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Health-related fake news during the COVID-19 pandemic: perceived trust and information search

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Abstract

Purpose – Health-related online fake news (HOFN) has become a major social problem. HOFN can lead to the spread of ineffective and even harmful remedies. The study aims to understand Internet users' responses to HOFN during the coronavirus (COVID-19) pandemic using the protective action decision model (PADM).

Design/methodology/approach – The authors collected pandemic severity data (regional number of confirmed cases) from government websites of the USA and China (Studies 1 and 2), search behavior from Google and Baidu search engines (Studies 1 and 2) and data regarding trust in two online fake news stories from two national surveys (Studies 2 and 3). All data were analyzed using a multi-level linear model.

Findings – The research detected negative time-lagged relationships between pandemic severity and regional HOFN search behavior by three actual fake news stories from the USA and China (Study 1). Importantly, trust in HOFN served as a mediator in the time-lagged relationship between pandemic severity and search behavior

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(Study 2). Additionally, the relationship between pandemic severity and trust in HOFN varied according to individuals' perceived control (Study 3).

Originality/value – The authors' results underscore the important role of PADM in understanding Internet users' trust in and search for HOFN. When people trust HOFN, they may seek more information to implement further protective actions. Importantly, it appears that trust in HOFN varies with environmental cues (regional pandemic severity) and with individuals' perceived control, providing insight into developing coping strategies during a pandemic.

Keywords Online fake news, Health-related fake news, Trust in fake news, Search behavior, Perceived control

Paper type Research paper

1. Introduction

In the context of the COVID-19 pandemic, the phenomenon of online fake news has attracted increasing attention from the public and from the academic community (Zarocostas, 2020). The World Health Organization (WHO) has declared this phenomenon as an "infodemic," a worldwide epidemic of fake news that spreads quickly through the Internet and causes more damage to the world than the virus itself (Bunker, 2020).

Recently, the spread of online fake news during the pandemic has been studied, most of which involved health-related information about how to disinfect coronavirus (Naeem and Bhatti, 2020). In fact, the rapid spread of COVID-19 left many questions unanswered about the virus (Fleming, 2020), which leads to an urgent need for health-related information. According to a 13-country survey, two out of three respondents spent more time engaging in information seeking during the pandemic than before (Fleming, 2020; Mander, 2020). This situation provides a breeding ground for HOFN, which meets the huge demand for health-related information (Mukherjee and Bawden, 2012; Zhou *et al.*, 2021). However, HOFN can cause considerable health problems owing to its inaccurate and often incorrect advice regarding prevention and treatment (Kim *et al.*, 2020; Pennycook *et al.*, 2020; Zarocostas, 2020). Therefore, more effort is needed to understand which factors enhance the search behavior of Internet users.

According to the PADM, information searching is a protective action in response to environmental hazards (Lindell and Perry, 2012). The process of PADM starts from environmental and social cues that transmit risk information, which then results in psychological processes, and ends with behavioral responses that can protect against environmental hazards. As environmental risk (i.e. regional pandemic severity) varies across regions during the pandemic (Reed *et al.*, 2013; Zheng *et al.*, 2020), HOFN search behaviors may also vary under different pandemic severity conditions. In the PADM, perceived information reliability can lead to information seeking for implementing further protective actions (Heath and Palenchar, 2000; Lindell and Perry, 2012), and trust in HOFN may be a link in the relationship between pandemic severity and HOFN search behavior. Thus, this study adopted the PADM to understand the impact of COVID-19 on trust in HOFN, HOFN search behavior and its boundary conditions.

2. Theoretical background and literature review

2.1 HOFN during COVID-19

COVID-19 is a life-threatening disease that can easily be transmitted through respiratory droplets during general interpersonal contact (Rubin and Wessely, 2020). However, at the acceleration stage of the pandemic, most people knew little about how to protect themselves from transmitting or contracting the disease (Fleming, 2020). This information insufficiency drove people to engage in protective activities by seeking health-related information online (Mukherjee and Bawden, 2012; Zhou *et al.*, 2021). For example, a recent survey found 67% respondents spent more time watching news about COVID-19 than before, and half of them

reported spending significantly more time engaging in information seeking than before the pandemic (Fleming, 2020; Mander, 2020).

However, the pandemic has been accompanied by an "infodemic," in which a tremendous amount of misleading and unreliable information has rapidly spread online (Ale, 2020; Gever, 2020). HOFN is a type of untrue information that mimics media content and is presented as health-related online news (Lazer *et al.*, 2018; Pennycook *et al.*, 2018; Roozenbeek and van der Linden, 2019).

According to Fleming (2020), information insufficiency provides a breeding ground for HOFN-seeking behavior during the pandemic. Additionally, HOFN comprised a large proportion of online untrue health-based information during the pandemic (Naeem and Bhatti, 2020). For example, Al-Zaman (2021) found that HOFN was the most common kind of (67.2%) COVID-19-related online fake news in India. Importantly, HOFN is not only easily available, but it is also largely indistinguishable from online news for most people lacking medical knowledge (Chua and Banerjee, 2018).

Mukherjee and Bawden (2012) found that people rely heavily on the Internet to search for health-related information in a health emergency. During the COVID-19 pandemic, many people showed strong concerns about their health conditions (Qiu *et al.*, 2020). Their survival needs motivated them to learn how to prevent and treat COVID-19 on the Internet (Bento *et al.*, 2020; Garfin *et al.*, 2020). As there are many unanswered questions about the prevention and treatment of the virus, HOFN provided "answers" that met their needs (Mukherjee and Bawden, 2012; Zhou *et al.*, 2021).

However, HOFN falsely appears to benefit health by providing prevention or treatment tips on how to deal with diseases (Kim *et al.*, 2020; Zhou *et al.*, 2021). In fact, 63.2% of HOFN contains incorrect and harmful practices that could be a real threat to public health (Chua and Banerjee, 2018). For example, unproven myths about alcohol, chlorine, snow and hot baths were circulated as ways to prevent coronavirus infection during the pandemic (Islam *et al.*, 2020). Such information carry the associated risk of adverse health effects. Importantly, online fake news not only spreads faster and deeper than true news, but is also difficult to correct (Roozenbeek and van der Linden, 2019; Vosoughi *et al.*, 2018).

Therefore, efforts have been made to understand the mechanisms of the spread of online fake news during the pandemic. Although prior studies underscored the role of machine learning algorithms in the detection of such information, current bot regulation only affords temporary solutions because any successful detection will promote countermeasures in the future (Lazer *et al.*, 2018). Some researchers propose psychological approaches to understand fake news (Allport and Postman, 1947). In health emergencies, people experience uncertainty about their risk of contracting diseases (Rettie and Daniels, 2020). As they do not know who the potential disease carriers are and how to combat it, they wish to consume health-related news to satiate their uncertainty (Chua and Banerjee, 2018; Rosnow, 1991). Thus, HOFN easily earns people's trust and spreads rapidly. This literature emphasizes the role of negative emotions (e.g. anxiety) in explaining HOFN online behaviors. However, psychological reactions involve subjective mental processing after exposure to a stimulus (e.g. environmental threat). As the risks of contagion differ widely across regions in a health emergency (Reed *et al.*, 2013; Zheng *et al.*, 2020), environmental cues may lead to distinct psychological responses toward HOFN. To our knowledge, no studies have yet attempted to examine the environmental effects of COVID-19 on HOFN behavior.

2.2 PADM

According to the PADM, people adopt protective behaviors (e.g. information seeking) in response to environmental hazards and disasters (Lindell and Perry, 2012). This model comprises three stages: environmental and social contexts, psychological processes and behavioral responses. The first stage of this model includes information derived from

environmental and social cues, such as environmental hazard cues, protective information and warning messages from social networks. The first stage initiates the PADM, elicits the psychological processing of environmental threats and provides the basis for implementing protective behaviors.

Subsequently, the psychological processes stage includes three critical sets of activities for individuals: reception (whether they receive it), attention (whether they heed it) and comprehension (whether they understand it). At this stage, individuals automatically process information about environmental cues, alternative protective actions and societal stakeholders. Therefore, inappropriate behavior is more likely to be associated with receiving inadequate information. Finally, behavioral responses consist of information search, protective response and emotion-focused coping. Among the three behaviors, information seeking usually occurs when there is uncertainty caused by environmental hazards (Heath *et al.*, 2018; Liu *et al.*, 2019).

The three-stage sequential PADM is based on findings from previous studies on environmental hazards and disasters. It provides an explanation of how people implement actions to protect against environmental threats. However, as PADM includes many factors in each stage, few people are likely to follow each step when they adopt protective actions (Lindell and Perry, 2012). This study mainly focuses on the mechanism of Internet users' HOFN search behavior over regions with different pandemic severity, and we, therefore, adopt three stages of the model: environmental cues, psychological process and information search.

When people engage in health-related information seeking, they encounter challenges in evaluating the credibility and trustworthiness of the sources in the absence of medical knowledge (Chu *et al.*, 2017). As online fake news is more available than true news (Roozenbeek and van der Linden, 2019; Vosoughi *et al.*, 2018), seeking HOFN often occurs as a protective reaction against a health emergency (Fleming, 2020). Thus, information seeking for HOFN appears to "benefit" people, despite providing unverified health information without scientific evidence and despite the risk of detrimental health-related consequences (Zhou *et al.*, 2021). For example, fake news that drinking alcohol to prevent or cure COVID-19 was circulated. Unfortunately, this misinformation has been regarded as a major cause of alcohol poisoning among a number of Iranian people during the pandemic (Heidari and Sayfouri, 2021).

HOFN has been regarded as a preventive strategy, as seeking HOFN alleviates uncertainty caused by the disease (Sudhir and Unnithan, 2019) and provides information support to deal with the disease (Zhou *et al.*, 2021). According to the PADM, when there is uncertainty about how to protect oneself from environmental hazards, information seeking is vital for people to make protective action decisions (Lindell and Perry, 2012; Liu *et al.*, 2019). Therefore, HOFN search behavior may serve as a protective response to processing information and making further protective decisions.

2.3 Trust in HOFN

A sense of credibility or trust in the news has been widely thought to affect the way people process the information (Chua and Banerjee, 2018; Rosnow, 1991). Lindell and Perry (2012) proposed that perceived information reliability is associated with people's adaptation to hazard adjustment in response to an environmental disaster. When possible consequences of the event are life-threatening and the level of uncertainty that people face is higher, they are more likely to follow reliable information to guide their behaviors toward hazard mitigation (Paton, 2007).

According to PADM, environmental cues influence a person's behavioral responses via psychological processes (Lindell and Perry, 2012). During the COVID-19 pandemic, people experienced uncertainty about their risk of contracting the disease (Rettie and Daniels, 2020).

They wish to consume news to relieve this uncertainty (Chua and Banerjee, 2018; Rosnow, 1991) and to reduce their risk of infection. Importantly, online fake news usually delivers information that is attributable to either desired or undesired consequences (Chua and Banerjee, 2018; Rosnow *et al.*, 1986). For example, the HOFN story that "Hot baths kill coronavirus" spread widely in China (WHO, 2020), because it provided an expected consequence (i.e. it kills coronavirus) and relieved uncertainty by providing an (incorrect) coping strategy. HOFN regarding unwanted consequences often invokes fear and distress toward an object or a population, such as the "5G coronavirus conspiracy theory." Such online fake news may often lead to racism and xenophobia (Devakumar *et al.*, 2020), which serves as an intended approach to prevent unwanted outcomes. Allport and Postman (1947) proposed that, in a perplexing or unexpected situation, people have an urgent need to guide their behaviors by imposing credible meanings. When HOFN appears, they are willing to trust the news as if they hear what they want to trust (Chua and Banerjee, 2018).

Trust has also been regarded as associated with information seeking. In response to a disaster, trust in information can lead to either protective action or further information seeking (Heath and Palenchar, 2000). In fact, unverified information is usually ambiguous and rich/prevalent on the Internet (Zhou *et al.*, 2021). Greater ambiguity signals a warning to recipients, which subsequently leads them to spend more time on information seeking and processing (Lindell and Perry, 2012). In addition, the amount and variety of online fake news provides different and sometimes contrasting information about what prevents and treats the disease (Kim *et al.*, 2020). The ambiguity and prevalence of fake news circulating online may lead people to search for more information for confirmation. Therefore, in terms of the ambiguity of HOFN, trust in HOFN may be associated with further information seeking online. This could deepen our understanding of why regional pandemic severity (i.e. environmental cues) could drive the HOFN information seeking (i.e. human behaviors).

2.4 Perceived control

In the PADM, information processing is a sequential multi-stage process (Lindell and Perry, 2012). However, later research has suggested that some people are more susceptible to online scams than others (Williams *et al.*, 2017). Rosnow (1991) noted that trust attributed to fake news varies from one individual to the next. HOFN may be regarded as trustworthy by one person but dismissed as misinformation by another, which suggests individual differences in processing fake news.

As HOFN could meet people's urgent needs of information and certainty (Fleming, 2020), resisting its influence is a difficult task that requires mental effort and self-regulation (Williams *et al.*, 2017). In previous literature, perceived control has been regarded as a factor that facilitates exertion of effort and promotes self-regulation (Alonso-Ferres *et al.*, 2020), thus resulting in successful resistance to the influence of online misinformation (Burkley, 2008; Fransen and Fennis, 2014). The theory of perceived control refers to the extent to which people believe they have the capacity to handle or prevent a given event (Lachman, 2006). It has been regarded as an adaptive factor that helps people cope with disasters and alters people's attitudes and behavioral intentions toward online information (Dalila *et al.*, 2020; Hajli and Lin, 2016; Li *et al.*, 2020).

A sense of control has been thought to be associated with health-promoting behaviors (Specht *et al.*, 2013). In a health emergency, perceived control has been associated with the belief that people can prevent disease via their actions (Park *et al.*, 2018). People with high perceived control show a strong capacity to make good use of their resources (Alonso-Ferres *et al.*, 2020), improving their strength to override impulsivity and resist the influence of untrue information (Williams *et al.*, 2017). When people perceive loss of control in a disaster, they are motivated to regain a sense of control by using a range of strategies (Liu *et al.*, 2021). For example, untrue information, such as superstitions and conspiracies, provides "knowledge"

that addresses their unanswered questions, reduces uncertainty and increases their perceived control (Keinan, 2002; Kim *et al.*, 2020; Whitson and Galinsky, 2008; Zhou *et al.*, 2021).

During the pandemic, people were often sheltered at home with limited permission to leave the house to reduce disease transmission (Sibley *et al.*, 2020). This situation alters one's sense of control and causes adverse behavioral responses to the pandemic (Brooks *et al.*, 2020; Liu *et al.*, 2021). In fact, the loss of control caused by the pandemic is often associated with impulse control difficulties (Liu *et al.*, 2021). People with impulse control difficulties are less likely to utilize reason and analytic thinking (Zhou *et al.*, 2012). Thus, HOFN often earns trust among people with low control, as they fail to engage in analytical thinking (Bronstein *et al.*, 2019; Pennycook *et al.*, 2018, 2020; Zhou *et al.*, 2012). Additionally, perceived loss of control triggers negative feelings, such as anxiety and uncertainty (Rubin and Wessely, 2020). These emotions are found to be positively associated with trust in fake news (Allport and Postman, 1947; Anthony, 1973; Martel *et al.*, 2020). Thus, failures of control make people unable to resist the influence of untrue information (Williams *et al.*, 2017) and increases belief in online fake news (Martel *et al.*, 2020).

2.5 The present study

We present three studies that examine evidence for information processing of HOFN based on PADM (Figure 1). As mentioned above, HOFN spreads predominantly via the Internet during the pandemic (Ale, 2020; Gever, 2020; Naeem and Bhatti, 2020). As HOFN can provide "knowledge" to prevent infection, such information may be regarded as a protective measure against COVID-19. According to the PADM, people tend to seek information and implement protective behavior in response to environmental hazards (Lindell and Perry, 2012). In line with this, we proposed a time-lagged relationship between regional pandemic severity and regional HOFN search behavior in the USA and China, suggesting that environmental cues may be associated with people's behavioral responses toward information regarding the pandemic (i.e. HOFN search behavior, Study 1).

The COVID-19 pandemic, unlike smaller regional natural disasters (e.g. earthquakes, tidal waves or epidemics) is a global outbreak. Regional pandemic severity varies across regions within a country, as regions experience different numbers of positive cases (Reed *et al.*, 2013; Zheng *et al.*, 2020). For example, Hubei province in China (early in 2020) and New York in the USA were the severely affected regions and reported the largest number of confirmed cases (Gostin and Wiley, 2020). In response to the health emergency, governments implemented unprecedented measures, such as stay-at-home orders and lockdown policies, in these severely affected regions. People residing in severely affected regions receive verified health information from local official media. Importantly, they are required to stay at home, which reduces the risk of infection as well as health-related uncertainty. Accordingly, uncertainty and anxiety caused by the health emergencies may be attenuated as people gradually become accustomed to their environment after long-term high-risk exposure (Gan *et al.*, 2020; Xu *et al.*, 2020). People residing in severely affected regions are calmer than those residing in

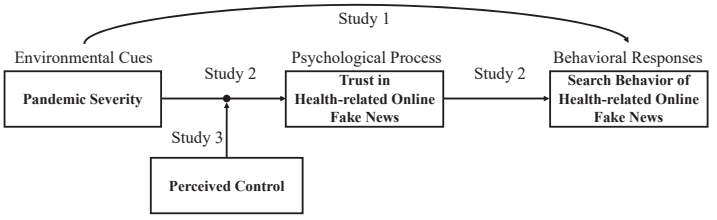


Figure 1.
Research framework of search behavior during COVID-19 pandemic

mildly affected regions (Zhang *et al.*, 2020). Given the PADM, such environmental cues may alter people's perceptions of HOFN, which, in turn, provides the basis for protective action decision-making, such as information seeking (Lindell and Perry, 2012). Thus, regional HOFN search behavior may be stronger in mildly affected regions but weaker in severely affected regions.

H1. Pandemic severity negatively predicts regional HOFN search behavior.

Next, we adopted the psychological processes of PADM theory to deepen our understanding of the role of trust in HOFN in the relationship between environmental cues (i.e. regional pandemic severity) and human online behaviors (i.e. information seeking) in Study 2. In the pandemic, governments in severely affected regions implemented tighter controls over movement compared to governments in mildly affected regions. Those residing in mildly affected regions may need more knowledge to protect them against the disease, as the advice to stay at home and maintain social distance is merely a recommendation and not a mandate. As HOFN provides health information about how to prevent and treat the disease, people who have insufficient information about disease prevention and treatment are more likely to trust such information. Moreover, people may experience different levels of uncertainty due to environmental cues. After exposure to the disease, people exhibited lower anxiety in severely affected regions or in the acceleration (Zhang *et al.*, 2020). The stronger the emotions people feel, the more likely they are to believe in fake news (Martel *et al.*, 2020). Thus, trust in HOFN may be higher among people residing in mildly affected regions but lower among those residing in severely affected regions. In addition, although HOFN helps to relieve the uncertainty caused by environmental hazards, its ambiguity may lead people to engage in seeking additional information (Kim *et al.*, 2020; Pennycook *et al.*, 2020; Zarocostas, 2020). Subsequently, trust in information may be associated with information seeking for protective action in a risk environment, as it can lead to spending more time in further information seeking (Lindell and Perry, 2012).

H2a. Pandemic severity negatively predicts trust in online fake news.

H2b. Trust in HOFN serves as a mediator in the relationship between pandemic severity and regional HOFN search behavior.

Finally, given the adaptive function of perceived control in the pandemic (Zheng *et al.*, 2020), this factor may also alter people's psychological reactions toward online fake news. A sense of control bolsters mental efforts and promotes self-regulation (Alonso-Ferres *et al.*, 2020), leading to an enhanced ability to resist the persuasive impact of online misinformation (i.e. HOFN) (Williams *et al.*, 2017). In fact, people who perceive themselves to be more in control are more likely to utilize analytic thinking for online news (Sindermann *et al.*, 2020; Zhou *et al.*, 2012), which is negatively associated with trust in the news because of its low perceived accuracy (Pennycook *et al.*, 2018, 2020). Conversely, the perception of a loss of control often drives people to make efforts to increase their control over a situation (Alonso-Ferres *et al.*, 2020; Liu *et al.*, 2021). For example, a piece of fake news about supply shortages can result in panic-buying and hoarding (Lufkin, 2020). People hoard food and other daily necessities to prevent environmental threats and promote a sense of control (Liu *et al.*, 2021). Thus, people who perceive lower control are more likely to trust HOFN, as such information provides approaches to regain their perceived control. Thus, perceived control may serve as a boundary (moderating) condition that alters the impact of pandemic severity on trust in HOFN. In Study 3, we developed a fake news piece based on an online report, re-tested whether the psychological effect occurs again for trust in HOFN and determined if perceived control served as a boundary condition of such an effect.

H3. Perceived control moderates the relationship between pandemic severity and trust in online fake news. In particular, the impact of pandemic severity on trust in HOFN is seen in people with high perceived control. However, people with low perceived control are more likely to trust HOFN, regardless of their regional pandemic severity.

3. Study 1: pandemic severity and HOFN search behavior

3.1 Methods

In this preliminary study, we collected online search data from the USA and China to examine the relationship between pandemic severity and HOFN search behavior. Such relationships were tested for one common piece of online fake news ("Microwaves kills coronavirus") in the USA (Islam *et al.*, 2020; Naeem and Bhatti, 2020) and two online fake news pieces ("Hot baths kill coronavirus" and "honeysuckle kills coronavirus") in China (Lim, 2021; WHO, 2020). Although a recent study found that absorbed plant MIR2911 (a plant microRNA) in honeysuckle decoction accelerates the negative conversion of infected patients (Zhou *et al.*, 2020), the online news ("honeysuckle kills coronavirus") was regarded as fake news on February 2020 by social medias (Jiang, 2020).

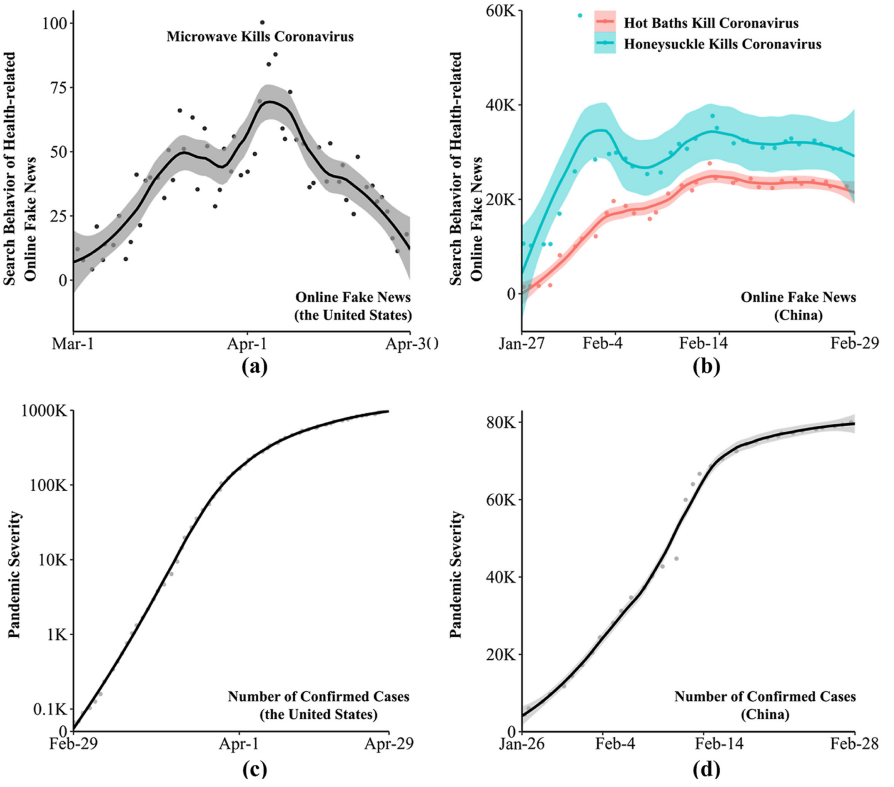
The regional *HOFN search behavior* was evaluated by Google trends and Baidu search index data. The Google trends is the index that reflects actual search requests in the Google search engine across states in the USA (Chen *et al.*, 2017; Stephens-Davidowitz, 2017). We extracted online search data from Google trends ranging from March 1, 2020 to April 30, 2020 and keywords = "Microwave AND Coronavirus." The Google trends showed that the first and second most search queries with these keywords were "microwave kills coronavirus" and "does microwave kill coronavirus" in the USA (National Google trends data is shown in Figure 2A).

As Baidu is the most frequently used search engine in mainland China, we collected online data from Baidu in China (Chen *et al.*, 2017; Liu *et al.*, 2016). The data were extracted across regions of China with search dates ranging from January 27, 2020 to February 29, 2020 and search keywords = "Baths AND Coronavirus" for the first online fake news story and "Honeysuckle AND Coronavirus" for the second online fake news story (National Baidu index data is shown in Figure 2B). As the Baidu search index is highly correlated with regional population size ("Baths AND Coronavirus": $r = 0.59$, $p < 0.001$; "Honeysuckle AND Coronavirus": $r = 0.72$, $p < 0.001$), this study adjusted the regional HOFN search behavior by division with regional population size.

Regional *Pandemic Severity* was assessed by the regional number of confirmed COVID-19 cases reported daily at websites from the Centers for Disease Control and Prevention (CDC) of the USA and National Health Commission (NHC) of China. The number of confirmed cases in a region has been regarded as an indicator of regional severity (Zheng *et al.*, 2020). This study used the total number of confirmed cases at the state-level in the USA, and region-level in China, because the larger number of confirmed cases a region reported, the more severely affected the region was. In order to examine the time-lagged effects, we extracted the pandemic data on the days before search dates from the CDC in the USA (from February 29, 2020 to April 29, 2020) and from the NHC in China (From January 26, 2020 to February 28, 2020), because the number of confirmed cases increased quickly during these times in these countries and the search data are available during this period (Figures 2C and 2D). Regional pandemic severity was transformed by logarithm with base 10 due to its skewed distribution.

3.2 Results

Descriptive statistics and correlation coefficients are presented in Table 1.



Note(s): In Figure 2A, Search Behavior of Health-related Online Fake News (Microwave kills coronavirus) was assessed by Google trends; According to Google trends, a value of 0 indicates there was not enough data for this term; A score of 100 is the peak value of google trends for the term; The data were extracted across states in the United States with search dates ranging from March 1, 2020 to April 30, 2020, and search keywords = "Microwave AND Coronavirus;" In Figure 2B, Search Behavior of Health-related Online Fake News (Hot baths kill coronavirus and honeysuckle kills coronavirus) was assessed by Baidu Search Index. The data were extracted across regions of China with search dates ranging from January 27, 2020 to February 29, 2020, and search keywords = "Baths AND Coronavirus" or "Honeysuckle AND Coronavirus;" In Figure 2C, Pandemic Severity was measured by the number of confirmed cases in the United States (from February 29, 2020 to April 29, 2020); In Figure 2D, Pandemic Severity was measured by the number of confirmed cases in China (from January 26, 2020 to February 28, 2020)

Figure 2.
Number of confirmed cases and search behavior of health-related online fake news over time in the USA and China

As pandemic severity varies over regions within a country, such regional cue may serve as an environmental factor that results in different behavioral responses toward HOFN in different regions. In particular, people residing in the same regions may respond more similarly to each other compared to people residing in other regions, as pandemic severity differs across regions. Given the nested data structure and the differences of regional severity (Nezlek, 2008), we conducted a multi-level analysis with date as the cluster ID, regional pandemic severity at time t as the predictor and HOFN search behavior at time $t+1$ as the dependent variable. The model was fitted with the lme4 package in R.

The null model showed that the intraclass correlation was 0.26 for online search behavior for microwave, 0.27 for hot baths and 0.17 for the honeysuckle news effect.

	M ± SD	1	3	4
1. Pandemic severity (the USA)	3.21 ± 0.92			
2. Search behavior of health-related online fake news (the USA; microwave kills coronavirus)	31.72 ± 21.19	−0.22**		
3. Pandemic severity (China)	2.25 ± 0.77			
4. Search behavior of health-related online fake news (China; hot baths kill coronavirus)	0.23 ± 0.15		−0.15**	
5. Search behavior of health-related online fake news (China; honeysuckle kills coronavirus)	0.33 ± 0.20		−0.12**	0.87**

Note(s): **$p < 0.01$; pandemic severity as measured by the number of confirmed cases at the state/region level – the number was transformed by logarithm with base 10; search behavior of HOFN (microwave kills coronavirus) was assessed by Google trends; search behavior of HOFN (hot baths kill coronavirus and honeysuckle kills coronavirus) was assessed by Baidu Search Index – the number was corrected by the regional population size; the correlation matrix appears incomplete, since the USA and China samples were independent from each other

Table 1.
Descriptive statistics and correlation coefficients of all variables in Study 1

Next, we tested time-lagged effects of pandemic severity on search behavior for the microwave news by a random slope model. Pandemic severity at time *t* negatively predicted HOFN search behavior at time *t + 1* ("Microwave kills coronavirus"; $\beta = -14.15$, SE = 1.72, 95% CI [-17.53, −10.78] and $p < 0.001$, Figure 3A). Second, according to the other two news stories, results showed that pandemic severity at time *t* negatively predicted HOFN search behavior at time *t + 1* ("Hot baths kill coronavirus": $\beta = -0.07$, SE = 0.006, 95% [−0.08, −0.06] and $p < 0.001$, Figure 3B; "Honeysuckle kills coronavirus": $\beta = -0.06$, SE = 0.008, 95% CI [−0.08, −0.05] and $p < 0.001$, Figure 3C). Our results suggest that people residing in the severely affected regions exhibited less HOFN search behavior compared to those residing in mildly affected regions in both the USA and mainland China.

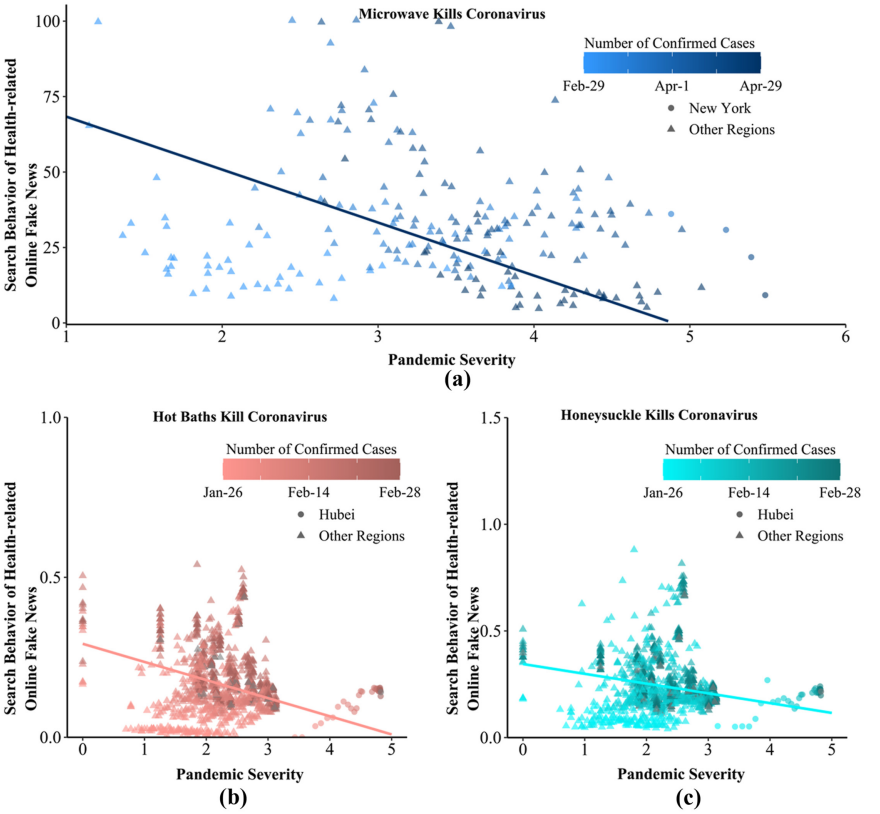
4. Study 2: pandemic severity, trust in HOFN and HOFN search behavior

4.1 Methods

This study recruited 3,248 participants (*mean* age = 24.66 ± 8.44; 1,018 men and 2,230 women) from 31 regions of mainland China. Participants were recruited by a social media platform (i.e. WeChat) from February 5, 2020 to February 8, 2020 in mainland China, which directed them to an online survey. The study protocol was approved by the ethics committee of the first author's university. Only those reading and accepting online consent could continue this study, otherwise redirected to the closing page. After finishing the survey, they were compensated with 13 Chinese RMB (about US$2).

Regional *pandemic severity* and *HOFN search behavior* was assessed in the same manner as in Study 1. We extracted data from NHC on February 4, 2020 (the day before our data collection) for regional *pandemic severity* and from the Baidu search index on February 8 (the last day of our data collection) for *HOFN search behavior*. The data were also adjusted in the same manner as in Study 1. Participants' location data were obtained from their Internet Protocol (IP) address.

Trust in HOFN was measured by the subjective credibility of the two online fake news stories mentioned in Study 1, namely, "Hot baths kill coronavirus" and "Honeysuckle kills coronavirus." The statement we queried for each fake news story was "I found the news was credible," which was adapted from Johnson *et al.* (2019). Participants were required to rate their responses on a five-point scale (1 = strongly distrust to 5 = strongly trust). The reliability (Pearson correlation between the two items) was 0.64 in the current sample.



Note(s): Pandemic Severity as measured by the number of confirmed cases at the state/region level — the number was transformed by logarithm with base 10; Figure 3A shows the relationships between pandemic severity and search behavior of health-related online fake news over time in the\United States; Search Behavior of Health-related Online Fake News (Microwave kills coronavirus) was assessed by Google trends at the state level; The data were extracted across states in the United States with search dates ranging from March 1, 2020 to April 30, 2020, and search keywords = "Microwave AND Coronavirus;" In Figures 3B and 3C Search Behavior of Health-related Online Fake News (Hot bath\kill coronavirus and honeysuckle kills corona virus) was assessed by Baidu Search Index at the region level—the number was corrected by the regional population size; The data were extracted across regions of China with search dates ranging from January 27, 2020 to February 29, 2020, and search keywords = "Baths AND Coronavirus" for Figure 3B, and "Honeysuckle AND Coronavirus" for Figure 3C

Figure 3.
The time-lagged relationships between pandemic severity and search behavior of health-related online fake news in the USA and China

4.2 Results

Descriptive statistics and correlation coefficients are presented in Table 2.

To test the time-lagged effect, we conducted a multi-level mediation model with regional name as cluster ID, regional pandemic severity on February 4 as the predictor, trust in HOFN from February 5 to 8 as the mediator and HOFN search behavior on February 8 as the outcome. The null model showed that the intraclass correlation of trust in HOFN was 0.13. According to H2a, results showed that pandemic severity negatively predicted trust in HOFN ($\beta = -0.18$, SE = 0.07, 95% CI [−0.32, −0.04] and $p = 0.010$), suggesting a negative relationship between regional pandemic severity and regional trust in HOFN.

Next, we found trust in HOFN significantly predicted regional HOFN search behavior (β = 0.17, SE = 0.06, 95% CI [0.06, 0.29] and p = 0.004). Subsequently, a Monte Carlo approach was conducted to test the mediating effect. Our results indicated a mediating effect of trust in HOFN on the relationship between pandemic severity and search behavior of HOFN (Effect = −0.03, SE = 0.02, 95% CI [−0.07, −0.01], Figure 4).

5. Study 3: pandemic severity and trust in HOFN: the moderating role of perceived control

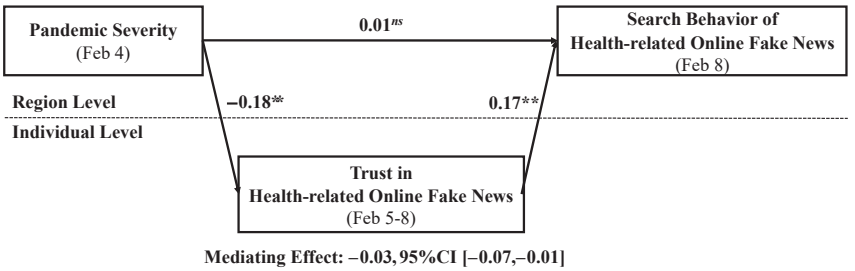
5.1 Methods

Study 3 recruited 1847 participants (*mean* age = 30.64 ± 9.19; 767 men and 1,080 women) from 32 regions of mainland China. Among them, 257 had completed high school education, 465 had completed junior college education, 868 held bachelor's degrees and 257 held master's or doctorate degrees.

	M ± SD	1	2
1. Pandemic severity	2.66 ± 0.58		
2. Trust in health-related online fake news	1.74 ± 1.04	−0.12**	
3. Search behavior of health-related online fake news	0.23 ± 0.08	−0.16**	0.10**

Note(s): **p < 0.01; pandemic severity as measured by the number of confirmed cases at the region level in China – the number was transformed by logarithm with base 10; the pandemic data were extracted on February 4, 2020 (the day before our data collection); search behavior of health-related online fake news (hot baths kill coronavirus and honeysuckle kills coronavirus) was assessed by Baidu search index at the region level – the number was corrected by the regional population size; The data were extracted across regions of China with search dates ranging from February 5, 2020 to February 8, 2020 and search keywords = "Baths AND Coronavirus" or "Honeysuckle AND Coronavirus"

Table 2. Means, standard deviations and Pearson correlation coefficients for variables in Study 2 (n = 3,248)



Note(s): *ns* $p \geq 0.05$, **p < 0.01; Pandemic Severity as measured by the number of confirmed cases at the region levelin China—the number was transformed by logarithm with base 10; The pandemic data were extracted on February 4, 2020 (the day before our data collection); Trust in Health-related Online Fake News was assessed by the subjective credibility of the two online fake news stories(Hot baths kill coronavirus and honeysuckle kills coronavirus); The data were collected from February 5, 2020 to February 8, 2020 in mainland China; Search Behavior of Health-related Online Fake News (Hot baths kill coronavirus and honeysuckle kills coronavirus) was assessed by Baidu Search Indexat the region level—the number was corrected by the regional population size; The data were extracted across regions of Chinawith search dates ranging from February 5, 2020 to February 8, 2020, and search keywords = "Baths AND Coronavirus" or "Honeysuckle AND Coronavirus"

Figure 4. The time-lagged mediation effect of trust on the relationship between pandemic severity and search behavior of health-related online fake news

Participants were recruited by a social media platform (i.e. WeChat) from mainland China that directed them to an online survey on February 7, 2020. Participants who read and accepted online consent could continue this study. After they completed the perceived control scale, they were instructed to read fabricated news regarding personal protection against infection of COVID-19 (see Appendix) and to complete the trust in HOFN scale. Last, they were told the online news is not true and compensated with 6 Chinese RMB (about US$1).

Regional *pandemic severity* was assessed in the same manner as in Study 2. The pandemic data were extracted on February 6, 2020 (the day before our data collection).

Trust in HOFN credibility was measured with three items adapted from Johnson *et al.* (2019), such as "I found the post was credible," "I found the post convincing" and "I found the post reliable." Each item was answered using a five-point scale ranging from 1 (*Strongly disagree*) to 5 (*Strongly agree*). Cronbach's alpha was 0.97 for this sample.

Perceived control was measured by the scale developed by Whitaker *et al.* (2000). This scale includes five items, such as "I have little control over the things that happen to me." The participants were asked to rate a seven-point Likert scale (1 = "strongly disagree" to 7 = "strongly agree"). Cronbach's alpha was 0.90 for this sample.

5.2 Results

Descriptive statistics and correlation coefficients are presented in Table 3.

First, we conducted a null model and found that the intraclass correlation was 0.04. Second, pandemic severity and perceived control were entered in the model as additional predictors. The results showed that perceived control negatively predicted the trust in HOFN ($B = -0.12$, SE = 0.03, 95% CI [−0.19, −0.06] and $p < 0.001$). However, there was a non-significant effect of pandemic severity on trust in HOFN ($B = 0.05$, SE = 0.07, 95% CI [−0.10, 0.19] and $p = 0.521$). Third, we included the interaction item of pandemic severity and perceived control to test moderation. The results revealed that perceived control moderated the relationship between pandemic severity and trust in HOFN ($B = -0.08$, SE = 0.03, 95% CI [−0.13, −0.02] and $p = 0.007$). Therefore, H3 was supported.

Subsequently, we conducted a simple slopes analysis. The results showed that pandemic severity negatively predicted trust in HOFN for people with high perceived control ($B = -0.18$, SE = 0.10, 90% CI [−0.06, −0.30] and $p = 0.060$) but not for those with low perceived control ($B = 0.03$, SE = 0.08, 95% CI [−0.12, 0.17] and $p = 0.743$; Figure 5).

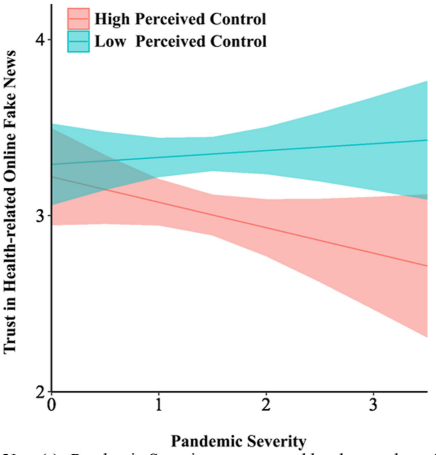
6. General discussion

The COVID-19 pandemic has undoubtedly changed people's behaviors. Since people have insufficient knowledge about how to protect against the disease and HOFN provides health-related information about it, people may view HOFN as a way of disease prevention. This research adopted PADM to understand people's responses to HOFN during the COVID-19

Table 3.
Means, standard deviations and Pearson correlation coefficients for variables in Study 3 ($n = 1847$)

	M ± SD	1	2
1. Perceived control	3.87 ± 1.41		
2. Pandemic severity	1.42 ± 0.61	−0.02	
3. Trust in health-related online fake news	3.18 ± 1.27	−0.13**	−0.02

Note(s): **$p < 0.01$; pandemic severity as measured by the number of confirmed cases at the region level – the number was transformed by logarithm with base 10



Note(s): Pandemic Severity as measured by the number of confirmed cases at the region level in China—the number was transformed by logarithm with base 10; The pandemic data were extracted on February 6, 2020 (the day before our data collection)

Figure 5.
The moderating effect of perceived control on the relationship between pandemic severity and trust in health-related online fake news

pandemic, using three genuine fake news stories and one fabricated news story from the USA and China.

Using online information-seeking data, we confirmed that pandemic severity had a negative time-lagged effect on regional HOFN search behavior in Study 1. Regional HOFN search behavior was higher in the mildly affected regions but lower in the severely affected regions, suggesting that environmental cues have been associated with information seeking behavior in terms of HOFN during the COVID-19 pandemic.

Subsequently, in Study 2, we identified trust serving as a mediator in the time-lagged relationship between pandemic severity and regional HOFN search behavior, which confirmed that environmental cues affect behavioral responses via the psychological process. People residing in mildly affected regions are more likely than those residing in severely affected regions to trust HOFN, which, in turn, has been associated with more frequent regional HOFN search behavior.

Finally, in Study 3, we found that perceived control, as a boundary condition, moderated the relationship between pandemic severity and trust in HOFN. Our results suggest that people's psychological process toward an environmental hazard varies according to their perceived control of the situation. The effect of pandemic severity on trust in HOFN during the pandemic was significant among people with high perceived control but not for those with low perceived control.

6.1 Findings

First, given the reality that online fake news has become a new societal threat that spreads widely and at a global pace (Bunker, 2020), our study provides direct evidence of regional search behavior in response to a global hazard (Lindell and Perry, 2012). This phenomenon is in line with the PADM, as people tend to seek information to implement protective behaviors as a means of disease prevention (Heath *et al.*, 2018; Liu *et al.*, 2019). Our findings extend PADM in a context of "infodemic," in which regional HOFN search behavior is more frequent in mildly affected regions than in severely affected regions. This finding suggests that people

in mildly affected regions exhibit a stronger need to learn about protective actions through online information.

This research demonstrates that the perceived credibility of HOFN is stronger among people in mildly affected regions than among those in severely affected regions. One possible explanation for this effect is anxiety or uncertainty caused by the pandemic. People experience emotional tension and uncertainty (Rettie and Daniels, 2020), which may lead them to trust fake news attributable to the pandemic (Rosnow, 1991). In line with previous findings that people tend to become gradually accustomed to an environmental hazard after long-term high-risk exposure (Gan *et al.*, 2020; Xu *et al.*, 2020), those residing in severely affected regions are less likely to experience uncertainty and anxiety. Consequently, people in mildly affected regions are more likely than those in severely affected regions to trust HOFN in order to relieve their uncertainty and anxiety (Chua and Banerjee, 2018; Rosnow, 1991).

Another possible explanation is that people residing in severely affected regions tend to pay more attention to news accuracy, since the news used in this study is relevant to public health. According to Pennycook *et al.* (2018), when people are concerned about news accuracy, they are more capable of identifying fake news and less likely to share fake news. Likewise, people in mildly affected regions are less discerning about news regarding COVID-19 (Pennycook *et al.*, 2020). Conversely, people in the epicenter may also be more concerned about online news accuracy, which thus leads to low trust in HOFN.

Second, our study found that trust serves as a mediator in the relationship between pandemic severity and HOFN search behavior. This finding is in line with previous literature that trust in information or perceived information credibility is a strong predictor of information seeking (Heath and Palenchar, 2000). As people who perceive stronger uncertainty are more likely to rely on credible information to guide their adaptive behavior (Paton, 2007), they tend to spend more time in information seeking and information processing (Lindell and Perry, 2012). Therefore, our findings provide empirical evidence of the PADM (Heath *et al.*, 2018; Liu *et al.*, 2019), in which trust in HOFN, as a psychological process, explains the link between pandemic severity and regional HOFN search behavior. It must be noted, however, that people in this study believed that the fake news was true. This might be due to their general trust in online news. Further research is needed to determine whether trust in fake news is similar to trust in news in general.

Third, we found that perceived control serves as a boundary condition in which the impact of pandemic severity on trust in HOFN was seen for people with high perceived control but not for those with low perceived control. Although studies have found that perceived control of information is positively related to both trust in the information and information-sharing behaviors (Hajli and Lin, 2016; Li *et al.*, 2020), we found that perceived control was negatively related to trust in HOFN. This could be explained by the fact that in prior literature, perceived control involved the sense of capability in handling the information. However, our study measured perceived control as the general belief that people can determine their internal states and behaviors. Our findings suggest that people who perceive a lack of control are more likely to trust HOFN. Conversely, a sense of lacking control motivates people to adopt actions to regain perceived control (Alonso-Ferres *et al.*, 2020; Liu *et al.*, 2021), which subsequently promotes trust in untrue information (Burkley, 2008; Fransen and Fennis, 2014). Therefore, perceived control over life may affect information processing for HOFN differently than perceived control of information.

In information processing, a sense of control can enhance the mental strength required to resist the influence of untrue information (Williams *et al.*, 2017). When people in severely affected regions perceive a high level of control, this adaptive factor may facilitate analytical thinking that is able to critically examine HOFN, which leads to less trust in such information (Bronstein *et al.*, 2019; Pennycook *et al.*, 2018, 2020). People with low perceived control are more eager to consume news about how to maintain their health during the pandemic (Liu

et al., 2021). In line with this, our study found that people who perceive low levels of control reported high levels of trust regarding HOFN, regardless of regional pandemic severity. This finding is consistent with previous literature that lack of control usually leads to maladaptive behaviors (Brandão *et al.*, 2018; Cheng *et al.*, 2013) and trust in fake news (Keinan, 2002; Whitson and Galinsky, 2008). Since our research cannot distinguish trust in fake news from trust in general news, lack of perceived control may make people believe in any news regarding the pandemic they see, but this hypothesis will require further research to examine.

Additionally, this research demonstrated that perceived control may serve as a boundary condition for individual differences that alters the sequential stages of the PADM (Lindell and Perry, 2012; Liu *et al.*, 2019). In particular, people with low levels of perceived control may perceive a high credibility of HOFN regardless of the environmental cues. This is a cause for caution, as people may implement inadequate protective action recommended by HOFN (Kim *et al.*, 2020; Zhou *et al.*, 2021), which could lead to substantial harmful practices for their health. Therefore, our results shed light on individual differences in the unfolding of the PADM in response to a global disaster.

6.2 Implications

Although many studies underscore the role of social media platforms in the detection of online fake news (Lazer *et al.*, 2018), current bot regulation is a cat-and-mouse game that only affords temporary solutions. This study adopted the PADM to provide insights into people's behavioral responses toward an "infodemic." In our study, people residing in mildly affected regions were more likely to believe online fake news regardless of trust in or search for HOFN.

According to the PADM, people tend to seek health-related information as a protective behavior in response to an environmental disaster (Lindell and Perry, 2012). With respect to government crisis management, diverse policies should be implemented in regions with differential severities. In this pandemic, regions that have been relatively mildly affected should be monitored for better "infodemic" management. Practitioners should deliver accurate information to correct HOFN, especially for people who reside in mildly affected regions and who feel uncertain about methods to protect themselves. For severely affected regions, our results found that perceived control can serve as an adaptive factor that alters people's trust in HOFN. Thus, programs that increase perceived control for people in the epicenter may not only prevent them from believing online fake news, but may also help the local government cope with panic-buying and hoarding problems caused by HOFN.

Additionally, our research finds that people tend to search for HOFN after exposure to such information. Governments should develop a platform for fake-news corrections. In fact, the spread of online information can be strengthened through an echo chamber effect, in which the information is repeatedly propagated and reinforced and finally accepted as credible (DiFonzo *et al.*, 2014). If corrections to fake news stories could be reposted as quickly and easily as the HOFN itself, people may be less likely to trust the information and implement risky behaviors because of different and inconsistent recommendations on what prevents and cures the disease.

Finally, crisis response preparedness is a key factor for successful governance responses (e.g. Shankar *et al.*, 2011). We suggest that governments develop pre-specified measures for dealing with "infodemics." Activity theory offers a framework for planning, analyzing and implementing measures (Engeström, 1999) that can help the Government improve and set a standard for future crisis response. For example, some researchers suggest that libraries help governments and citizens recognize fake news, as well as the consequences of reducing its spread (Ale, 2020; Gever, 2020); the promotion and maintenance of libraries could be viewed as an approach to prevent the spread of online fake news.

6.3 Limitation and future directions

This study has several limitations. First, this study evaluated regional HOFN search behavior using Google trends in the USA and the Baidu search index in China. Although the search index reflects the relative frequency of information seeking, it is a regional indicator. In addition, pandemic severity was evaluated using confirmed regional cases with data transformation. Although this study tested the hypothesis using both subjective and objective data, causal inferences should be made with caution. Further research could repeat our methods by using subjective pandemic severity and direct indicators of people's search behaviors. Second, this study focused mainly on trust in and seeking of online fake news. However, it is still unclear what the differences in trust and search behavior between online fake news and verified news are – particularly, how people handle news when they do or do not know if the news is fake. Such a comparison may help understand why fake news spreads faster and deeper than true news. Studies can fill this gap in the future by directly comparing people's trust in legitimate news to that in fake news. Third, we proposed perceived control as a boundary condition for the relationship between pandemic severity and trust in HOFN. However, it is still unclear whether perceived control can alter the relationship between pandemic severity and information seeking. Future studies are required to confirm the more speculative suggestions of this study.

7. Conclusion

HOFN has become a societal problem and has caused considerable changes to our behavior (Bunker, 2020; Nature, 2020); in-depth research is required in order to better understand people's responses toward HOFN. Our results provide empirical evidence of the PADM in an "infodemic" by demonstrating that trust in and search for HOFN vary under conditions of pandemic severity. This impact is moderated by perceived control, in which people with low levels of control are more likely to fall prey to online fake news regardless of the severity of the pandemic in their region.

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Appendix

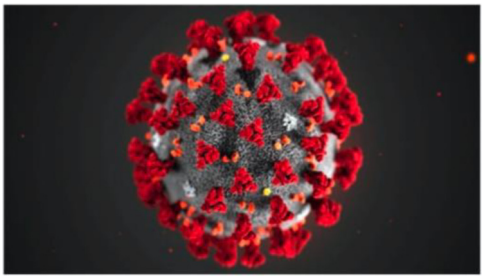
Research material

COVID-19 can survive up to five days

Wash clothes with salt water to block infection

Modern News

The Wuhan Municipal Headquarters for COVID-19 Epidemic Prevention and Control held a regular press conference on February 5. Experts from the headquarters answered questions raised by reporters.



Jiang Rongmeng, a member of the expert team at the NHC and the chief physician of the 2nd Division of Infectious Disease at Beijing Di'tan Hospital, said that the virus is transmitted by droplets, through coughing and sneezing of infected persons. Studies found that the virus can survive on cloth, under ideal conditions, for up to several days. For example, the viable virus particles can be found on a cloth surface for up to five days if the room temperature is 20 C and the room humidity is about 40–50%.

Jiang pointed out that a person can be infected only after the person is exposed to the virus, such as touching contaminated clothing. However, saltwater can kill the virus, which has been able to interrupt the chain of the disease's transmission. Therefore, Jiang suggested people wash their clothes with saltwater.

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