (32.9% in the Altrustic message group versus 27.6% in the MHLW (Control) message group). The Altruistic message effects could differ between the two groups, as the regression analysis also suggests later.

Figure 3 depicts the proportions of intention for vaccination for the *default incentive* group (Panel A) and the *opt-in incentive* group (Panel B). Results show that in the two incentive groups, most text reminders, including the Altruistic messages, do not statistically significantly increase vaccination intentions compared to NHLW (control). In the *opt-in incentive* group, the Social Comparison message may lower vaccination intention than the MHLW (Control) message (44.6% in the Social Comparison message group versus 52.8% in the MHLW (Control) message group).[16]

[16]Free-riding may explain why the Social Comparison message content does not increase intention. The Social Comparison message emphasizes that "one in five people do not have antibodies." Conversely, four out of five individuals have antibodies. The readers of such a message may have believed that even if they lacked rubella antibodies, the likelihood of infection would

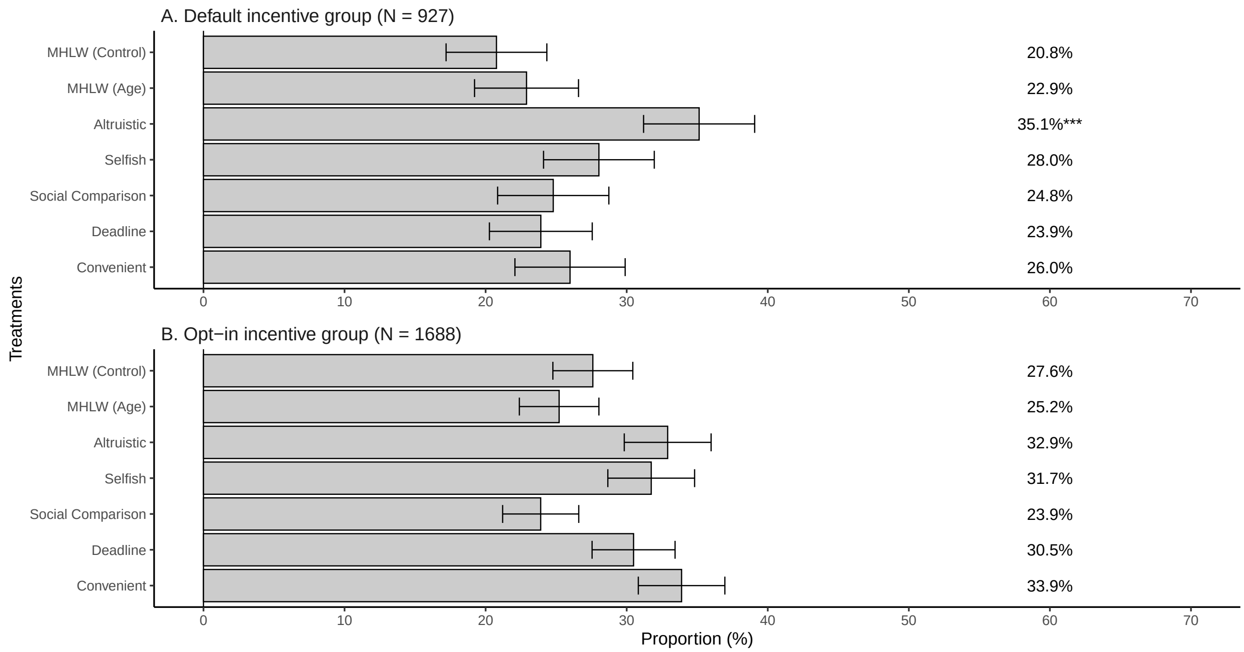

Figure 2: Effect of Text Reminders on Intention for Antibody Testing Notes: Numbers in the figure indicate the proportion of each experimental arm. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Note that the intention ratio of vaccination in all experimental arms is higher than that of antibody testing in both incentive groups. This result may be explained by the stimulus of the question eliciting the vaccination intention. We asked respondents to report their willingness to vaccinate if they did not have antibodies. This condition may strongly stimulate the need for vaccination. Thus, when assessed by actual behavior, the results may differ.

4.2.2 Regression Analysis

Since age determines whether eligible men received the free vouchers automatically in FY2019, the different effect of text reminders for two groups is influenced by the presence or absence of monetary incentives, and by the differences of other dimentions (especially, age) between the two groups. This motivates us to estimate a following linear probability model:

$$\begin{aligned} Y_{ij} =& \alpha + \sum_j \beta_j \text{Message}_j + \sum_j \gamma_j (\text{Message}_j \times \text{Opt-in}_i) + \delta \text{Opt-in}_i \\ &+ \lambda X'_{ij} + \epsilon_{ij}, \end{aligned} \tag{1}$$

be low because 80% of the population possesses them. When eligible men were required to undergo costly procedures to receive free vouchers, this belief may have made vaccination less beneficial.

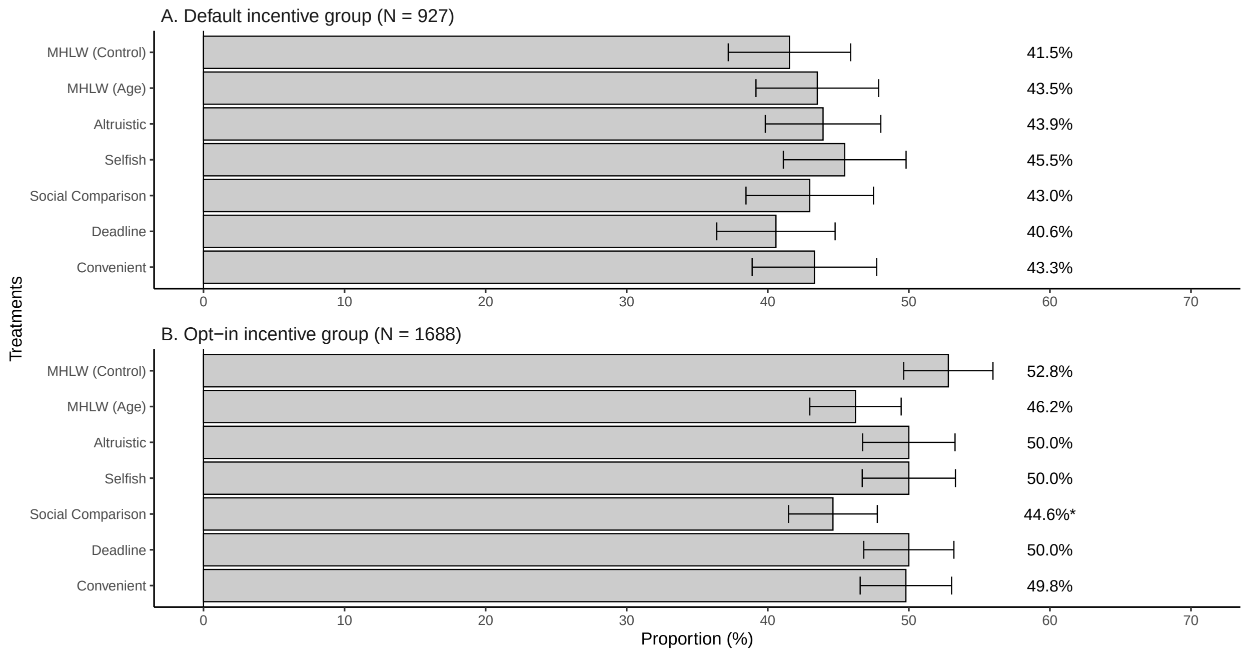

Figure 3: Effect of Text Reminders on Intention for Vaccination Notes: Numbers in the figure indicate the proportion of each experimental arm. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

where Message_j is a treatment dummy (the reference group is MHLW (Control) message), Opt-in_i is a binary variable indicating the *opt-in incentive* group (47–56 years old), and X is a set of covariates including age. Our parameter of interest is β_j and γ_j. The parameter β_j represents a text message effect for the *default incentive* group. The linear combination of parameters, $\beta_j + \gamma_j$, is a text message effect for the *opt-in incentive* group. The parameter γ_j shows a difference in the message effect between the two groups.

The regression analysis also shows that the Altruistic messages increase the intention to take the antibody test only in the *default incentive* group (Table 2). Controlling for covariates, the Altruistic message increases the intention to take the antibody test by 16.6 pp in the *default incentive* group (column (2)). Furthermore, although marginally statistically significant, the effect of this message weakens by 12.1 pp as the cost of obtaining a free vaccination ticket becomes more expensive. As a result, the effect of the Altruistic message in the *opt-in incentive* group is $4.5(= 16.6 - 12.1)$ pp, which is not statistically significant. Also statistically insignificant or marginal, the effect of other text reminders change in a negative direction as the cost of obtaining free vaccination tickets increases.

4.3 Effect of Text Reminders on Behavior

This subsection estimates the effect of text reminders on behavior. We tested a balance of individual characteristics again because a few respondents dropped out between waves 1 and 2. The results show that

Table 2: Regressions of Intention

	Testing		Vaccination	
	(1)	(2)	(3)	(4)
MHLW (Age)	0.021	0.038	0.020	0.049
	(0.051)	(0.048)	(0.061)	(0.058)
Altruistic	0.144***	0.161***	0.024	0.048
	(0.053)	(0.050)	(0.060)	(0.057)
Selfish	0.073	0.115**	0.039	0.091
	(0.053)	(0.050)	(0.061)	(0.057)
Social Comparison	0.040	0.075	0.014	0.052
	(0.053)	(0.050)	(0.063)	(0.058)
Deadline	0.031	0.041	−0.010	0.010
	(0.051)	(0.048)	(0.060)	(0.057)
Convenient	0.052	0.060	0.018	0.034
	(0.053)	(0.050)	(0.062)	(0.058)
Opt-in	0.068	0.083*	0.113**	0.081
	(0.046)	(0.050)	(0.054)	(0.059)
MHLW (Age) × Opt-in	−0.045	−0.078	−0.086	−0.132*
	(0.065)	(0.061)	(0.076)	(0.071)
Altruistic × Opt-in	−0.091	−0.120*	−0.052	−0.091
	(0.068)	(0.064)	(0.075)	(0.071)
Selfish × Opt-in	−0.031	−0.098	−0.067	−0.143**
	(0.068)	(0.063)	(0.077)	(0.072)
Social Comparison × Opt-in	−0.077	−0.124**	−0.096	−0.141**
	(0.066)	(0.062)	(0.077)	(0.072)
Deadline × Opt-in	−0.003	−0.012	−0.018	−0.033
	(0.065)	(0.062)	(0.075)	(0.071)
Convenient × Opt-in	0.011	−0.001	−0.048	−0.062
	(0.067)	(0.064)	(0.077)	(0.071)
Linear combination test: Treatment + Opt-in × Treatment				
MHLW (Age) (Opt-in incentive)	−0.024	−0.040	−0.066	−0.083**
	(0.040)	(0.037)	(0.045)	(0.041)
Altruistic (Opt-in incentive)	0.053	0.041	−0.028	−0.043
	(0.042)	(0.041)	(0.046)	(0.043)
Selfish (Opt-in incentive)	0.041	0.017	−0.028	−0.053
	(0.042)	(0.039)	(0.046)	(0.043)
Social Comparison (Opt-in incentive)	−0.037	−0.049	−0.082*	−0.089**
	(0.039)	(0.037)	(0.045)	(0.041)
Deadline (Opt-in incentive)	0.029	0.029	−0.028	−0.023
	(0.041)	(0.039)	(0.045)	(0.042)
Convenient (Opt-in incentive)	0.063	0.060	−0.030	−0.028
	(0.042)	(0.040)	(0.045)	(0.042)
Covariates		X		X
Num.Obs.	2615	2615	2615	2615
R2	0.009	0.109	0.005	0.128

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in parentheses. Covariates are age, education year, annual income, usual health behavior (exercise, medical checkup and ful shot habit) and psychological factors potentially associated with these biases (following social norm, accepting bad behavior in anonymous conditions). Reminder effects in the opt-in incentive group are estimated by a sum of main term of treatment dummy and cross term between treatment dummy and opt-in dummy.

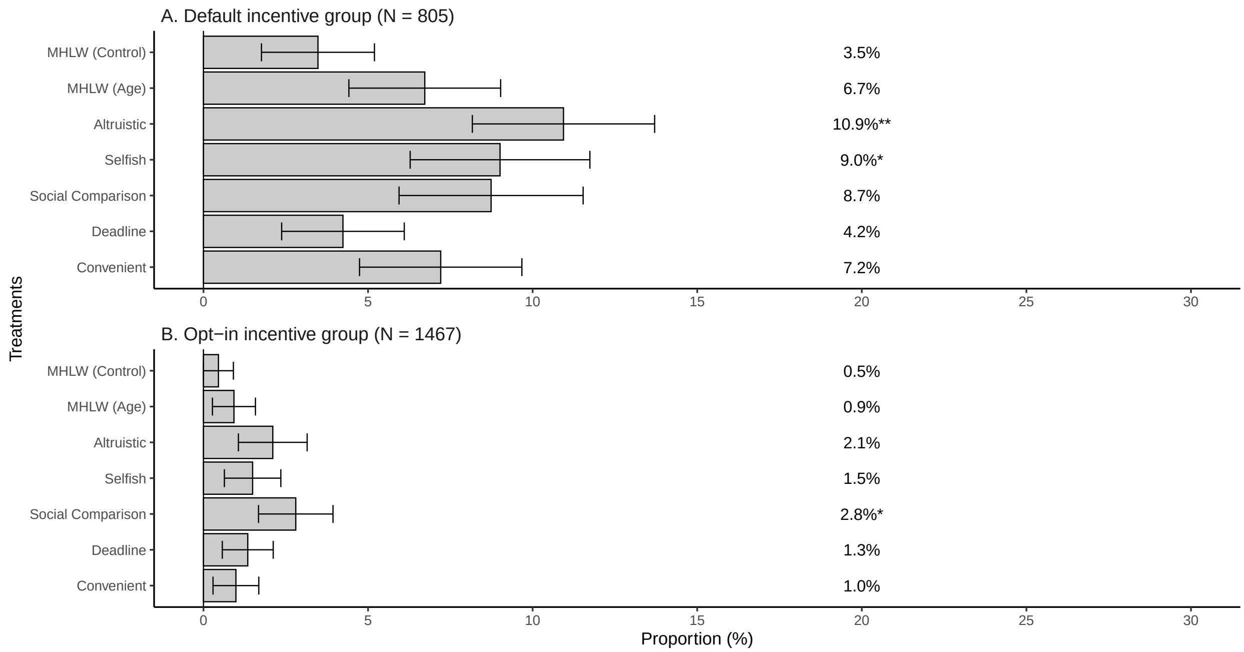

Figure 4: Effect of Text Reminders on Behavior for Antibody Testing Notes: Numbers in the figure indicate the proportion of each experimental arm. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the observable characteristics are balanced across experimental arms in both *default incentive* and *opt-in incentive* group (see Table 9 and 10 in the Appendix C). Therefore, we first present the difference-in-mean test (t-test) for each group.

4.3.1 Difference-in-mean Test

We show the uptake rate of antibody testing in each experimental arm for the *default incentive* group (Panel A) and the *opt-in incentive* group (Panel B) in Figure 4. We find that, as in the intention case, the Altruistic message statistically significantly increases the antibody test uptake rate compared to the MHLW (Control) message by 7.4 pp in the *default incentive* group only (10.9% in the Altruistic message group versus 3.5% in the MHLW (Control) message group).

Selfish messages may boost antibody testing uptake in the *default incentive* group by 5.5 pp (9% in the Selfish message group versus 3.5% in the MHLW (Control) message group). Moreover, Social Comparison message may also increase antibody testing uptake in the *opt-in incentive* group (4.9% in the Social Comparison message group versus 3.5% in the MHLW (Control) message group). These effects are statistically significant at the 10% level.

Figure 5 shows the vaccination rates in each experimental arm for the *default incentive* group (Panel A) and

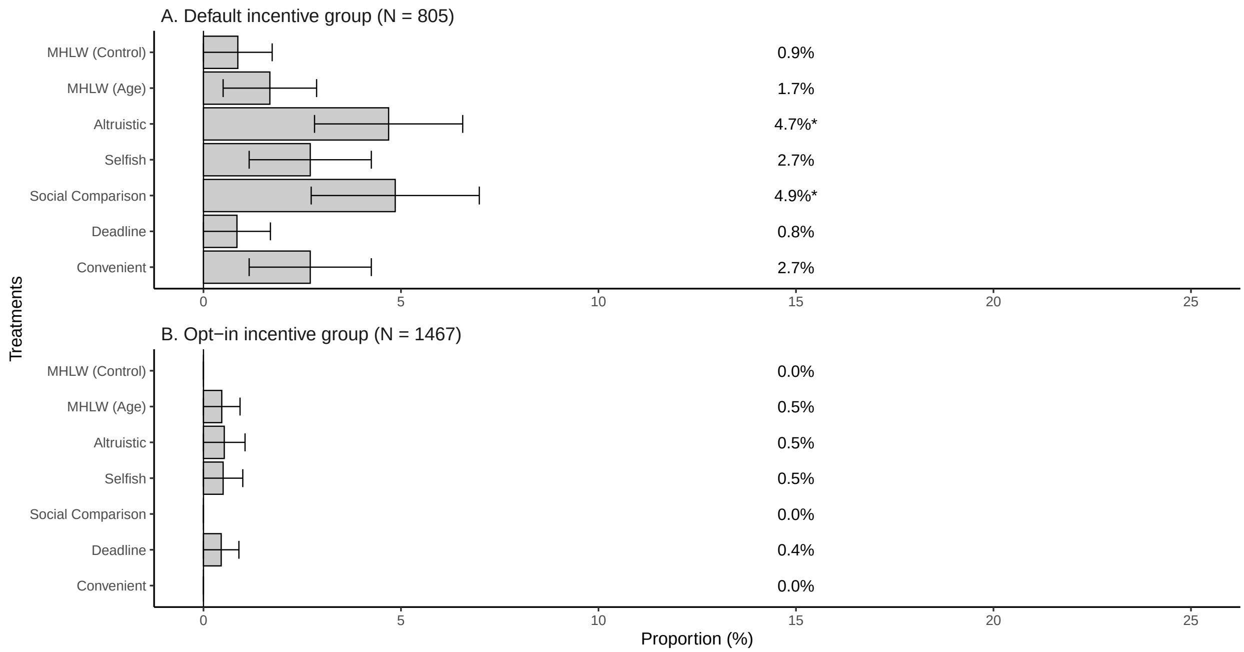

Figure 5: Effect of Text Reminders on Behavior for Vaccination. Notes: Numbers in the figure indicate the proportion of each experimental arm. Error bars indicate the standard error of the mean. Asterisks are p-values of t-tests for the difference-in-mean: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the *opt-in incentive* group (Panel B).[17] In the *default incentive* group, the Altruistic message may increase the vaccination rate by 3.8 pp (4.7% in the Altruistic message group versus 0.9% in the MHLW (Control) message group). In the same group, the Social Comparison message may also increase vaccination rate by 4 pp (4.9% in the Social Comparison message group versus 0.9% in the MHLW (Control) message group). These effects are statistically siginificant at 10% level.

4.3.2 Regression Analysis

As in the case of intention, the different effects of text reminders for two incentive group is influenced by dimentions including age difference other than the presence or absence free vouchers. Thus, we estimate a linear probability model (1) and shows results in Table 3.

Regression analysis also shows that the Altruistic message increases antibody test uptake only in the *default incentive* group. Controlling for covariates, the Altruistic messages increase antibody test uptake by a statistically significant 7.3 pp in the *default incentive* group (column (2)). Furthermore, although the statistical significance is weak, the effect of this message weakens by 5.7 pp as the cost of obtaining a free vaccination ticket becomes more expensive. As a result, the effect of the Altruistic message in the *opt-in*

[17] Vaccination is a dummy variable that takes the value of 1 if respondents have been tested and vaccinated. Thus, the vaccination rate can be regarded as the proportion of newly acquired antibodies through vaccination. This outcome variable matches MHLW's policy goal.

Table 3: Regressions of Behavior

	Testing		Vaccination	
	(1)	(2)	(3)	(4)
MHLW (Age)	0.032	0.028	0.008	0.005
	(0.029)	(0.028)	(0.015)	(0.015)
Altruistic	0.075**	0.072**	0.038*	0.037*
	(0.033)	(0.032)	(0.021)	(0.020)
Selfish	0.055*	0.060*	0.018	0.018
	(0.032)	(0.032)	(0.018)	(0.017)
Social Comparison	0.053	0.056*	0.040*	0.039*
	(0.033)	(0.033)	(0.023)	(0.023)
Deadline	0.008	0.005	0.000	−0.002
	(0.025)	(0.025)	(0.012)	(0.012)
Convenient	0.037	0.037	0.018	0.017
	(0.030)	(0.030)	(0.018)	(0.018)
Opt-in	−0.030*	−0.019	−0.009	−0.004
	(0.018)	(0.020)	(0.009)	(0.012)
MHLW (Age) × Opt-in	−0.028	−0.026	−0.003	−0.001
	(0.030)	(0.030)	(0.015)	(0.016)
Altruistic × Opt-in	−0.058*	−0.057*	−0.033	−0.032
	(0.034)	(0.034)	(0.021)	(0.021)
Selfish × Opt-in	−0.045	−0.054	−0.013	−0.013
	(0.034)	(0.033)	(0.018)	(0.018)
Social Comparison × Opt-in	−0.029	−0.034	−0.040*	−0.039*
	(0.035)	(0.035)	(0.023)	(0.023)
Deadline × Opt-in	0.001	0.004	0.005	0.007
	(0.027)	(0.026)	(0.013)	(0.013)
Convenient × Opt-in	−0.032	−0.031	−0.018	−0.018
	(0.031)	(0.031)	(0.018)	(0.018)
Linear combination test: Treatment + Opt-in × Treatment				
MHLW (Age) (Opt-in incentive)	0.005	0.003	0.005	0.004
	(0.008)	(0.009)	(0.005)	(0.005)
Altruistic (Opt-in incentive)	0.017	0.016	0.005	0.005
	(0.011)	(0.011)	(0.005)	(0.005)
Selfish (Opt-in incentive)	0.010	0.007	0.005	0.005
	(0.010)	(0.010)	(0.005)	(0.005)
Social Comparison (Opt-in incentive)	0.023*	0.021*	0.000	0.000
	(0.012)	(0.013)		(0.001)
Deadline (Opt-in incentive)	0.009	0.008	0.004	0.005
	(0.009)	(0.009)	(0.004)	(0.005)
Convenient (Opt-in incentive)	0.005	0.007	0.000	0.000
	(0.008)	(0.009)		(0.001)
Covariates		X		X
Num.Obs.	2272	2272	2272	2272
R2	0.030	0.047	0.019	0.029

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in parentheses. Covariates are age, education year, annual income, usual health behavior (exercise, medical checkup and ful shot habit) and psychological factors potentially associated with these biases (following social norm, accepting bad behavior in anonymous conditions). Reminder effects in the opt-in incentive group are estimated by a sum of main term of treatment dummy and cross term between treatment dummy and opt-in dummy.

incentive group is 1.6(= 7.3 − 5.7) pp, which is not statistically significant. A same trend is observed for the effect on vaccination, but statistical significance becomes weak.

We summarize the results for the other messages. As confirmed by the difference-in-means test, controlling for covariates, the Selfish message may have increased the antibody test-taking rate in the *default incentive* group, although the statistical significance is weak (column (2) in Table 3). We also find that the Social Comparison message may have increased antibody testing rates in the two incentive groups, controlling for covariates (column (2) in Table 3). However, the effect size is larger in the *default incentive* group than in the *opt-in incentive* group (not a statistically significant difference).

As confirmed by the difference-in-means test, the Social Comparison message may increase vaccination rates in the *default incentive* group (column (4) in Table 3). Although weakly statistically significant, the effect of this message weakens by 5.7 pp as the cost of obtaining vaccination tickets increases. As a result, the Social Comparison message does not increase vaccination rates in the *opt-in incentive* group. Again, the effect of the Altruistic message follows a similar trend.

4.4 Mechanisms of Altruistic Message

The reminders with nudge-based messages other than the MHLW (Age) message modify the age expression and the message content. Thus, the effect of these text reminders relative to MHLW (Control) should be interpreted as the combined effect of the two modifications. Here, we examine which modification is more effective in the Altrustic message, which has a positive effect on antibody test intention and uptake in the *default incentive* group. The only difference between the MHLW (Age) message and the MHLW (Control) message is the age expression, while the only difference between the Altruistic message and the MHLW (Age) message is the message content. Therefore, by estimating the effect of each difference, we can decompose the combined effect of the Altruistic message.

Compared to MHLW (Control), MHLW (Age) increases the intention to test for antibodies in the default incentive group by only 2.1 pp (22.9% in the MHLW (Age) message group versus 20.8% in the MHLW (Control) message group in Figure 2), but this effect is not statistically significant. On the other hand, compared to MHLW (Age), the Altruistic message increases the intention for antibody testing by 12.2 pp (35.1% in the Altruistic message group versus 22.9% in the MHLW (Age) message group in Figure 2), which is statistically significant (see Table 8 in the Appendix C).[18] Therefore, in terms of effect size and statistical significance, the effect of the Altruistic message on antibody testing intentions is strongly influenced by

[18] Even in the *opt-in incentive* group, the Altruistic message content may increase testing intention. Compared to the MHLW (Age) message group, the Altruistic messages increased the intention to take the antibody test by 7.7 pp (32.9% in the Altruistic message group versus 25.2% in the MHLW (Age) message group), which is statistically significant at the 10% level. Moreover, an interesting finding is that only in the *opt-in incentive* group did the content of the Convinient message statistically significantly increase the intention to take the antibody test by about 9 pp. This group may not have a full understanding of the routine immunization campaign. In fact, the Wave 1 survey shows that only about 20% of the *opt-in incentive* group are aware of routine vaccination (see Table 8 in the Appendix C).

changing the message content.

Which individuals were influenced by the content of the Altruistic message? Since this message emphasizes the possibility that infected pregnant women may give birth to children with disabilities (CRS), we examine heterogeneity in terms of CRS knowledge and altruistic preferences.

First, in Wave 1, we examine the CRS knowledge and test the heterogeneity of the effect of the Altruistic message on antibody testing intentions depending on whether respondents possessed the knowledge (see column (1) of Table 12 in the Appendix C). The results show that the effect of the Altruistic message content may be more effective for those who do not possess the knowledge than for those who do. Although there are no statistically significant difference between the effects with and without knowledge, the effects of message content for those with knowledge are not statistically significant. Thus, Altruistic message content may modify knowledge about the negative externalities of infection.

Second, we investigate whether he feels pleasure in actions for others on a 5 scale in Wave 1 and test the heterogeneous effect of the Altruistic message content by the extent to which he does (see column (2) of Table 12 in the Appendix C). The results show that the more altruistic one is, the stronger the effect of the Altruistic message content (this trend is statistically significant). Thus, the Altruistic message may not be effective for those who do not care about others, even if they perceive negative externalities from reading messages.

Unlike the intention case, the effect of the Altruistic message on the uptake rate of antibody testing is not solely due to the content of the message. Compared to MHLW (Age), which only changed the expression of age, the Altruistic message group increases the antibody test uptake rate by 4.2 pp (10.9% in the Altruistic message group versus 6.7% in the MHLW (Age) message group). However, regression analysis indicates that this increase is not statistically significant (see Table 11 in the Appendix C). Also, although the regression analysis is not statistically significant, modifying the age expression increases the antibody test uptake rate by 3.2 pp (6.7% in the MHLW (Age) message group versus 3.5% in the MHLW (Control) message group). Thus, the effect of the Altruistic message on behavior is a combination of the addition of a simple age expression and the revision of the message content.

4.5 Monetary Value of Text Reminders

So far, we have examined the effects of combining financial incentives and nudges. The results show that the Altruistic (and possibly Social Comparison) messages encourage men who received free vouchers by default (who already received monetary incentives) to get an antibody test and be vaccinated. Here, we evaluate the monetary value of adding nudges by examining how much more monetary compensation would be required if the effects of the combination were achieved by monetary compensation alone.

We use willingness to pay (WTP) for the rubella vaccine.[^other-studies] We estimate the demand function

Table 4: Estimated Monetary Value of Text Reminders

			Monetary value (JPY)		Monetary value (USD)	
Text messages	Effect	Baseline + effect	pp	total	pp	total
MHLW (Age)	0.032	0.732	367.854	1.946	3.679	17.690
Altruistic	0.075	0.774	2037.553	10.779	20.376	97.988
Selfish	0.055	0.755	744.045	3.936	7.440	35.782
Social Comparison	0.053	0.752	596.335	3.155	5.963	28.678
Deadline	0.008	0.707	86.059	0.455	0.861	4.139
Convenient	0.037	0.737	422.789	2.237	4.228	20.332

Notes: We use the effect size of each text reminder on antibody testing. Baseline is the sum of the rate of antibody test in the control and the free vaccination rates. The monetary value is the amount per person multiplied by the number of people who received the coupon in 2019 but did not use it until January 2020 (5.29 million). We valued it in Japanese Yen and US Dollars (1 USD = 110 JPY). The unit of monetary value per person is 1 JPY and 1 USD, respectively. The unit of total monetary value is 1 billion JPY and 1 million USD, respectively.

using willingness to pay (WTP) for rubella vaccine. We then examine the extent to which the corresponding price (WTP) changes when the baseline vaccination coverage is increased by the effect of the text reminder. This price change is the additional subsidy equivalent to the effect of the text reminder. Since we want to estimate the monetary value of the text reminder in the *default incentive* group, the baseline vaccination rate is the vaccination rate when the vaccination price is zero. Furthermore, since vaccination requires an exogenous condition that men do not have antibodies, we use the effect on the uptake of antibody testing. Since those willing to be vaccinated must undergo antibody testing, the effect on antibody testing should be viewed as the true intention to vaccinate inferred from behavior. See Appendix B for detail estimation method.

Table 4 shows the estimated message value. The second and third columns show the effect of text reminders on antibody testing and baseline vaccination rates plus the effect of text reminders, respectively. The fourth column shows monetary value of text reminders in terms of the value of the Japanese yen (in U.S. dollar value, shown in the sixth column). The Altruistic and Social Comparison message, which promotes antibody testing, value about 2,000 JPY (about 18 USD; 40% of assumed vaccination price) and 600 JPY (about 5.5 USD; 12% of assumed vaccination price), respectively. The total monetary value is the product of the per capita value and the number of people who have not yet used the free vouchers issued in FY2019 (5.29 million as of January 2020). In the fifth column, the Altruistic and Social Comparison messages are worth 10 billion JPY (about 98 million USD) and 3 billion JPY (about 28 million USD), respectively.

5 Discussion and Conclusions

This study uses RCTs to investigate effective messages for promoting rubella antibody testing and vaccination in two situations regarding financial incentives. Our experiment reveals that the Altruistic message, which emphasizes the negative externality of infection, increases the intention for antibody testing uptake by 14.3 pp among men who already received free vaccination tickets in FY2019. This message was particularly effective for those who were unaware of the negative externalities of infection and for altruistic individuals who consider the benefits of others.

The Altruistic message has a positive effect on the antibody test uptake. Among men who had already received vaccination vouchers in FY 2019, the Altruistic message increases the antibody test uptake by 7.5 pp, which is equivalent to a subsidy of 40% of the vaccination price.

However, the Altruistic message is less effective for men who incur transaction costs to obtain the vaccination tickets. There may be a statistically significant difference in the effect of this message between the two groups. This finding suggests that text message reminders are effective when financial incentives and reminders are closely combined. In addition to the Altruistic message, the Selfish and the Social Comparison message may also raise the intention and the acutual uptake rate for the antibody testing among men who already received the vaccination tickets by default. However, these effect sizes are not large enough to maintain statistical power, requiring a re-examination with a large sample size.

One potential concern is that all behavior-related outcomes were self-reported. These outcomes may contain recall bias. We believe that these biases are less problematic because Wave 2 measures behavior within the last month (the time of Wave 1). The self-reported behavioral outcomes may also be subject to the experimenter demand effect and social desirability bias. To address these biases, our regression analysis directly controls for respondents' psychological factors potentially associated with these biases (following social norm, accepting bad behavior in anonymous conditions). Even if these biases cannot be eliminated perfectly, they are not fatal to the identification of message effects since this study is a RCT and if these biased exist to the same extent in each group.

Finally, we offer two arguments for future research. First, why are text reminders are ineffective in groups that must incur transaction costs to obtain the free vaccination tickets? Our messages may not increase the value of antibody testing and vaccination sufficiently to outweigh their cost. In addition, another possibility is low awareness of rubella immunization campaign beginning in FY2019. Before presenting the messages, we inquire about the MHLW's policy in Wave 1. As a result, approximately 77.5% are unaware of the vaccination campaign Thus, even if they read the messages and realized the importance of rubella antibody testing and vaccination, they would believe they had to pay for these preventive actions.[19]

The second argument is channels of effect on vaccination. Our experiment reveals that the Altruistic and the Social Comparison messages may increase vaccination rates among men who received free vaccination tickets by default. The message effect on vaccination is created through two channels. First, the messages

[19]The fact that many people are unaware of the additional routine rubella vaccinations precludes the possibility that they stopped getting antibody testing and were vaccinated in the first year (FY2019) because they expected to automatically receive the voucher the following year.

increase the number of negative individuals who need to be vaccinated. Second, the messages encourage unvaccinated negative individuals to vaccinate.

Our data suggest that the first channel is more important than the second. Table 13 in the Appendix shows the number of men who had antibody testing, who had a negative antibody test, and who were vaccinated in each experimental arm in the *default incentive* group. This table shows that most of those with negative antibody test results were vaccinated in all experimental arms. Furthermore, the number of negative antibody tests varied between experimental arms. Especially, the 25% (= 1/4) antibody tests are negative in the MHLW (Control) message group. In contrast, the negative ratios of antibody tests for the Altruistic and Social Comparison messages, which may have a positive effect on vaccination, are 50% (= 7/14) and 56% (= 5/9), respectively.[20] Thus, the experimental arms with higher vaccination rates have a greater negative ratio, resulting in a positive effect on vaccination.

This argument is related with the targeting of interventions (e.g., Finkelstein & Notowidigdo 2019). That is, the question is whether marginal individuals whose behavior is changed by intervention receive significant benefits from a policy. In our context, we suggest that the Altruistic message increases the number of negative individuals who receive a large benefit (vaccination) from the FY2019 vaccination campaign. Thus, the Altruistic message improves targeting. However, since we cannot test the difference in the ratio of negative antibody tests due to small sample, the experimental data in this study alone do not allow us to fully explore this argument, and this is a topic for future research.

[20] The negative ratio of antibody testing for the Selfish message, which is only effective for antibody test uptake, is 30% (= 3/10). This value is similar to the MHLW (Control) message.

A Antibody Testing and Vaccination Questions

In wave 2, participants are asked if they have had antibody testing and vaccination since wave 1. The antibody testing question asks, "Have you had rubella antibody testing since the end of the last survey?" Participants were given the following choices:

- (a) Yes, I have taken antibody testing;
- (b) No, I have not taken antibody testing;
- (c) I have taken antibody testing before the last survey.

We create a binary variable taking 1 if the respondent chooses option (a) and use it as an outcome variable for the uptake rate of antibody testing. Meanwhile, the vaccination question is "Have you been vaccinated against rubella since the end of the last survey?" Respondents were given one of five options:

- (a) I have been vaccinated;
- (b) I do not need the vaccine due to a positive test or infection experience;
- (c) I have taken antibody testing but have not been vaccinated yet;
- (d) I have not taken antibody testing or gotten vaccinated;
- (e) I have been vaccinated before the last survey.

We create a binary variable taking 1 if the participant chooses option (a) for both the antibody testing and vaccination questions. Then, we use it as the outcome variable on vaccination.

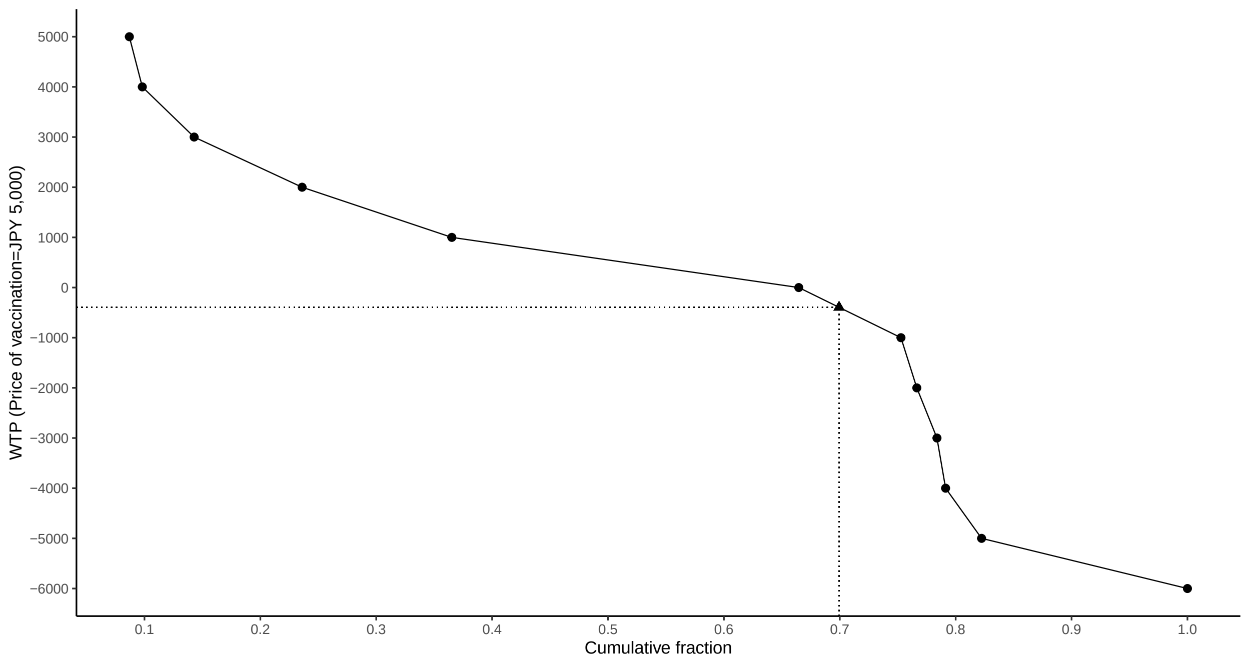

Figure 6: Demand Curve of Rubella Vaccination for Default Incentive Group. Notes: Black triangles indicate the baseline vaccination rate F_0 and the corresponding WTP.

B Estimation Method of Monetary Value of Test Reminders

We seek to determine the extent to which the text reminders increase the monetary value of the rubella vaccination. We use willingness to pay (WTP) for the rubella vaccine. Let WTP_i be an individual's willingness to pay and follow a cumulative distribution F. Then, for a given cost C, men will be vaccinated if $WTP_i \geq C$. The vaccination rate is $F_0 = 1 - F(C)$. Suppose that our treated text reminders change WTP by β. An individual who receives a treated text reminder will be vaccinated if $WTP_i \geq C - \beta$. The vaccination rate of the treated group is $F_1 = 1 - F(C - \beta)$. Thus, the treatment effect is $\tau = F_1 - F_0 = F(C) - F(C - \beta)$. From the perspective of government subsidies, the amount of subsidy equal to the effect of the nudge message τ is β. We want to estimate β.

Once F, C, and τ are determined, we obtain β. To begin, let us discuss the estimation of F (demand function). We elicit the WTP for vaccination in the first wave before participants read messages. If the vaccination costs 5,000 JPY, we ask respondents if they will get it if the local government pays s_j. The subsidy amounts are $s_j \in \{0, 1000, 2000, \dots, 10000\}$. Let $s_i^{\min}$ be the lowest subsidy at which respondents indicate that they would vaccinate. Let $s_i^{\max}$ be the highest subsidy that respondents indicate they would not vaccinate. We can identify the willingness to pay for vaccination within the range $[5000 - s_i^{\max}, 5000 - s_i^{\min})$. Thus, without additional assumptions, the demand curve is step-wise, and we estimate the monetary value of the message effect with bounds. Note that if respondents indicated that they would not vaccinate at all subsidy amounts, then $s_i^{\max} = 10000$. However, we cannot define $s_i^{\min}$ in the data. Therefore, we assume $s_i^{\min} = 11000$. This assumption does not affect the monetary value of the messages. To obtain a point estimate, we assume that the true WTP is uniformly distributed within the range $[5000 - s_i^{\max}, 5000 - s_i^{\min})$. Then, The vaccination demand curve can then be linearly interpolated (see Figure 6).

In the *default incentive* group, eligible males receive free vaccination at no cost. Therefore, the natural setting is $C = 0$. In addition, the message effect τ is used for the effect on antibody test uptake. The person taking the antibody test wants to get the antibody, i.e. the vaccination, against rubella. However, the effect of the message on vaccination is different from the effect on (true) vaccination intention, because people with a positive antibody test result cannot be vaccinated. Therefore, τ is not the effect on vaccination, but the effect on antibody testing.

In our framework, $F_0 = 1 - F(0)$, but one potential concern remains. The message effect τ is estimated by the difference from the MHLW (Control) group. Assuming that everyone who did not participate in our survey did not take the antibody test after the survey, the uptake rate of MHLW (Control) can be considered as an effect of providing the message in the survey. To remove this effect, we instead use $F_0 = (1 - F(0)) + (F(0) - F(-\alpha))$. The second term is the antibody testing rate of the control group (3.5%) under no vaccination cost. The demand function is estimated to be $F_0 = 0.7$ and $\alpha = 394$. Finally, we find β holding that $\tau = F(-\alpha) - F(-\beta)$.

C Tables and Figures

Table 5: List of Covariates

	Description	Mean	Std.Dev.
age	(Wave1) Age as of April 2019 based on year of birth and month of birth.	48.66	5.69
married	(Wave1) Dummy variable taking one if a respondent is married.	0.58	0.49
education	(Wave1) Years of education.	14.75	2.31
income	(Wave1) Household income. For those who did not respond with household income, the overall average was substituted.	684.90	375.74
noinfo_income	(Wave1) Dummy variable taking one if a respondent did not answer household income.	0.15	0.36
exercise_w1	(Wave1) Dummy variable taking one if a respondent exercises or plays sports more than once a week.	0.22	0.42
health_check	(Wave1) Dummy variable taking one if a respondent has had a medical examination at his/her city or place of employment in the past year from the time of the wave 1.	0.68	0.46
flushot	(Wave1) Dummy variable taking one if a respondent is vaccinated against influenza every year.	0.27	0.45
norm_waiting_line	(Wave2) Five-point Likert scale for the question ”I wash my hands and gargle frequently during the period from the end of the previous questionnaire response to today.”	4.07	0.96
selfish_anonymous	(Wave2) Five-point Likert scale for the question ”I take my temperature frequently during the period from the end of the previous questionnaire response to today.”	2.33	0.98
handwash	(Wave2) Five-point Likert scale for the question ”I am refraining from going out during the end of the previous questionnaire response to today.”	3.91	1.04
temp_check	(Wave2) Five-point Likert scale for the question ”I avoid crowded places when I go out from the end of the previous questionnaire response to today.”	2.26	1.22
avoid_out	(Wave2) Five-point Likert scale for the question ”I always wear a medical mask when I go out or meet people during the period from the end of the previous questionnaire response to today.”	2.96	1.20
avoid_crowd	(Wave1) Five-point Likert scale for the question ”I never interrupt someone in line.”	3.38	1.10
wear_mask	(Wave1) Five-point Likert scale for the question ”If I can never find it, I can do bad things (littering, parking tickets, etc.).”	3.14	1.38

Table 6: Balance Tests for Default Incentive Groups (Sample for Estimating Effect on Intention)

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Conevenient	F-test, p-value
age	42.862	43.046	43.135	43.045	42.909	42.906	42.866	0.874
married	0.408	0.458	0.412	0.417	0.455	0.478	0.480	0.785
education	14.654	14.473	14.595	14.205	14.099	14.348	14.575	0.446
income	557.562	645.556	613.156	623.542	569.530	590.422	633.487	0.149
noinfo_income	0.162	0.168	0.203	0.197	0.157	0.130	0.181	0.706
exercise_w1	0.246	0.176	0.277	0.189	0.165	0.217	0.213	0.285
health_check	0.654	0.626	0.696	0.538	0.603	0.674	0.614	0.150
flushot	0.238	0.260	0.203	0.144	0.140	0.239	0.236	0.055
norm_waiting_line	4.100	3.908	3.892	3.970	4.050	3.906	4.024	0.447
selfish_anonymous	2.377	2.435	2.331	2.371	2.446	2.355	2.425	0.945

Notes: Table 5 describles variables. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-value of the joint null hypothesis (F-test).

Table 7: Balance Tests for Opt-In Incentive Group (Sample for Estimating Effect on Intention)

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Conevenient	F-test, p-value
age	51.632	51.408	51.226	51.657	51.582	51.545	51.502	0.712
married	0.600	0.588	0.628	0.657	0.602	0.549	0.619	0.334
education	14.572	14.655	14.530	14.830	14.566	14.634	14.393	0.578
income	712.622	707.190	687.764	677.141	656.419	707.708	710.713	0.540
noinfo_income	0.184	0.164	0.145	0.117	0.155	0.163	0.205	0.211
exercise_w1	0.156	0.193	0.239	0.230	0.183	0.203	0.218	0.252
health_check	0.632	0.664	0.701	0.683	0.653	0.659	0.644	0.742
flushot	0.228	0.244	0.197	0.270	0.275	0.228	0.251	0.433
norm_waiting_line	4.136	4.134	4.137	4.078	4.004	4.028	4.063	0.590
selfish_anonymous	2.416	2.231	2.325	2.374	2.223	2.337	2.368	0.201

Notes: Table 5 describles variables. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-value of the joint null hypothesis (F-test).

Table 8: Massage Content Effects on Intentions Compared to MHLW (Age)

	Testing		Vaccination	
	(1)	(2)	(3)	(4)
Altruistic	0.122**	0.124**	0.004	−0.001
	(0.054)	(0.051)	(0.060)	(0.057)
Selfish	0.051	0.077	0.019	0.041
	(0.054)	(0.051)	(0.061)	(0.058)
Social Comparison	0.019	0.037	−0.005	0.004
	(0.054)	(0.052)	(0.063)	(0.059)
Deadline	0.010	0.003	−0.029	−0.041
	(0.052)	(0.049)	(0.060)	(0.058)
Convenient	0.031	0.022	−0.002	−0.015
	(0.054)	(0.051)	(0.062)	(0.058)
Opt-in	0.023	0.019	0.027	−0.038
	(0.046)	(0.052)	(0.054)	(0.060)
Altruistic × Opt-in	−0.045	−0.044	0.034	0.040
	(0.068)	(0.065)	(0.075)	(0.071)
Selfish × Opt-in	0.014	−0.022	0.018	−0.012
	(0.068)	(0.064)	(0.077)	(0.072)
Social Comparison × Opt-in	−0.032	−0.046	−0.011	−0.011
	(0.067)	(0.063)	(0.077)	(0.072)
Deadline × Opt-in	0.043	0.066	0.067	0.100
	(0.066)	(0.063)	(0.076)	(0.071)
Convenient × Opt-in	0.056	0.077	0.038	0.069
	(0.068)	(0.065)	(0.077)	(0.072)
Linear combination test: Treatment + Opt-in × Treatment				
Altruistic (Opt-in incentive)	0.077*	0.080**	0.038	0.040
	(0.042)	(0.040)	(0.046)	(0.043)
Selfish (Opt-in incentive)	0.065	0.055	0.038	0.029
	(0.042)	(0.039)	(0.046)	(0.043)
Social Comparison (Opt-in incentive)	−0.013	−0.008	−0.016	−0.007
	(0.039)	(0.036)	(0.045)	(0.042)
Deadline (Opt-in incentive)	0.053	0.068*	0.038	0.059
	(0.041)	(0.038)	(0.046)	(0.042)
Convenient (Opt-in incentive)	0.087**	0.099**	0.036	0.054
	(0.042)	(0.039)	(0.046)	(0.042)
Covariates		X		X
Num.Obs.	2235	2235	2235	2235
R2	0.008	0.105	0.004	0.121

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in parentheses. We exclude from the sample those assigned to MHLW (Control). The reference group is MHLW (Age). Covariates are age, education year, annual income, usual health behavior (exercise, medical checkup and ful shot habit) and psychological factors potentially associated with these biases (following social norm, accepting bad behavior in anonymous conditions). Reminder effects in the opt-in incentive group are estimated by a sum of main term of treatment dummy and cross term between treatment dummy and opt-in dummy.

Table 9: Balance Tests for Default Incentive Group (Sample for Estimating Effect on Behavior)

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	F-test, p-value
age	42.861	43.059	43.102	43.036	42.893	42.898	42.964	0.953
married	0.391	0.454	0.391	0.360	0.437	0.466	0.477	0.467
education	14.496	14.471	14.547	14.126	14.010	14.407	14.595	0.474
income	548.244	649.778	614.512	599.124	555.083	591.597	637.056	0.102
noinfo_income	0.174	0.126	0.203	0.207	0.146	0.136	0.171	0.522
exercise_w1	0.252	0.185	0.266	0.171	0.165	0.195	0.225	0.375
health_check	0.643	0.639	0.680	0.532	0.631	0.661	0.640	0.391
flushot	0.235	0.261	0.227	0.135	0.146	0.246	0.207	0.082
norm_waiting_line	4.174	3.933	3.922	4.036	4.078	3.898	4.063	0.219
selfish_anonymous	2.339	2.412	2.367	2.333	2.447	2.373	2.414	0.977
handwash	3.861	3.916	3.797	3.757	3.767	3.915	3.829	0.835
temp_check	2.139	2.235	2.414	2.126	2.204	2.203	2.117	0.535
avoid_out	3.096	3.034	3.047	2.793	2.932	3.025	2.928	0.544
avoid_crowd	3.296	3.336	3.273	3.234	3.350	3.305	3.324	0.990
wear_mask	2.930	3.076	3.109	3.009	3.010	3.144	3.207	0.794

Notes: Table 5 describles variables. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-value of the joint null hypothesis (F-test).

Table 10: Balance Tests for Opt-in Incentive Group (Sample for Estimating Effect on Behavior)

	MHLW (Control)	MHLW (Age)	Altruistic	Selfish	Social Comparison	Deadline	Convenient	F-test, p-value
age	51.695	51.394	51.179	51.662	51.421	51.605	51.512	0.564
married	0.591	0.560	0.611	0.652	0.598	0.547	0.596	0.407
education	14.505	14.620	14.553	14.876	14.593	14.610	14.345	0.472
income	712.165	707.809	686.355	671.407	644.798	699.289	718.575	0.370
noinfo_income	0.173	0.157	0.137	0.114	0.159	0.166	0.222	0.142
exercise_w1	0.159	0.194	0.232	0.229	0.173	0.211	0.202	0.432
health_check	0.632	0.667	0.684	0.677	0.645	0.673	0.631	0.849
flushot	0.223	0.245	0.189	0.264	0.280	0.215	0.241	0.376
norm_waiting_line	4.159	4.162	4.126	4.065	3.991	4.063	4.030	0.431
selfish_anonymous	2.436	2.227	2.311	2.343	2.234	2.300	2.379	0.240
handwash	3.823	3.889	3.926	3.751	3.836	3.861	3.867	0.769
temp_check	2.095	2.204	2.221	2.100	2.136	2.085	2.182	0.841
avoid_out	2.886	2.889	2.932	2.866	2.855	2.964	2.941	0.960
avoid_crowd	3.295	3.361	3.447	3.239	3.313	3.309	3.433	0.437
wear_mask	3.082	3.176	3.116	3.144	2.977	2.942	3.010	0.533

Notes: Table 5 describles variables. Columns 2–8 show sample averages for each experimental arm. Column 9 shows p-value of the joint null hypothesis (F-test).

Table 11: Message Content Effects on Behavior Compared to MHLW (Age)

	Testing		Vaccination	
	(1)	(2)	(3)	(4)
Altruistic	0.042	0.045	0.030	0.032
	(0.036)	(0.036)	(0.022)	(0.022)
Selfish	0.023	0.032	0.010	0.014
	(0.036)	(0.035)	(0.019)	(0.019)
Social Comparison	0.020	0.028	0.032	0.035
	(0.036)	(0.036)	(0.024)	(0.025)
Deadline	−0.025	−0.024	−0.008	−0.007
	(0.030)	(0.029)	(0.015)	(0.014)
Convenient	0.005	0.010	0.010	0.013
	(0.034)	(0.034)	(0.019)	(0.020)
Opt-in	−0.058**	−0.045*	−0.012	−0.001
	(0.024)	(0.027)	(0.013)	(0.015)
Altruistic × Opt-in	−0.030	−0.032	−0.029	−0.031
	(0.038)	(0.038)	(0.023)	(0.024)
Selfish × Opt-in	−0.017	−0.028	−0.010	−0.012
	(0.037)	(0.037)	(0.021)	(0.021)
Social Comparison × Opt-in	−0.001	−0.009	−0.036	−0.039
	(0.038)	(0.039)	(0.025)	(0.025)
Deadline × Opt-in	0.029	0.030	0.008	0.008
	(0.031)	(0.031)	(0.016)	(0.016)
Convenient × Opt-in	−0.004	−0.005	−0.015	−0.017
	(0.035)	(0.035)	(0.020)	(0.020)
Linear combination test: Treatment + Opt-in × Treatment				
Altruistic (Opt-in incentive)	0.012	0.013	0.001	0.001
	(0.012)	(0.013)	(0.007)	(0.007)
Selfish (Opt-in incentive)	0.006	0.004	0.000	0.001
	(0.011)	(0.011)	(0.007)	(0.007)
Social Comparison (Opt-in incentive)	0.019	0.019	−0.005	−0.004
	(0.013)	(0.013)	(0.005)	(0.005)
Deadline (Opt-in incentive)	0.004	0.006	0.000	0.001
	(0.010)	(0.010)	(0.006)	(0.007)
Convenient (Opt-in incentive)	0.001	0.004	−0.005	−0.005
	(0.010)	(0.010)	(0.005)	(0.005)
Covariates		X		X
Num.Obs.	1937	1937	1937	1937
R2	0.029	0.047	0.019	0.031

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in parentheses. We exclude from the sample those assigned to MHLW (Control). The reference group is MHLW (Age). Covariates are age, education year, annual income, usual health behavior (exercise, medical checkup and ful shot habit) and psychological factors potentially associated with these biases (following social norm, accepting bad behavior in anonymous conditions). Reminder effects in the opt-in incentive group are estimated by a sum of main term of treatment dummy and cross term between treatment dummy and opt-in dummy.

Table 12: Heterogeneous Effects of Altruistic Message Contents

	Intention for testing (1)	(2)
Altruistic	0.199***	−0.104
	(0.068)	(0.112)
Altruistic × Handicap	−0.126	
	(0.082)	
Altruistic × Generosity		0.075**
		(0.035)
Other nudges	0.038	0.033
	(0.039)	(0.040)
Linear combination test		
Altruistic + Altruistic × Handicap	0.073	
	(0.063)	
Altruistic + Altruistic × Most generous		0.270***
		(0.089)
Covariates	X	X
Num.Obs.	797	797
R2	0.128	0.148

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors are in parentheses. We exclude from the sample those assigned to MHLW (Control), The reference group is MHLW (Age). Covariate "Other nudges" is a dummy that indicating respondents are assigned to the Selfish, Social Comparison, Deadline, and Covenient message group. Covariate "Handicap" is a dummy that respondent knows that infants born to infected pregnant women may have disabilities. Covariates "Generosity" indicates on a 5-point scale the degree to which respondent feels pleasure in actions for others. Respondents who give a score of 5 to this are the most generous. Covariates are age, education year, annual income, usual health behavior (exercise, medical checkup and ful shot habit) and preference for compliance with social norm.

Table 13: Number of Anitbody Testing, Negatives, and Vaccinations in Default Incentive Group

Text message	Sample size	Anitbody test N	Anitbody test % of sample	Negatives N	Negatives % of test	Negatives % of sample	Vaccination N	Vaccination % of negatives	Vaccination % of sample
MHLW (Control)	115	4	3.5	1	25.0	0.9	1	100.0	0.9
MHLW (Age)	119	8	6.7	2	25.0	1.7	2	100.0	1.7
Altruistic	128	14	10.9	7	50.0	5.5	6	85.7	4.7
Selfish	111	10	9.0	3	30.0	2.7	3	100.0	2.7
Social Comparison	103	9	8.7	5	55.6	4.9	5	100.0	4.9
Deadline	118	5	4.2	1	20.0	0.8	1	100.0	0.8
Convenient	111	8	7.2	5	62.5	4.5	3	60.0	2.7

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