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ORIGINAL RESEARCH

COVID-19 Vaccine Uptake in the Context of the First Delta Outbreak in China During the Early Summer of 2021: The Role of Geographical Distance and Vaccine Talk

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Purpose: Vaccination is essential to control the prevalence of COVID-19. However, vaccine hesitancy has been a major issue globally. Some studies have suggested that community outbreaks might boost vaccine uptake. Consistent with that idea, vaccination rates increased dramatically during the first outbreak of the COVID-19 Delta variant in Guangdong, China, in June 2021. Based on the risk perception attitude theory, this study attempted to explore the joint effect of geographical distance to the outbreak and the frequency of talking about the COVID-19 vaccine (vaccine talk) on people's COVID-19 vaccine uptake.

Methods: An anonymous self-report online questionnaire was completed by citizens living in Guangdong Province, China, from June 6 to 11, 2021, during the Delta variant outbreak in that region. The relationship between COVID-19 vaccine uptake, geographical distance to the epicenter of the outbreak, and vaccine talk was analyzed using logistic regression analysis.

Results: Data from 350 respondents were included in the final analysis. Results showed a negative association between geographical distance and COVID-19 vaccine uptake. Furthermore, the relationship was moderated by vaccine talk. Specifically, when individuals infrequently discussed vaccine talk with others, close distance to the epicenter of the outbreak served as a motivator for getting vaccinated, whereas for people who frequently discussed the vaccine, geographical distance might have played less of a role in motivating them to get vaccinated.

Conclusion: This research highlights the joint effect of geographical distance to the outbreak of COVID-19 and vaccine talk in COVID-19 vaccine uptake. While the findings may only be a starting point for launching a public health awareness campaign, encouraging people to engage in more conversations about vaccines may be a promising solution for future health emergencies, especially among people far from the outbreak.

Keywords: COVID-19 vaccination, geographical distance, risk perception attitude, health communication

Introduction

The World Health Organization declared the novel coronavirus (COVID-19) outbreak as a global pandemic in March 2020, yet the pandemic remains a major global health crisis. As of this writing (April 30, 2022), the pandemic has infected over 510 hundred million and killed more than 6 million people worldwide.[1] Immunologists and policy-makers have proposed vaccination as the most effective way of combating COVID-19, and campaigns for mass COVID-19 vaccination have been initiated worldwide.[2] Nevertheless, vaccine hesitancy, whereby people postpone or refuse vaccination,[3] is prevalent in both developed countries (eg, the United States,[4] Italy,[5] New Zealand[6] and Portugal[7]) and developing countries (eg, Bangladesh,[8] Turkey,[9] Nepal,[10] South Africa[11] and China[12]). This leads to insufficient vaccination rates to stop COVID-19 from breaking out and further infecting more people.[13] The negative consequences of vaccine hesitancy are especially detrimental when more contagious variants of COVID-19 emerge.[14] As such,

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reducing vaccine hesitancy and encouraging uptake of the COVID-19 vaccine has received close attention from researchers.

Although adopting healthy behaviors is a recommended response to any health crisis, people often do not do so, and for a variety of reasons; however, it has been noted that people's hesitation may decrease when a health crisis occurs explosively.[13,15,16] For instance, one study found a significant association between an increase in local measles vaccination coverage and promoted public attention due to a measles outbreak in Berlin.[15] Similarly, the first COVID-19 Delta variant explosion in China caused the local vaccination rate to rise from 36.13% to 75.77% over the course of three weeks in Guangdong Province.[17] In addition, the outbreak of COVID-19 was also reported to increase the uptake of influenza vaccine by nurses.[18] As a result, in the context of the COVID-19 Delta outbreak in Guangdong Province, this study investigated the factors contributing to the increase of vaccine uptake in severe health crises. Based on the risk perception attitude (RPA) framework,[19,20] we focused on the role of geographical distance to the epicenter of the outbreak, COVID-19 talk, vaccine talk, and their interactions in predicting COVID-19 vaccine uptake.

Geographical Distance to the Epicenter

Geographical distance to the epicenter of a crisis has long been recognized as an important risk factor that influences health preventative behaviors.[21–24] Many studies have noted the effect of geographical distance on vaccine uptake.[15,25] For instance, participants in one study reported that they were willing to pay more for the appropriate vaccine of a flu virus that was closer to them.[25]

In the context of the COVID-19 outbreak, geographical distance to the epicenter is particularly critical for people to determine their risk of exposure to the virus, which can be transmitted through aerosols.[26] Researchers have reported that people living closer to the epicenter of a COVID-19 outbreak had higher levels of anxiety, which was probably caused by their high level of risk perception.[23] Studies on COVID-19 vaccination intention have also revealed the influence of geographical distance. For example, a study in the United States showed that residents closer to the epicenter were more willing to get the COVID-19 vaccine than those farther away from the outbreak.[27] Consistent with this finding, a study in China suggested that the closer people lived to Wuhan, the initial epicenter of COVID-19, the more inclined they were to get vaccinated.[22]

These studies provide empirical reasoning for the role of geographical distance on vaccination, but their data collection occurred after rather than during an abrupt crisis outbreak. Furthermore, these studies have generally measured vaccination intention rather than real vaccine behavior. According to the Theory of Planned Behavior, intention is an important predictor of behavior, but the two are not equivalent.[28] As a result, the first goal of the current study was to examine the relationship between individuals' geographical distance to the epicenter and COVID-19 vaccine uptake during the abrupt COVID-19 Delta outbreak in Guangdong Province, China. We proposed the following hypothesis:

H1: Individual's geographical distance to the epicenter of the COVID-19 outbreak will be negatively correlated with COVID-19 vaccine uptake.

COVID-19 Talk and Vaccine Talk

The second purpose of this study was to investigate the potential psychological variables that can mitigate the effect of geographical distance on COVID-19 vaccine uptake. We conceptualized a health discussion of the vaccine otherwise known as "vaccine talk".

When faced with an abrupt COVID-19 Delta outbreak that requires people to stay at home, wear face coverings, and socially distance, people naturally talk about the outbreak itself (ie, COVID-19 talk) and the recommended preventative measures, of which vaccination is recognized as one of the most effective (ie, vaccine talk).[29] Various studies have illustrated that such health communications enhance health preventative behaviors.[30] To facilitate measurement, some studies have combined the two forms of communication into one index. For example, mother–daughter communication about the human papillomavirus virus and the vaccine has contributed to daughters' willingness to receive the vaccine.[31] There are also some studies that focus only on one of the two talks. For instance, a study on COVID-19 solely evaluated the role of vaccine talk among family members on the vaccination intention of young African Americans and found that

participants who communicated with their families about COVID-19 vaccines were more willing to be vaccinated.[32] Another study has investigated the positive impact of COVID-19 communication in the mass media on physical distancing behaviors.[30] However, rarely have studies examined the respective impact of COVID-19 talk and vaccine talk on health preventative behaviors, especially on COVID-19 vaccine uptake.

Inspired by the RPA framework, the current study suggests that, of the two types of discussion, vaccine talk may moderate the negative relationship between geographical distance and COVID-19 vaccine uptake. However, COVID-19 talk may not play a moderating role (see Figure 1 for the framework of hypotheses).

The RPA framework is one of the most widely adopted theories in understanding health behaviors. It proposes that health preventative behaviors are determined by two key factors—perceived risk and perceived efficacy.[20,33] Perceived risk refers to the belief that one is vulnerable to a threat, and it consists of perceived severity and perceived susceptibility.[20] Perceived efficacy is usually conceptualized as including both perceived self-efficacy (PSE) and perceived response efficacy (PRE).[20] PSE is defined as individuals' perception of their capacity to perform preventative behaviors to avoid a health risk (eg, COVID-19), and PRE is defined as the perceived effectiveness of a suggested solution (eg, vaccines) in reducing the health risk. When it comes to people's discussions about the COVID-19 situation and vaccines, COVID-19 talk includes COVID-19 disease knowledge, the epidemic spreading, and confirmed cases of COVID-19,[34] while vaccine talk consists of vaccine knowledge and opinions and emotions about vaccination.[35] As such, the former is likely to contribute to the formation of perceived risk of COVID-19, and we proposed the latter may have an impact on the formation of perceived efficacy of the COVID-19 vaccine.

Furthermore, several studies have demonstrated the interaction effect between perceived risk and perceived efficacy on health preventative behaviors proposed by the RPA framework.[20] For example, scholars have found that people with high perceived efficacy, which was usually measured as an averaged index of PRE and PSE, were more likely to adopt information-seeking behaviors regarding breast cancer regardless of the perceived risk.[19] Another study on individuals' engagement in cancer treatment extended the interaction to societal-level perception, and found similar significant interaction effect between perceived risk and perceived efficacy.[36] Accordingly, while the effect of geographical distance on perceived risk is indisputable, the current study considered vaccine talk as another potential method to increase individuals' perceived efficacy of the vaccine, which could in turn moderate the negative relationship between geographical distance and COVID-19 vaccine uptake. Synthesizing the RPA framework and existing evidence on the interaction effect,[19,36] we expected to find a stronger relationship between geographical distance and COVID-19 vaccine uptake in those who talk about vaccines less frequently compared with those who frequently talk about vaccines. Therefore, we proposed the following hypotheses:

H2: The relationship between geographical distance and COVID-19 vaccine uptake will be stronger for those who talk about vaccines less frequently than for those who talk frequently about vaccines.

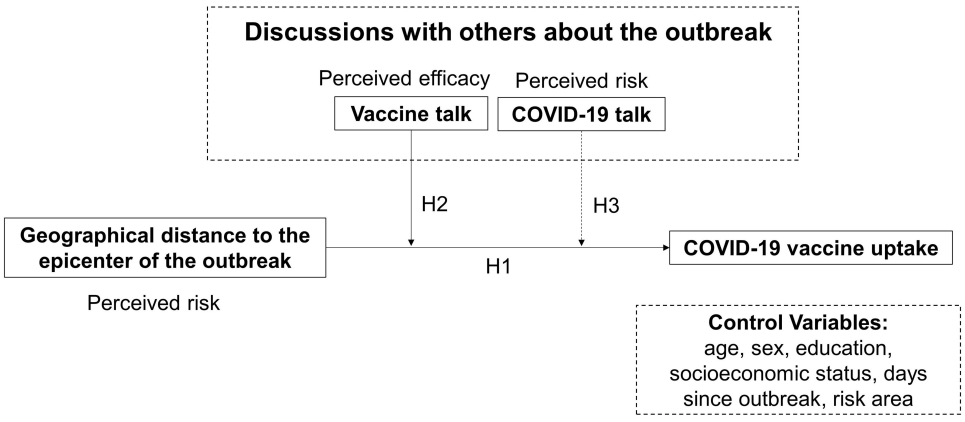

Figure 1 The hypothesized model of the current study.

Different from vaccine talk, COVID-19 talk might contribute to individuals' perceived risk of the pandemic. For example, it is possible for individuals to discuss the recent COVID-19 developments, and that might spark an increased sense of perceived risk or concern for people around them.[37] Since COVID-19 talk has been conceptualized as talking about the current pandemic situation—such as sharing stories, news, or information[38]—we do not expect the relationship between distance and vaccine uptake to differ based on COVID-19 talk, as discussion also contributes to the perception of risk. Consequently, we expect that COVID-19 talk may not influence the relationship between geographical distance and COVID-19 vaccine uptake.

H3: COVID-19 talk will not moderate the negative relationship between geographical distance to epicenter and an individual's COVID-19 vaccine uptake.

Materials and Methods

Guangdong Province is roughly the size of Cambodia (177,000 km^2) and has a population of 113 million people and a GDP roughly the same as South Korea's. On May 21, the first Chinese COVID-19 Delta variant case was identified in Liwan District, Guangzhou, Guangdong Province, and the virus quickly spread across Guangdong; this resulted in a mass COVID-19 testing campaign of all citizens and a quarantine of risk areas.[39]

We conducted an online survey in Guangdong Province from June 6 to 11, 2021. During this period, there was a 53% increase in diagnosed cases, which indicated the continuity of the outbreak. Liwan District was initially listed as a medium-risk area on May 22, and was then re-classified as a high-risk area on June 2. This was the only high-risk area in the province during our data collection period, and the "epicenter" in this paper thus refers to Liwan District. Seven other districts of Guangdong Province gradually escalated from low-risk to medium-risk areas as our data collection continued.

Participants

Participants were 18 to 60 years old, currently lived in Guangdong Province, and met COVID-19 vaccination requirements (eg, no history of vaccine allergy). We chose this age range because it was the recommended vaccination age range proposed by the Chinese government at that time. During the outbreak, most citizens in risk areas were required to comply with the "stay-at-home" recommendation. As a result, participants were recruited online using snowball sampling via a WeChat invitation, which was the most feasible method for recruiting participants.[40]

Among all respondents, 86 were required to get vaccinated because of their careers (eg, taxi drivers and public servants), rather than out of complete voluntariness. Since we focused on the impact of the Delta outbreak on citizens' voluntary vaccine uptake, they were not included in the final data analysis to prevent confounding of the results. In addition, previous studies have shown that COVID-19 vaccine acceptance is significantly associated with personal, family, or friends' history of COVID-19 diagnosis;[41,42] therefore, it is important to differentiate the participants based on these factors. Meanwhile, China has a low infection rate. As a result, we decided to exclude participants who had already been infected with COVID-19 (n = 0) or whose family members or friends had been infected with COVID-19 (n = 13) from the final data analysis.

The final sample included 350 participants; 61.1% were women, and their ages ranged from 18 to 53 years (M_{age} = 24.95 years, *SD* = 5.75). Participants came from 45 districts across 19 different cities (see Tables S1 and S2 for full demographics). Prior to the statistical analysis, we checked the sample size issue. We had a total of 10 predictors in the final model, which included all of the regressors, covariates and alternative theories. Based on the rule of event per variable as n = 100 + 20i,[43] where i refers to the number of predictors, we calculated a required sample size of 300. Therefore, the current sample size was enough to achieve sufficient statistical power to reach a reasonable conclusion.

Measures

COVID-19 Vaccine Uptake

COVID-19 vaccine uptake was measured by asking participants to choose a binary option (1 = yes; 0 = no) in response to the question, "Have you been vaccinated with the COVID-19 vaccine?"

Geographical Distance to the Epicenter

Consistent with previous research,[13,44] the current study calculated straight-line distances (in km) between participants' self-reported district locations and Liwan to measure geographical distance. Given that we were unable to obtain the specific address of each participant, we used the locations of local district government buildings instead. The longitude and latitude of each location were captured from the Baidu map (http://api.map.baidu.com/lbsapi/getpoint/index.html) for these calculations.

COVID-19 Talk

Adapted from Qin et al's scale,[38] COVID-19 talk was assessed using five items that were rated on a 5-point Likert scale (1 = almost never, 5 = almost always, Cronbach's $\alpha = 0.87$). A sample item is as follows: "People around me communicate with each other about the COVID-19 situation."

Vaccine Talk

Based on the measurement of COVID-19 talk,[38] we developed three items to measure vaccine talk. Participants rated the following items on a 5-point Likert scale (1 = almost never, 5 = almost always, Cronbach's $\alpha = 0.83$): "People around me talk about the progress of COVID-19 vaccine uptake," "People around me share their feelings about getting the COVID-19 vaccine," "People around me share their physical reactions after getting the COVID-19 vaccine."

Control Variables

We incorporated a few control variables into our model to account for some disparities in vaccination decisions. First, we controlled for demographic factors such as age, sex, education, and socioeconomic status (SES). Next, we controlled for risk factors, such as days since the outbreak and a binary variable "risk area," which we created to assess whether participants lived in a risk area when completing the survey (detailed measurements and rationale of choosing these variables are presented in Table S3). Eliminating these control factors did not change the statistical significance of our results.

Data Analysis Plan

IBM SPSS software 23.0 (IBM Corp, Armonk, New York, United States) was used for statistical analysis. The geographical distance was positively skewed and was log-transformed prior to all analyses. We ran a point-biserial correlation analysis to test the associations between vaccine uptake and the other variables. Next, we conducted logistic regression analysis using PROCESS macro 3.5 (Model 1) for SPSS[45] to test main effect of geographical distance (H1) and the moderating effect of vaccine talk (H2 Geographical Distance × Vtalk) and COVID-19 talk (H3 Geographical Distance × Ctalk) on COVID-19 vaccine uptake.

According to the Theory of Planned Behavior, attitude and subjective norms are important predictors of individuals' health behaviors.[46] Thus, to check the robustness of our model against other potential theories, we conducted further regression analyses by including attitude towards COVID-19 vaccination, perceived descriptive norm, and perceived injunctive norm of COVID-19 vaccination into the previous models (detailed measurements of these variables are presented in Table S3).

Results

Associations Between Vaccine Uptake and Distance to the Epicenter (H1)

The correlation analysis indicated that individual's COVID-19 vaccine uptake was negatively associated with geographical distance to the outbreak ($r = –0.14$, $p = 0.01$), while vaccine uptake was not directly associated with vaccine talk ($r = 0.05$, $p = 0.40$) and COVID-19 talk ($r = 0.01$, $p = 0.86$).

Testing Vaccine Talk Moderation (H2)

The logistic regression analysis revealed a significant moderating effect of vaccine talk on the relationship between geographical distance to the epicenter and vaccine uptake ($B = 0.58$, $Wald\ \chi^2 = 6.47$, $p = 0.01$, odds ratio [OR] = 1.79; see Model 1 in Table 1). The significant interactive effect of vaccine talk was further interpreted using simple

slope analysis (Figure 2), which showed that geographical distance to the epicenter and vaccine uptake was negatively correlated when people engaged in low-frequency vaccine talk (B = –0.78, p = 0.01, 95% confidence interval [CI] [–1.36, –0.21]), while high-frequency vaccine talk eliminated the negative relationship between geographical distance and vaccine uptake (B = 0.14, p = 0.55, 95% CI [–0.32, 0.59]). These results remained stable when including control variables in the model (B = 0.61, $Wald\ \chi^2$ = 6.67, p = 0.01, OR = 1.84, Model 2).

Testing COVID-19 Talk Moderation (H3)

The interaction between COVID-19 talk and distance did not significantly predict vaccine uptake (B = 0.28, $Wald\ \chi^2$ = 1.15, p = 0.28, Model 3). This result remained stable after including all control variables in the model (B = 0.32, $Wald\ \chi^2$ = 1.42, p = 0.23, Model 4).

Testing Results Against Alternative Theories

We further tested the possibility that attitude towards COVID-19 vaccination, perceived descriptive norm, and perceived injunctive norm of COVID-19 vaccination could explain the interaction between vaccine talk and

Table 1 Logistic Regression Models Predicting COVID-19 Vaccine Uptake by Geographical Distance, Vaccine Talk, and Their Interaction

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
(Intercept)	12.90**	12.73*	8.44	8.95	5.81	10.09	7.57
	(4.36)	(5.73)	(4.91)	(6.19)	(6.05)	(5.71)	(6.11)
Age		−0.03		−0.03	−0.02	−0.02	0.0004
		(0.03)		(0.03)	(0.03)	(0.03)	(0.03)
Gender		−0.08		−0.09	−0.27	0.09	0.07
		(0.40)		(0.40)	(0.40)	(0.41)	(0.44)
Education		0.0002		0.08	0.07	0.05	−0.04
		(0.33)		(0.32)	(0.34)	(0.33)	(0.36)
SES		−0.12		−0.14	−0.01	−0.19	0.06
		(0.22)		(0.21)	(0.23)	(0.22)	(0.24)
Days since outbreak		0.09		0.05	0.12	0.05	−0.01
		(0.19)		(0.19)	(0.19)	(0.19)	(0.21)
Risk area (1 = yes)		0.66		0.61	0.82	0.65	0.87
		(0.57)		(0.56)	(0.58)	(0.58)	(0.61)
GD	−2.85**	−2.86*	−1.58	−1.63	−2.82**	−3.60*	−2.33*
	(1.00)	(1.04)	(1.15)	(1.20)	(1.07)	(1.04)	(1.07)
Vtalk	−2.22*	−2.37*			−2.46*	−2.26*	−2.04
	(0.98)	(1.02)			(1.05)	(1.01)	(1.07)
GD X Vtalk	0.58*	0.61**			0.60*	0.57*	0.51*
	(0.23)	(0.24)			(0.24)	(0.24)	(0.25)
Ctalk			−1.17	−1.39			
			(1.10)	(1.16)			
GD X Ctalk			0.28	0.32			
			(0.26)	(0.27)			
Vaccine attitude					1.27		
					(0.35)		
Descriptive norm						0.03**	
						(0.01)	
Injunctive norm							0.05***
							(0.01)
χ^2	6.93	7.24	6.55	8.84	12.07	10.07	18.79
N	350	350	350	350	350	350	350

Notes: ***p < 0.001; **p < 0.01; *p < 0.05. Geographical distance was log-transformed before all analyses.
Abbreviations: SES, Socioeconomic status; GD, Geographical distance; Vtalk, Vaccine talk; Ctalk, Covid-19 talk.

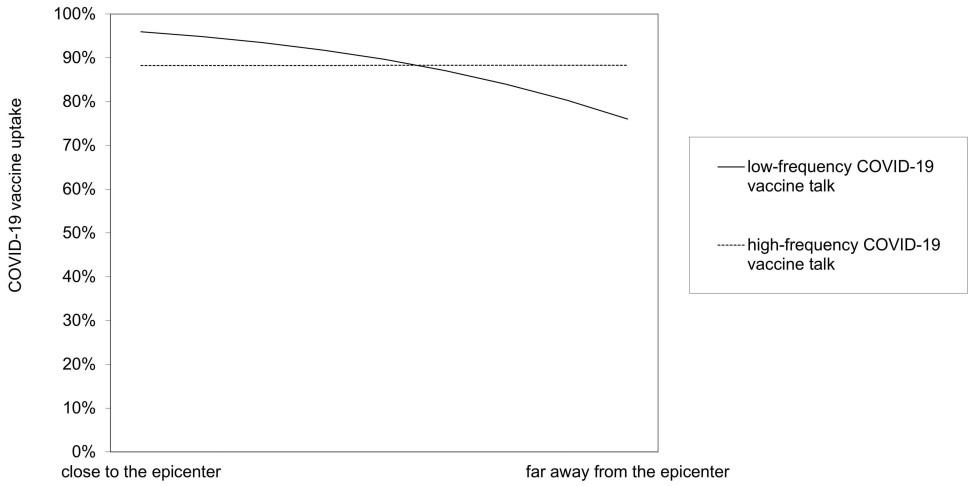

Figure 2 Simple slopes of the interaction between geographical distance and vaccine talk on COVID-19 vaccine uptake.
Notes: The geographical distance and vaccine talk variables were z-scored prior to the analyses for easy interpretation. The simple slope effect of geographical distance to the epicenter and vaccine uptake on the vaccine uptake was significant. Geographical distance to the epicenter and vaccine uptake was negatively correlated when people engaged in low-frequency vaccine talk (B = –0.78, p = 0.01, 95% confidence interval [CI] [–1.36, –0.21]), while high-frequency vaccine talk eliminated the negative relationship between geographical distance and vaccine uptake (B = 0.14, p = 0.55, 95% CI [–0.32, 0.59]). Analyses take into account several control variables (gender, age, socioeconomic status, education, days since outbreak, risk area).

geographical distance to the epicenter. The interaction remained significant when we added vaccine attitude ($B_{interaction}$ = 0.60, *Wald* χ^2 = 6.19, p = 0.01, OR = 1.83, Model 5), perceived descriptive norm of COVID-19 vaccination ($B_{interaction}$ = 0.57, *Wald* χ^2 = 5.77, p = 0.02, OR = 1.76, Model 6), and perceived injunctive norm of COVID-19 vaccination ($B_{interaction}$ = 0.51, *Wald* χ^2 = 4.09, p = 0.04, OR = 1.66, Model 7) into the previous model, one by one. All results are shown in Table 1.

To summarize, our results indicated that geographical distance and vaccine talk jointly predicted COVID-19 vaccine uptake. This finding was robust after including a number of control and additional variables.

Discussion

Entering the third year of the pandemic, the world is still adapting to a life after the coronavirus; one changing aspect might include an increased awareness of public health issues, such as the role of vaccination programs for citizens. While some research has discovered that infectious community outbreaks can increase inoculation and reduce vaccine hesitancy, very few have been carried out in a naturalistic setting to our knowledge.[13,15,16] Thus, the present study sought to explore which factors would influence vaccination acceptance during a localized coronavirus outbreak. The data was collected during the first COVID-19 Delta outbreak in Guangdong Province, China, in which more than 500 people were infected and isolated. We hypothesized that geographical distance to the outbreak (ie, direct risk) might be an essential factor. Based on the risk perception attitude theory, we further proposed that discussions about the vaccine (vaccine talk) would moderate the relationship between geographical distance and COVID-19 vaccine uptake. We also expected that discussions about the disease (COVID-19 talk) would not interact with geographical distance. Below we will describe our results and contributions.

Firstly, results supported H1, whereas greater geographical distance to the outbreak (less risk) was associated with less vaccine uptake. As one of the fundamental dimensions of psychological distance, geographic distance has been identified as a risk factor for various crises, such as tsunamis and volcanic eruptions.[21,25,47] In accordance with these findings, our results indicate that the farther away an individual is from the epicenter, the less likely they are to get vaccinated when faced with a sudden localized COVID-19 Delta outbreak. This result is also consistent with a previous study conducted in China, which has observed that individuals' willingness to get vaccinated increased with closer proximity to Wuhan, the initial epicenter of COVID-19 outbreak in China, even 8 months after the outbreak had ended.[22] In the present study, we eliminated this time lag and tested the immediate danger of the COVID-19 Delta outbreak, thus

providing additional evidence for the onset of the distance-to-vaccination effect and the immediate response of people in surrounding areas.

In the context of real-world situations, this finding suggests that geographical distance may impact an individual's vaccination behavior and is valuable for policymakers in several ways. First, governments and public health officials might want to consider information about distance from the outbreak epicenter when allocating vaccine resources. Since populations closer to the outbreak are likely to have a stronger willingness to vaccinate, prioritizing areas with a strong willingness to vaccinate can be very efficient in improving vaccine coverage. Second, public health officials and governments should work in a timely and efficient manner to discover COVID-19 outbreaks quicker and provide more transparent and up-to-date information regarding the geographic location of outbreaks and confirmation of virus spread. Such fast response and public sharing of information might help people quickly identify and calculate their COVID-19 risk in a timely manner, thus affecting vaccine uptake.

Next, in support of the rationale for H2, we hypothesized that discussions about vaccine knowledge would play an important role in the relationship between geographical distance and vaccine uptake. We conceptualized a new variable known as "vaccine talk," where individuals actively engaged in health interpersonal communication regarding the COVID-19 vaccine. While not conceptually novel, this variable acted as an important facilitator of COVID-19 health communication, which suggested knowledge of the vaccine might influence vaccine uptake as opposed to knowledge of the disease (eg, COVID-19 talk). As presented in Figure 2, the moderating effect revealed that when individuals had low levels of vaccine talk, close distance to the epicenter of the outbreak served as an incentive for getting vaccinated, whereas the same incentive was less consequential when individuals had high levels of vaccine talk. One possible explanation is that vaccine talk might also increase the opportunity to obtain prosocial information about COVID-19 vaccines. For example, scholars have reported that individuals' COVID-19 vaccination intention was enhanced when they were exposed to herd immunity information and realized that vaccination could protect not only them but also others.[48] Hence, frequent discussion of vaccines with others is more conducive to awareness of the prosocial nature of vaccination, thus facilitating individuals to adopt such behaviors, regardless of whether they reside in a low-risk area that is far from the epicenter.

The result of H2 regarding vaccine talk is important for increasing general vaccine uptake and preventing highly transmissible infectious diseases from spreading to areas far away from the original outbreak. In addition to taking a variety of effective prevention and control measures in response to the localized outbreak of COVID-19, policymakers can encourage more discussions on vaccine-related topics to promote COVID-19 uptake, especially among citizens who live far from the epicenter of the outbreak. While we caution our result as only a mere starting point for how public health awareness campaigns could unfold, this finding could prove to be promising in future health emergencies.

Additionally, results confirmed our third hypothesis; that even though COVID-19 talk conveyed important information among close people about COVID-19, it did not serve as a facilitator like vaccine talk did in influencing the relationship between distance and vaccine uptake. In fact, previous health discussion research has generally measured COVID-19 talk (disease knowledge) and vaccine talk (vaccine knowledge) mutually, or has only examined the direct effect of vaccine talk or COVID-19 talk on health preventative behaviors independently.[30–32] To the best of our knowledge, this is the first study to distinguish and measure the two types of talk, and observe the different impact they have on vaccine uptake. As suggested in Figure 1, our results illustrated the necessity of differentiating the content of discussions of an abrupt virus outbreak. Put simply, if people infrequently discuss the viral outbreak, close proximity is associated with greater vaccine uptake, regardless of whether the content is about the disease itself or vaccines. However, if they discuss an outbreak frequently, it appears that only the discussion of vaccines would affect the relationship between distance and vaccination, as opposed to the discussion of disease itself. This may be attributed to the fact that the COVID-19 talk is more about highlighting the risk and threat of the disease,[37] and represents a similar function to geographical distance thus enhancing people's perceived risk. In contrast, vaccine talk is more likely to provide prevention and protection information that is different from risk, thus helping individuals to respond when the perceived risk is low. We hope these results can also improve scholars' knowledge about the effectiveness of health communication content. For example, when individuals' perceived risk is low, more discussions about the health risk may not be helpful, however if individuals engage in more discussions about health protection (eg, vaccine) it might foster more action.

This study also made another important extension to health communication studies. Previous investigations have focused on how medical professionals can increase vaccine acceptance,[49] however, this study focused on how vaccine discussions with individuals' friends and family could increase COVID-19 vaccine uptake. In the information technology age where social media is an important tool for people to learn more about health prevention, our study found that interpersonal communication was an important predicting factor of health promotion behavior. Future studies can further explore which type of personal relationship (eg, family member, close friend, teacher) might increase uptake in other circumstances.

In addition to the main hypotheses, we also tested potential alternative theories that also influence people's decision to get vaccinated. Some studies have suggested that social norms might increase vaccine uptake, these include vaccinated behaviors of others (descriptive norm) and approval of vaccination by important individuals around them (injunctive norm).[50] Previous studies found a positive correlation between both norms and COVID-19 vaccine acceptance.[51,52] Our results found that, while considering the role of social norms, the RPA conceptual model still provided robust evidence of vaccine uptake. In other words, social norms did have an impact, yet geographical risk and vaccine talk remained significant. Another surprising and important result to note is that demographic variables like age, gender, education and socioeconomic status did not have a significant direct effect on vaccine uptake. These insignificant results could be due to the vaccine roll-out plan in China. China has taken a zero-covid policy toward strictly managing the pandemic and it has had very few covid cases,[53] thus it is possible that there has not been an urgent need to vaccinate elderly or to promote vaccinations other than through voluntary uptake. From a cross-cultural perspective, it is also important to note the COVID-19 situation in China is vastly different compared to Western countries and this could account for why demographic variables were insignificant.

Limitations

This study has some limitations that should be noted. First, we only measured the frequency of COVID-19 talk and vaccine talk, but not the specific content of the communication. The frequency of discussion is thought to reflect public concern, and some studies have identified it as having a positive impact on COVID-19-related health behaviors.[30,32] Thus, the measure of vaccine talk in this study was not fully comprehensive and might not accurately depict which factors would negatively influence vaccination behaviors. For example, it is undeniable that people may also acquire misinformation about the vaccine from social media, which may, in turn, reduce vaccine uptake.[54] Additionally, conversations concerning the risk of the COVID-19 vaccine, such as vaccine side effects, suggest that they also might impact vaccination choices.[51,55] Some developed countries also have anti-vaccination concerns, such as England[56] and the United States,[57] hence people may be delivering negative messages when talking about these concerns. Future research could consider adding methods such as sentiment analysis and content analysis to further consider the impact of discussion content on vaccination behavior.

Next, the present research is based on cross-sectional data, and thus causality of the relationship between variables cannot be inferred. Although geographical distance is an objective variable, we are not completely certain about its causal relationship with COVID-19 vaccine uptake. This is because the local vaccine program was initiated before the Delta outbreak. Even though the pre-outbreak vaccination rate was not very high (36.13%), we did not obtain data on the timing of individuals' COVID-19 vaccination, and cannot draw conclusions about causality. Further longitudinal studies are needed to address this question.

The third limitation is regarding the sampling method. Given that data collection commenced during the peak of the first Delta variant outbreak, researchers had limited access to local people due to the government's stay-at-home policy. Thus, researchers initiated an online survey using snowball and convenience sampling method, which has been recognized as an effective approach to collect data in numerous COVID-19 related studies.[58–60] However, this sampling method leads to a bias as the participants are young internet users. It is worth noting that Guangdong Province's median age is 33.9 years old, and most participants came from cities such as Shenzhen where the median age is 33.3 years old,[61] and thus our sample is still somewhat representative. Future studies should also consider collecting data from older populations, as vaccine uptake appears to be more crucial for preventing severe illness and death in older populations.[62]

Finally, although trust has been proven to be an important factor in predicting individuals' COVID-19 vaccination decision, we did not consider this variable. In China, people reported having high vaccine trust (69%) and even higher

trust in government (81.3%),[63] thus we assume that it is less likely to influence vaccination intention. We recognize that in other western countries like England,[54] the United States[64] and Austria,[65] trust (eg, public health or government) might be an impactful factor with regard to COVID-19 vaccine hesitancy. Thus, future studies conducted in other countries should consider trust as a potential influencing factor.

Conclusions

The study applies the RPA framework to explore the joint effect of geographical distance to the epicenter of a localized COVID-19 outbreak and the frequency of individuals' discussions about the COVID-19 vaccine with others. Our findings indicate that when individuals infrequently discuss vaccine talk with others, close distance to the epicenter of the outbreak served as a motivator for getting vaccinated, whereas for people who frequently discuss the vaccine, geographical distance might play less of a role in motivating them to get vaccinated.

These findings have practical value; health policymakers could consider the information provided by these results when developing strategies for future vaccination campaigns during health emergencies. Specifically, when a new infectious disease outbreak occurs, efforts could be made to stimulate vaccine-related conversations, particularly among individuals living far from the epicenter. Overall, the current study contributes new knowledge about variables that influence COVID-19 vaccine uptake during a localized outbreak.

Abbreviations

RPA, Risk Perception Attitude; PRE, Perceived response efficacy; PSE, Perceived self-efficacy.

Data Sharing Statement

The datasets generated and analyzed during the current study are available at Open Science Framework [https://osf.io/umrg9/files/]. Readers interested in obtaining the scales we used can contact us directly.

Ethics Approval and Consent to Participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Zhejiang Gongshang University (03-18-2021). Informed consent was obtained from all subjects involved in the study by clicking the "I agree" button after reading the necessary information.

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Disclosure

The authors declare that they have no competing interests in this work.

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