Identification of optimum combinations of media channels for approaching COVID-19 vaccine unsure and unwilling groups in Japan

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Summary

Background Optimizing media campaigns for those who were unsure or unwilling to take coronavirus disease (COVID-19) vaccines is required urgently to effectively present public health messages aimed at increasing vaccination coverage. We propose a novel framework for selecting tailor-made media channels and their combinations for this task.

Methods An online survey was conducted in Japan during February to March, 2021, with 30,053 participants. In addition to their sociodemographic characteristics, it asked the attitude toward vaccination and information sources (i.e., media channels) for COVID-19 issues. Multinomial logic regression was fitted to estimate the combinations of the media channels and their odds ratio (OR) associated with vaccination attitudes.

Findings The proportion of respondents who were unsure or unwilling to take the vaccination was skewed toward younger generation: 58.1% were aged under 35, while 28.1% were 65 years or older. Media channels such as "*Non-medical* and *Non-TV*" and "*Non-medical* and *Non-government*" were associated with the unsure group: OR (95% Confidence intervals, (CI)) = 1.75 (1.62, 1.89) and 1.53 (1.44, 1.62), respectively. In addition, media channels such as "*Newspapers* or *the Novel Coronavirus Expert Meeting*", "*Medical* or *Local government*", and "*Non-TV*" were associated with the unwilling group: OR (95% CI) were 2.00 (1.47, 2.75), 3.13 (2.58, 3.81), and 2.25 (1.84, 2.77), respectively.

Interpretation To effectively approach COVID-19 vaccine unsure and unwilling groups, generation-specific online and offline media campaigns should be optimized to the type of vaccine attitude.

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Research in context

Evidence before this study

Unsurety and unwilling to COVID-19 vaccines is a major challenge worldwide to improve vaccination coverage.

Our previous research, Nomura *et al.* (2021), which conducted a survey with 30053 participants, showed that the vaccine unsurety and unwillingness were 32.9% and 11.0% of the population, respectively. These percentages seemed to be different from the existing literatures: for example, Neumann-Böhme *et al.* (2020) reported 18.9% of 7,664 adults in seven European countries were unsure of a vaccination against COVID-19 when it became available, and 7.2% were unwilling to the vaccine. Our study also showed that the following features are unique predictors for the unsurety or unwillingness of a COVID-19 vaccination after adjusting several socio-demographic covariates: younger people, women, and people with lower education levels and incomes. It also revealed that the perceived benefits of the vaccination, perceived trust in scientists and authorities, and the perceived belief in the necessity of vaccination among healthcare workers were significantly associated with the unsurety and unwillingness. Existing literature on the attitude toward the vaccination focuses mainly on the specific characteristics of those who were unsure or unwilling to take the vaccination. However, while these studies are useful, it is limited in explaining what type of media campaign should be developed to approach them.

Added value of this study

This study examined the media channels and their combination to approach those who were unsure or unwilling to take COVID-19 vaccine in Japan. This study is a continuation of Nomura *et al.* (2021). By using an online survey with 30053 participants aged ≥20 years in Japan, we found that the proportions of respondents who were unsure and unwilling to take the vaccination were skewed toward the younger generation: 58.1% were aged under 35, while 28.1% were 65 years or older. After adjusting for socio-demographic covariates in the multinomial logic regression (not a logistic regression) models with logistic link function identified that the non-use of media channels that are generally considered to be authoritative such as reports from medical professionals, government and TV are associated with the unsure group. It also showed that the use of media channels such as newspapers and the expert meeting and the non-use of TV were associated with the unwilling group.

Implications of all the available evidence

Japanese COVID-19 vaccination campaign began on February 17, 2021 and healthcare workers, the elderly and residents with underling disease were given priority at the initial stage. Then, it was extended to the rest of the general population, and as of August 18, 2021, the current percentage of people who have completed the required number of vaccinations reached about 37.9%. Our findings provide important evidence on the tendency of unsurety and unwillingness of COVID-19 vaccination in Japan. In addition, to the best of our knowledge, we used the largest survey to date, which allows us to estimate the parameters and complex combinations of media channels in the state-of-the-art statistical regression model (i.e., the logic regression model). The model provided important evidence on suitable media channels to effectively approach those who feel unsure or unwilling to take COVID-19 vaccination. As with other studies that showed a large prevalence of reluctant attitude toward the COVID-19 vaccine in other countries, Japan is shown to be one of the countries with the lowest trust in vaccination. To approach those who have not yet been vaccinated, media campaign strategies should be constructed based on the evidence. We believe that our study helps not only policy makers but also medical experts to inform public health messages efficiently and directly to the people. Research in Context

Introduction

The coronavirus disease (COVID-19) reached pandemic status on March 11, 2020, and continues to impose enormous burdens of morbidity and mortality, while damaging global and local societies and economies.[1,2] Since the first human clinical trial of the COVID-19 vaccine started in March, 2020 in the United States, more than 2.39 billion people have been vaccinated worldwide as of September 17, 2021.[3] Ensuring easy access to large-scale and well-prepared distribution of COVID-19 vaccine to achieve herd immunity requires sufficient health care capacity and strong government engagement. However, in many countries vaccine-hesitancy stands as a major potential obstacle to effective roll-out of the vaccine, and strategies to foster trust in and acceptance of vaccines are urgently needed to boost vaccination coverage.[4-6]

Resistance and hesitancy to vaccination, which was defined by the World Health Organization in 2015 as a

decay in acceptance of, or outright refusal of vaccination despite having access to vaccination,[7] is a major challenge and has been extensively studied globally.[4-6] In June 2020 a study with 13,426 participants in 19 countries showed that 14.2% of respondents indicated disagreement with taking a potential COVID-19 vaccine, including 8.1% who completely disagreed.[4] Previous studies have identified the main reasons for this opposition including explicit concerns about vaccine safety and side effects, and dissatisfaction with government.[4-6,8] More importantly, in February, 2020, the World Health Organization announced that the COVID-19 pandemic was accompanied by an 'infodemic' of misinformation. It is well known that miscommunication or misinformation about vaccine-related issues leads to substantial delay in achieving higher coverage.[4,9,10] Under the COVID-19 pandemic, Brennen *et al.* (2020) reported 5% of misinformation was related to vaccines and 59%, 27% and 24% of misinformation were from Twitter, YouTube and Facebook, respectively [11]. Roozenbeek *et al.* (2020) identified that susceptibility to misinformation negatively affects people's willingness to get vaccinated.[12] Moreover, anti-vaccination activists have already started campaigns of resistance to vaccine uptake in many counties.[13,14] Those who are working in public authorities to advocate vaccination such as governmental spokesman and public health experts must be well prepared to address this uncertainty or unwillingness regarding intention to be vaccinated against COVID-19, while respecting the choice not to take the vaccine, and strategically communicate vaccination information to cultivate vaccine literacy among their citizens.

In the current era, misinformation, rumor and miscommunication can easily spread faster than anticipated through multiple media channels and have the potential to slow down vaccination.[15] In contrast, these multi-media channels offer a good opportunity to convey tailor-made public health messages in multiple ways that are optimized to the individual's circumstance. To select the media channel to convey optimized public health messages and maximize COVID-19 vaccine coverage, we should gauge current levels of willingness and attitude of users by media channels and identify which channels should be used to approach those who are unsure or unwilling to take the vaccination and encourage them. We present the findings of a nationwide survey of willingness to take a vaccine and primary information sources from a sample of 30,053 respondents in Japan, which is one of the largest surveys in the world under the COVID-19 pandemic, with the aim of identifying the most effective avenues of communication for people who are unsure of or unwilling about vaccination, disaggregated by age and gender.

Methods

Study participants

Details of the survey used in this study have been described elsewhere.[16] Briefly, study participants were recruited from an online panel of a web survey company, Cross Marketing Inc.[17] Panel members were aged ≥20 years and able to complete the online questionnaire, and received "points" after the completion of the questionnaire as an incentive. The points can be used to purchase products or services from partner companies. The survey was designed to recruit approximately 30,000 participants to ensure national population using a quota sampling approach. The samples were matched to the Japanese population by age, gender, and prefecture population based on estimates from the 2015 National Census, which was the latest available data at the time of our survey,[18] and the survey weight was not used. Recruitment was on a first-come-first-served basis and closed upon reaching the pre-determined number of respondents. The survey was conducted from February 26 to March 4, 2021. In order to complete the survey and obtain their points, respondents were required to respond to all questions and thus there was no missing data. Lastly, to avoid uncommitted or dishonest answers, we asked respondents to take an oath that they would be serious before answering the questionnaire before starting the answers, which has been shown to be effective in Japan.[19] The oath was required, and no one could proceed without the oath.

Questionnaire

The questionnaire was developed based on a comprehensive literature review of similar topics.[4,6,8,20-25] It asked about willingness to receive vaccination against COVID-19 with the question "when a vaccine for COVID-19 becomes available, will you get vaccinated?" Response options were "Yes," "Not sure," and "No". Based on this response, each individual was categorized into three vaccine response groups: yes (accept), not sure (unsure), and no (unwilling). In addition, the survey asked questions about the sociodemographic and health-related characteristics of participants and information sources used to gather COVID-19 information. All questions were single- or multiple-answers and Likert scale formats when necessary. More detailed explanation can be found in Nomura *et al.* (2021).[26]

Statistical analysis: multivariate logic regression with logistic link function

As with many other countries, in Japan high-risk populations for COVID-19, such as the elderly, are prioritized to get the vaccine because of limited supplies in the initial stage of the program. To reflect this prioritization,

we stratified the data by age group: (Group A) 20-34 years, (Group B) 35-49 years, (Group C) 50-64 years, (Group D) ≥65 years old (yr), and (ALL) all-ages groups. Basic demographics of each group were compared using Fisher's exact, chi-squared or t-test. For statistical two-sided tests for single-answer questions, a *p*-value less than 0.05 was considered statistically significant. Bonferroni corrections were applied where necessary to control type 1 error inflation due to multiple testing.

Then, multinomial logic regression models were fitted to each of age groups A−D and the ALL group to identify the important information sources, referred to as *media channels* in the below sections, about COVID-19 issues and their combinations associated with being unsure or unwilling to be vaccinated against COVID-19. The logic regression framework proposed by Ruczinski *et al.* (2003) is an adaptive classification approach that builds on standard regression models to construct predictors as Boolean combinations of binary covariates[27]: for example, given a set of binary covariates $\{X_1, X_2, \ldots, X_P\}$, where $X_p \in \{1\ (TRUE),\ 0\ (FALSE)\}$ for $p = 1, \ldots, P$, we can create a new covariate such as "(Ex.1) $X_1 \wedge X_2 \wedge X_4$ are TRUE" or "(Ex.2) $(X_5 \vee X_9) \wedge !X_3$ are TRUE", where $\wedge$ and $\vee$ are logical operators that mean "AND" and "OR", respectively, and "!X" means "not X" (i.e., the complement operator). The logic regression framework adds this form of covariate construction technique onto the standard generalized linear model framework, so that in addition to the specialized methods for identifying logical covariate sets, we use a standard multinomial logistic regression framework to estimate the impact of these logical covariate sets after adjusting for confounders. Thus, in total the logic regression model presented here can be thought of as a logic regression with multinomial logistic response.

In this study, X_p corresponds to the binary variable that takes 1 (TRUE) if an individual obtains the information about COVID-19 from the *p*th media channel and takes 0 (FALSE) otherwise. Then, the class of generalized linear regression model, more precisely the multinomial logistic regression model, was fitted to model the association between the outcome of interest and media channels. As implemented in the *logicFS* package in R, we fitted the model with the following logistic link function:

$$log\left(\frac{P[Y=j]}{P[Y=accept]}\right) = \alpha_{j0} + \boldsymbol{Z_j}\boldsymbol{\alpha_j} + \sum_{k=1}^{K} \beta_{jk} L_{jk},$$

where $Y \in \{accept,\ unsure,\ unwilling\}$ is a three level outcome of interest, and $j \in \{unsure,\ unwilling\}$ are the two levels of interest relative to the reference level of acceptance of vaccination; $\boldsymbol{Z_j}$is a covariate vector; L_{jk} is the *k*th Boolean expression of the binary covariates such as Ex.1 and Ex.2 (see below for the detailed estimation procedure) for the *j*th category; and αs and β_js are regression parameters. The estimated regression parameters are denoted as $\hat{\alpha_{j0}}$, $\hat{\boldsymbol{\alpha}}_j$ and $\hat{\beta}_j$. Here, $Y = accept$ is defined as a baseline category and $Y = unsure$ or $Y = unwilling$ are modeled separately in the form of a logistic regression model. We specially note that, as shown in the following results section, for example, the case where $\hat{\beta}_{jk} < 0$ (i.e., the odds ratio (OR) <1) and $L_{jk} = !X_k$ is equivalent with the case where $\hat{\beta}_{jk} > 0$ (i.e., OR > 1) and $L_{jk} = X_k$ since $X_k \in \{1,\ 0\}$ is a binary variable and $!X_k = 1 - X_k$, although the intercept term α_0 should be changed.

Both of $\boldsymbol{L_j} = (L_{j1}, \ldots, L_{jK})^T$ and the regression coefficients $\boldsymbol{\beta_j} = (\beta_{j1}, \ldots, \beta_{jK})^T$ for $j = \{unsure,\ unwilling\}$ can be simultaneously estimated using a simulated annealing algorithm, (reversible jump) Markov Chain Monte Carlo method, or other similar optimization techniques. Details can be found elsewhere.[27-30] In this study, the set of $(\boldsymbol{L_j}, \boldsymbol{\beta_j})$ was first estimated using the simulated annealing algorithm, and then we estimated $(\alpha_0, \boldsymbol{\alpha_j})$ after plugging the estimated $(\boldsymbol{L_j}, \boldsymbol{\beta_j})$ into the model using the maximum likelihood method. Based on previous studies,[16,25,26,31,32] the vector $\boldsymbol{Z_j}$ includes the following socio-demographic and health-related covariates (see Table 1 for more detailed sub-categories): Occupation type (categorical),[16,25,31] Income (continuous)[27,31,32] Education level (continuous),[25,31,32] Gender (category of women, men or others),[26,31] and underlying diseases (categorical).[26] We asked the existence of underlying diseases such as "do you have an underlying disease (diabetes, heart failure, and respiratory disorders [COPD], etc.)? Or are you on dialysis, or using immunosuppressive or anticancer drugs?". We used these simple binary questions for the underlying disease in order to keep the questionnaire simple and to 1) reduce the number of questions as much as possible to reduce the burden on respondents and 2) avoid the technical terms and use expressions that can be easily understood by the general public. In the simulated annealing algorithm, the annealing chain ranged from 10^{-3} to 10^{3} of temperature with a total length of 1,000,000 with early-stopping rule of 500 iterations. The number of trees in one model, which corresponds to each *L*, was searched from 1 to 3 and the optimal size was selected. The maximum number of leaves in one tree, which corresponds to each X_p, was also searched from 1 to 5, which means that (at most) five media combinations were considered. Other parameter settings follow the default values in the *LogicReg* and *logicFS* packages in R (Version 4.0.5)[33]. The predictive performance of each model was measured by Area Under the receiver operating characteristic Curve (AUC) on the training dataset. Lastly, to check the overall impact of media channels on the attitude towards vaccination, we also ran conventional logistic regression models including several major channels such as Medical professionals, TV, Newspapers, The Novel Coronavirus Expert Meeting and Local government that appeared in the estimated logic regression models more than 5 times (i.e. the five most frequent media channels).

	Age group				
	20-34 yr (Group A)	35-49 yr (Group B)	50-64 yr (Group C)	≥65 yr (Group D)	*p*-value
Sample size	5419	7880	8132	8622	
Vacctination attitude (SA)					<0.001
Acceptance	2259 (41.7)	3721 (47.2)	4693 (57.7)	6196 (71.9)	
Unsure	2113 (39.0)	3051 (38.7)	2728 (33.5)	1982 (23.0)	
Unwilling	1047 (19.3)	1108 (14.1)	711 (8.7)	444 (5.1)	
Mean age (SD)	27.72 (4.04)	42.45 (4.47)	57.64 (4.40)	71.69 (4.61)	<0.001
Gender (SA)					<0.001
Women	2768 (51.1)	3774 (47.9)	4488 (55.2)	4560 (52.9)	
Men	2630 (48.5)	4091 (51.9)	3637 (44.7)	4052 (47.0)	
Other	21 (0.4)	15 (0.2)	7 (0.1)	10 (0.1)	
Highest Educational Level (SA)					<0.001
Middle school	157 (2.9)	243 (3.1)	125 (1.5)	319 (3.7)	
High school	1452 (26.8)	2201 (27.9)	2830 (34.8)	3691 (42.8)	
Junior college	839 (15.5)	1747 (22.2)	1887 (23.2)	1360 (15.8)	
University	2671 (49.3)	3164 (40.2)	3022 (37.2)	3023 (35.1)	
Graduate school (master's course)	261 (4.8)	418 (5.3)	204 (2.5)	156 (1.8)	
Graduate school (doctoral course)	39 (0.7)	107 (1.4)	64 (0.8)	73 (0.8)	
Occupational type (SA)					<0.001
Agriculture, forestry and fisheries	49 (0.9)	58 (0.7)	35 (0.4)	60 (0.7)	
Construction	167 (3.1)	313 (4.0)	275 (3.4)	125 (1.4)	
Manufacturing	678 (12.5)	1272 (16.1)	935 (11.5)	185 (2.1)	
Information and communications	244 (4.5)	354 (4.5)	247 (3.0)	59 (0.7)	
Transportation and postal services	174 (3.2)	327 (4.1)	258 (3.2)	62 (0.7)	
Wholesale and retail trade	389 (7.2)	712 (9.0)	627 (7.7)	263 (3.1)	
Finance and insurance	139 (2.6)	263 (3.3)	240 (3.0)	42 (0.5)	
Real estate and goods rental and leasing	63 (1.2)	118 (1.5)	125 (1.5)	132 (1.5)	
Scientific research, professional and technical services	74 (1.4)	142 (1.8)	130 (1.6)	64 (0.7)	
Accommodations, food and beverage services	197 (3.6)	219 (2.8)	159 (2.0)	85 (1.0)	
Living-related and personal services and amusement services	121 (2.2)	175 (2.2)	118 (1.5)	69 (0.8)	
Education and learning support	168 (3.1)	304 (3.9)	413 (5.1)	150 (1.7)	
Healthcare and welfare	483 (8.9)	635 (8.1)	547 (6.7)	224 (2.6)	
Combined services	60 (1.1)	73 (0.9)	73 (0.9)	33 (0.4)	
Services (not elsewhere classified)	477 (8.8)	799 (10.1)	836 (10.3)	441 (5.1)	
Public service (not elsewhere classified)	209 (3.9)	323 (4.1)	322 (4.0)	78 (0.9)	
Students	641 (11.8)	0 (0.0)	0 (0.0)	0 (0.0)	
Homemaker	467 (8.6)	1028 (13.0)	1891 (23.3)	3328 (38.6)	
Others	619 (11.4)	765 (9.7)	901 (11.1)	3222 (37.4)	
Annual household income in 2020 (million JPY) (SA)					<0.001
[0−1)	531 (9.8)	501 (6.4)	595 (7.3)	482 (5.6)	
[1−2)	384 (7.1)	578 (7.3)	703 (8.6)	1050 (12.2)	
[2−3)	727 (13.4)	824 (10.5)	902 (11.1)	1712 (19.9)	
[3−4)	811 (15.0)	907 (11.5)	1043 (12.8)	1881 (21.8)	
[4−5)	756 (14.0)	994 (12.6)	951 (11.7)	1148 (13.3)	
[5−6)	565 (10.4)	950 (12.1)	757 (9.3)	751 (8.7)	
[6−7)	423 (7.8)	796 (10.1)	631 (7.8)	419 (4.9)	
[7−8)	348 (6.4)	668 (8.5)	619 (7.6)	343 (4.0)	
[8−9)	210 (3.9)	477 (6.1)	429 (5.3)	201 (2.3)	
[9−10)	177 (3.3)	418 (5.3)	428 (5.3)	206 (2.4)	
≥10	487 (9.0)	767 (9.7)	1074 (13.2)	429 (5.0)	
Underlying disease (Do you have an underlying disease?)					
Yes (diabetes, heart failure, and COPD, etc.)	302 (5.6)	583 (7.4)	1106 (13.6)	1986 (23.0)	<0.001
Information sources about COVID-19 (MA)					

(*continued*)

Table 1 (Continued)

	Age group				
	20-34 yr (Group A)	35-49 yr (Group B)	50-64 yr (Group C)	≥65 yr (Group D)	*p*-value
Medical professionals	750 (13.8)	928 (11.8)	1076 (13.2)	1475 (17.1)	<0.001
Newspapers	690 (12.7)	1815 (23.0)	3153 (38.8)	4966 (57.6)	<0.001
Books and magazines	272 (5.0)	402 (5.1)	534 (6.6)	608 (7.1)	<0.001
Scientific literature	105 (1.9)	119 (1.5)	92 (1.1)	90 (1.0)	<0.001
Television	3650 (67.4)	6047 (76.7)	6973 (85.7)	7843 (91.0)	<0.001
Radio	307 (5.7)	835 (10.6)	1061 (13.0)	1503 (17.4)	<0.001
Internet news sites	2322 (42.8)	4459 (56.6)	4656 (57.3)	4579 (53.1)	<0.001
Search engines (Google, Yahoo, etc.)	1431 (26.4)	1970 (25.0)	1525 (18.8)	1473 (17.1)	<0.001
LINE	624 (11.5)	521 (6.6)	501 (6.2)	480 (5.6)	<0.001
Facebook	115 (2.1)	163 (2.1)	155 (1.9)	173 (2.0)	0.820
Twitter	1124 (20.7)	748 (9.5)	344 (4.2)	172 (2.0)	<0.001
Instagram	236 (4.4)	115 (1.5)	52 (0.6)	28 (0.3)	<0.001
YouTube	431 (8.0)	434 (5.5)	382 (4.7)	360 (4.2)	<0.001
Medical information websites	141 (2.6)	202 (2.6)	219 (2.7)	194 (2.3)	0.288
Blogs or web pages of celebrities and famous people	106 (2.0)	186 (2.4)	144 (1.8)	135 (1.6)	0.002
Local governments such as prefectures and municipalities	860 (15.9)	1788 (22.7)	2468 (30.3)	3556 (41.2)	<0.001
Government	704 (13.0)	1189 (15.1)	1510 (18.6)	2080 (24.1)	<0.001
The Novel Coronavirus Expert Meeting	267 (4.9)	502 (6.4)	686 (8.4)	1007 (11.7)	<0.001
Family or frieds	841 (15.5)	1397 (17.7)	1683 (20.7)	2512 (29.1)	<0.001
Scientists and researchers	102 (1.9)	153 (1.9)	206 (2.5)	363 (4.2)	<0.001
Pharmaceutical companies	73 (1.3)	94 (1.2)	62 (0.8)	75 (0.9)	0.001
Other companies excluding pharmaceutical companies	360 (6.6)	281 (3.6)	161 (2.0)	97 (1.1)	<0.001

***Table 1*: Basic characteristics of 30,053 participants. SA: Single answer, MA: Multiple answer, SD: Standard deviation.**

Results

We recruited 30,053 participants including 5,419 (18.0%), 7,880 (26.2%), 8,132 (27.1%) and 8,622 (28.7%) respondents for Groups A-D, respectively. Among the ALL group, 56.1% (41.7, 47.2, 57.7 and 71.9% for Groups A-D) of respondents accepted the vaccine, 32.9% (39.0, 38.7, 33.5 and 23.0% for Groups A-D) were unsure of, and 11.0% (19.3, 14.1, 8.7 and 5.1% for Groups A-D) were unwilling to take the vaccination (Table 1). In addition, 13.2% of the ALL group had underlying diseases (5.6, 7.4, 13.6 and 23.0% for Groups A-D). Mean (standard deviation, SD) age was 52.3 (16.4) years old, 41.8% of respondents earned more than $46,000 per year, and 43.9% of respondents had a university degree or higher among the ALL group. The proportion of respondents who were unsure and unwilling to take the vaccination was skewed toward the younger generation: 58.1% of Group A were unsure or unwilling to take the vaccination, while only 28.1% of Group D, the oldest group, indicated so. Regarding the media channels to obtain COVID-19 related information, television (81.6% for ALL group, 67.4, 76.7, 85.7 and 91.0% for Groups A-D), internet news sites (53.3% for ALL group, 42.8, 56.6, 57.3 and 53.1% for Group A-D) and newspapers (35.4% for ALL group, 12.7, 23.0, 38.8 and 57.6% for Group A-D) were the top three popular sources. The popularity of media channels was significantly different by age group ($p<0.05$ for most information sources except Facebook and Medical information websites).

Table 2 shows the estimated Boolean expression, the associated OR and the 95% confidence intervals (CI) after adjusting for socio-demographic and health-related confounders using 10 multinomial logic regression models (denoted M1-10 in Table 2). Among the ALL group, we observed that those who were unsure of the vaccination tended not to obtain information from media that are generally regarded as authorities such as *Med* (Medical professionals), *Gov* (Government), and *TV*, and those who obtained information from *News* (Newspaper) tended to accept the vaccination (or conversely, those who did not obtain information from *News* tended to be unsure of the vaccination): in M1, $!Med \wedge !TV$ with OR (95% CI) = 1.75 (1.62, 1.89), $!Med \wedge !Gov$ with OR (95% CI) =1.53 (1.44, 1.62), and *News* with OR (95% CI) = 0.67 (0.63, 0.71). On the other hand, media channels related authorities such as *News*, *Exp* (The Novel Coronavirus Expert Meeting), *Med*, and *Loc* (Local government) were associated with being unwilling, while note that the non-use of *TV* were also associated with the unwilling group: in M2, $News \vee Exp$ with OR (95% CI) = 2.00 (1.47, 2.75), $Med \vee Loc$ with OR

Unsure† Boolean expressions	OR*	*p*-value	Corresponding sample size	Unwilling† Boolean expressions	OR*	*p*-value	Corresponding sample size
ALL ages: M1 (left, AUC=64.4) and M2 (right, AUC=73.6)							
!Med ∧ !TV	1.75	<0.001	3263	*News ∨ Exp*	2.00	<0.001	8542
(Ref: those who use Med or TV. i.e., Med ∨ TV)	(1.62, 1.89)			*(Ref: those who do not use both News and Exp. i.e., !News ∧ !Exp)*	(1.47, 2.75)		
!Med ∧ !Gov	1.53	<0.001	18961	*Med ∨ Loc*	3.13	<0.001	8080
(Ref: those who use Med or Gov. i.e., Med ∨ Gov)	(1.44, 1.62)			*(Ref: those who do not use both Med and Loc. i.e., !Med ∧ !Loc)*	(2.58, 3.81)		
News	0.67	<0.001	10013	*!TV*	2.25	<0.001	3585
(Ref: those who does not use News. i.e., !News)	(0.63, 0.71)			*(Ref: those who use TV. i.e.,TV)*	(1.84, 2.77)		
20-34 yr (Group A): M3 (left, AUC=66.6) and M4 (right, AUC=69.9)							
!Exp	0.51	<0.001	4122	***Exp***	0.65	<0.001	202
(Ref: those who use Exp. i.e., Exp)	(0.44, 0.60)			*(Ref: those who do not use Exp. i.e.,!Exp)*	(0.57, 0.74)		
!Loc ∧ !Med	0.71	<0.001	3147	*!TV ∧ News*	1.40	<0.001	1036
(Ref: those who use Loc or Med. i.e., Loc ∨ Med)	(0.64, 0.79)			*(Ref: those who use TV or do not use News. i.e., TV ∨ !News)*	(1.20, 1.62)		
Com ∨ Loc	1.64	<0.001	991	*Med ∨ Loc*	1.28	<0.001	1012
(Ref: those who do not use both Com and Loc. i.e., !Com ∧ !Loc)	(1.42, 1.90)			*(Ref: those who do not use both Med and Loc. i.e., !Med ∧ !Loc)*	(1.16, 1.42)		
35-49 yr (Group B): M5 (left, AUC=64.4) and M6 (right, AUC=69.6)							
Med ∨ Book	2.27	<0.001	1068	***!Fam ∧ (Exp ∨ News)***	0.46	<0.001	672
(Ref: those who do not use both Med and Book. i.e., !Med ∧ !Book)	(1.89, 2.74)			*(Ref: those who use Fam or do not use both Exp and News. i.e., Fam ∨ (!Exp ∧ !News))*	(0.42, 0.50)		
!Fam ∧ TV	0.37	<0.001	4339	***!Loc***	0.51	<0.001	3667
(Ref: those who use Fam or do not use TV. i.e., Fam ∨ !TV)	(0.29, 0.46)			*(Ref: those who use Loc. i.e., Loc)*	(0.46, 0.56)		
!Gov	0.75	<0.001	5699	*!TV*	4.02	<0.001	1156
(Ref: those who use Gov. i.e., Gov)	(0.68, 0.84)			*(Ref: those who use TV. i.e., TV)*	(3.68, 4.39)		
50-64 yr (Group C): M7 (left, AUC=61.6) and M8 (right, AUC=70.1)							
	0.33	<0.001	1480		0.46	<0.001	2793

(continued on next page)

Table 2 *(Continued)*

Unsure† Boolean expressions	OR*	*p*-value	Corresponding sample size	Unwilling† Boolean expressions	OR*	*p*-value	Corresponding sample size
Exp ∨ ***Med*** *(Ref: those who do not use both Exp and Med. i.e., !Exp ∧ Med)*	(0.19, 0.54)			***Exp*** ∨ ***Med*** ∨ ***News*** *(Ref: those who do not use Exp, Med and News. i.e., !Exp ∧ !Med ∧ !News)*	(0.35, 0.58)		
!TV *(Ref: those who use TV. i.e., TV)*	2.90 (2.45, 3.42)	<0.001	908	*TV* *(Ref: those who do not use TV. i.e., !TV)*	1.92 (1.58, 2.33)	<0.001	4626
!News ∨ ***YouTube*** *(Ref: those who use News and do not use YouTube. i.e., News ∧ ! YouTube)*	0.44 (0.36, 0.53)	<0.001	4548	*!YouTube* *(Ref: those who use YouTube. i.e., YouTube)*	3.41 (2.92, 3.97)	<0.001	5158
≥65 yr (Group D): M9 (left, AUC=63.6) and M10 (right, AUC=70.2)							
!Med ∧ ***(!TV*** ∨ ***Exp)*** *(Ref: those who use Med or TV but do not use Exp. i.e., Med ∨ (TV ∧ ! Exp))*	0.47 (0.40, 0.56)	<0.001	1113	***News*** ∨ ***LINE*** *(Ref: those who do not use both News and LINE. i.e., !News ∧ LINE)*	0.54 (0.44, 0.66)	<0.001	4122
Exp *(Ref: those who do not use Exp. i. e., !Exp)*	0.24 (0.20, 0.29)	<0.001	971	*!Med* ∧ *!TV* *(Ref: those who use Med or TV. i.e., Med* ∨ *TV)*	6.63 (5.11, 8.57)	<0.001	384
News *(Ref: those who do not use News. i. e., !News)*	0.43 (0.31, 0.58)	<0.001	4786	***!YouTube*** *(Ref: those who use YouTube. i.e., YouTube)*	0.35 (0.25, 0.50)	<0.001	6383

***Table 2*: Estimated Boolean expressions and OR (95% CI) by age groups using multinomial logic regression models.**

† reference group is acceptance.

* estimated odds ratios (OR) are adjusted for socio-demographic and health-related confounders including occupation type, income, educational level, gender and underlying diseases **Bold**: the associated odds ratio ≤ 1 *A*: A is TRUE (i.e., use media A) !*A*: A is FALSE (i.e., not use media A) *A* ∧ *B*: A and B are both TRUE *A* ∨ *B*: A or B is TRUE *Med:* Medical professionals, *TV*: TV program, *Exp*: The Novel Coronavirus Expert Meeting, *Gov*: Government, *Loc*: Local government, *Book*: Books or magazines, *News*: Newspapers, *LINE*: LINE app, *Fam*: Family or close friends, *Pha*: Pharmaceutical companies, *Com*: Company excluding pharmaceutical companies

(95% CI) = 3.13 (2.58, 3.81), and *!TV* with OR (95% CI) =2.25 (1.84, 2.77).

According to the results of age-stratified analyses, those who were unsure of the vaccination among the younger generation (20-49 yr, Groups A and B) tended to obtain information from authorities such as *Exp, Loc, Med*, and *Gov* (M3 and 5), while among the older generations (≥50 yr, Groups C and D), such people tended not to obtain information from such authorized media channels (M7 and 9). In addition, *Com* ∨ *Loc* in M3 (OR = 1.64 (1.42, 1.90)) and *Med* ∨ *Book* in M5 (2.27 (1.89, 2.74)) indicates the preferable media channel to approach those who were unsure of the vaccination. As for the comparison between acceptance and unwilling to take the vaccination (i.e., M4, 6, 8 and 10), those aged 35-64 yr (Groups B and C) who obtained information from *Exp* and *News* tended to accept the vaccination (M6 and 8) (or conversely, it also means that those who do not use these media channels tended to be unwilling). Among those who were ≤ 34 yr (Group A), those who do not obtain information from *Exp*, but obtain information from *News, Med*, or *Loc* without watching *TV* tended to be unwilling to take the vaccination (M4). Among those who were ≥65 yr (Group D), those who do not obtain information from *Med* or *TV* tended to be unwilling to take the vaccination (M10). It is interesting to note that social networking services such as *YouTube* and *LINE* were identified as the media channel only for those who were ≥ 50 yr (Groups C and D) and were not identified among younger generations. In particular, among 50-64 year age group (Group C), those who do not obtain information from *YouTube* tended to be unwilling to take the vaccination. In contrast, those who obtain information from *YouTube* tended to be unwilling to take the vaccination among the group of ≥65 yr (Group D). Lastly, note that since our logic regressions used boolean type covariates, it is generally impossible to compare the results of the logic and typical logistic regression that included the top five major media channels for checking the overall effect. However, we observe that the most included media channels in the typical logistic regression models had a strong association with vaccine attitudes with statistically significant p-values (in the Supplemental file).

Discussion

Our study showed that, among approximately 30,000 individuals aged ≥20 years, the proportion of respondents who responded 'Not sure' or 'No' regarding intention to take COVID-19 vaccine was skewed toward younger generations, with 58.1% of those aged ≤34 years old reporting unwillingness or refusal compared to 28.1% of those aged ≥65 years old. Such a high percentage of unsure and unwillingness and such a large skewness across generations was not observed in other surveys [6]. As already reported in Nomura *et al.* (2021),[26] 56.1% of the general population indicated acceptance, 32.9% were unsure, and 11.0% were unwilling to take the vaccine. These proportions of acceptance are relatively lower than the result of Machida *et al.* (2021), which was published just three months before and indicated that 62.1% might accept the vaccination in a much smaller Japanese sample.[23] We found that the proportions of those who were unsure or unwilling to take the COVID-19 vaccination might be higher than in Western or other Asian countries,[4,6] and this observation is consistent with the well-known fact that Japanese citizens tend to have the least trust in vaccination.[34]

Media channels to approach those who were unsure or unwilling to take the COVID-19 vaccine

Previous studies have identified several psychological factors associated with the attitude toward vaccination, such as perceived risks and benefits of the vaccination as well as perceived norms.[5,8,21,23] In addition, Wood and Schulman (2021)[35] suggested that different approaches might be required to effectively disseminate information for those who are addressing hesitation and apathy towards vaccination. However, little effort has been made to clarify the best media strategy to effectively approach them. In this sense, this is the first study to identify key media channels and their combination that can help develop media strategies.

After adjusting for socio-demographic and health-related confounders, the multinomial logic regression with logistic link function identified some important media channels and their combinations that were strongly associated with being unsure or unwilling to take the COVID-19 vaccination. It suggests a tailor-made PR campaign strategy. For example, the non-use of media channels that are generally considered to be authoritative such as reports from medical professionals, government and TV, are associated with being unsure of the vaccination among ALL groups. A similar tendency is observed among elder generations (Groups C and D). Therefore, a basic media campaign strategy for the whole population to approach such people should be initiated and led by spokespersons other than experts or medical professionals in practice. However, especially for younger generations (Groups A and B), our analysis suggests the opposite association: the use of such authoritative media channels was associated with the unsure group. In addition, especially among younger generations, our results on M3 and M5 show that advertisement based on private companies, local government, books or magazines might be good alternative channels. In contrast, the use of media channels such as newspapers and the expert meeting and the non-use of TV were associated with being unwilling to take the vaccination among ALL group. The same tendency to not use TV was also observed in all the other sub-age groups except Group C. Therefore, a basic

media campaign strategy to approach them should be led via non-TV channels. One idea might be that an expert or someone in authority gives positive statements about the vaccination program on newspapers or web blogs.

There were also interesting and informative combinations such as *!Med* ∧ *!TV* and *!Med* ∧ *!Gov* among ALL groups which suggest that the promotion on TV by experts or government officials, which is the current main PR strategy, would not effectively reach those who are unsure of the vaccination. Another interesting finding was that social networking services such as *YouTube* and *LINE* were identified as media channels only for those who were ≥ 50 years old. This might suggest that older people are likely to have different perceptions of online information, but are more sensitive to it, compared with the younger generation. Therefore, we recommend that the media campaign should differ from generation to generation and be optimized for the type of attitude toward vaccination. Campaigns for those who are unsure or unwilling to take the vaccination should be conducted in different manner, and, lastly, be provided on a mixture of online and offline media channels.

It is also important to foster trust among those who are unsure and unwilling to take the vaccination. In general, disseminating public health messages is often considered the responsibility of experts and scientist as well as public authorities. Vaccination recommendations by public authorities and scientists sometimes lead people to being unsure or unwilling to take the COVID-19 vaccination if they have a higher level of distrust in the messages sent from them.[36,37] In fact, in Japan, perceived distrust in government and experts involved in COVID-19 vaccines was strongly correlated with vaccine hesitancy and resistance.[16] To make reliable and smooth communication between government, experts and residents, it is important to build a relationship that fosters trust in the authorities, in addition to understanding what media channels should be used to promote vaccination. In addition, messages through the selected media channels should also be optimized to their target audience. Our previous study showed that, to decide about vaccination, most people tried to request further detailed information about the side-effect, effectiveness, other people's vaccination situation, and doctor's recommendations.[16] This indicates that early and accurate messages from public authorities and experts that includes this information may work as a practical strategy to increase the vaccination. It is important to fairly convey not only the benefit but also disadvantages of vaccines such as side-effects, and to properly report the balance of these risks so that those concerned about side-effects can properly understand the relative risk of these side-effects compared to the disease they are vaccinated against.

Finally, it is important that mainstream and authoritative media channels report responsibly on vaccination. We identified that use of newspapers was associated with being unsure of the vaccination in the Japanese population. Many Japanese newspapers have been reporting rumors and focusing excessively on very rare side-effects rather than reporting on the balance of risks in the context of this pandemic.[38,39] Therefore, health and public policy reporters in these newspapers need to recognize their responsibility to help in the promulgation of public health messages, consult with experts about the proper facts regarding the vaccination program, and report responsibly and accurately about this issue. The Japan government also needs to develop guidelines for the responsible reporting of vaccines in the media, and obtain cooperation from all major media outlets in adhering to these guidelines.

As discussed in Nomura *et al.* (2021),[26] this study has several limitations. Firstly, the sampling biases commonly associated with online surveys could have affected this study.[40] Since we used the quota sample method to match the samples and Japanese population in terms of the distribution of age, gender, and prefecture population ratio, the distribution of demographic background in our dataset should be similar to that of the total population.[18] Note that education level was adjusted in the model, but there may still be a selection bias against people who do not use the Internet. Secondly, in general, online surveys tend to attract those who have lower concerns about certain social issues compared to interviews or other survey methods, which leads to selection bias in our dataset.[41]. In addition, since we kept the questionnaire publicly open until the pre-defined sample size was reached, this procedure might also include the selection bias (i.e., those who are interested in vaccines are more likely to fill out the questionnaire first). Lastly, this is an observational study and thus it gives the limited estimates and implications for the causal effect of media choice on vaccination acceptance. We welcome the re-evaluation of our results in interventional trial studies and randomized controlled study to estimate the causal effect of the choice of media and public health messages on them is our ongoing project.

Conclusions

Despite these limitations, our findings provide important evidence on suitable media channels to approach those who feel unsure or unwilling to take COVID-19 vaccination. Further, to the best of our knowledge, we collected the largest survey data to date, which allows for stratified analysis according to generations and offers tailor-made media strategies for the vaccine campaign. As with other studies that showed a large prevalence of reluctant attitude toward the COVID-19 vaccine in other countries, Japan is shown to be one of the

countries with the lowest trust in vaccination. To effectively approach COVID-19 vaccine unsure and unwilling groups, media campaign strategies should be constructed based on the evidence. Our study helps not only policy makers but also medical experts to inform public health messages efficiently and directly to the people.

Author Contributions

DY, AE and SN made substantial contributions to conception and design, analyzed the data, wrote the first draft of the manuscript, and interpreting the results. DY, AE, SN, TK, YT, MM, HS, KS, SG, SS, HK, SK, MA, KS, YY and HM provided substantial scientific input in interpreting the results and drafting the manuscript. All authors were involved in data interpretation and made meaningful contributions to the final submitted manuscript.

Declaration of Competing Interest

None.

Availability of data and material/code availability

The datasets generated during and/or analyzed during the current study are not publicly available due to ethical considerations but are available from the corresponding author on reasonable request.

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Ethics approval

Ethical approval was granted by the Ethics Committee of Keio University School of Medicine under authorization number 20200340. Respondents had to provide their consent before they proceeded to the questionnaire response page.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lanwpc.2021.100330.

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