Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Opt-out policy and its improvements promote COVID-19 vaccinations

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ABSTRACT

Rationale: Vaccination uptake is a major strategy to prevent infection with SARS-CoV-2 and curb the transmission of COVID-19. However, many people remain unwilling to receive the COVID-19 vaccine.
Objective: Using default nudges, the present study examines (a) whether opt-out policy and its improvements could increase intention and attitude to get vaccinated and (b) whether these default effects differ across diverse risk-perception groups.
Method: An online experiment with 1926 unvaccinated Chinese respondents was conducted in February 2021. We measured willingness to be vaccinated after informing opt-in policy, standard opt-out policy, and its five improvements (opt-out education, opt-out opportunity, opt-out social norm, opt-out feedback, and opt-out opportunity). Risk perception of the pandemic of COVID-19 and vaccination were also measured.
Results: (a) Opt-out policy and its improvement (except the opt-out transparency) increased intentions to be vaccinated. Policies with a vaccination default did not weaken people's attitude toward policy and policymakers compared with the opt-in policy, but participants in the transparent improvement group reported lower freedom of choice than those in the opt-out group. (b) Further latent profile analysis revealed four classes underlying risk perception: risk exaggerators, risk deniers, disease-specific risk perceivers, and vaccine-specific risk perceivers. But there was no conclusive evidence that the effect of risk perception differs as a function of defaults.
Conclusions: These findings provide new psychological evidence for formulating more targeted vaccination policies and highlight the importance of risk perception to understand vaccination intentions.

1. Introduction

As of November 2021, the novel coronavirus 2019 (COVID-19) pandemic has led to over 200 million diagnosed cases, including more than 5 million deaths worldwide. The global pandemic, and the associated public health response, has also raised significant economic and social costs (Coibion et al., 2020; Yamin, 2020). Given its substantial morbidity, widespread vaccination could be a critical protective behavior to prevent further infection and mortality (Hodgson et al., 2021). Through vaccination uptake, a sufficient proportion of the population could acquire immunity and then reach herd immunity thresholds for coronavirus (John and Samuel, 2000; Randolph and Barreiro, 2020; Sridhar and Gurdasani, 2021).

Although a series of COVID-19 vaccines have been authorized and recommended for use throughout the world, global vaccination rates are still far below the number required for herd immunity (Kadkhoda, 2021). The World Health Organization has demonstrated that public acceptance and uptake of COVID-19 vaccines is facing an unprecedented challenge (WHO, 2020). A recent search for published articles related to COVID-19 vaccine hesitancy has revealed that the percentage of vaccine acceptance is not very high (Troiano and Nardi, 2021). For example, around 25% of French people investigated did not agree to get vaccinated (Detoc et al., 2020), 56% of Portuguese citizens wanted to wait, and 9% refused the vaccine (Soares et al., 2021), while nearly one-third of American adults indicated that they would refuse COVID-19 vaccination when a vaccine became available (Motta, 2021; Reiter et al., 2020; Thigpen and Funk, 2020). People's hesitancy or refusal to be vaccinated depends on multiple factors, among which trust in clinical efficacy (Tentori et al., 2021; Troiano and Nardi, 2021) and concerns about safety (Machingaidze and Wiysonge, 2021) are regarded as primary reasons. These factors shape how people perceive the risk of being vaccinated, although they may also have varying degrees of disease risk perception. Specifically, a high-risk perception of vaccination but low-risk perception of the disease may be associated with a lower probability of receiving vaccination, while those who only have higher anxiety related to the disease would be more likely to get vaccinated

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(Freimuth et al., 2017; Renner and Reuter, 2012). Given the enormous human and economic costs of the pandemic, it is our responsibility to identify effective and low-cost approaches that can be easily conducted to promote COVID-19 vaccine uptake, especially among high vaccine risk perceivers.

Defaults in a decision-making context, as a highly cited example of nudges, have been increasingly used to improve the public approval for social policies in recent years. It is a condition that is automatically imposed when the decision-maker fails to make a decision (Johnson and Goldstein, 2003). In 1993, a study related to choice framing first demonstrated the default effect, with a pre-selected option promoting insurance-purchase choice (Johnson et al., 1993). A growing line of research has demonstrated default effects in various areas, such as saving behavior (Madrian and Shea, 2001), pro-environmental behavior (Ebeling and Lotz, 2015; Pichert and Katsikopoulos, 2008), and organ donation (Li et al., 2013; van Dalen & Henkens, 2014). Defaults both preserve freedom of choice, with no explicit prohibition against people choosing other alternatives, and effectively exert an influence on the target behavior, making defaults preferred by policymakers (Dinner et al., 2011; Thaler and Sunstein, 2008).

The literature on vaccination defaults generally involves two types of vaccination policies: an opt-in policy (vaccination is rejected by default; explicitly opting in is required if a person wants to be vaccinated) and an opt-out policy (vaccination is accepted by default; explicitly opting out is required if a person does not want to be vaccinated). However, the effects of opt-out policy (vs. an opt-in policy) on promoting vaccine uptake is not well understood. Taking the influenza vaccination as an example, Chapman et al. (2010) found that opt-out with a priority rule system increased the probability of influenza vaccination, while Wootton et al. (2018) suggested that opting out did not perform better than the opting-in approach in promoting influenza immunization. In another study, although there was no statistically detectable difference between two policies on being vaccinated against influenza, health care workers with an opt-out policy were more likely to have an appointment for influenza vaccination (Lehmann et al., 2016). Findings were also mixed in the case of childhood immunization. Researchers found that parents' consent to obtain an HPV vaccination for their sons was higher with an opt-in policy than with an opt-out policy (Reiter et al., 2012), while another study indicated that the opt-out approach achieved high participation in childhood immunization (Berry et al., 2012). Given the aforementioned controversy regarding the default effect on vaccination behavior and the research gap in using defaults to foster COVID-19 vaccination, the present study aimed to explore whether modifying the defaults could influence COVID-19 vaccination, especially for people with different classes of risk perception.

In addition, a growing discussion has appeared concerning the acceptability of the default nudge. Felsen et al. (2013) indicated that people prefer conscious decisional enhancement over subconscious manipulation such as nudges. Sunstein (2019) demonstrated that, out of 12 unpopular nudges, seven include using the opt-out default. Researchers have been aware of people's concerns about opt-out policy. In Hagman et al.'s (2015) study, a majority of respondents perceived opt-out nudge interventions as intrusive to freedom of choice. Another survey reported that only 36% of Europeans investigated supported using default rules (Reisch and Sunstein, 2016). Default nudges even displayed a backfire effect on target behavior when they triggered individuals' perceived inference of manipulation (Fan et al., 2019).

These critical voices on the acceptability and ethicality of default nudge have generated various improved versions of opt-out nudges. For example, a series of studies reported that information disclosure about the opt-out nudge would not undermine the policy's effectiveness and even increased positive attitude towards the policy (Kroese et al., 2016; Paunov et al., 2019; Yan and Yates, 2019). In these transparent improvements, information such as the purpose of default, its potential influence, or both will be provided with the conventional opt-out policy (Bruns et al., 2018). Recent research compared people's perceptions of opt-in and three opt-out improvements: transparency, education, and emphasis on low cost (Yan and Yates, 2019). Specifically, transparency and emphasis on low-cost opt-out were more effective than education at addressing concerns about retirement savings and carbon emission offsets, while all of the improved opt-out policies failed to decrease ethical concerns and most emotional discomfort concerns in organ donation. Indeed, improvements to the conventional opt-out approach will occur by highlighting different characteristics. More improvements need to be examined, such as emphasis on feedback channels and group information. It is reasonable to expect that emphasizing feedback channels will enhance the sense of procedural justice (Kim and Beehr, 2020), and emphasizing group information will generate a social norm (Berger, 2019) and thus may increase acceptance of the opt-out policy. The current study attempts to compare the effectiveness and acceptability of opt-out approaches that possess various improvements.

As Yan and Yates (2019) showed, each type of improved version has strengths as well as weaknesses in a specific scenario. In this study, we aimed to compare the relative effectiveness and acceptance of opt-out policies to an opt-in policy and to identify whether any of improved default nudges (transparency, education, emphasis on social norm, emphasis on feedback, and emphasis on opportunity) would yield similar acceptability to that of opt-in without impairing effectiveness. In addition, several factors affect defaults' effectiveness (Jachimowicz et al., 2019; Zhao et al., 2022). For example, defaults are more effective when they are perceived as conveying an endorsement by the choice architect (McKenzie et al., 2006). The more decision-makers feel that the preselected option reflects the status quo, the more effective the default is likely to be (Jachimowicz et al., 2019). Risk attitudes toward the disease and vaccine are related to the extent to which vaccination is perceived as a status quo. Decision-makers may be less likely to adhere to defaults when they perceive a high risk of the vaccination and a low risk of the disease. Hence, we speculate that the effectiveness of vaccination defaults may vary depending on the classes of risk perception for the vaccine and disease. Recent studies have revealed that risk perception of COVID-19 vaccine side effects was negatively associated with vaccination intention (Paudel et al., 2021; Zheng et al., 2022). We hypothesized that vaccination uptake would always be acceptable for people who perceive low risk for vaccines and high risk for disease, and thus a ceiling effect on the effectiveness of vaccination policies may be observed in this population. Secondly, those who don't worry about the disease but perceived a high risk for vaccine would have the lowest level of vaccination intention and opt-out improvements may be more effective than opt-in policy and traditional opt-out policy for them. However, vaccination intention was complicated for those who perceived an overlaid risk for both disease and vaccination, and we hypothesized that opt-out education policy and opt-out social norms might be effective for this subgroup.

2. Method

2.1. Participants

The experiment was conducted during February 4 to 8, 2021, when the COVID-19 vaccine was approved for use in China. We contacted 2220 Chinese citizens through an online survey platform totally, and 2020 (91%) respondents completed the survey. After excluding those who failed the comprehension check questions and those who had been vaccinated ($n = 94$), our final sample consisted of 1926 unvaccinated Chinese citizens (mean age = 29.77, $SD = 8.70$). The details of the demographic information are shown in Table 1. We divided education level and average monthly income into three categories and included them in statistical analysis as factor variables (high school or below and low income were coded as reference levels). The study was approved by the Institutional Review Board of the Institute of Psychology at the Chinese Academy of Sciences. Informed consent was provided by all participants.

Table 1
Characteristics of participants (N = 1926).

Characteristic		*n*	Overall
Gender	Male	836	43.4%
	Female	1090	56.6%
Age (years)	16–25	696	36.1%
	26–35	852	44.2%
	Over 35	378	19.7%
Education level	High school or below	123	6.4%
	College	1650	85.7%
	Master's or above	153	7.9%
Average monthly Income (yuan)	≤5000	652	33.9%
	5001–10,000	823	42.7%
	>10,000	451	23.4%

2.2. Materials and procedure

Participants were randomly assigned to one of the vaccination policies. We assessed their risk perception, vaccination status, willingness to be vaccinated with the specific policy, attitude towards the policy, and demographic information.

There were seven vaccination policies, including an opt-in policy without defaults, an opt-out policy with vaccination as the default, and five improved versions of the latter. The opt-in policy was a policy form in which people were assumed to be unwilling to be vaccinated against COVID-19 unless they actively chose to be, while the opt-out condition assumed that people were willing to be vaccinated unless they chose to unregister. In the improved opt-out versions, different information was provided for the opt-out policy. The opt-out transparency condition explained the purpose and the fact that people may be subconsciously affected by the default. The opt-out education condition offered more knowledge about the COVID-19 vaccine, for example, "high vaccination rates could help establish herd immunity, thereby controlling the spread of the virus."

In addition to the policies of opt-out transparency and opt-out education used in Yan and Yates (2019), we also developed three opt-out improvements. First, social norms are regarded as one of the explanations for the default effect, with people often motivated to act following perceived social norms (Everett et al., 2015). Brewer et al. (2017) found that social processes can motivate people to be vaccinated. Thus, we proposed an opt-out social norm condition, in which participants were informed that many people have been vaccinated, and the more people who have been vaccinated in an area, the easier it is to achieve herd immunity. Second, a recent study has indicated that feedback channels influence procedural justice and the likelihood of policy acceptance (Kim and Beehr, 2020). We also developed an improved opt-out version that adds a feedback channel, telling people that they can leave any advice or comments on the relevant website during the vaccination process. Lastly, the opt-out opportunity condition added information that participants who did not get vaccinated this time would still have the chance to apply for vaccinations in the future (similar to the low-cost opt-out approach in Yan and Yates, 2019).

After participants read the given policy scenario, they responded to willingness to be vaccinated against COVID-19 on a 6-point Likert scale (1 = totally unwilling to, 6 = totally willing to). Vaccination intention has been widely adopted as a key dependent variable measure in studies related to COVID-19 vaccination promotion (see Davis et al., 2022 and James et al., 2021). Therefore, the current study also used vaccination intention as a nudging target. The attitude outcome measures were adapted from Yan and Yates (2019), including four items (trust in policy-makers, perceived ethicality of the policy, perceived restriction of choice freedom, and perceived deception and manipulation), and a higher score represented a more positive perception. For example, "Please indicate how deceptive and manipulative you think this policy is, ranging from 1 (not at all) to 5 (very much)."

Risk perception was measured by asking participants the following six items, ranging from 1 to 100. Specifically, three items measured the risk perception of the disease (Man et al., 2019; Sobkow et al., 2020): 1) worry about the pandemic: "Please rate the current level of your worry about COVID-19"; 2) perceived vulnerability to the pandemic: "Please rate the possibility that you will catch the disease"; 3) perceived controllability of the pandemic: "Please rate the controllability of the disease for the whole society." Cronbach's α of the measure was 0.621. Items measuring COVID-19 vaccine risk perception were drawn on previous measures on risk perception of safety behavior (Edmonds et al., 2011; Wilson et al., 2019): 1) worry about the vaccine: "Please rate the level of risk of your vaccination"; 2) perceived safety of the vaccine: "Please rate the level of your worry about negative reactions after being vaccinated"; 3) perceived effectiveness of the vaccine: "Please rate the effectiveness of the current vaccines against the disease." Cronbach's α of the measure was 0.66.

3. Results

3.1. Willingness to be vaccinated

Primary analyses were tested using analyses of covariance (ANCOVAs) with post-hoc contrasts. Group means of willingness to be vaccinated and attitude are reported in Table 2. Data sets and relevant scripts for data analysis are available online at https://osf.io/4m9eg/. Controlling for demographic variables, including age, gender, education, economic status, physical health, and health concerns, an ANCOVA showed that a framings of vaccination policy had a significant effect on participants' willingness to be vaccinated: $F(6, 1911) = 3.72$, $p = .001$, $\eta_p^2 = 0.01$. The comparisons between the opt-in policy and opt-out policies showed that compared with the opt-in policy, the conventional opt-out policy ($p = .007$, 95% CI = [0.07, 0.45]), opt-out education ($p < .001$, 95% CI = [0.20, 0.58]), the opt-out social norm condition ($p = .002$, 95% CI = [0.10, 0.48]), the opt-out feedback condition ($p = .007$, 95% CI = [0.07, 0.45]), and opt-out opportunity ($p < .001$, 95% CI = [0.16, 0.54]) all significantly increased participants' willingness to be vaccinated, while there was no statistically significant difference between the opt-in condition and the opt-out transparency condition ($p = .143$, 95% CI = [−0.05, 0.33]). However, no detectable significant difference was observed in further comparisons between the conventional opt-out policy and improved opt-out policies; that is to say, none of the improved versions caused a significant change in participants' willingness to be vaccinated compared to conventional opt-out conditions.

3.2. Attitude toward vaccination policies

Responses on attitude measures have been reversed, so that a higher score was transformed to represent a more positive attitude towards vaccination policies. We conducted ANCOVAs respectively on recoded trust in policymakers, perceived ethicality, perceived freedom of choice, as well as perceived deception and manipulation. The results revealed that main effect of policy framings was significant only for perceived freedom of choice ($F(6, 1913) = 2.28$, $p = .034$, $\eta_p^2 = 0.01$). Group mean on freedom of choice was higher for opt-out education condition than for the opt-in condition ($p = .035$, 95% CI = [0.00, 0.01]). However, none of the improved opt-out policies significantly improved people's perceived freedom compared with the conventional opt-out approach, and opt-out transparency even decreased participants' perceived freedom compared with the opt-out policy ($p = .026$, 95% CI = [−0.37, −0.02]). Meanwhile, there was no significant effect of vaccination policies on participants' trust in policy-makers ($F(6, 1913) = 1.54$, $p = .160$), perceived ethicality [$F(6, 1913) = 1.29$, $p = .261$], and perceived deception and manipulation [$F(6, 1913) = 0.83$, $p = .548$].

3.3. Further analyses

A latent profile analysis (LPA) was used to identify individuals' risk

Table 2
Means (SDs) of Willingness to be Vaccinated and Attitude for the Seven Policies.

Condition	Willingness to be Vaccinated	Attitude			
		Trust	Restriction of Freedom	Ethicality	Deception and Manipulation
Opt-in (n = 274)	4.39 (1.19)	3.83 (.81)	3.44 (1.05)	3.85 (.83)	3.62 (1.19)
Conventional Opt-out (n = 269)	4.64 (1.12)	3.95 (.77)	3.54 (1.08)	3.88 (.88)	3.68 (1.04)
Improved Opt-out					
Opt-out Transparency (n = 276)	4.50 (1.17)	3.88 (.88)	3.33 (1.03)	3.77 (.92)	3.59 (.98)
Opt-out Education (n = 269)	4.76 (1.15)	4.00 (.86)	3.62 (1.01)	3.97 (.95)	3.75 (.97)
Opt-out Social Norm (n = 283)	4.63 (1.17)	3.94 (.84)	3.52 (1.00)	3.80 (.89)	3.65 (1.03)
Opt-out Feedback (n = 274)	4.63 (1.21)	3.89 (.88)	3.56 (1.09)	3.87 (.96)	3.65 (1.06)
Opt-out Opportunity (n = 281)	4.74 (1.12)	3.94 (.78)	3.55 (1.07)	3.86 (.89)	3.65 (1.11)

perception types using the R package tidyLPA with the standardization of risk perception of COVID-19 and the standardization of risk perception of vaccination. As summarized in Table 3, the four-class model had a possibly smaller AIC and SABIC but a better entropy, which represented a higher classification accuracy (Peugh et al., 2013; Wang et al., 2017). To avoid the risk of over-extracting and a complex solution that would be difficult to interpret, we selected the four-class model as the final model. Fig. 1 presents the standard score of the perceived risk of COVID-19 and perceived risk of the COVID-19 vaccine. The first and largest latent class (n = 695, 36.1%) included individuals who reported high risk perception of getting vaccinated but low risk perception of COVID-19, which we labeled as "vaccine-specific risk perceivers." The second latent class (n = 548, 28.4%), named "risk deniers," consisted of participants who perceived low risk of both COVID-19 and vaccination. The third class (n = 393, 20.4%), named "risk exaggerators," consisted of those who had high scores on both the perceived risk of COVID-19 and the perceived risk of vaccination. Lastly, the fourth class (n = 290, 15.1%) included those who reported high risk perception of COVID-19 but low risk perception of the vaccine. We named this class the "disease-specific risk perceivers." Individuals belonging to a specific group could display similar levels of risk perception of COVID-19 and vaccination uptake. Thus, participants were grouped into four classes based on their score on two dimensions of risk perception (Fig. 1). Table 4 shows the size of each classification. Vaccine-specific risk perceivers accounted for the largest proportion in the sample, followed by risk deniers and risk exaggerators, and disease-specific risk perceivers accounted for the smallest proportion. As shown in Fig. 2, vaccination intentions appeared to be different across diverse risk-perception groups. We then explored how diverse risk-perception groups respond to default nudges.

A two-way (vaccination policies; risk perception groups) ANCOVA was conducted to explore whether the effect of default nudges on vaccination intentions was influenced by risk perception groups. There was still a main effect of policy intervention (F(6, 1892) = 3.36, p = .003, η_p^2 = 0.01), with opt-out education (adjusted p = .002, 95% CI [0.09, 0.67]) and opt-out opportunity (adjusted p = .018, 95% CI [0.03, 0.61]) being more effective than opt-in policy. The main effect of risk-perception patterns was significant (F(3, 1892) = 107.55, p < .001, η_p^2 = 0.15). Disease-specific risk perceivers were more likely to get vaccinated against COVID-19 than risk exaggerators (adjusted p < .001, 95% CI [0.83, 1.27]) and vaccine-specific risk perceivers (adjusted p < .001, 95% CI [0.75, 1.15]). Risk deniers also reported higher willingness to be vaccinated than risk exaggerators (adjusted p < .001, 95% CI [0.70, 1.07]) and vaccine-specific risk perceivers (adjusted p < .001, 95% CI [0.62, 0.94]). There was no significant difference between the vaccination intentions of disease-specific risk perceivers and risk deniers, or vaccine-specific risk perceivers and risk exaggerators. However, there was no statistically detectable interaction effect on vaccination intentions (F(18, 1892) = 0.86, p = .633).

Table 3
Criteria for latent profile models of risk perception types.

Model Tested	AIC	BIC	SABIC	Entropy	BLRT (p-value)
Three-class	30964.39	31109.04	31026.43	0.71	<.001
Four-class	30568.24	30751.82	30646.98	0.74	<.001
Five-class	30492.09	30714.62	30587.54	0.72	<.001
Six-class	30319.19	30580.66	30431.34	0.72	<.001

Note. AIC = Akaike information criterion, BIC = Bayesian information criterion, SABIC = sample size-adjusted BIC, BLRT = bootstrapped likelihood ratio test.

4. Discussion

Vaccine uptake is a major step against infection in vaccinated persons and can help prevent disease transmission across the population. However, COVID-19 vaccine hesitancy and resistance still haunt governments worldwide (Du et al., 2021; Murphy et al., 2021). A growing number of studies have begun to explore effective approaches that overcome the vaccine uptake barrier and promote vaccination rates in the context of COVID-19, such as initiation of beliefs about herd immunity and empathy (Pfattheicher et al., in press), mobile phone caller tunes (Appiah et al., 2021), as well as monetary and legal incentives (Sprengholz et al., 2022). Our findings add to the existing work by way of behavioral science insights instead of high-cost monetary incentives and inefficient legal policy.

First, compared with the current voluntary vaccination policy (the opt-in policy), we found that the conventional opt-out policy and improved opt-out policies (except opt-out transparency) increased Chinese people's willingness to be vaccinated, which is consistent with the effect of the default nudge on flu vaccination (Böhm et al., 2016; Chapman et al., 2010). However, the comparison between the improved opt-out policies and convention opt-out policy showed that the improvements had relatively little effect on promoting vaccine willingness. A possible explanation is that our Chinese sample already had a high willingness to vaccinate; thus, there might be a ceiling effect of the nudging approaches in the current study. According to a recent review on global COVID-19 vaccine acceptance (Salomoni et al., 2021), the highest rates of vaccine acceptance were reported in Asia, including 91.9% in China in March 2020 (Wang et al., 2021); the highest rates of vaccine acceptance (96.9%) among the health care works were also observed in Eastern Asian countries, including China, India, the Republic of Indonesia, Singapore, Vietnam, and Bhutan (Chew et al., 2021). Among factory workers, Chinese workers also reported a high behavioral intention (80.6%) to receive a COVID-19 vaccination (Zhang and Zhou, 2021). Therefore, it is understandable that people's willingness to be vaccinated was as high in the improved conditions as in the conventional opt-out condition.

Second, although the opt-in vaccination policy has no default assumption and provides the public the most freedom of choice, it is not always as acceptable as opt-out vaccination policies. We found that people's trust in policymakers, perceived ethicality, perceived freedom of choice, as well as perceived deception and manipulation were not undermined by the defaults, and even people in the opt-out education condition reported higher freedom of choice than those in the opt-in condition. Inconsistent with the critical voices on default nudges, participants in our study found it was acceptable to be unconsciously

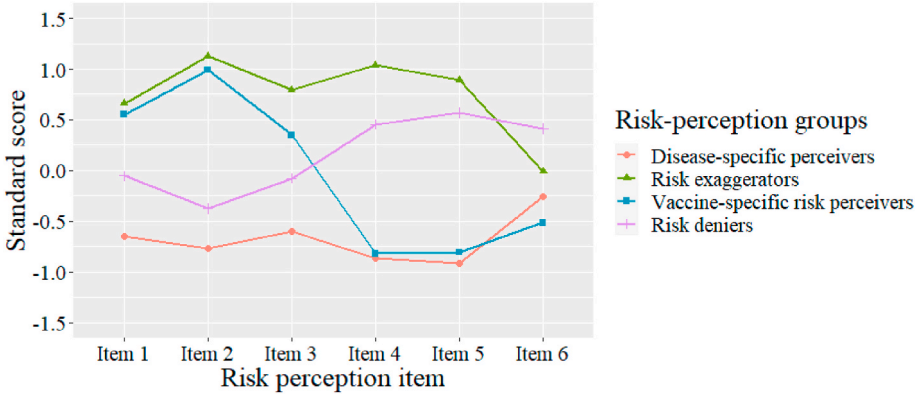

Fig. 1. Four Classes of Participants With Various Levels of Risk Perception of COVID-19 and Vaccination Uptake *Note.* Item 1 = *"Worry of the COVID-19"*; Item 2 = *"Perceived vulnerability of COVID-19"*; Item 3 = *"Perceived controllability of COVID-19"*; Item 4 = *" Worry of COVID-19 vaccine"*; Item 5 = *"Perceived safety of COVID-19 vaccine"*; Item 6 = *" Perceived efficiency of COVID-19 vaccine"*.

Table 4
The classification of risk perception.

		Risk perception of COVID-19	
		High	Low
Risk perception of COVID-19 vaccine	High	Risk exaggerator (n = 393, 20.4%)	Vaccine-specific risk perceivers (n = 695, 36.1%)
	Low	Disease-specific risk perceivers (n = 290, 15.1%)	Risk deniers (n = 548, 28.4%)

influenced by defaults. In fact, a series of studies reported a strong association between inherent behavioral intention and acceptance of default intervention. For example, people are more inclined to accept nudges that target behaviors that they are autonomously motivated to engage in (Entwistle, 2021). Venema et al. (2018) found that employees who have a higher intention to work standing up were more likely to accept the default setting of sit–stand desks. In addition, as Kahn and Costa (2013) found out, liberals were more supportive and responsive to green nudges than conservatives. Tannenbaum et al. (2017) also observed that both US adults and policymakers evaluate policy nudges in ways that are colored by their political preference, which has been called 'partisan nudge bias'. The matching of inherent psychological stance and ends pursed seem to dominate people's attitude toward nudge. In our context, China was the first country to be hit by the COVID-19 pandemic, and Chinese people may have high confidence in vaccines and a relatively positive attitude toward vaccination already. On the other hand, acceptance of opt-out approaches may be easier to enhance in some domains than others (Yan and Yates, 2019). A pre-selected option may represent a kind of protective signal issued by authorities under the pandemic. People may indeed prefer to be provided a clear option preselected by policymakers than to make an active choice themselves in such a highly uncertain scenario. Whether the effect of the default nudge varies in situations with different levels of uncertainty has yet to be studied.

Among the improvements, the opt-out education approach has relatively better performance in promoting vaccination willingness, as well as keeping perceived attitudes from being weakened. In the opt-out education variant, the policy emphasized the direct benefit of vaccination (reducing the likelihood of infection) and the final benefit that reaching herd immunity, which has been widely used in public policy and empirical research (Miyoshi et al., 2020; Pfattheicher et al., in press). Our findings suggest that the opt-out framing with educational intervention is an effective tool for elevating unvaccinated individuals' intention to get vaccinated. However, the transparency variant exerted as little impact as the opting-in approach and even diminished individuals' perceived freedom to make a choice. These findings are inconsistent with recent studies, in which transparency was advocated as an effective tool to increase acceptance of the conventional opt-out policy (Bruns et al., 2018; Paunov, 2020; Paunov et al., 2019; Yan and Yates, 2019). Indeed, there is still an ethicality and effectiveness debate on the addition of transparency to conventional nudges (Paunov, 2020). It should be acknowledged that COVID-19 vaccination behavior differs significantly from target behavior in existing studies; that is to say, taking a COVID-19 vaccine is more uncertain compared with deciding

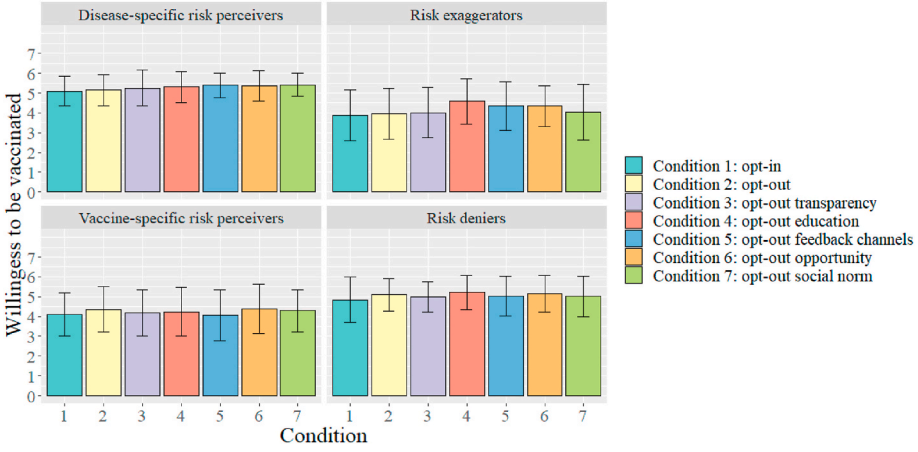

Fig. 2. Mean vaccination intentions by risk-perception type and policy condition.

the time individuals want to spend on participating in an experiment (target behavior in Paunov et al., 2019). Furthermore, one defining characteristic of the default nudge could be that some pattern of irrationality is being exploited, such as endorsement (McKenzie et al., 2006; Dinner et al., 2011), or ease (Zúñiga-Fajuri, 2015). As Bovens (2009) predicted, these psychological mechanisms work best in the dark. If we try to influence our own behavior by means of these mechanisms, then efforts will be most effective when our knowledge of having done so is latent (Bovens, 2009). Therefore, default interventions on COVID-19 vaccination may still work better when they are not transparent, although this remains to be clarified by future research.

Finally, we adopted a person-oriented approach and illustrated the patterns of risk perception in the case of COVID-19. Recent studies have illustrated patterns of risk perception of COVID-19 (Yang and Xin, 2020) or patterns of risk perception and adopted preventive behavior (Wang et al., 2021), but people's perceived risk of the vaccine has been ignored. Our study is the first to distinguish risk perception patterns concerning disease risk as well as vaccine risk. The results showed four latent classes: risk exaggerators, risk deniers, disease-specific risk perceivers, and vaccine-specific risk perceivers. Risk exaggerators and vaccine-specific risk perceivers, who accounted for approximately 60% of our sample, reported the lowest willingness to be vaccinated. Recent studies have shown the association between perceived risk of COVID-19 and behavior in response to it, such as social distancing (Barrios and Hochberg, 2020; Xie et al., 2020), hand washing (Abdelrahman, 2022; Wise et al., 2020), panic purchasing (Zhang and Zhou, 2021), as well as vaccination (Caserotti et al., 2021; Karlsson et al., 2021). Although the intention to accept the vaccine increased as risk perception of the disease increased, risk perception of the vaccine could weaken that intention at the same time (Freimuth et al., 2017; Liu and Yang, 2021). Our findings suggested that governments and health professionals should take the variety of patterns of risk perception into consideration and develop targeted vaccination policies for different classes.

In discussing these findings, we also acknowledge the limitations of the present research and attempt to propose future directions. First, we examined Chinese citizens' consent to receive the COVID-19 vaccine instead of actual consent decisions people may make in a clinical setting. Although intention usually predicts behavior (Morwitz and Munz, 2021; Sheeran, 2002), there may be a gap between the two. We want to highlight that the studies were conducted in the situation where a vaccine had just been approved by the Chinese authority, and thus, intention was the best proxy available for us at that time. On the other hand, there is evidence suggesting that default policies affect hypothetical and actual behavior in a similar way. The effects of opt-out conditions on the willingness to donate organs in the laboratory (Huang et al., 2018) were qualitatively similar to those observed for actual organ donation consent throughout Europe (Johnson and Goldstein, 2003). Similarly, there are default effects on both hypothetical influenza vaccination (Keller et al., 2011) and actual influenza vaccination (Patel et al., 2017; Chapman et al., 2010). These studies suggest a strong link between behavioral intention and actual behavior influenced by defaults. Currently, newer, more aggressive SARS-CoV-2 viral strains have spread across the globe. Booster COVID-19 vaccination remains our best hope of containing the pandemic. Therefore, more research is needed to show whether there are default effects on actual COVID-19 vaccination rates. Second, since the interaction effect of policy interventions and risk-perception patterns was not significant, there was no conclusive evidence that the size of the effect of risk perception differs as a function of defaults. We should acknowledge that the sample size of this study was insufficient to explore a 7×4 interaction effect. Future research should systematically test how diverse risk-perception groups respond to default nudges, both to understand what kinds of interventions are most or least effective in diverse populations and to provide more precise nudges. Third, although the mechanism by which the default effects of improved opt-out policies performed more effectively was not the focus of this study, we also explored the mediating effect of attitudes (see Appendix). Our findings suggest that opt-out education policy may increase vaccination intention through perceived trust and freedom of choice. Future studies could test people's perception of opt-in and opt-out approaches and explore what makes these improvements especially impactful.

Under the COVID-19 pandemic, researchers have been encouraged to take the opportunity to test behavioral nudges, which are only subtle and covert changes in how choices are framed, to boost immunization (Patel, 2021). In response to this call, the current study examined the effectiveness of a default nudge on promoting COVID vaccination. Our findings lend further support to the generalizability and robustness of the effect of defaults, although our Chinese sample already showed a high vaccination willingness. In future research, a more systematic investigation of the effectiveness and acceptance of the default nudge and its different improvements should be conducted, which is critical to advancing COVID-19 vaccination, especially when booster shots are being recommended.

5. Conclusion

The present study demonstrated that, compared with an opting-in policy, an opting-out policy and its improvements (except opt-out transparency) tended to increase people's acceptance of the COVID-19 vaccine. The addition of educational information to opting out was the most effective policy among the seven approaches we used. Perceived trust toward policymakers, perceived ethicality, and perceived deceptiveness and manipulativeness were not increased or weakened by the opt-out framing and its improvements, while a transparent default nudge decreased people's perceived freedom to make choices. This study also examined different classes of people based on the perceived risk of COVID-19 as well as the perceived risk of the vaccine and identified the effectiveness of vaccination policies within the four classes of people. Our findings provide new evidence that contributes to the development and implementation of effective strategies to promote the COVID-19 vaccine.

Credit author statement

Xin Liu, Writing - Original Draft, Writing - Review & Editing, Data analyses. **Ning Zhao**, Writing - Original Draft, Data collection. **Shu Li**, Writing - Reviewing & Editing. **Rui Zheng**, Conceptualization, Methodology, Writing- Reviewing & Editing, Funding acquisition.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2022.115120.

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