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From warning messages to preparedness behavior: The role of risk perception and information interaction in the Covid-19 pandemic

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ABSTRACT

During infectious disease outbreaks, early warning is crucial to prevent and control the further spread of the disease. While the different waves of the Covid-19 pandemic have demonstrated the need for continued compliance, little is known about the impact of warning messages and risk perception on individual behavior in public health emergencies. To address this gap, this paper uses data from the second wave of Covid-19 in China to analyse how warning information influences preventive behavior through four categories risk perception and information interaction. Drawing on the protective action decision model (PADM) and the social amplification of risk framework (SARF), risk warning information (content, channel, and type), risk perception (threat perception, hazard- and resource-related preparedness behavior perception and stakeholder perception), information interaction, and preparedness behavior intention are integrated into a comprehensive model. To test our model, we run a survey with 724 residents in Northern China. The results show that hazard-related preparedness behavior perception and stakeholder perception act as mediators between warning and preventive action. Stakeholder perception had much stronger mediating effects than the hazard-related attributes. In addition, information interaction is effective in increasing all categories risk perception, stimulating public response, while functioning as a mediator for warning. The risk warning information content, channel, and type are identified as key drivers of risk perception. The research found that information channel was more related to different risk perception than other characteristics. Overall, these associations in our model explain core mechanisms behind compliance and allow policy-makers to gain new insights into preventive risk communication in public health emergencies.

1. Introduction

In the past two decades, the world has been confronted with a series of public health threats, such as SARS (2003), H1N1 (2009), MERS (2012), Ebola (2014), Zika virus (2016), and now SARS-CoV-2, or Covid-19 (2019) [1]. The Covid-19 pandemic has had an enormous impact on individual and public health, with profound economic and social consequences for many years to come. Now the world is hopeful that with the increasing availability of vaccines, we will be able to combat the disease more effectively. Yet, much about the novel coronovirus disease remains uncertain, such as its origin, mutations, re-infection rates, case fatality rate, seasonal influence [2].

Exemplary for the unpredictable nature of the virus is the mutation B1.617, or delta variant. On April 26, 2021, there were 350,000

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new cases in India, pushing the confirmed cases worldwide to exceed 148 million [3]. On May 10, the World Health Organization (WHO) officially claimed that the variants virus B1.617 was a global concern, and patients infected with the variant were identified in at least 17 countries [4]. The second wave of Covid-19 variants broke out with a vengeance, resulting in a rapid increase of confirmed cases worldwide. Cases of the mutation virus have also been found in various cities in China, such as Guangdong, Shenyang, Chongqing. Even though the policymakers formulated strict measures and border controls, flareups of the infections still occur.

As any early warning, the warnings to take precautionary measures to prevent the spread of respiratory diseases directly relates to people's life and health. While it is known from previous epidemics that early action is vital to combat the spread of a virus, one obvious lesson from the first wave of the Covid-19 outbreak in 2020 was that the warnings had not been given sufficient attention, leaving many countries unequipped to deal with the virus [5]. This is important because, even if a warning message is confirmed to be effective in promoting proactive preparedness response, its impact will be restricted if it is rarely used by the public. Mileti and Sorensen first presented a cognitive theory for public warning response [6]. They argued that warnings do not directly persuade the public to take the recommended action, because the warning receivers go through a range of cognitive processes. These cognitive processes are especially important in infectious disease prevention: in contrast to earthquakes or tsunamis, a virus creating a public health emergency is intangible and invisible. This makes it more important to enhance public awareness, improve understanding and ensure compliance. Ineffective communication may cause panic, breed rumors and obstruct risk mitigation.

In the context of epidemics, an abundance of publications have investigated the influencing factors of risk perception and also have assessed the link between risk perception and precautionary behavior [7–10]. To date, a significant limitation of the existing studies is that they ignore the role of information especially warning that initiates the cognitive processes [11]. The perception-behavior process takes warning cues as input. People react to the warning cues in different ways, resulting in unpredictable behavior. While prior research demonstrated that risk perception is important in encouraging preparedness behavior, the underlying mediation processes remain unexplored [12]. Thus, understanding how warning notifications motivate individual behavior through risk perception is necessary to shed new light on the design of appropriate risk communication strategies. Few publications focused on whether a warning before an outbreak affected public risk perception and behavioral response, highlighting problems in noncompliance [5]. In addition, compared to natural [13] and technological disaster [14], there has been little empirical research on how warning affected public behavior for emerging infectious diseases. Therefore, the efficiency and effectiveness of warnings in preventing an aggravation of the pandemic remain unclear.

To address this gap, we use the protective action decision model (PADM) to identify the antecedents of people's intentions to engage in preventive behaviors against the Covid-19. We start by examining how the use of warning information contributes to risk perception and behavior. Moreover, this study concluded that relying on risk perception alone will not be sufficient for a comprehensive understanding of warning and preparedness behavior. For this reason, interpersonal information interaction from the social amplification of risk framework (SARF) has been introduced as an essential mediating variable in shaping perceptions and behaviors [15]. By integrating the above theoretical foundations, six hypotheses are developed regarding the relationships between risk warning information, information interaction, core risk perceptions and preparedness behavior intention. To test our model, a survey was conducted in three northern cities in China. The findings provide empirical evidence for scientific and effective warning dissemination and allow to stimulate preparedness response during Covid-19 pandemic.

This paper is organized as follows. We review the literature and theoretical frameworks that guide this research in Section 2. In Section 3, the key variables, relationship between variables and our hypotheses development is presented. Section 4 provides details about the methodology including samples, data collection, and instruments measures. Section 5 outlines the data analysis and results. In Sections 6 and 7, discussion as well as the conclusion and implications are summarized.

2. Literature review and theoretical background

2.1. Risk perception and Covid-19 pandemic

Risk perception is an extensively explored construct in emergency management. In its original sense, risk perception is a concept that represents the intuitive and subjective judgment a person makes by evaluating a hazard [16]. Beyond the initial cognitive aspects, today also emotional and social dimensions are understood as a part of risk perception, such as fear, sadness, or political issues [17].

Prior publications on risk perception during epidemics have focused on several specific contexts, including H1N1 [18], H7N9 [7] and Ebola [19]. With rapid and worldwide spread of Covid-19, there is a growing body of studies that addresses publicly perceived risk associated with Covid-19, which can be mainly categorized into two research streams, (1) regarding the factors that drive risk perception, and (2) on the impact of risk perception on behavior.

1. **Factors that drive Risk Perception.** The first research stream revolves around the factors and the mechanisms that drive risk perception, such as demographic characteristics [20–22], trust [23,24], emotions [25], and social media use [26,27]. Many studies have attempted to investigate the link between individual characteristics and risk perception. For example, a study conducted by Rana et al. showed that males were found to perceive risks lower than females in response to Covid-19 in Pakistan [21]. Abu et al. pointed out the role of demographics in risk perception. The less educated, the younger, and the unemployed population had lower risk perception scores in sub-Sahara Africans [22]. Some publications explore the relationship between trust and the formation of risk perception. By using data collected during the first wave in Switzerland, Siegrist et al. found that social and general trust had different effects on risk perceptions [23]. Dryhurst et al. presented qualitative data collected in ten countries across Asia, Europe and America about risk perception and other variables [24]. They demonstrated that risk perception was significantly influenced by trust in the local government, science, and medical professionals. In terms of emotions, studies have reported a positive association

between negative affective states and risk perception among Italian participants [25]. Consistent conclusions also were obtained by using data collected during the 2015 Middle East Respiratory Syndrome Coronavirus in South Korea [28].

Findings on information cues and risk perception are still preliminary in the ongoing Covid-19 pandemic. Most studies measured the effects of information by focusing on social media. Tsoy et al. emphasized that social media have long been regarded as drivers of risk perceptions, especially when people were quarantined at home [26]. Rui et al. proposed that individuals rely on official social media for information are more driven to increase risk perception than those that rely on unofficial sources [27]. Ranjit et al. considered three major sources (information communication, traditional and social media) of Covid-19 information at the same time to understand how each contributed to threat evaluations [29].

2. **The relation of risk perception and preventive behavior.** The majority of studies regards risk perception as a principal determinant for the adoption of preventive behavior, rather than a mediator variable. For example, Xie et al. found that the higher risk perception motivated people to comply with social distancing through perceived understanding by using data from citizens of China [30]. Caserotti et al. indicated that as Italy participants' risk perception increased, so did their willingness to accept the vaccine [31]. Furthermore, several social cognitive models have been successfully applied to interpret preparedness behavior in Covid-19, including the protection motivation theory (PMT), the theory of planned behavior (TPB), the health belief model (HBM) [8–10,32]. Both models have described the decisive role cognitive mechanisms play in determining preparedness behavior. During the lockdown in Japan, Okuhara et al. explored the relationship between PMT constructs and the intention of staying at home [8]. Curșeu et al. evaluated the role of negative messages towards the intention to enact security measures in Romanians and Kazakhs of the Covid-19 pandemic based on the theory of TPB [9]. Prasetyo et al. used a combination of PMT and extended TPB to assess factors influencing the perceived effectiveness of Covid-19 protective measures among Filipinos [10].

To sum up, while the studies mentioned above provide valuable insights, it remains unclear how risk information, especially warning information, interacts with risk perception and whether their interaction has an impact on preparedness behaviors. Little attention has been given to an integrated information-perception-action mediation model to elucidate individual's precautions during Covid-19. We argue that policymakers are not able to design a fully effective risk communication strategy to encourage individuals' compliance without a clear understanding of relationship between warning information and precautions. In the next two sections, the protective action decision model (PADM, Section 2.2) and the social amplification of risk framework (SARF, Section 2.3) as the theoretical fundamentals of this study are discussed.

2.2. Protective action decision model (PADM)

The protective action decision model (PADM) was proposed by Lindell and Perry in 2004 [11]. PADM was built to explain how people respond to and protect themselves against hazards and disaster events. In contrast to other models, the protective action decision model (PADM) focuses on psychological decision-making processes in combination with information flows. The PADM combines the processing of information obtained from the environment with messages sent to individuals at risk through communication channels [33]. According to the PADM, first, individuals collect risk information across various communication channels. Second, their risk perceptions are updated. Finally, they determine whether to engage in preparedness behavior. Pre-decision processes can be triggered by warning, which can affect three core risk perceptions namely threat perception, protective action perception and stakeholder perception [34]. These dimensions together form the foundation upon which individuals decide how to respond to risk. PADM is an established, integral theoretical foundation for risk communication to create and disseminate community-oriented information that motivates risk-reduction action. It has broad empirical support in the context of hurricane [33], flood [35], bushfires [36], and hazardous chemical incidents [37].

However, there is a lack of studies that empirically test the way, in which three core risk perceptions mediate the connection between warning information and behavior adoption such as social distancing and vaccination in epidemic. Only Rahn et al. examined how threat appraisal and socioeconomic characteristics effect the intention to follow behavioral recommendations from warnings regarding Covid-19 outbreak under PADM [38]. As shown in 2.1, studies of information, risk perception and people's responses to epidemic have addressed some, but not all of the variables outlined by the PADM. Thus, additional variables such as protective behavior perceptions and stakeholder perceptions also should be considered to explain the direct and indirect relationships between warning notifications and compliance behavior in Covid-19.

2.3. Social amplification of risk framework (SARF)

Originally proposed by Kasperson and his colleagues in the 1988, the social amplification of risk framework (SARF) described the dynamic processes to understand how risks are perceived and conveyed as they are communicated throughout a society [39]. Communication is at the core of SARF, since individuals are exposed to risk information most frequently through their use of media or discussions with others [40]. SARF aims to establish a framework that included diverse findings from the risk communication literatures. According to the definition of SARF, risk perception is intensified and ignored by information transmission, individual characteristics, institutional structure, and group behavior [41]. Importantly, SARF explains how individuals as well as various "amplification stations" including media outlets, social groups, and interpersonal networks process risk information [42]. The idea of risk amplification, which permits different "amplification stations" to compete for public attention, is crucial in helping us understand how the public perceive and response to risk. Because of its focus on information recipients' reaction to risk information, SARF is deemed an appropriate theoretical framework for our study.

Kasperson et al. [40] and Binder et al. [43] indicated that a disproportionate share of research focused on mass media compared to interpersonal information interaction in the amplification or attenuation of risk perception in society. A handful of recent Covid-19 publications mention the SARF [41]. These publications demonstrate that government agencies (e.g., CDC, WHO) and online media (e.g., Twitter, Weibo) serve as “amplification stations” for transmitting risk information to the general public and influencing risk perception [44]. Indeed, government or social media information are not the only driving force for perceived risk, rather, discussions with others (e.g., family members, neighbours, relatives, and friends) also can cultivate perceptions and attitudes of risk [15]. Day-to-day information interactions among citizens in larger society may have a significant impact on risk perception. However, few attempts have been made to test how information interaction between individuals can shape various perceptual outcomes.

3. Hypotheses development

Based on protective action decision model (PADM), we introduce threat perception, hazard- and resource-related preparedness behavior perception, and stakeholder perception into our research model. We also introduce information interaction based on social amplification of risk framework (SARF). In addition, risk warning information including content, channel, and type has been discussed comprehensively under the extended framework. Fig. 1 represents Theoretical Research Framework for this paper. Below, we provide further information on each element.

3.1. Risk warning information

In our research, risk warning information refers to the alert of public health emergencies which occur or could occur and have implications or could have implications for the countries and territories. Understanding which and how warning messages are transmitted at the beginning of a public health emergency is crucial because warnings influence what people understand about the virus and how they will protect themselves [14]. Warning information can be obtained through various sources, such as local governments, experts, medical staff, or social networks. Once issued and generated, the warning is distributed to related institutions as well as directly to the public via a variety of channels [26]. The use of social media channels in government agencies to distribute warnings in disasters, especially via Facebook, Twitter and Microblog, has attracted the interest of many scholars [28,29,45]. Although transmission channels determine how (and how many) people are reached, more attention also be paid to the content, style and frequency of the warning [46]. Brenkert-Smith et al. and Basolo et al. focused on the answer to the central questions of warning, such as what the potential threat is, what possible geographical area is influenced, how people can protect themselves [15,47]. The content of warning given to inhabitants was important to their definition of risk warning information. According to Jagtman, the degree to which the warning is understood depends on text features such as length and structure [48]. Ash et al. noted that real-time reporting with graphical information is particularly useful [49]. Their researches mainly emphasized warning information type. Risk warning information have been reported in other crises, however, it is often operationalized via single components rather than as a multidimensional construct.

Therefore, in the present study, multidimensional characteristics are used to understand risk warning information including content, channel, and type. This classification not only represents warning comprehensively but also captures the results of the comparative role in the model regarding the epidemic. The content is defined as the text of risk warning information received by people, which usually includes the description of potential risk, the possible harm, measures taken by government and directions for the community (e.g., stockpiling supplies, behavioural guidelines) [12]. The channel reflects the multiple communication means used to repeatedly distribute risk warning information (e.g., newspapers, radio, television, and the internet). The type refers to the manifestations of risk warning information, including audio, image, numeric, or video files.

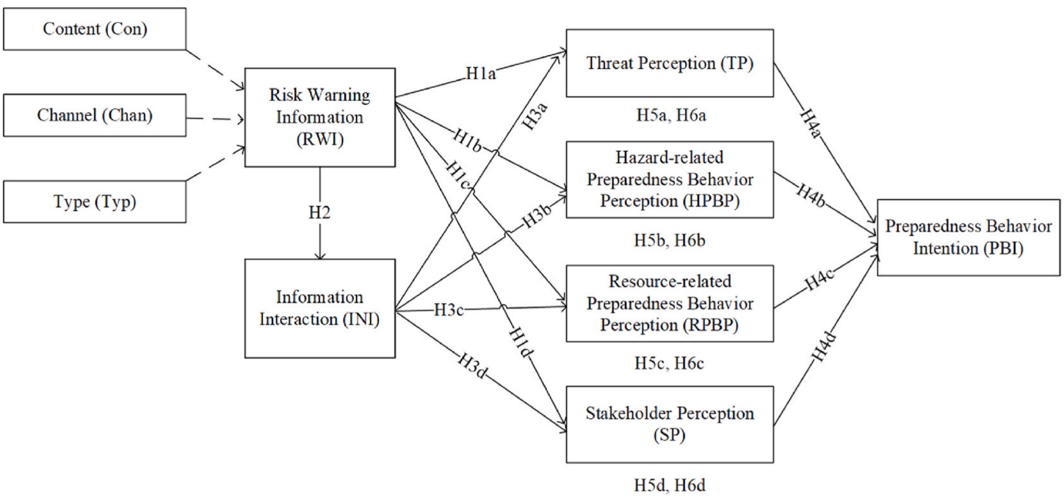

Fig. 1. Theoretical research model.

3.2. Core risk perception

The protective action decision model (PADM) offers researchers a tool for investigating respondent risk perceptions. Therefore, based on PADM, there are four categories of mediators for risk perception in this study: threat perception, the hazard-related, resources-related attributes preparedness behavior perception, and stakeholder perception [11].

- Threat perception refers to the subjective judgment a person makes by assessing a threat. It means the individual's cognition of likelihood (probability) and consequence (seriousness) (e.g., physical injury, loss of property and disruption to daily routine) of potential threat [16,50].
- Preparedness behavior perception is the belief that taking preparedness action is effective in reducing the risk and that action can be taken successfully [34]. PADM examined two aspects of attributes that people consider when exploring, selecting, and adopting a preparedness behavior: the hazard-related and resources-related attributes [35]. The degree to which a person assumes that preparedness action to be effective at mitigating the hazard is referred to as hazard-related attributes, including perceived efficacy for protecting lives, property and perceived utility of preparedness action for other purposes [11]. The assessment of how costly it will be to comply with preparedness behavior is referred to as resource-related attributes [37]. The resource-related attributes involved perceived money, time, knowledge, tools, or effort required to take precautions.
- Stakeholder perception refers to the extent of cognitive evaluations of authorities (state government, local government), providers of critical services (medical, police) or societal functions (media) in hazard [50,51]. Stakeholder perception pertains to views on trustworthiness, proficiency, and protection responsibility [52].

3.3. Preparedness behavior intention

The information transmitted in epidemic communication proposes preventive steps. In the context of Covid-19 this ranges from wearing masks and cleaning hands to social distancing. Here, we aim to understand how information changes behavior. Yet, a change in individual behavior is hard to measure, especially if it is not easily observable such as hand washing. Given that preparedness behavior intention has a strong association with actual behavior, which is also been proven by the protection motivation theory and theory of planned behavior [10]. We adopt it here as a surrogate of actual behavior. Preparedness behavior intention refers to the individual's willingness to adopt some precautions to protect themselves from injuries.

3.4. Relationship between risk warning information and risk perception processes

When confronted with a crisis, risk perception is shaped in part by intuitive judgment of the information received. If the information is novel, not well understood or disputed, it is more likely to amplify risk perception. Under the PADM paradigm, there are four different forms of risk perception (see 3.2). The empirical literatures have confirmed that the information about the evolving pandemic situation and the increase in cases enhance threat perception [27]. People assess threat depending on what they think and how they feel about it, warning could change the thoughts and feeling, then influence perception. Previous publications under extreme weather disasters mainly focus on the link between warning content and threat perception. Weyrich et al. tested effects of impact-based warnings (IBWs) and behavioral recommendations (BRs) separately and in combination, in terms of threat perception [53]. According to Potter et al., impact-based warnings are more effective than phenomenon-based warnings in affecting recipients' sense of threat, concern, and knowledge of the unexpected consequences [54]. For preparedness behavior perception, when individuals are confronted with a warning message that includes an explanation of preventive measures, they are able to better understand the effectiveness of preparedness behavior [55]. Descriptions and guidelines in warnings teach people what to do and why, thereby promoting the understanding of preventive behavior [56]. Basolo et al. proposed that people exposed to warning can feel more knowledgeable and confident about self-protective behavior [47]. Further, if it is possible to reduce effort and cost, citizens usually more easily follow the recommendations. For stakeholder perception, the official warnings show the risk communication capacity of the authorities and ideally inform about the government's handling of the crisis. The warnings that contain measures stakeholders have taken in disaster response help residents evaluate stakeholders' obligations and decide whether they are trustworthy [57]. Thus, the following research hypotheses are proposed:

H1a-d. Risk warning information (content, channel, type) is positively related to **(a)** threat perception, **(b)** hazard- and **(c)** resource-related preparedness behavior perception and **(d)** stakeholder perception.

3.5. Information interaction and its antecedents and consequences

The literature contends that information interaction refers to the discussions among people and the exchange of information with others [43,44]. In our research, we follow the above definition, also taking into account the frequency, willingness, and depth of information interaction. Even though (social) media has changed the way, in which risks are communicated, interpersonal information interaction still is a central factor influencing individual behavior in a crisis. In order to check the reliability of information and remind the surrounding to be vigilant, individuals who continuously receive warning are more likely to exchange information with surroundings. Especially in the period when the threat became serious, with the volume of warning information continue to grow, the social interaction frequency increases [11]. Mileti and Fitzpatrick indicated that received messages regarding extreme events can be better understood and motivate interaction if it is frequently repeated through various channels [58]. Therefore, we propose the following hypothesis.

H2. The amount of risk warning information is positively related to information interaction.

The warning message is shared and interpreted through one's own social network (friends, relatives and colleagues), which increases understanding of the contents and aids in making informed decisions. Several publications indicate that information interaction (especially frequency and valence) is a predictor of risk cognition [15,59]. Threat perception is constantly moderated by a continuous likelihood assessment, leading to reinforcing or attenuating perception. Existing studies on information interaction have demonstrated its impact on threat perception of wildfires [15] and nuclear accidents [59]. Individuals, communities, and institutions can operate as amplifiers when they communication about a threat [40]. Binder et al. found that if people with neutral attitudes talked about a hazard 'often', they had a higher threat perception [43]. It seems reasonable to assume that conversation valence works in the same way as emotional arousal such that interactions will trigger greater threat concern. For hazard-related preparedness behavior perception, Yang found that information interaction establishes and strengthens shared norms, through which virus-related risk perception is likely to increase [19]. Binder et al. noted that the frequency of interaction between neighbours, community members, and other social contacts will significantly affect resource-related preparedness behavior perception [43]. For stakeholder perception, members of the public who take part in community events or exchange risk information with others frequently may have more trust in local government [52]. Therefore, we propose the following hypotheses.

H3a-d. Information interaction is positively related to **(a)** threat perception, **(b)** hazard- / **(c)** resource-related preparedness behavior perception, as well as **(d)** stakeholder perception.

3.6. Relationship between risk perception processes and preparedness behavior intention

Prior empirical studies show that risk perception is a crucial factor for compliance with epidemics guidelines generally, and Covid-19 specifically [30,31]. However, which of the four types of risk perception has dominant effect on preventive behavior has triggered the interests of various scholars [7,50]. One study on H1N1 has found contradictory effects of perceived possibility and severity on intention to avoiding congested areas and maintain good indoor ventilation [17], while another study found no significant effect of either variable on vaccination intention [60]. As a result, the specific role that threat perception plays in promoting behavioral response in epidemics remains unclear. The hazard-based preparedness behavior perception was proven to motivate individuals to take appropriate action more for floods under PADM framework [35], yet there are no results for epidemics. Resource-related attributes are thought to have a negative association with preparedness measures on environmental hazards [33,36]. Costing a lot of money, requiring a lot of effort and equipment increase the adopting preventive measures burden, although these have received far less attention in pandemics. For stakeholder perception, Siegrist et al. showed that for novel or uncertain threats, behavior intention depends on public trust in the authorities providing information [61]. The stronger the trust, the higher the level of positive disaster responses intention is, and vice versa. Wang et al. also found evidence that stakeholder perception has a direct effect on the preventive behavior adherence [50]. As mentioned earlier, warning and information interaction may influence different types of risk perception, which in turn influence preparedness behavior intention. In other words, four types of risk perception mediate the relationship between warning and preparedness behavior intention (or information interaction and preparedness behavior intention). Therefore, we come to the following hypotheses.

H4a, b, d. **(a)** Threat perception, **(b)** Hazard-related preparedness behavior perception, and **(d)** Stakeholder perception is positively related to preparedness behavior intention.

H4c. Resource-related preparedness behavior perception is negatively related to preparedness behavior intention.

H5a-d. **(a)** Threat perception, **(b)** Hazard- / **(c)** Resource-related preparedness behavior perception, as well as **(d)** Stakeholder perception will mediate the relationships between warning and preparedness behavior intention.

H6a-d. **(a)** Threat perception, **(b)** Hazard- / **(c)** Resource-related preparedness behavior perception, as well as **(d)** Stakeholder perception will mediate the relationships between information interaction and preparedness behavior intention.

4. Methodologies

4.1. Participants and questionnaire administration

Our study gathered data on information, perception and behavior in the context of the second wave of Covid-19 in northern China via web-based questionnaire surveys (Wenjuanxing) from May 14 to May 31, 2021. Few confirmed cases of the then-new delta variant had been identified in Liaoning (Yingkou) prior to the survey. The survey was sent to participants in Heilongjiang, Jilin and Beijing. The distance between these three locations and Liaoning was similar, and they all had similar infection risk during the period of data collection. The local government has released a series of risk warning information to remind residents to be cautious and follow the established epidemic prevention protocol.

While given the spread of the disease, Covid-19 mutations were likely to occur, for the local communities and authorities they still came as a surprise. As the data about the actual scope and scale of the outbreak is only available ex post, hypothetical outbreak scenarios were added to the questionnaire. Each questionnaire started with an introductory text that outlined a scenario, in which the participants were asked to imagine that they lived in a city with a high risk of variant epidemic and received a series of warning messages. In this way, we aimed to invoke the representative warning which they were exposed to during the pandemic. The warning included a series of information about the variant, the response by the authorities, and recommendations for preventive action. We utilized a filter question to eliminate any residents who had no experience with the above scenario.

As a professional data gathering platform with 2.6 million samples, "Wenjuanxing" is adopted by many scholars for its convenience and dependability. More than 133 million people have used this platform to collect surveys, and over 1 million people respond to questionnaires every day. To ensure the quality of the sample, the online platform restricted quota sampling through gender and age. The minimum sample size is 150 according to the infinite population sample size and the number of paths needed to be estimated [62]. For each city, 350 questionnaires were planned, based on the questionnaire recovery and quality. A total of 1050 online questionnaires were sent to citizens. Participants who completed the questionnaires were rewarded a small monetary reward (five RMB approximately $0.75). To prohibit a participant from engaging in the questionnaire more than once, two data offsets with the same IP address were rejected. Following the questionnaire selection and missing value treatment, 724 useable questionnaires were retrieved, yielding an effective response rate of 63%.

The socioeconomic and demographic details (gender, age, education, income, career background and location) of respondents are summarized in Table 1. According to the comparison of demographic characteristics to census data, the samples slightly over-represented women, higher education, age from 20 to 40, and medium income.

Respondents belonging to the age groups of 20–29 and 30–39 accounted for the largest proportion (42.3% and 31.9%, respectively) of the study sample. Only 43 respondents are over 50 years old. The reason is that people in this group infrequently use electronic equipment and they also don't have strong willingness to participate in online questionnaires [63]. According to national statistics, by the end of March 2020, there are 904 million Chinese netizens, only 16.9% of them aged 50 and above [64]. The practical utility of electronic equipment remains at a low level in some of the economically underdeveloped northern regions of China [65]. Thus, they are less likely to receive questionnaires via the Internet, and the possibility of completing the questionnaires is low. In fact, their preventive behaviour deserves attention because many people in this group choose to live alone or live in the sheltered accommodation, and they have limited access to warning information under the epidemic, which has a great impact on their risk perception and response to the virus. Although the data of people over 50 years old are limited in this study, this is a valuable area for future research and needs further investigation.

The majority of those who responded (67.3%) had a bachelor degree and 55.3% have an income above 4000 RMB per month (approximately $650). Participants from diverse professions (students, employees from the public and private sectors, workers) as well as businessmen are included in the sample. Respondents are evenly distributed in three cities in Northern China. Jilin held the maximum number of samples (267 citizens). The lowest sample size in Heilongjiang is 226, which also larger than the minimum sample size requirements.

4.2. Instruments and key measures

We conducted a preliminary analysis of previous publications to determine the scales of the variables. Each variable was assessed using multi-item questionnaires derived from prior research, and the context was adjusted to fit the Covid-19 outbreak in China. Three characteristics of risk warning information (RWI) are independent variables (IV), preparedness behavior intention is the dependent variable (DV). Formative constructs are used to measure RWI, while other constructs are subjected to reflective measurement models. A pilot study was conducted prior to formal administration to ensure that all items were clear and relevant for gathering the data needed for this study. This pilot study included a total of fifty students from university. To refine the phrasing of the instrument items,

Table 1
Demographic information of samples (N = 724).

Demographics		Frequency	Percentage
Gender	Male	308	42.5
	female	416	57.5
Age	Below 20	90	12.4
	20–29	279	42.3
	30–39	231	31.9
	40–49	81	11.2
	50 and over	43	5.9
Education	Junior high school or below	40	5.5
	Senior high school or vocational school	197	27.2
	Junior college or university	365	50.4
	Master's degree or PHD	122	16.9
Income	Under 2000 RMB	16	2.2
	[2000, 4000) RMB	308	42.5
	[4000, 6000) RMB	249	34.4
	[6000, 8000) RMB	70	9.7
	Above 8000 RMB	81	11.2
Career background	Student	193	26.7
	Government staff	262	36.2
	Private organization staff	112	15.5
	Factory worker/agricultural worker	54	7.5
	Businessmen	76	10.5
	Others	27	3.7
City	Heilongjiang	226	31.2
	Jilin	267	36.9
	Beijing	231	31.9
Total		724	100

an expert review was conducted. On the basis of the suggestions, the construct measures were revised, wordings and item sequence were modified. The final and full questionnaire including constructs and detailed items, translated from Chinese, is available in the Appendix. The participants were asked to score on a five-point Likert scale.

Following prior research conducted by Steelman et al. [66] and Wood et al. [67], three dimensions (content, channel, type) of warning were measured, where each variable contains four questions (see 3.1). For instance, information content was measured by questions about whether participants had received information about the warning levels and severity of the pandemic; the typical symptoms and transmission; the policies and mitigation measures taken; or steps for personal protection.

To measure the level of individual threat perception, we followed Slovic et al. [16], and Shapira et al. [68] and distinguish three items in two dimensions: perceived probability and perceived impact. The first two items were addressing the perceived probability, as the perceived likelihood of an individual to get sick. The third item assessed severity perception by asking the respondents to rate perception about the impact of Covid-19 on safety and daily life.

Preparedness behavior perception is decomposed into two aspects [35]: hazard-related attributes, which are defined as the individuals' awareness about mitigation actions against the virus, and resource-related attributes, which refer to resources required to take implement these measures such as money, equipment, effort, and cooperation. Hazard-related attributes was assessed by three items which were developed from Wang et al. [7] and Lindell et al. [13]. The resource-related attributes were evaluated by the means of three questions from Lindell &Perry [11] and Terpstra & Lindell [35], for more information, see Appendix.

Like prior researches, stakeholder perception was constructed by combining seven questions belonging to three dimensions, including expertise (knowledge and experience about virus), trust (brief in the reliability, goodwill and other qualities of individuals and institutions, which can be called perceived honesty), and protection responsibility (protect people from being infected with the virus) [18,34]. Authorities, the media, and medical institutions are frequently classified as relevant stakeholders by disaster researchers in the epidemic context [7]. We computed the total scores of three characteristics with each stakeholder as the items.

To evaluate information interaction, we followed Binder et al. [43] and Vyncke et al. [59] with 4-item. Two questions tapped dimensions about the willingness to communicate. The third item assessed the frequency to seek further information with others. The fourth focused on the willingness to deeply understand warning be discussed.

To measure compliance for the context of Covid-19, four items were employed from Kim et al. [18], Li & Liu [37], and Wang et al. [50], including virus adaptation strategies (e.g., wear mask, clean hands) one question, virus aversion strategies (e.g., stay away from crowds, reduce public transportation) using two questions, and virus transfer strategies (e.g., buy insurance) using one question.

Table 2
Result of confirmatory factor analysis.

Constructs	Item	Factor loading	VIF	Cronbach's alpha	Composite reliability	AVE
Content (Con)	Con1	0.792	1.666	0.795	0.867	0.620
	Con2	0.836	1.818			
	Con3	0.784	1.578			
	Con4	0.735	1.429			
Channel (Chan)	Chan1	0.784	1.535	0.764	0.867	0.586
	Chan2	0.759	1.460			
	Chan3	0.772	1.514			
	Chan4	0.746	1.457			
Type (Typ)	Typ1	0.767	1.556	0.788	0.863	0.612
	Typ2	0.806	1.735			
	Typ3	0.800	1.703			
	Typ4	0.756	1.525			
Threat perception (TP)	TP1	0.854	1.958	0.815	0.890	0.730
	TP2	0.878	2.136			
	TP3	0.831	1.580			
Hazard-related preparedness behavior perception (HPBP)	HPBP1	0.843	1.703	0.776	0.870	0.703
	HPBP2	0.846	1.548			
	HPBP3	0.802	1.580			
Resource-related preparedness behavior perception (RPBP)	RPBP1	0.826	1.603	0.749	0.876	0.690
	RPBP2	0.789	1.631			
	RPBP3	0.830	1.756			
Stakeholder perception (SP)	SP1	0.862	1.833	0.814	0.890	0.729
	SP2	0.841	1.772			
	SP3	0.857	1.773			
Information interaction (INI)	INI1	0.789	1.594	0.783	0.860	0.606
	INI2	0.754	1.452			
	INI3	0.777	1.514			
	INI4	0.793	1.602			
Preparedness behavior intention (PBI)	PBI1	0.849	2.218	0.899	0.929	0.767
	PBI2	0.892	2.736			
	PBI3	0.900	2.948			
	PBI4	0.862	2.676			

4.3. Data analysis method

A path analysis was conducted to verify the proposed hypotheses with partial least squares (PLS). PLS has been successfully used for defining complicated relationships since it eliminates two major issues: inadmissible solutions and factor indeterminacy [69]. Instead of covariance-based structural equation modelling (SEM) like linear structural relations, PLS employs a component-based path modelling program for estimation. We choose PLS, because our model involves both reflective and formative constructs, which requires measures consistent with the nature of the constructs. Due to the exploratory attributes of this study, partial least squares structural equation modelling (PLS-SEM) has been chosen.

5. Data analysis result

5.1. Measurement model testing

Table 2 provides an overview of the results of the tests we performed to test reliability and validity. To test structure reliability, Cronbach's alpha was utilized to assess the internal consistency of all questionnaires. The Cronbach's alpha of each construct ranges from 0.749 to 0.899, which is higher than the recommended level of 0.7 [70]. The factor loading, composite reliability and average variance extracted (AVE) were evaluated to assess convergent validity. All factor loadings are significant and exceed 0.735. As shown in Table 2, the composite reliability and AVE of all questionnaires are greater than 0.8 (0.860–0.929), and 0.5 (0.586–0.767), respectively, indicating that each construct had convergent validity.

To assess discriminant validity, we compared the square roots of AVEs and the correlation among two constructs. The results demonstrated that the square roots of the AVEs are all higher than the inter-construct correlations shown in the off-diagonal entries in Table 3. Hence, our measurement model has appropriate discriminant validity. We believe that the measurement model matches the sample well.

Formative constructs (Risk warning information, RWI) were modeled as multidimensional constructs. A two-stage approach was applied to estimate it following the guidelines proposed by Petter et al. and Hair et al. [71,72]. First, the indicators belonging to sub-constructs (Content, Channel, Type) were reused to estimate the first-order constructs' (RWI) latent variable score. Second, the latent variable score was used to calculate the path coefficients between RWI and the other constructs. To test the multicollinearity, we evaluate the variance inflation factor (VIF) for each item, as suggested by Mason and Perreault [73]. The values for VIF range from 1.429 to 2.948 are reported in Table 2, all of which are less than the threshold of 3.3. As a result, multicollinearity is not a concern in our study.

5.2. Common method bias

Because all samples were self-reported and gathered from a single source, common method bias (CMB) can limit the validity of our study. The following statistical operations were performed to test for CMB. First, a Harman's one-factor test was applied. The results identified nine factors, with the most covariance explained by one factor accounting for 21.29% of the total variance. Second, we added a common method component following the suggestion by Liang [74], integrating all primary construct items, and calculated if each indicator's variations are substantively explained by the principal construct and method. As shown below in Table 4, the average substantively explained variance of the indicators is 0.666, while the average method-based variance is 0.015. The ratio of the substantive variance to method variance is roughly 44:1. Thus, we conclude that the effect of CMB in our results is negligible.

5.3. Structural model testing

The structural model assessment was used to test the hypothesized relationships between the above nine latent constructs (Hypotheses H1-4). Fig. 2 depicts the path coefficient (β) and significance of the hypothetical model. Most hypotheses and directions were significant except for H1a, H4a and H4c.

For the relation between risk warning information and perceptions we found that the relation between risk warning information and threat perception was not significant ($\beta = 0.097$; H1a not supported), while risk warning information was positively correlated with hazard- and resource-related preparedness behavior perception, and stakeholder perception ($\beta = 0.331$, $p < 0.001$, H1b supported; $\beta = 0.334$, $p < 0.001$, H1c supported; $\beta = 0.364$, $p < 0.001$; H1d supported). Risk warning information also had a significantly positive influence on information interaction ($\beta = 0.277$, $p < 0.001$, H2 supported).

Table 3
Assessment of discriminant validity.

Construct	Con	Chan	Typ	TP	HPBP	RPBP	SP	INI	PBI
Con	**0.788**								
Chan	0.482**	**0.766**							
Typ	0.385**	0.520**	**0.782**						
TP	0.130**	0.149**	0.119**	**0.854**					
HPBP	0.307**	0.300**	0.258**	0.175**	**0.830**				
RPBP	0.292**	0.325**	0.332**	0.146**	0.314**	**0.838**			
SP	0.309**	0.365**	0.324**	0.107**	0.431**	0.586**	**0.854**		
INI	0.163**	0.286**	0.293**	0.244**	0.196**	0.314**	0.288**	**0.779**	
PBI	0.276**	0.314**	0.293**	0.195**	0.238**	0.430**	0.418**	0.471**	**0.876**

Notes: The diagonal elements are the square roots of AVEs. **$p < 0.01$.

Table 4
Common method bias analysis.

Constructs	Indicator	Substantive Factor loading (R1)	$R1^2$	Method Factor Loading (R2)	$R2^2$
Content (Con)	Con1	0.796**	0.634	−0.051	0.003
	Con2	0.833**	0.694	0.023	0.001
	Con3	0.785**	0.616	−0.026	0.001
	Con4	0.733**	0.537	0.056	0.003
Channel (Chan)	Chan1	0.782**	0.612	0.046	0.002
	Chan2	0.754**	0.569	0.084*	0.007
	Chan3	0.775**	0.601	−0.069*	0.005
	Chan4	0.750**	0.563	−0.063	0.004
Type (Typ)	Typ1	0.762**	0.581	−0.036	0.001
	Typ2	0.809**	0.654	−0.121	0.015
	Typ3	0.803**	0.645	0.109	0.012
	Typ4	0.754**	0.569	0.019	0.000
Threat perception (TP)	TP1	0.863**	0.745	0.261	0.068
	TP2	0.887**	0.787	−0.040	0.002
	TP3	0.812**	0.659	0.063	0.004
Hazard-related preparedness behavior perception (HPBP)	HPBP1	0.850**	0.723	−0.010	0.000
	HPBP2	0.821**	0.674	0.049	0.002
	HPBP3	0.823**	0.677	−0.039	0.002
Resource-related preparedness behavior perception (RPBP)	RPBP1	0.828**	0.686	0.033	0.001
	RPBP2	0.830**	0.689	−0.255**	0.065
	RPBP3	0.856**	0.733	0.202**	0.041
Stakeholder perception (SP)	SP1	0.860**	0.740	0.139**	0.019
	SP2	0.849**	0.721	−0.053*	0.003
	SP3	0.852**	0.726	0.013	0.000
Information interaction (INI)	INI1	0.791**	0.626	−0.119	0.014
	INI2	0.753**	0.567	0.112	0.013
	INI3	0.773**	0.598	0.107	0.011
	INI4	0.796**	0.634	0.101	0.010
Preparedness behavior intention (PBI)	PBI1	0.845**	0.714	0.205	0.042
	PBI2	0.887**	0.787	0.258*	0.067
	PBI3	0.900**	0.810	−0.230	0.053
	PBI4	0.871**	0.759	−0.077**	0.006
Average		0.815	0.666	0.0021	0.015

*P < 0.05; **P < 0.01.

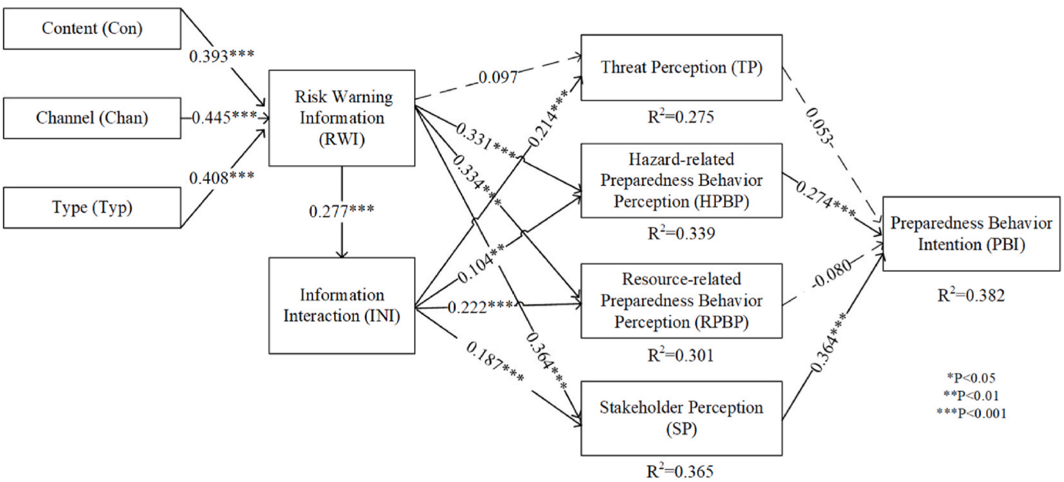

Fig. 2. Results of the hypothetical model Hypothesized model.

Information interaction was associated with threat perception (β = 0.214, p < 0.001, H3a supported), hazard-related preparedness behavior perception (β = 0.104, p < 0.01, H3b supported), resource-related preparedness behavior perception (β = 0.222, p < 0.001, H3c supported) and stakeholder perception (β = 0.187, p < 0.001, H3d supported).

For the relations between perception and preparedness behavior intention, our findings show mixed results. Our result show that hypotheses H4b (Hazard-related attributes is positively related to preparedness behavior) (β = 0.274, p < 0.001) and H4d (Stakeholder perception is positively correlated with preparedness behavior intention) (β = 0.364, p < 0.001) were supported. However, the data did not support H4a (Threat perception is positively related to preparedness behavior intention) (β = 0.053) and H4c (Resource-related preparedness behavior perception is negatively associated with preparedness behavior intention) (β = −0.008).

H5a-d and H6a-d proposed that four categories of risk perception mediated the relationship between warning and preparedness behavior intention (or information interaction and preparedness behavior intention). To test the mediating role of risk perception and information interaction, the first step is to test the correlation between IV and DV. Subsequently, we follow the suggestion by Preacher and Hayes to adopt the bootstrapping method [75]. Bootstrapping has a more statistical effect of reducing the likelihood of discard true errors in non-normal distribution conditions. We set the sample size to 5000 times for the 95% bias-corrected confidence intervals (CI), the indirect effects and conditional indirect effects to be estimated and tested. The estimated value of the indirect effect is statistically significant when the CI excludes zero.

The results indicate that the variable has a significant mediating effect. Table 5 shows that hazard-related preparedness behavior perception (H5b supported, indirect effect = 0.058***, 95% CI [0.035, 0.129]) and stakeholder perception (H5d supported, indirect effect = 0.073***, 95% CI [0.030, 0.125]) are mediators between risk warning information and preparedness behavior intention, respectively. The combination of information interaction and stakeholder perception has a chain mediating effect (indirect effect = 0.010**, 95% CI [0.003, 0.024]). Following the same steps, there are two paths from information interaction to preparedness behavior intention, including 'INI-HPBP-PBI' (H6b supported, indirect effect = 0.051**, 95% CI [0.016, 0.100]) and 'INI-SP-PBI' (H6d supported, indirect effect = 0.037**, 95% CI [0.012, 0.076]). The detailed mediating effects of each path are shown in Table 5.

Finally, we analysed how different characteristics of risk warning information influence preparedness behavior via risk perception and information interaction. Table 6 shows findings of a structural model that used information content, channel, and type instead of warning construct in the prior model. Content has a positive influence on hazard-related preparedness behavior perception (β = 0.194, $p < 0.001$), resource-related preparedness behavior perception (β = 0.139, $p < 0.001$) and stakeholder perception (β = 0.141, $p < 0.05$). Information channel has a positive effect on information interaction (β = 0.240, $p < 0.001$), hazard-related preparedness behavior perception (β = 0.131, $p < 0.001$), resource-related preparedness behavior perception (β = 0.101, $p < 0.05$) and stakeholder perception (β = 0.173, $p < 0.001$). Information type has a positive effect on information interaction (β = 0.137, $p < 0.05$) and hazard-related preparedness behavior perception (β = 0.180, $p < 0.001$), but not on the resource-related attributes and stakeholder perception.

6. Discussion

6.1. Mediating effects of different categories risk perception

Hypotheses H1,4,5 were concerned with the associations between warning, four categories of risk perception and preparedness behavior intention. These hypotheses were partially supported, the findings shows that not all types of risk perception act as mediators in the implementation of preventive measures from warning. Specifically, the effects of warning on preparedness intention through indirect-mediation followed three paths: (1) through hazard-related preparedness behavior perception (H5b), (2) through stakeholder perception (H5d), (3) and via information interaction through stakeholder perception. Stakeholder perception had much stronger mediating effects on the relationship between warning and compliance than the hazard-related preparedness behavior perception. Results of this study indicate that, of four types core risk perception, those regarding hazard-related preparedness behavior perception and stakeholder opinions, but not threat, arousing precautions decision making.

The findings on hazard-related preparedness behavior perception confirm that the more warnings, the stronger the awareness of preparedness action usefulness and effectiveness, the more citizens are likely to accept active measures during the Covid-19 pandemic (H1-b, H4-b), which is consistent with Health et al. [34]. As the warnings explain the mitigation measures, the improved understanding is likely to increase the willingness and confidence to adopt the measures against Covid-19. The result implies that increasing citizens' awareness of the preparedness steps is vital. However, the above partial findings have not been verified on resource-related

Table 5
Results of mediating effect test.

IV	Model 1(IV, DV)			Model 2(IV, MV, DV)			
	Path	path coefficient	T Statistics	path	Unstandardized coefficient	95% Confidence Interval	
						Boot LLCI	Boot ULCI
RWI	RWI-PBI	0.368	10.289***	RWI-TP-PBI	0.012	0.002	0.029
				RWI-HPBP-PBI	**0.058*****	**0.035**	**0.129**
				RWI-RPBP-PBI	0.003	−0.041	0.035
				RWI-SP-PBI	**0.073*****	**0.030**	**0.125**
				RWI–INI–TP-PBI	0.007	0	0.016
				RWI–INI–HPBP-PBI	0.014	0.004	0.030
				RWI–INI–RPBP-PBI	0.001	−0.003	0.005
				RWI-INI-SP-PBI	**0.010****	**0.003**	**0.024**
INI	INI-PBI	0.320	7.772***	INI-TP-PBI	0.024*	0	0.055
				INI-HPBP-PBI	**0.051****	**0.016**	**0.100**
				INI-RPBP-PBI	0.004	−0.011	0.017
				INI-SP-PBI	**0.037****	**0.012**	**0.076**

*P < 0.05 **P < 0.01 ***P < 0.001.
Note: Abbreviations: RWI = Risk warning information; HPBP=Hazard-related preparedness behavior perception; TP = Threat perception; SP=Stakeholder perception; RPBP = Resource-related preparedness behavior perception; INI=Information interaction; PBI=Preparedness behavior intention.

Table 6
Path coefficients.

	T- Statistics	Path coefficients
RWI- INI R2 = 0.77		
Content- INI	0.373	0.015
Channel- INI	4.761	0.240***
Type- INI	2.025	0.137*
RWI- HPBP R2 = 0.13		
Content- HPBP	5.357	0.194***
Channel- HPBP	3.036	0.131***
Type- HPBP	4.226	0.180***
RWI- RPBP R2 = 0.21		
Content- RPBP	3.441	0.139***
Channel- RPBP	2.191	0.101*
Type- RPBP	1.589	0.090
RWI- SP R2 = 0.25		
Content- SP	2.444	0.141*
Channel- SP	4.034	0.173***
Type- SP	1.264	0.041
Mediator- PBI R2 = 0.269		
TP- PBI	1.265	0.111
HPBP- PBI	4.832	0.227***
RPBP- PBI	2.855	−0.102**
SP- PBI	6.237	0.398***

*P < 0.05 **P < 0.01 ***P < 0.001.

attributes (H4-c). The results, to some extent, were consistent with Wang et al.'s study in 2013 Chinese H7N9 Influenza outbreak, which revealed that the hazard-related attributes had effect on behavioral expectations [7], while the negative effect of resource-related attributes was not significant. We think a possible reason is that respondents thought the preparedness behavior required a lot of time (e.g., staying at home) in the epidemic instead of much money and equipment. While in the realistic situation, citizens pay more attention on the spending of financial resources, which could explain why the resource-related attributes have less prominence as compared to the hazard-related attributes.

Stakeholder perception, as important psychological cognitive processes, was confirmed to be influenced by warning (H1-d). Warnings help the public obtain information about available response measures and strategies of authorities in public health emergency, and then form their perception on expertise, trustworthiness, and responsibility for taking action to protect households. And stakeholder perception also facilitates the adoption of preparedness actions (H4-d), which support past researches of Wang et al. [50] and Wachinger et al. [76]. That is, even if people are not personally particularly concerned about the epidemic or do not believe the preventive behavior is effective, they also can be encouraged by stakeholders (authorities, news media, and peers) to comply with recommendations.

A more interesting finding is threat perception failed to drive preparedness intentions from warning (H5a). The first to note is that the early warning did not increase attention for the severity and possible threat of the delta variant (H1-a). At the same time, no relationship between threat appraisal and the intention to comply with disaster preparedness action was found (H4-a). These results seem to be ***not*** in line with previous studies that demonstrated the connection between threat perception on compliance regarding epidemic [7,30,31]. A possible explanation is in the duration of the pandemic, extended and repeated warnings, combined with a feeling of being familiar with the disease, resulting in information fatigue [12]. This sense of familiarity and the lack of novelty implied that the threat potential of the new variant was underestimated. Another explanation for this phenomenon may be that the mediating role of threat perception is concealed by other perceptions like stakeholder perception [37].

6.2. The role of information interaction

What is more, as proposed by hypothesis H3, this research found that information interaction had positive effects on all types of risk perception. It shows the greatest impaction on resource-related preparedness behavior perception (with a path coefficient of 0.222) and the second strongest impaction on threat perception (with a path coefficient of 0.214). The support for H3a is inconsistent with Ahn et al. [77] and Brenkert-Smith et al. [15], who argued that social diffusion of warning cues did not have a significant effect on understanding, threat perception or response. This is potentially due to warnings being socially disseminated not always accurate, complete and consistent. As a result, it's difficult for those warnings to provide a direct driving force. However, our finding suggests that discussion about warning of delta variant can alert people a serious and imminent threat exists (H3a). People who join the interaction perceive the danger of variations Covid-19 to be more severe than those who did not. Participants also receive additional knowledge regarding the cost and efficacy of preventive action against Covid-19 as a result of the information interaction, which enhances their hazard- and resource-related behavior perception (H3b-c). In addition, sharing messages between neighbours, friends, and colleagues also increases the trust in authorities. This finding (H3d) aligns with literatures about social identity [78]. Given that the Chinese government had made great efforts to control rumor propagation, the above results about information interaction seem reasonable. Moreover, the findings confirm that a positive effect of information interaction on promoting behavioral response were mediated by hazard-related preparedness behavior perception (H6b) and stakeholder perception (H6d). To conclude, information interaction played an important, central role because it increased risk perceptions, and preparedness intentions, while functioning as a mediator for warning.

6.3. Difference between warning channel, content and type

The results also show that different warning characteristics (channel, content, and type) are significantly related to adopting preventive measures through various risk perception and information interaction. Specifically, risk perception is cultivated by adjusting various aspects of warning attributes, where citizens are expected to adopt more preventive behaviors. The effect of warning channel on all mediating variables were verified. Multi-channel warnings for epidemic are beneficial and necessary, what is known as 'crying wolf' effect didn't happen in our test [28]. We observe evidence that individuals used a range of communication channels to gather information during the Covid-19 crisis to make sense of an unclear situation, as proposed by media dependency theory [79]. Warning content contributes to hazard-, resource-related preparedness behavior perception and stakeholder perception. However, despite the fact that more warning contents are disseminated often in a more comprehensive way, this characteristic still demonstrated no significant effect on information interaction.

7. Conclusion and implications

To conclude, this study proposes an information-perception-action framework to link risk warning information with public's preparedness behavior compliance via mediation constructions. By integrating social amplification of risk framework (SARF) into the protective action decision model (PADM), we built a new hypothetical model with a comprehensive warning flow and cognitive processes. Thereby, the application range of the PADM model is extended from natural hazard and technological crises to an epidemic. This research also empirically tested the core relationships between warning and preventive behavior, expanding the current understanding of the drivers of precautions during the variant outbreaks of the Covid-19 epidemic in China.

This study found that hazard-related attributes and stakeholder perception are mediators in the process by which warnings positively impact individuals' intention to comply with preventive measures. Furthermore, our survey clearly defined the various attributes of warning, and regard it as multidimensional variables that can be directly observable. Because the current empirical research on warning in an epidemic is limited, some of our findings can contribute to the field of risk communication as it relates to warning notification and policies for continued compliance.

To combat the variants Covid-19 pandemic effectively, there are several implications of our findings that are relevant for practice. First, the research highlighted the mediating roles of hazard-related preparedness behaviour perception and stakeholder perception. If policy-makers could release more warnings about how and why the specific preparedness measures are effective, the following behavior (e.g., mask wearing, cleaning hands, and social distancing) could be motivated. Meanwhile, it is imperative for authorities to maintain their reputation as trusted, and credible source of advice is important to foster compliance in response to a pandemic.

Second, the results indicate that information interaction raise all types of risk perception and spur preparedness response. Accordingly, a possible meaningful intervention would target improving the frequency and valence of interpersonal information interaction. More interaction programs, such as live video streaming and community outreach could be provided by local centers for disease control and prevention. Policy-makers also should encourage those who have followed the warning recommendations and already have taken preparedness actions to share their impressions, understanding, and feeling with others. As such, the effect of interaction between social groups on risk perceptions is positive.

Third, considering a combined effect of multiple warning channels on elevating people's risk perception, information provider should ensure a diverse communication network for comprehensive warning coverage. The extensive fund needs to be invested into developing Chinese epidemic warning channels like APPs and online social media in order to provide efficient dissemination of warnings directly from authorities. What's more, the contents and types (e.g., text, verbal and visual-based) of warning delivered should be abundant and consistent to the most possible extent, with an aim to enhance risk perception and drive preparedness action [80].

Despite this study's potential contributions, there are still several limitations that can be addressed by further research. First, the research relied on self-report data, instead of observations of actual behavior. In social-psychological investigations, self-reported past behavior has been proven as a proxy for actual behavior quite effectively [12]. However, the accuracy of our results can also be affected by deviations from the stated versus actual behavior. This study was set against the backdrop of the second wave of the Covid-19 pandemic, the outbreak of the delta variant. As the pandemic will soon enter its third year and new variants of the Coronavirus still appear, further investigations are required to test the continuous validity of the hypotheses over a longer period by longitudinal designs that are increasingly characterized by over-saturation and Covid-19 fatigue.

Second, only a small percentage of respondents are under 20 and over 50, the reason is people in these two age groups are less likely to receive questionnaires via the Internet. The preferences of this group on variables are likely different from others, especially as the virus disproportionately affects people above 60. This limitation in the sample may bias the conclusions, and we advocate for dedicated studies comparing different vulnerable populations. Potential child-friendly and elder-friendly risk communication design solutions are also needed for general hazard information and warnings in epidemic.

Third, the model was verified in China, cross-cultural comparisons in other countries have not been tested. For instance, because of the setting, we excluded factors such as rumors and disinformation, which are driving the proverbial 'infodemic' in Europe and the US. samples from other countries may therefore display different results, especially the effects of information interaction. Cross-culture comparative research will enrich studies on pandemic preparedness behavior intention.

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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.

Appendix

Constructs and items include in the questionnaire (Translated from Chinese).

Threat perception[a] - Reflective
(Slovic et al., 2004; Shapira et al., 2018; Wang et al., 2018)
TP1. I think there is a chance that my family and me will be infected by mutation virus
TP2. Infection with this virus will face a life-threatening situation
TP3. Infection with this virus will cause disruption of daily life (work and daily activities)
Preparedness behavior perception[a] - Reflective
(Lindell and Perry 2012; Terpstra and Lindell 2013; Li and Liu 2020; Wang et al., 2018; Heath et al., 2018)
Hazard-related preparedness behavior perceptiona[a]
HPBP1. Implementing risk reduction measures will reduce the possibility of infection
HPBP2. Implementing risk reduction measures will reduce viral damage
HPBP3. Implementing risk reduction measures will protect my health effectively
Resource-related preparedness behavior perception[a]
RPBP1. I am willing to spend money buying anti-epidemic supplies
RPBP2. I am willing to spend time learning prevention knowledge and skills
RPBP3. I am willing to spend energy learning prevention knowledge and skills
Stakeholder perception[a] - Reflective
(Kim et al., 2015; Heath et al., 2018; Wang et al., 2018; Liu et al., 2020; Cvetković et al., 2021)
Perceived expertise[a]
SP1. The government is professional in epidemic control
SP2. Medical institutions are professional in epidemic judgment and treatment
SP3. The media is professional in epidemic information report
Perceived protection responsibility[a]
SP4. The government has the responsibility to protect the public
Perceived trustworthiness[a]
SP5. I trust the government in epidemic control
SP6. I trust the medical institutions in epidemic judgment and treatment
SP7. I trust the media in epidemic information report
Information interaction[a]- Reflective
(Binder et al., 2011; Vyncke et al., 2017; Zhang and Cozma 2022)
INI1. I am willing to share my thoughts and judgments on warning with others
INI2. I am willing to tell others about warning I received
INI3. I am willing to get warning more times with others
INI4. I am willing to explain to others the warning I received
Preparedness behavior intention[a]- Reflective
(Kim et al., 2015; Wang et al., 2018; Li and Liu 2020)
PBI1. Wearing mask, clean hands with soap and water or alcohol-based hand rub
PBI2. Try not to go to public spaces and stay away from crowds
PBI3. Reducing public transportation, travel, large-scale party
PBI4. Buy insurance
Risk warning information[b] - Formative
(Wood et al., 2012; Steelman et al., 2015; Brenkert-Smith et al., 2013; Dai et al., 2020)
Information Content[b]- Reflective
Thinking about information on epidemic warning, I have received information on:
Con1. Warning level, Spread range, Severity
Con2. Symptom, Route of transmission, Mode of transmission
Con3. Government measures, Coronavirus treatment
Con4. Suggestions on personal epidemic precautions
Information Channel[b]- Reflective
Thinking about information on epidemic warning, I have heard information from:
Chan1. TV, Radio
Chan2. WeChat, Weibo, QQ, TIK TOK
Chan3. Short message service, Email
Chan4. Newspaper, Brochures, Banners, Community notices
Information Type[b]- Reflective
Thinking about information on epidemic warning, I have received information in:

(*continued on next page*)

(*continued*)

Typ1. Text (Short message, Blog post)
Typ2. Graph
Typ3. Short videos (Less than 1 min: Tik Tok videos)
Typ4. Long videos (More than 1 min: news broadcast, press briefing)

[a]The items are measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).
[b]The item is measured on a 5-point Likert scale ranging from 1 (never) to 5 (frequent).

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