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Heuristics in vaccination Decision-Making for newly developed Vaccines: Understanding the public's imitative behavior

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A R T I C L E I N F O

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A B S T R A C T

This study aims to investigate the extent to which the public engages in imitative behavior in their vaccination decisions for newly developed vaccines in the Chinese context. Given the crucial role of newly developed vaccines in preventing and controlling the COVID-19 pandemic, a better understanding of how people make decisions about vaccination with new vaccines is important for overcoming vaccine hesitation and promoting widespread adoption of the vaccines. Our results indicate that the public's decision-making about the newly developed vaccine is influenced by a range of heuristics, including a privileged information heuristic, competence heuristic, and consensus heuristic. Specifically, individuals are more likely to imitate the vaccination behavior of those with privileged information, such as insiders, and those with perceived competence in the field, such as experts. Our findings also demonstrate the impact of majority influence, as the popularity of new vaccines leads to an increase in vaccination uptake through herd behavior. Our data highlights the importance of the first movers who are insiders with privileged information or experts with competence, as their behavior can significantly shape the vaccination decisions of others. Our study provides valuable insights into the complex interplay of heuristics and imitative behavior in vaccination decision-making for newly developed vaccines.

1. Introduction

The COVID-19 pandemic continues to pose a significant threat globally, and the widespread availability of vaccines is seen as a crucial aspect in controlling its spread (Excler et al., 2021). To date, numerous newly developed vaccines have been approved worldwide, with several in clinical trials and over 200 still in development (Sharma et al., 2020). Despite the significance of these measures, the public has demonstrated skepticism and hesitation toward newly developed COVID-19 vaccines, owing to a lack of vaccine data and experience (AlShurman et al., 2021). Vaccine hesitancy (VH) encompasses the reluctance or refusal to receive vaccines despite their availability (MacDonald, 2015). Studies on vaccine hesitancy, delay or rejection are not novel, and long before the COVID-19 pandemic, many attempted to find out the drivers of vaccine hesitancy, including vaccine for HIV, papillomavirus, HPV, influenza and so on (Xiao et al., 2022; Jiang et al., 2022; Ledent et al., 2019; Wong et al., 2018). A substantial body of research has investigated the underlying factors contributing to VH from the perspective of rational cognition, which are primarily linked to perceptions and attitudes towards vaccine risks, benefits, and safety (Ritchie et al., 2021; Kreps et al., 2020; Prati, 2020; Fisher et al., 2020; Grech et al., 2020; Olagoke et al., 2021; Kose et al., 2021; Al-Mohaithef & Padhi et al., 2020; Grüner & Krüger et al., 2020; Khan et al., 2020; Harapan et al., 2020). While strategies like offering external incentives, changing default choices, or providing reliable information have been widely applied to promote vaccine uptake and have shown efficacy (Renosa et al., 2021), these strategies often focus more on altering the external decision environment. Additionally, intrinsic cognition is crucial for a deeper understanding of vaccine decisions and becomes a research hotspot.

According to behavioral economics theory, people's internal cognition consists of two systems, which have been proposed to explain risk decision-making: the analytic system based on rationality and the heuristic system based on intuition (Evans, 2008). As Simon (1956) noted, individuals tend to exhibit "bounded rationality" and often rely on heuristics in their decision-making practices. Heuristics have been used to explore how individuals discover, process, and use vaccine information, and the roles that medical personnel and society can play in vaccination decision-making (Smith et al., 2013). At present, some

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scholars proposed that vaccination decisions may be influenced by heuristics (Luz & Nadanovsky, 2020 ; Seethaler,2016). However, Current empirical research into the role of heuristics in vaccine decision-making remains scarce, and there is a notable gap in understanding how various heuristic cues influence these decisions. A deeper understanding of heuristics could lead to a more transparent and efficient decision-making process, which could enhance vaccine confidence and uptake.

A growing body of literature has confirmed that people employ simpler heuristic strategies based on survival needs, especially in complex and uncertain environments (Hertwig & Herzog, 2009; Taylor, 2017). These heuristic strategies can have a high degree of predictive accuracy, even surpassing that of more complex analytic strategies (Gigerenzer & Goldstein, 1996). One type of heuristic strategy is social heuristics, which are particularly useful in situations where information is limited (Gigerenzer & Gaissmaier, 2011). Social heuristics are based on social information and emphasize the influence of social norms, such as imitation, tit-for-tat, social circle, and the aggregation of judgments from others (Hertwig & Herzog, 2009). According to social heuristic theory, an informational cascade can occur when individuals make decisions based on the choices made by others, rather than the attributes of the choice alternatives (Bikhchandani et al., 1992).

In the context of vaccination decision-making, social heuristics can play a role when individuals are faced with the unknown adverse reactions and consequences of a newly developed vaccine. The decision-making of a member of one's social network can serve as a reference point in the absence of information about the vaccine, leading to imitation behavior and the emergence of a herd effect. This can be especially pronounced when the initial decision-makers, such as insiders with privileged information or experts with competence, take the vaccine, which triggers imitation from the general public (Bikhchandani et al., 1992). As more information about the vaccine becomes available and its popularity grows, the herd effect may shift from following insiders and experts to following the majority of individuals (Bikhchandani et al., 1992). This aligns with research on majority versus minority influence in social psychology (De Dreu & De Vries, 2001; Martin & Hewstone, 2009), suggesting that the characteristics of previous decision-makers have a greater impact than the information content that lies behind their actions. Therefore, we assume that the diffusion process of vaccine adoption is depicted in Fig. 1.

The adoption of the Covid-19 vaccine can be thought of as a process that involves the interaction of three types of social heuristics: competence heuristic, privileged information heuristic, and consensus heuristic (Quiamzade & L'Huillier, 2009), as illustrated in Fig. 2. First, people trust the expertise of individuals who have a reputation for being knowledgeable in a particular field, without necessarily understanding the underlying reasoning behind their decisions. This phenomenon can be explained by what is known as the "competence heuristic" — people assume that experts are competent and their decisions are more likely to be right (Romer, 2010). Second, experts such as doctors may initially lack important knowledge and information about the vaccine. At this point, insiders who possess non-public information or special knowledge about the vaccine become important decision-makers (Boubacar & Morris, 2011). In this case, the "privileged information heuristic" may be more relevant for vaccination decisions than the competence heuristic. In the Chinese context, government officials are typically the holders of privileged information. This is because vaccines must undergo government review and approval before they can be sold and administered. As a result, government officials have access to non-public information during this process, including data regarding the safety and efficacy of vaccines. This information may not necessarily reflect their expertise, but it does make them decision-makers with privileged information. Third, as the decisions of the majority of individuals become an aggregation of signals, people tend to conform because they think the majority is right, which is known as the consensus heuristic. These heuristics play different roles in different stages of vaccination campaigns. However, theoretical research on this topic is basically blank at present, and it is not yet clear whether and how individual vaccination decisions are affected by these three heuristics.

This study, using data collected during the 2022 COVID-19

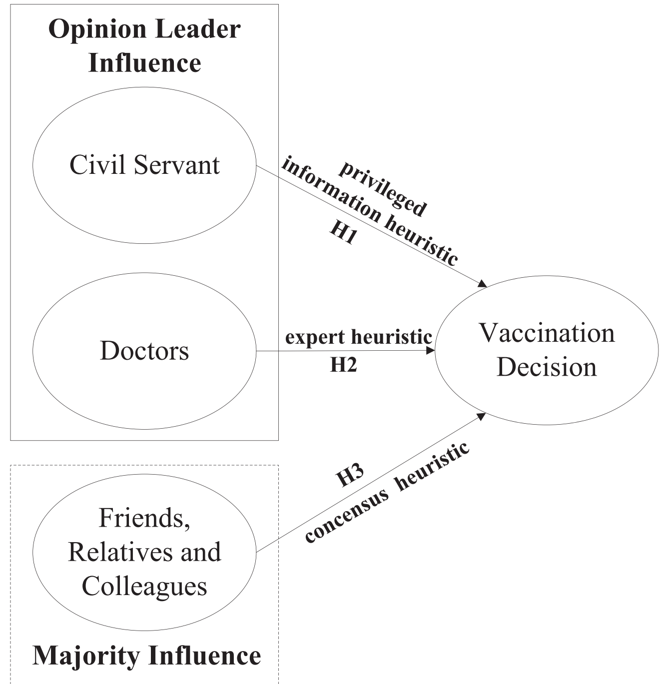

Fig. 2. Conceptual framework.

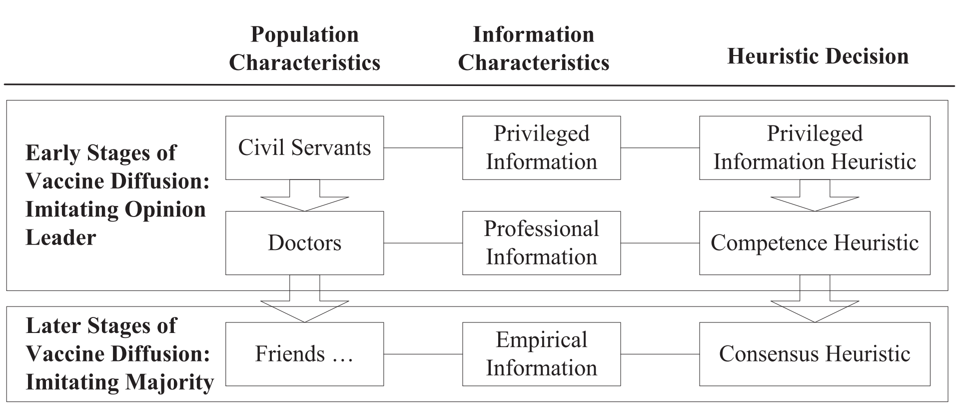

Fig. 1. Diffusion process of newly developed vaccine adoption.

pandemic, examines the effect of imitating insiders with privileged information, experts with competence, and the majority on vaccination decisions. The results of this study offer a novel perspective from the heuristics approach to enhance vaccine confidence and uptake and contribute to the literature on vaccine decision-making for newly developed vaccines.

2. Data and methods

2.1. Data and sampling

The present study utilized data collected from a survey investigating public risk perception and behavior during the COVID-19 epidemic, which was conducted between March and December 2022. The survey was a collaborative effort between the School of Government and the School of Public Health at Nanjing University of Chinese Medicine, Nanjing Drum Tower Hospital, Jiangsu Province Hospital of TC, and other national institutions. A stratified sampling method was employed to ensure a representative sample. Initially, 11 cities were selected, including Shanghai, Nanjing, Suzhou, Wuxi, Qingdao, Changzhou, Hefei, Taizhou, Nantong, Yangzhou, and Rizhao, as they are representative cities of East China. Then, based on the per capita gross value of industrial output, 24 counties (districts) were randomly selected from the 11 cities using the isometric random sampling method. Next, two or three typical communities were selected from each county (district) that had vaccination sites capable of providing vaccination services. Finally, participants were randomly selected from the adult residents of each community who were aged 18 years or older, able to communicate independently or with the help of investigators, and willing to take part in the survey.

The research team, which included six specialists and 42 well-trained students, collected information on participants' personal sociodemographic characteristics, risk perception, and vaccination intention and behavior through anonymous questionnaires. Ethical guidelines were strictly followed during the data collection process, and the research team estimated the sample size based on the population of adults who were eligible for COVID-19 vaccination in each community. Approximately 9,000 adults living in the community were contacted, and a total of 7,781 agreed to participate in the survey. After filtering out questionnaires with missing data on personal sociodemographic characteristics, vaccine cognition, and behavior, 6,920 valid samples were obtained, resulting in a final response rate of 88.93 %.

2.2. Measurement

2.2.1. Outcome variables

To measure vaccine decision-making, we used two outcome variables, namely, vaccinated behavior and vaccination intention. Following previous literature (Oyekale & Maselwa, 2021), vaccinated behavior was defined as whether the respondent has received COVID-19 vaccination (vaccinated = 1, not vaccinated = 0). In contrast, vaccination intention was defined as the willingness to receive COVID-19 vaccines (willing to be vaccinated = 1, not willing to be vaccinated = 0).

2.2.2. Independent variables

The independent variables in this study included person with privileged information, expert with competence heuristic, and majority. In China, vaccine-related information must be submitted to government departments for review and approval before the vaccine can be sold and administered. Therefore, we hypothesized that government officials who have privileged information and doctors who possess professional knowledge and judgment represent persons with privileged information and experts with competence, respectively, and are likely to set a good example for others in vaccination decision-making. To measure these two independent variables, respondents were asked whether any of their friends who had received COVID-19 vaccination are civil servants or doctors (yes = 1, no = 0). Additionally, we included majority as an independent variable, which reflects an individual's perception that a large proportion of people within their social circle have been vaccinated. This variable was measured using a dummy variable and was determined by the response to the question "whether the majority of people around you have been vaccinated?" (yes = 1, no = 0). All variables were measured in a binary format to facilitate data analysis. The reliability and validity of the measurement tools were assessed before the study to ensure that they were appropriate for their purpose. Ethical guidelines were followed, and all participants provided informed consent prior to participating.

2.2.3. Control variables

Control variables included gender of respondent (male = 1, female = 0), age of respondent, occupation (student = 1, enterprise employee = 2; public sector employee = 3, otherwise = 4), yearly income (less than 50,000 ¥ = 1, between 50,000 ¥ and 100,000 ¥ = 2, between 100,000 ¥ and 200,000 ¥ = 3, between 200,000 ¥ and 400,000 ¥ = 4, between 400,000 ¥ and 600,000 ¥ = 5, between 600,000 ¥ and 1 million ¥ = 6, and more than 1 million ¥ = 7), registered place of residence (city = 1, rural = 0), and educational level of respondent (primary school and below = 1, junior middle school = 2, senior school = 3, bachelor's degree = 4, graduate and higher degree = 5), risk perception of COVID-19 infection (far less than average infection rate = 1, less than average infection rate = 2, equal to average infection rate = 3, higher than average infection rate = 4, far higher than average infection rate = 5), and risk perception of COVID-19 vaccine sequelae (far less than actual vaccine adverse reaction = 1, less than actual vaccine adverse reaction = 2, equal vaccine adverse reaction = 3, higher than actual vaccine adverse reaction = 4, and far higher than actual vaccine adverse reaction = 5).

2.3. Estimated models

The Instrumental Variable Probit regression model was used for data analysis. This model is preferred if one or more independent variables are endogenous (Skeels & Tarlor, 2015). Estimating this model requires the formulation of the Probit regression model, which would have inconsistent parameters if the suspected endogeneity problem is not properly addressed. A standard Probit regression model can be stated as follows:

$$Prob(VAC_i = 1|\mathrm{X}) = \int_{-\infty}^{\beta X_i} 2\pi^{-1/2}\exp\left(-\frac{t^2}{2}\right)dt = \varphi(\beta X_i) \quad (1)$$

In Eq. (1), φ is the cumulative distribution function of a standard normal variable. The operation of this function, which is an advantage over the linear probability model, is that estimated probabilities (p_i) comply with the condition, $0 \leq pi \leq 1$. Additionally, X represents the vector of explanatory variables, and β is a vector of the parameters of the explanatory variables. Eq. (1) can be restated with the introduction of an endogenous regressor and be presented in a reduced form as:

$$VAC_i = \alpha + \sum_i^k \beta_i X_i + \gamma S_i + \varepsilon_i \quad (2)$$

The model for those willing to be vaccinated, which in this estimation also included those who had been vaccinated in order to retain the degree of freedom and to ensure complete capturing of vaccination compliance, is stated as:

$$VAC\_I_i = \alpha' + \sum_i^k \beta_i' X_i + \gamma' S_i + \varepsilon_i' \quad (3)$$

In Eq. (2), VAC_i is COVID-19 vaccination status (yes = 1, 0 otherwise), X_i is a vector of explanatory variables, and S_i is vaccination behavior of social circle members. In addition, α, β_i and γ are the estimated parameters. In Eq. (3), VAC_I_i denotes COVID-19 vaccine vaccination intention coded as 1 for those who were willing to be vaccinated and 0 otherwise. Further, α', β_i' and γ' are estimated parameters and ε_i and ε_i' are the error terms.

The estimation of social influence effects with observational data has many challenges (Eckles et al., 2016). The most basic problem is that each respondent influences doctors, civil servants, and the majority in their social circle just as they influence him (simultaneity). In addition, respondents may choose doctors, civil servants, and friends who are similar to themselves (homophily), as well as other possible unobserved factors that are common among social circle members. To address these sources of bias, we used an instrumental variables approach to estimation that is common in the econometric literature on acquaintance effects (Blume et al., 2011). We follow the identification of peer effects of Bramoullé et al. (2009). Based on our dataset, we can use the number of doctors and civil servants a subject knows as valid instruments of familiar civil servants vaccinated and familiar doctors vaccinated. In addition, the proportion of vaccinated people in a subject's social circle can be used as an instrumental variable for "majority vaccination.".

This approach yields consistent estimates as long as the average number of members in each category within the social circle (doctors, civil servants, and majority) meet two criteria. First, it has no direct influence on an individual's COVID-19 vaccination willingness because the number of doctors that others know will not affect the vaccination decision of the respondents. Second, the average number of each category of members in the social circle must be sufficiently predictive of the vaccination behavior and intention. We assessed this with a test for weak instruments commonly used in the literature (Stock & Yogo, 2005). The average number of each category of members in the social circle were sufficiently predictive in social circle members vaccinated, with first-stage F-statistics above 10. As a consequence of this assessment, we consider the estimated effects of social circle member vaccine intention and vaccinated behavior to be statistically reliable.

Therefore, instrumental variable(s) must be engaged in the specification of the vaccination behavior and intention model. The social circle members' vaccinated equation is represented as Eq. (4):

$$S_i = \omega + \sum_i^k \tau_i * X_i + \rho * IV_i + \rho_i \tag{4}$$

In order to correct the endogeneity problem, Eq. (2) was restated as:

$$VAC_i = \alpha + \sum_i^k \beta_i X_i + \gamma \widehat{S}_i + \tau \rho_i + \varepsilon_i \tag{5}$$

and Eq. (3) was restated as:

$$VAC\_I_i = \alpha' + \sum_i^k \beta_i' X_i + \gamma' \widehat{S}_i + \sigma \rho_i + \varepsilon_i' \tag{6}$$

The variable IV_i in Eq. (4) is an instrumental variable, the number of doctors the subject knows, civil servants the subject knows, and proportion of vaccinated people in the subject's social circle. This is the instrumental variable for S_i. Although instrumental selection is a major hurdle in estimating models with endogenous regressors, one critical rule of thumb applies. This is the fact that the selected instrument(s) must be correlated with the endogenous regressor (S_i) but not correlated with the dependent variables in Eqs. (5) and (6). The explanatory variables for Eqs. (2)–(4) are:

where y_i is the binary indicator of vaccination willingness for COVID-19, and our variable of interest (doctor, civil servant, majority) reflects "Are there familiar doctors, civil servants, and the majority vaccinated" representing our social circle member's effect measure. Covariates included: characteristics of the individual (x_i) such as gender, age, education, marriage, and income; self-reported health status; registered permanent residence and occupation are also included in xi; ε_i is the individual-specific error term. Note that correlated effects emerging from common environmental factors are addressed by using city-specific fixed effects (λ_i) (captured by the city where the subject lives). This set of fixed effects would eliminate any unobserved city characteristic that might influence the vaccination intention of subjects and social circle members who are in the same city or who are exposed to the same local environment.

STATA 17 software was used for data analysis, and it generated the statistics for Wald's test of exogeneity. If this parameter is not statistically significant, the null hypothesis of exogeneity is to be accepted. This also implies that the parameters of the residuals from Eq. (4) (τ and σ) in Eqs. (5) and (6) are not statistically significant ($p > 0.05$). However, if it is statistically significant, the null hypothesis of exogeneity should be rejected. This implies that S_i is truly endogenous, and estimating the model with standard Probit regression model would produce inconsistent parameters.

2.4. Ethical review

The study has been approved by the Medical Ethics Sub-Committee of the Ethics Committee for Science and Technology at Nanjing University (Approval Number: OAP20230407001).

3. Results

3.1. Descriptive data

The percentages of vaccination intention and behavior of the respondents are who willing to be vaccinated (88.84 %) and not willing to be vaccinated (11.16 %), and those being vaccinated (65.79 %) and not being vaccinated (34.21 %). Table 1 shows the distribution of the respondents' socioeconomic characteristics across their COVID-19 vaccination intentions and behaviors. The results show that 58.50 % of the respondents were females. However, 58.88 % and 56.01 % of those willing to be vaccinated and already vaccinated were females. Female respondents constituted 55.44 % and 63.29 % of those who were not willing to be vaccinated and not vaccinated. The age distribution of the respondents shows that 24.60 % of all the respondents belonged to age group < 25 years. This age group also constituted the highest proportion (34.68 %) of those who were vaccinated. Registered place of residence shows that 52.08 % of all the respondents came from rural areas. In addition, 49.32 % of all the respondents had received a college education, 39.65 % had a bachelor's degree, 9.67 % had a master's or doctoral degree. Occupation distribution of the respondents shows that 24.86 % were students, 24.99 % were enterprise employees, 11.46 % were government workers, 38.70 % were others. Income shows that the income of more than 50 % was between 100,000 ¥ and 400,000 ¥.

Table 2 further shows the distribution of respondents' perceived vulnerability to COVID-19 and the vaccine decisions of their social circle members. The table shows that across all groups of the respondents, the majority of them perceived sequelae after vaccination as a substantial threat. Specifically, about 79.37 % of all the respondents felt they had a low risk of being infected with COVID-19 (44.41 % far lower than the average infection rate, and 34.96 % lower than the average infection rate), and about 56.80 % of all the respondents felt there was a high risk of sequelae after being vaccinated (24.15 % far higher than average adverse sequelae, and 32.75 % higher than average adverse sequelae). In addition, 78.80 % of the respondents who knew doctors were vaccinated; 79.65 % of the respondents who knew civil servants working in public sector were vaccinated; and 95.27 % of the respondents who thought that majority in their social circles were vaccinated were, themselves, vaccinated.

3.2. Determinants of vaccination intention and behavior

Table 3 shows the results of the estimated models of being vaccinated

Table 1
Characteristics and vaccination status of respondents (n = 6920) who participated in the online questionnaire in China from March 1, 2022 to December 31, 2022.

Variables	Willing to be vaccinated (n = 6,148)		Not willing to be vaccinated (n = 772)		Vaccinated (n = 4,553)		Non-vaccinated (n = 2,367)		All respondents (n = 6920)	
	Freq	% of Total	Freq	% of Total	Freq	% of Total	Freq	% of Total	Freq	% of Total
Gender										
female	3260	58.88	428	55.44	2550	56.01	1498	63.29	4048	58.50
male	2528	41.12	344	44.56	2003	43.99	869	36.71	2872	41.50
Age										
< 25	1643	26.73	59	7.64	1579	34.68	123	5.20	1702	24.60
25 < 35	956	15.55	107	13.86	649	14.25	414	17.49	1063	15.36
35 < 45	1124	18.28	447	57.90	698	15.33	873	36.88	1571	22.70
45 < 55	594	9.66	47	6.09	599	13.16	42	1.77	641	9.26
55 < 65	715	11.63	5	0.65	248	5.45	472	19.94	720	10.40
65 ≤	1116	18.15	107	13.86	780	17.13	443	18.72	1223	17.68
Registered place of residence										
city	2921	47.51	395	51.17	2260	49.64	1056	44.61	3316	47.92
rural	3227	52.49	377	48.83	2293	50.36	1311	55.39	3604	52.08
Education										
≤ primary school	808	13.14	104	13.47	484	10.63	428	18.08	912	13.18
junior middle school	1,139	18.53	52	6.74	713	15.66	478	20.19	1,191	17.21
senior school	1,176	19.13	228	29.53	628	13.79	776	32.79	1,404	20.29
bachelor degree	2,557	41.59	187	24.22	2,392	52.54	352	14.87	2,744	39.65
graduate ≤	468	7.61	201	26.04	336	7.38	333	14.07	669	9.67
Occupation										
student	1,646	26.77	74	9.59	1,642	36.06	78	3.3	1,720	24.86
enterprise employee	1,430	23.26	299	38.73	1,044	22.93	685	28.94	1,729	24.99
public sector employee	719	11.69	74	9.59	445	9.77	348	14.7	793	11.46
otherwise	2,353	38.27	325	42.1	1,422	31.23	1,256	53.06	2,678	38.70
Income										
< 50,000 ¥	913	14.85	98	12.69	655	14.39	356	15.04	1,011	14.61
50,000 ¥ < 100,000 ¥	1,419	23.08	61	7.9	1,125	24.71	355	15	1,480	21.39
100,000 ¥ < 200,000 ¥	1,806	29.37	276	35.75	1,126	24.73	956	40.39	2,082	30.08
200,000 ¥ < 400,000 ¥	1,179	19.18	245	31.74	881	19.35	543	22.94	1,424	20.58
400,000 ¥ ≤ 600,000 ¥	408	6.64	37	4.79	408	8.96	37	1.56	445	6.43
600,000 ¥ ≤1 million ¥	217	3.53	50	6.48	176	3.80	91	3.84	267	3.86
1 million ¥ ≤	206	3.35	5	0.65	182	4.00	29	1.23	211	3.05

and intention to get the vaccine. This conclusion was reached because the computed Wald test statistics for both models were found to be statistically significant at the $p < 0.01$ level, indicating that the vaccination decision imitated variable was truly endogenous in both models. The implication is that estimating the models using a standard Probit model would produce inconsistent parameters. The model also produced good fits for the data. This is reflected by statistical significance of the computed Wald Chi Square statistics ($p < 0.01$). This also shows that the estimated parameters are not jointly equal to zero. Therefore, the included variables have some influences on vaccine choices (behaviors and intentions).

Models 1, 2, and 3 show that having a familiar doctor ($p < 0.01$), civil servant ($p < 0.01$) or social majority ($p < 0.01$) vaccinated has a significant positive effect on the vaccination intention of respondents. When these three variables are included in the model simultaneously, Model 4 also shows that they have parameters consistent with the previous three models. The results suggest that if some doctors and civil servants are familiar to the survey subjects or if the majority of the subject's social circle are vaccinated, the subject's vaccination intention increases.

Because there are differences between vaccination intention and actual vaccination behavior, we further conducted regression analysis on vaccination intention. Models 5, 6 and 7 show that a familiar doctor ($p < 0.01$), civil servant ($p < 0.01$) and having the majority of one's social circle ($p < 0.01$) vaccinated has a significant positive effect on vaccine behavior of respondents. When these three variables were included in the model simultaneously, Model 8 also shows parameters consistent with the previous three models. The results show that if some doctors and civil servant subjects are familiar to the survey subjects, and if the majority in the subject's social circle are vaccinated, the probability of the subject being vaccinated increased.

Gender showed statistical significance ($p < 0.01$) in eight models, and there is no consistency in the sign of the parameters. Age of respondents showed statistical significance ($p < 0.1$) in six models and with a negative sign. These results show that as age increased, the probability of being COVID-19 vaccinated or having a vaccination intention decreased. Interestingly, the parameter of education is statistically significant ($p < 0.1$) and has a negative sign. This shows that people with more education had a significantly lower probability of being vaccinated or intention to be vaccinated. This may be due to two reasons: first, people with good education are more optimistic about their ability to cope with the epidemic and overestimate the adverse reactions caused by the vaccine. Second, highly educated people believe in scientific data, and tend to hold a wait-and-see attitude when there is no research on vaccine impact based on large-scale scientific research.

Furthermore, among the variables included to capture risk perception, the perception of the likelihood of getting infected with COVID-19 shows positive statistical significance ($p < 0.10$). These results suggest that compared to those respondents who perceived a low likelihood of COVID-19 infection, those who perceived a high likelihood were more likely to get vaccinated or express an intention to get vaccinated. However, the perception of the risk of sequelae caused by COVID-19

Table 2
Perceived Vulnerability to COVID-19 and Vaccination Decisions of Objects Imitated among respondents (n = 6920) in China from March 1, 2022 to December 31, 2022.

Variables	Willing to be vaccinated (n = 6,148)		Not willing to be vaccinated (n = 772)		Vaccinated (n = 4,553)		Non-vaccinated (n = 2,367)		All respondents (n = 6920)	
	Freq	% of Total	Freq	% of Total	Freq	% of Total	Freq	% of Total	Freq	% of Total
COVID 19-infection										
far less than AIR[a]	2,915	47.41	158	20.47	1,931	42.41	1,142	48.25	3,073	44.41
less than AIR	2,021	32.87	398	51.55	1,669	36.66	750	31.69	2,419	34.96
equal to AIR	899	14.62	196	25.39	753	16.54	342	14.45	1,095	15.82
higher than AIR	298	4.85	10	1.3	175	3.84	133	5.62	308	4.45
far higher than AIR	15	0.24	10	1.3	25	0.55	0	0.00	25	0.36
Vaccine sequelae										
far less than VAR [b]	572	9.3	233	30.18	500	10.98	305	12.89	805	11.63
less than VAR	785	12.77	223	28.89	553	12.15	455	19.22	1,008	14.57
equal to VAR	1,106	17.99	64	8.29	1,062	23.33	108	4.56	1,170	16.91
higher than VAR	2,039	33.17	227	29.4	1,193	26.2	1,073	45.33	2,266	32.75
far higher than VAR	1,646	26.77	25	3.24	1,245	27.34	426	18	1,671	24.15
Doctor										
vaccinated	4886	79.47	56	73.45	3666	80.52	1787	75.50	5453	78.80
non-vaccinated	1262	20.53	205	26.55	887	19.48	580	24.50	1467	21.20
Civil servant										
vaccinated	4938	80.32	574	74.35	3951	86.79	1561	65.95	5512	79.65
non-vaccinated	1210	19.68	198	25.65	602	13.22	806	34.05	1408	20.35
Majority										
vaccinated	5939	94.96	755	97.80	4359	95.74	2234	94,38	6593	95.27
non-vaccinated	310	5.04	17	2.20	194	4.26	133	5.62	327	4.73

NOTE: a. AIR: average infection rate; b. VAR: vaccine adverse reaction

vaccines shows negative statistical significance ($p < 0.10$). These results suggest that respondents who are concerned about vaccine side effects are less likely to get vaccinated and show a lower willingness to vaccinate.

4. Discussion

The present study challenges the previous research, which primarily focused on rational cognitive factors, by indicating that the public's decision to get vaccinated is based on irrational heuristic reasoning. The study identifies three heuristic decision-making processes in vaccination behaviors with regard to newly developed vaccines, namely the privileged information heuristic, competence heuristic, and consensus heuristic. Specifically, the public tends to imitate the vaccination behavior of insiders with privileged information (such as civil servants), experts with competence (such as doctors), and the majority of their social circle.

The first heuristic identified in the study is the competence heuristic. The study found that the vaccination decisions of experts such as doctors has a positive impact on the vaccination behavior of others. This is because people tend to assume that doctors are competent experts, and their decisions are more likely to be right (Romer, 2010). In the case of decision-making with regard to newly developed vaccines, this competence heuristic is particularly pervasive due to unknown risks that may be associated with the novel product, and people trust the competence of experts even when the reasons for their decisions are unknown or unclear. This phenomenon can lead to herd behavior, where individuals imitate the behavior of the first mover, who is typically perceived as an expert. Importantly, the study expects that individuals will be more likely to adopt positive vaccination intentions and behaviors when they observe familiar experts engaging in vaccination behaviors.

The second heuristic identified in the study is the privileged information heuristic. The study found that the vaccination decisions of government officials with privileged information has a positive impact on the vaccination behavior of others. Insiders who possess non-public information or special knowledge about the vaccine become important decision-makers, particularly when experts such as doctors lack such knowledge and information (Boubacar & Morris, 2011). Vaccine R&D institutions or manufacturers must provide government departments with information such as clinical tests for marketing approval. Government staff can then obtain relevant internal information about the vaccine and disseminate it to the public. Thus, employees within government have privileged access to vaccine information, even if they lack expertise or ability. Consequently, people may imitate the behavior of insiders who are in a position to possess privileged information, such as civil servants.

The third heuristic identified in the study is the consensus heuristic. The study found that the vaccination decisions of the majority of a person's social circle has a positive impact on the vaccination behavior of the person. The prevalence of social conformity makes it plausible that individuals may be more likely to get vaccinated if they observe others around them doing the same. Majority influence arises partly because, in uncertain situations, individuals tend to believe that the majority is competent and that independent individuals arrive at the same conclusion (Quiamzade, Mugny & Darnon, 2009). The most popular explanation for the majority heuristic is that people conform to the majority because they assume that the majority is not deviating from the norm, and that multiple independent people making the same unanimous error is unlikely (Martin & Hewstone, 2009; Shiller, 1995). In other words, people conform to the majority not because they are always right, but because they make the same choice, so it is assumed that the majority is right.

It is worth noting that the data results in our study reflect a negative correlation between age and vaccination intention. This finding contradicts recommendations in many countries that prioritize COVID-19 vaccination for the elderly (Castro et al., 2021; Goldstein et al., 2021; Ritchie et al., 2021; Basta et al., 2022). It may due to the COVID-19 vaccine being a newly developed vaccine with a lack of

Table 3
Result of COVID-19 vaccination intentions and behaviors comparing respondents (n = 6920) with objects imitated in China from March 1, 2022 to December 31, 2022 using IV-probit models.

	Vaccine intention				Vaccinated			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
doctor	33.394***			10.561***	13.130***			3.310**
	[0.000]			[0.003]	[0.000]			[0.035]
civil_servant		10.848***		16.681***		5.352***		6.707***
		[0.000]		[0.000]		[0.000]		[0.000]
majority			35.082***	44.376***			18.133***	17.610***
			[0.000]	[0.000]			[0.000]	[0.000]
gender	−1.667***	1.436***	0.907***	1.402***	−0.658***	0.686***	0.439***	0.528***
	[0.001]	[0.000]	[0.000]	[0.001]	[0.002]	[0.000]	[0.000]	[0.004]
age	−0.106***	−0.004	−0.029***	−0.063***	−0.039***	−0.004	−0.015***	−0.015*
	[0.000]	[0.317]	[0.000]	[0.001]	[0.000]	[0.140]	[0.003]	[0.070]
edu	−0.439**	−0.523***	−0.653***	−0.392*	−0.316***	−0.486***	−0.134*	−0.332***
	[0.026]	[0.000]	[0.000]	[0.063]	[0.000]	[0.000]	[0.085]	[0.000]
registered place	−4.960***	−0.674***	−0.199	0.016	−2.344***	0.045	−0.414***	−0.025
	[0.000]	[0.000]	[0.307]	[0.979]	[0.000]	[0.642]	[0.001]	[0.927]
health	−0.609**	0.228***	1.009***	1.278***	−0.531***	−0.242***	0.201**	0.202
	[0.011]	[0.001]	[0.000]	[0.000]	[0.000]	[0.000]	[0.048]	[0.119]
1.occation	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
2.occation	−2.461***	−0.615***	4.219***	10.725***	−1.343***	−0.481***	1.984***	4.539***
	[0.000]	[0.001]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
3.occation	−2.076***	0.452*	0.451	7.629***	−0.656**	0.653***	0.477*	3.915***
	[0.001]	[0.074]	[0.313]	[0.000]	[0.015]	[0.000]	[0.084]	[0.000]
4.occation	−1.320**	−1.999***	0.212	3.617***	−0.844***	−1.097***	−0.025	1.732***
	[0.043]	[0.000]	[0.641]	[0.002]	[0.002]	[0.000]	[0.928]	[0.001]
income	0.108	0.031	−0.260***	−0.563***	0.045	0.002	−0.126***	−0.316***
	[0.373]	[0.419]	[0.000]	[0.000]	[0.380]	[0.941]	[0.004]	[0.000]
COVID19-infection	2.679***	0.031	2.254***	3.709***	0.936***	0.073*	1.010***	1.292***
	[0.000]	[0.610]	[0.000]	[0.000]	[0.000]	[0.079]	[0.000]	[0.000]
vaccine sequelae	−0.294*	−0.184***	−0.192**	−1.007***	0.314***	0.367***	0.316***	0.001
	[0.054]	[0.000]	[0.018]	[0.000]	[0.000]	[0.000]	[0.000]	[0.989]
_cons	−18.324***	−5.945***	−39.509***	−60.583***	−5.928***	−1.436***	−18.845***	−20.701***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Number of obs	6900	6900	6900	6900	6900	6900	6900	6900
Wald Chi Square (16)	72.07***	471.56***	131.72***	112.00***	10.46***	498.18***	241.88***	200.93***
Log likelihood	−6091.15	−6066.54	−1610.11	−6454.91	−5108.67	−4906.382	−39.8116	−6137.54
Wald test of exogeneity	1302.64***	983.03***	729.97***	1498.07***	226.20***	303.06***	171.40***	279.87***

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

comprehensive information regarding its safety and efficacy (Veronese et al., 2021), coupled with the presence of conspiracy theory (Malik et al., 2020), older individuals, compared to younger individuals, are more apprehensive about the potential secondary risks, namely adverse reactions associated with vaccination. This perspective is also supported by previous studies (Wang et al., 2021; Basta et al., 2022; Wang et al., 2023).

Furthermore, it is important to emphasize that this study is specific to the Chinese context, and we acknowledge that the concept of government officials having privileged information is a unique heuristic. However, we believe it complements rather than contradicts the competence heuristic associated with experts, both of which play a role in increasing vaccine uptake, especially for newly developed vaccines.

5. Conclusion

In summary, the study suggests that instead of weighing the pros and cons through private information, people tend to use heuristics when making vaccination decisions for newly developed vaccines. The privileged information heuristic and the competence heuristic can be used initially to promote vaccination when a vaccine requiring widespread vaccination is introduced. As more and more people get vaccinated, the consensus heuristic can then be employed to significantly improve the vaccination rate.

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CRediT authorship contribution statement

Biao Xu: Writing – review & editing, Supervision, Methodology, Conceptualization. **Baoxiang Song:** Investigation. **Shiyun Chang:** Supervision. **Shuyan Gu:** Writing – review & editing. **Hailing Xi:** Writing – review & editing, Writing – original draft.

Declaration of competing interest

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

Data availability

The authors do not have permission to share data.

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