The Role of Digital Information Accessibility in Shaping the Relationships of Exposure to COVID-19 Misinformation and Cognitive and Attitudinal Effects in Asia

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Introduction

It has been widely observed (Cinelli et al., 2020) that an information epidemic known as “infodemic” has been a hallmark of the on-going COVID-19 pandemic. Infodemic refers to an overabundance of “information associated with a specific topic and whose growth can occur exponentially in a short period of time due to a specific incident” (Pan American Health Organization, 2020, p. 1), such as rumours, misinformation, and fake news. In the context of the raging COVID-19 pandemic, inaccurate and false information concerning various aspects of the virus, ranging from its origin, infection mechanisms, treatments to doubts about the vaccines, has been spreading like a wildfire on social media platforms and interpersonal social networks.

The “infodemic” phenomenon has caught scholarly attention. The detrimental effects of misinformation exposure on individuals’ perceptions and behaviors include dysfunctional sharing (Rossini et al., 2021), negative emotions (Liu & Huang, 2020), reluctance in adopting preventive measures (Lee et al., 2020), and vaccine hesitancy (Dror et al., 2020). Other researchers have examined the antecedents of misinformation exposure and sharing to understand the contributing factors to the widespread of misinformation on social media platforms. These factors are diverse, ranging from individual-level variables, such as scientific knowledge and political identity (Buchanan & Benson, 2019; Pennycook et al., 2020), to message factors, such as negative sentiments (Kumar et al., 2021). However, few studies have explored societal-level factors that may accelerate or mitigate the spread of the COVID-19 misinformation that amplifies or lowers the negative effects of exposure to such misinformation.

The present study aims to fill the gap by investigating the role of a key societal factor—information accessibility—in shaping the context of exposure to and sharing of popular COVID-19 misinformation on social media that lead to harmful effects on cognitive and attitudinal outcomes (i.e., misinformation beliefs, anti-vaccine attitudes, knowledge of COVID-19).

The inclusion of information accessibility on digital media in the present study was based on the consideration that the widely diffused COVID-19 misinformation on social media differs in types, attributes, quantity, sources, and false claims across societies. Individuals living in societies with different social-political systems and media environments have either restricted or free access to such information online. As such, their cognitive processes and reflections of digital content would also differ (Cho et al., 2009; Eveland, 2001). Specifically, we situated the present study in four Asian societies (i.e., mainland China, Hong Kong, Singapore, and Taiwan) to explore if digital information accessibility makes a difference in viewing and sharing COVID-19 misinformation, which then weigh on the people's cognition and attitudes in these societies. To do so, we developed an integrated model to uncover the underlying process of how exposure and sharing affected people's beliefs, attitudes, and knowledge of the pandemic across the four societies.

The findings of this study will enrich the understanding of the harms of COVID-19 misinformation in several ways: First, the focus on the role of information accessibility in Asian societies contributes to literature on misinformation; accessibility as a social context holds the key to understand reception and viewing of such information, which then trigger follow-up behaviors such as sharing and counter-arguing. Second, the on-going COVID-19 pandemic is a global crisis and how to contain the infodemic is an urgent task for policymakers and social media platform operators around the world. Our findings will lead to some generalizations that may be applicable to a wider context beyond the four studied societies. Practically, the findings will provide valuable insights for developing strategies to contain the "infodemic" on digital media.

Literature Review

Information Accessibility on Digital Media

Recent research about COVID-19 misinformation (Chadwick & Vaccari, 2019; Seo et al., 2021) shows that the frequency of misinformation exposure and sharing is subject to individual differences, such as income, education, and partisanship. However, it is equally important to consider the effects of macro-level social contexts. To illustrate, in an environment where access to updated COVID-19 information, factual, scientific types as well as inaccurate and misleading ones, is free and timely, scholars (Gil De Zúñiga et al., 2020; Oeldorf-Hirsch, 2018) have suggested that citizens are more likely to debunk misinformation as they find it easier to seek factual information, gain COVID-19 knowledge through incidental exposure to fact-checking sheets, and benefit from the Internet-enabled high-choice media environment (Gil De Zúñiga et al., 2020, p. 1605). Therefore, access to an abundance of digital information is a necessary condition for individual-level factors to play out in affecting the exposure to misinformation and producing effects following exposing to such misinformation.

Wei and Lo (2021) defined information accessibility as the extent to which citizens can freely get access to various news sources online; this sort of access is an integral dimension of personal freedom enjoyed by citizens in open and democratic societies. In the context of this study, information accessibility in digital media refers to how freely respondents in the four societies in our study can have access to a wide range of COVID-19-related information, such as news updates from digital media (i.e., online news websites, news Apps, and social media platforms).

The four societies chosen for this study share similar cultural roots but feature different social-political systems and different levels of information accessibility, making them an ideal set of populations for investigating the influence of information accessibility on digital media as a societal factor on the exposure and sharing of COVID-19 misinformation.

As a multi-dimensional construct, information accessibility consists of the hardware component (e.g., Internet accessibility, information and communication technology (ICT) infrastructure), and the software component (e.g., global competitiveness, language diversity, and personal freedoms) (Biehal & Chakravarti, 1983; Kauffman & Techatassanasoontorn, 2010; Li et al., 2020; Wei & Lo, 2021). Jointly, they make up the digital media environment of a society. Table 1 depicts the level of each component in the four societies. With regard to ICT development, the ICT Development Index (IDI) published by the International Telecommunication Union (ITU) (2017) combines 11 indicators to measure each country's ICT development stage, including ICT readiness, intensity, and effective use. In the most recent 2017 report, while Taiwan was not included in the IDI ranking, Hong Kong took the lead, ranking 6th globally, followed by Singapore (18th) and China (80th). In the 2020 rankings of global competitiveness, China topped the four societies, followed by Hong Kong, Singapore, and Taipei.

As for Internet accessibility, Hong Kong, Taipei, and Singapore residents all enjoy widely available and unrestricted access to the Internet (Wei & Lo, 2021). However, the situation is different in China. Despite China's growing Internet penetration rate thanks to the diffusion of the smartphone, since 2009 the Chinese government has employed a great firewall to restrict its citizens from using global social media platforms. As such, residents in China were unable to get access to *Google, Facebook, Twitter, YouTube*, and international media outlets unless using virtual private networks (VPNs). In such an environment, access to different types of media and diversified information sources is highly controlled.

Personal freedom is highly intertwined with a city's political system. The Human Freedom Index (Vásquez & McMahon, 2021) measuring citizens' personal freedom with dimensions like expression and information access rated China at the bottom (125th globally), while Hong Kong ranked 32nd and Singapore ranked 53rd, among the middle level of the four societies. Taiwan was considered the freest society among the four societies, ranking 19th globally. Finally, in terms of linguistic diversity, with four official languages, Singapore is considered the most diverse, and Hong Kong, which is bilingual, ranked second. In comparison, Taipei and China have a single official language.

Based on the five indicators, Singapore and Hong Kong were rated as the most information accessible societies with high global competitiveness, promising ICT development, multilingual media, high levels of personal freedom, and unrestricted Internet access, followed by Taiwan (medium). China was at the bottom (low) as personal freedom and restricted Internet access largely hindered the information accessibility enjoyed by its residents.

Table 1 Information Accessibility in Beijing, Hong Kong, Taiwan, and Singapore

	Beijing	Hong Kong	Taipei	Singapore
Global City Index [a]	5	6	44	9
Freedom of expression [b]	5.92 (personal freedom), ranked #125 for China	8.53 (personal freedom), ranked #32	8.90 (personal freedom), ranked #19 for Taiwan	7.77 (personal freedom), ranked #53
ICT Development Index [c] rankings	80 for China	6	NA	18
Internet accessibility	Widely available but restricted access	Widely available and unrestricted access	Widely available and unrestricted access	Widely available and unrestricted access
Political systems	Authoritarian one-party rule	Limited democracy	Asia's leading democracy with a two-party system	Viable democracy
Official languages: bilingual or multilingual	Chinese	Chinese (Mandarin and Cantonese) and English	Chinese	English, Chinese, Malay, and Tamil
Information accessibility [d]	Low (1)	High (3)	Medium (2)	High (3)

Notes. This table is adapted and updated from Wei and Lo (2021). [a] Kearney (2021). [b] Vásquez and McMahon (2021). [c] International Telecommunication Union (2017). [d] The index was created by an overall evaluation on the indices of a, b, and c, as well as Internet accessibility and linguistic diversity.

Information Accessibility as Condition of Exposure to Disinformation

Given the differences in digital information accessibility across the four societies with different media environments, we expected that accessibility as a macro factor would account for differences in viewing and COVID-19 information circulating online. That is, it would provide a system-level antecedent that affects the exposure to such misinformation. From a media systems perceptive, as Iyengar et al. (2010) suggested, widely accessible information resources help the public acquire fresh information, understand major news topics, and gain knowledge. Li et al. (2020) also argued that societal influences would likely prevail over individual differences in affecting citizens' consumption and engagement with digital information, largely because they provide the necessary social conditions in which individuals' information-seeking and consumption take place.

Thus, a free and information-rich environment is structurally conducive for citizens to learn factual and accurate information about COVID-19 in a timely manner, even for those who engaged in limited cognitive processing of such information. On the other hand, in a restricted and information scarce environment, the role of individual-level cognitive ability would be more prominent. Only people with enthusiasm for fact-checking, ability to reflect, and access to multiple information sources can keep up with updated and accurate information concerning COVID-19 and acquire sufficient knowledge about the disease (Trilling & Schoenbach, 2013).

Furthermore, the digital media environment functions as space where aggregated messages of all sorts are available to users. As such, it should follow the principles of classic marketplace of ideas theory (Thorson & Stohler, 2017), which assumes that the truth will emerge from the competition of ideas in free exchanges of public discourses (Ingber,1984). Individuals are able to discard inferior information (e.g., misinformation or fake news), which loses out to superior information (e.g., truth) circulated in the marketplace. In the context of COVID-19 pandemic, when citizens can access a mixture of fact-checked content and misinformation, they are less likely to consume misinformation to stay informed because of the availability of fact checked accurate information. However, in environments with limited information accessibility, the fundamental assumption of the marketplace of ideas as a mechanism to weed out falsehood for the benefit of an informed citizenry may not hold (Hofstetter et al., 1999). In fact, restricted access to digital information may be counter-productive, motivating people to seek and consume more content online no matter whether it's true or not, resulting in greater likelihood of exposure to misinformation. Empirically, Lo et al. (2022) have provided preliminary evidence to support the possibility that free access to digital information reduces exposure to misinformation; whereas restricted access leads to increased viewing of such misinformation.

Therefore, in a society where COVID-19 information is not widely available to the public in a timely manner, citizens who are unable to seek a full range of information on the pandemic may feel anxious and their need for orientation to cope with uncertainty would increase (Matthes, 2006). It is unsurprising that they might rely on unverified information from user-generated content on social media, thus increasing the possibility of exposing themselves to misinformation. That is, scarcity of information concerning the pandemic due to limited access will likely result in vulnerability of consuming misinformation. Therefore, we anticipated that the level of information accessibility in society would be negatively related to the level of exposure to COVID-19 misinformation. Our first hypothesis:

H1: Information accessibility will be negatively associated with exposure to COVID-19 misinformation.

As we argued above, high information accessibility could decrease the chances of exposure to misinformation circulated on various social media platforms. It is also plausible that it could decrease the possibility of sharing misinformation on COVID-19. First, in highly information-accessible societies, citizens have the needed resources to fact-check and verify information that seems suspicious or misleading. Any such information concerning COVID-19 can be easily debunked by the well-informed public. Sharing information online such as news has social utility in generating mutual benefit between the sender and receiver (Goh et al., 2019). When it comes to sharing information based on user-generated content, previous research (Hopp, 2022) has shown that if people can correctly identify misinformation, they are less likely to share it with people in their social circles.

A study by Duffy et al. (2020) further showed that even though sharing online represents a social good, if the shared information turns out to be false or misleading, sharing negatively impacts the sender's interpersonal relationships. Under such a circumstance, the information is what they characterized "too good not to share" (p. 1965). Therefore, it is logical to assume that in societies with higher information accessibility, where digital information is freely accessible and sharing can be socially beneficial, sharing misinformation on COVID-19 would probably happen less frequently. Conversely, in societies with restricted information accessibility, misinformation sharing would likely to happen more frequently largely because diverse authoritative information is limited whereas user-generated content fills the void. The second hypothesis was raised accordingly:

H2: Information accessibility will be negatively associated with sharing COVID-19 misinformation.

Individual-level Factors Affecting Cognition and Attitudes

Next, the effects of individual-level factors on cognitive and attitudinal outcomes are analyzed. In medical psychology (Anderson et al., 2009; Laditka et al., 2009), the state of an individual's healthy cognition implies his/her ability to perform all necessary cognitive or mental processes of acquiring knowledge and understanding, e.g., attention, judgment, and perception. We were interested in examining how exposure to COVID-19 misinformation would affect sharing behavior as well as cognitive outcomes (i.e., misinformation beliefs, knowledge of COVID-19) and attitudes (i.e., anti-vaccine attitudes). The effect of exposure to COVID-19 misinformation on sharing the misinformation was elaborated first because scholars (Olmstead et al., 2011) have long argued that sharing news has become the most important dimension of social media engagement. According to the definition by Kümpel et al. (2015), sharing refers to the "act of distributing a specific kind of content instead of describing a general social media activity that can involve posting personal pictures, anecdotes, or simply talking about one's feelings" (p. 2).

Accordingly, we defined COVID-19 misinformation sharing as the practice of talking, posting, or recommending to people in their online and offline social networks seemingly true, but actually false information about COVID-19. Considering news sharing is a post-exposure practice, it is appropriate to assume that higher exposure to COVID-19 misinformation will increase the possibility of sharing the misinformation. In addition, COVID-19 is an issue with high individual relevance and societal significance. According to the theory of reasoned action (Hale et al., 2002), people will be likely to share related misinformation after exposure since they consider the information as very important to themselves and others (Kim et al., 2020). Therefore, we hypothesized the relationship between exposure to COVID-19 misinformation and sharing behavior in the next hypothesis:

H3: Exposure to COVID-19 misinformation will be positively associated with misinformation sharing behavior.

In addition to sharing behavior that facilitates the spread of misinformation, misinformation exposure could result in some negative cognitive and attitudinal consequences. Our expectation was based on the news learning model (Eveland, 2001) which proposes that a highly involved individual exposed to news will likely process the information and learn from it. Research has indicated that information processing mechanisms enable people to enhance their political knowledge (Eveland et al., 2002) and to stay informed of accurate health knowledge following exposure to relevant information (Lo et al., 2013; Wei et al., 2011). While these findings have acknowledged the positive effects of information processing, few studies have explored whether exposure to misinformation leads to any "de-learning" effects.

Furthermore, the Health Belief Model (HBM) proposes people's beliefs as their perception about a disease (e.g., COVID-19), including their susceptibility to infection, the disease's severity, and benefits of preventive behaviors (Champion & Skinner, 2008). The exposure to COVID-19 can alter an individual's beliefs and further influence their attitudes and knowledge. In this study, misinformation beliefs refer to the acceptance of misinformation on COVID-19 as true. For example, if a person thinks that a piece of misinformation like "eating garlics can prevent COVID-19 infection" is likely or definitely to be true, the person is considered to have misinformation beliefs.

Misinformation is more likely to be accepted as true when it is compatible with other information one stores in his or her memory (Petty & Cacioppo, 1986). In addition, repetition can also make the statement appear more credible in the eyes of the beholder (Allport & Lepkin, 1945). The phenomenon is known as "processing fluency." As Pluviano et al. (2017) argued, the more often people are exposed to false claims, the more likely they are to find the claims to be true (aka the *illusory truth effect*). Therefore, we anticipated that increased exposure to COVID-19 misinformation would produce belief in the credibility of the misinformation.

The misinformation false belief has been observed in a variety of contexts. Studies of fake news (e.g., the U.S. 2020 election) found that prior exposure to misleading information increased the perceived accuracy of fake news (Pennycook et al., 2018). Gerosa et al. (2021) examined how people's education levels relate to their knowledge about COVID-19 and susceptibility to fake news. Interestingly, they found that education level did not play a role in misinformation beliefs, but higher news consumption was associated with lower levels of knowledge and more false beliefs. Lee et al. (2020) found that COVID-19 misinformation exposure was positively associated with misinformation beliefs about COVID-19. As Greenspan and Loftus (2021) suggested, when the misinformation is discussed among experts, journalists, and the general public, the negative effect of misinformation exposure on people's knowledge and beliefs will be stronger. The altered perceptions and beliefs regarding COVID-19 due to acceptance of COVID-19 misinformation as true could result in reluctance to adopt recommended preventive measures and vaccination.

To be specific, as Smith (2017) reported, individuals holding anti-vaccine attitudes are reluctant or even refuse to be vaccinated. The anti-vaccine attitudes are one of the false perceptions that have hindered the collective efforts to control the global pandemic (Loomba et al., 2021). Misinformation prevailing on social media such as "COVID-19 vaccines will affect fertility" or "COVID-19 vaccines will alter human DNA" will likely make people falsely believe that the risk of vaccination is greater than getting infected with the COVID-19 virus (McKinley & Lauby, 2021). Thus, exposure to COVID-19 misinformation will likely enhance anti-vaccine attitudes.

Moreover, the negative effects of misinformation on knowledge were examined in a different context, including in politics and public health. Being exposed to misinformation in the form of fake news about political campaigns resulted in voters knowing less about political issues, candidates, and policies (Maurer & Reinemann, 2006; Munger et al., 2022). Similarly, during an unexpected health crisis, people's learning outcomes could also be negatively affected by popular misinformation due to the impression created by the misinformation that no consensus existed on the topic, which could generate confusion and mistrust. Then, individuals might further disengage from health information seeking, avoid appropriate preventive measures, or form wrong perceptions about pandemic control (Chou et al., 2020). A study of South Korean adults (Lee et al., 2020) found that exposure to COVID-19 misinformation was positively associated with misinformation beliefs, which in turn were positively associated with poor knowledge about COVID-19.

Based on the above review, we proposed that a higher level of misinformation exposure would exert negative effects on people's cognition and attitudes—that it will make them more likely to believe in the misinformation about the COVID-19 pandemic, form an anti-vaccine attitude, and know less about COVID-19. The hypotheses were proposed as follows:

H4a: Exposure to COVID-19 misinformation will be positively associated with misinformation beliefs about the disease.

H4b: Exposure to COVID-19 misinformation will be positively associated with anti-vaccine attitudes.

H4c: Exposure to COVID-19 misinformation will be negatively associated with knowledge on COVID-19.

Modeling the Mediation Effects of Sharing

As we discussed, sharing digital information is the hallmark of engagement on social media (Olmstead et al., 2011). Sharing, for instance, may extend the reach of a message to a large group of people. If the message is false, sharing it with others will lead to greater harms in confusing or misleading more people who receive it. Past research (Bobkowski, 2015; Su et al., 2019) has tested a number of predictors of news sharing behavior, such as perceived issue importance, information utility, and ideological congruence. According to Lee and Ma (2012), those who were driven by gratifications of information seeking, socializing, and status-seeking will be more likely to share news with others.

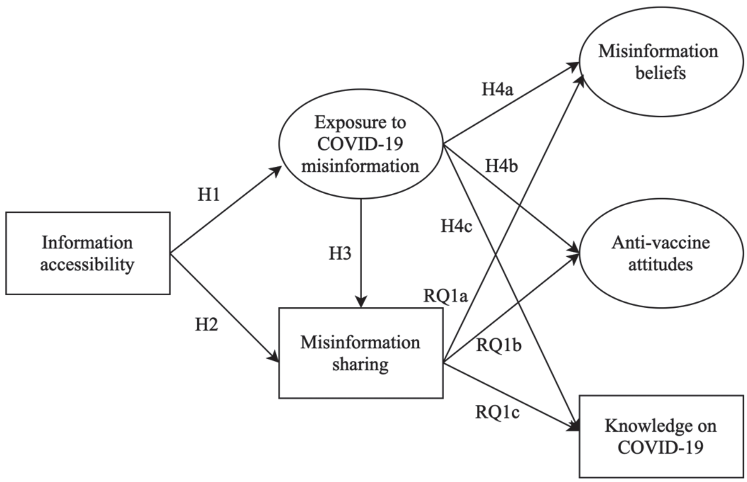
What is more, sharing with the purpose of convincing others that the information may be true will be more likely to accumulate misinformation beliefs and make the information senders further ignore updated factual knowledge (Oyserman & Dawson, 2020). In addition, the social networks in which senders share misinformation also account for a great deal of the possible consequences—when misinformation is shared with people who lack sophisticated media literacy and Internet skills, sharing is likely to consolidate their false beliefs about COVID-19 and prevent them from learning scientific knowledge from media outlets.

In sum, misinformation exposure results in misinformation sharing behavior, which affects false beliefs and correct knowledge. That is, sharing mediates the relationship between misinformation exposure and negative cognitive and attitudinal outcomes. To further explore the indirect effects of misinformation exposure on cognitive outcomes (i.e., misinformation belief, knowledge) and anti-vaccine attitudes through misinformation sharing, we raised a research question:

RQ1: To what extent will sharing misinformation mediate the relationship between exposure to COVID-19 misinformation and a) misinformation beliefs, b) anti-vaccine attitudes and c) knowledge of COVID-19?

Finally, to examine the exposure and effects of COVID-19 misinformation in mainland China, Hong Kong, Singapore, and Taiwan, we further proposed sharing misinformation as the underlying the mechanisms of how exposure affects people's beliefs, attitudes, and knowledge towards the pandemic. As Figure 1 shows, we also incorporated information accessibility in the four societies in the model to investigate how different accessibility under different socio-political systems makes a difference to misinformation exposure, sharing, and cognitive outcomes.

Figure 1 The Hypothesized Model



Method

Online parallel surveys were conducted to collect data in Beijing, China, Hong Kong, Taipei, and Singapore in a two-week period from August 4 to 18, 2021. The fieldwork protocol was approved by Institutional Review Board. Panel members for the sample were recruited by a professional survey company, Dynata. Specifically, respondents were randomly selected from a national panel with an invitation via email to complete a web-based survey. To increase the generalizability of the findings, we employed quota sampling to control for key demographics (age, gender, and ethnicity, only for Singapore) in order to reflect the population characteristics in each city. Given that the target group for this study was adults aged 18 years or older, we could not match the sample exactly to the age range estimated by the local census. Hence, some adjustments were made to the quota ratio to achieve even distribution of age groups in each city. The questionnaire was administered in traditional Chinese in Hong Kong and Taipei, in English in Singapore, and in simplified Chinese in China. Two bilingual researchers translated the complete questionnaire from Chinese to English. A total of 4,094 respondents successfully completed the surveys.

Among the 4,094 respondents, the average age was 40.36 (SD = 13.14, ranging from 18 to 84). Of the sample, gender was evenly distributed, consisting of 48.30% males and 51.70% females. The distribution of gender and age basically matched the general populations of each city. In terms of education background, 18.10% of respondents received high-school level education or lower, 19.20% held a diploma in vocational education, 52.70% obtained a Bachelor's degree, and 10% had a Master's degree or higher. Considering that Singapore is a multi-ethnic society, ethnicity in the Singapore sample was measured. The sample included 74% Chinese, 13.70% Malay, 7.60% Indian, and 4.70% other. Table 2 presents the sample profile by site of study.

Table 2 Sample Profile (N = 4,094)

Factors	Beijing (*N* = 1,033) *M* (*SD*) or %	Hong Kong (*N* = 1,017) *M* (*SD*) or %	Taipei (*N* = 1,019) *M* (*SD*) or %	Singapore (*N* = 1,025) *M* (*SD*) or %
Age, years	39.90 (11.80)	39.48 (12.84)	39.36 (13.08)	42.70 (14.46)
Gender (male) in %	49.30	45.10	47.70	51.10
Education in %				
High school or lower	12.70	25.90	13.70	20.20
Vocational school or non-degree program	22.70	14.40	16	23.80
Bachelor's degree	59.40	51.60	53.50	45.90
Master's degree or higher	5.20	8.10	16.80	10.10
Income in %				
US$0–1,566 (Beijing) US$0–2,564 (Hong Kong) US$0–1,079 (Taipei) US$0–2,189 (Singapore)	8.10	10.80	8.10	13.80
US$1,567–3,133 (Beijing) US$2,565–5,128 (Hong Kong) US$1,080–1,797 (Taipei) US$2,190–5,109 (Singapore)	27.80	26.90	14.90	30.20
US$3,134–4,700 (Beijing) US$5,129–7,692 (Hong Kong) US$1,798–2,516 (Taipei) US$5,110–8,029 (Singapore)	25.30	26.90	15	26.40
US$4,701–6,266 (Beijing) US$7,693–10,257 (Hong Kong) US$2,517–3,235 (Taipei) US$8,030-10,949 (Singapore)	19.40	20.70	16	15.60
US$6,267–7,833 (Beijing) US$10,258–12,821 (Hong Kong) US$3,236–3,954 (Taipei) US$10,950–13,869 (Singapore)	13.70	8.40	22	7.90
US$7,834 or above (Beijing) US$12,822 or above (Hong Kong) US$3,955 or above (Taipei) US$13,870 or above (Singapore)	5.70	6.40	24	6.10

Measures and Scales

Information accessibility

To construct the index of the information accessibility scale concerning the four societies in our study, five broad indices were used to build a digital information accessibility index in each society. They were (1) Internet accessibility, (2) the state of development in information and communication technology, (3) the global outlook in terms of development and competitiveness, (4) degree of personal freedoms, and (5) linguistic diversity (e.g., whether bilingual or multilingual).

Based on the constructed information accessibility index, the level of information accessibility in each society was ranked on a scale of 1 to 3, with "1" representing the least accessibility and "3" indicating the most accessibility.

Exposure to COVID-19 misinformation

Five items were used to measure how often the respondents were exposed to COVID-19 misinformation on popular social media platforms (e.g., Facebook, Twitter, and Weibo). A 4-point Likert scale (1 = never, 4 = often) was used. The items were selected from a pool of false messages or posts that circulated online during the pandemic; they were either fact-checked or refuted by established sources (e.g., World Health Organization, 2021). For example, 5G mobile networks can transmit the COVID-19 virus; Asians are more likely to be infected with COVID-19 virus than others; and non-inactivated COVID-19 vaccines will alter human DNA. Responses were averaged to create a combined measure of exposure to COVID-19 misinformation (M = 1.82, SD = .78, Cronbach's α = .88).

COVID-19 misinformation sharing

Using the same 4-point scale (1 = never, 4 = often), respondents were then asked to indicate how often they shared some of the COVID-19 misinformation that was used in the exposure measure (M = 2.23, SD = 1.07).

Misinformation beliefs

Respondents rated the extent to which they believed five statements concerning COVID-19 were true on a 4-point scale (1 = definitely false, 4 = definitely true). The statements were: (1) COVID-19 virus can spread through 5G mobile networks; (2) drinking bleach can kill COVID-19 virus; (3) eating garlic can prevent COVID-19 infection; (4) COVID-19 vaccines will affect fertility; and (5) COVID-19 vaccines will alter human DNA.

Responses were averaged to form an index of misinformation beliefs. The higher score represents a stronger belief in COVID-19 misinformation (M = 1.82, SD = .96, Cronbach's α = .90).

Anti-vaccine attitudes

Adapted from Shapiro et al. (2016), respondents answered three items on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree): (1) People are deceived about the effectiveness of COVID-19 vaccines, (2) Data about COVID-19 vaccine effectiveness is fabricated, and (3) People are deceived about COVID-19 vaccine safety. Responses were averaged to create a measure of anti-vaccine attitudes. A higher score indicates a more negative evaluation of COVID-19 vaccines (M = 2.50, SD = 1.10, Cronbach's α = .90).

Knowledge of COVID-19

Respondents' knowledge on COVID-19 was assessed using another five questions adapted from established sources (Centers for Disease Control and Prevention, 2021; World Health Organization, 2021). The factual questions include who the Director-General is of WHO (World Health Organization) in fighting COVID pandemic, the approximate death rate of COVID-19, and what is the new variant of COVID-19 virus, to list a few. Using the multiple-choice format, respondents were requested to choose one answer that they thought was correct from four options. They received one point from each correct answer and zero points for selecting the incorrect answer or "don't know" option. The total score for five questions yielded an index of knowledge about COVID-19. The higher the score, the more knowledgeable (Min = 0, Max = 5, M = 2.64, SD = 1.53, Cronbach's α = .61).

Results

To examine how exposure to and sharing of COVID-19 misinformation differed across the four societies with different levels of digital information accessibility, a series of one-way analyses of variance (ANOVA) was performed. Results revealed that respondents from Beijing, Hong Kong, Singapore, and Taiwan differed significantly in exposure to COVID-19 misinformation [$F(3, 4090) = 88.51$, $p < .001$]. The post-hoc Scheffe test indicated that Beijing respondents were most likely to view COVID-19 misinformation ($M = 2.15$, $SD = .83$), followed by respondents in Hong Kong ($M = 1.72$, $SD = .68$), Singapore ($M = 1.70$, $SD = .81$) and Taipei ($M = 1.69$, $SD = .71$).

Regarding sharing of COVID-19 misinformation with others, the differences among the four societies were also found to be significant [$F(3, 4090) = 70.94$, $p < .001$]. Results of the post-hoc Scheffe test showed that the Beijing respondents also shared more misinformation ($M = 2.61$, $SD = 1.09$) than did their counterparts in Hong Kong ($M = 2.21$, $SD = 1.01$) and Singapore ($M = 2.11$, $SD = 1.01$). Respondents in Taiwan shared misinformation the least ($M = 1.98$, $SD = 1.04$).

H1 and H2 hypothesized a negative relationship between information accessibility and exposure to/sharing COVID-19 misinformation. To test them, a series of hierarchical regression analyses were performed. For control purposes, the influences of demographic variables (i.e., age, gender, education, income) were entered as the first block. Based on causal order, information accessibility was entered in the second block, followed by exposure to and sharing COVID-19 misinformation in the third block. As shown in Table 3, information accessibility was significantly but negatively associated with exposure to COVID-19 misinformation ($\beta = -.22$, $p < .001$). The results also showed that information accessibility was negatively related to sharing COVID-19 misinformation ($\beta = -.09$, $p < .001$). H1 and H2 were both supported.

Consistent with past research (Li et al., 2020; Lo et al. 2022), these results suggest that in a society where access to digital information is limited or restricted, people who are worried about the pandemic use the social media to obtain updated information about the COVID-19 pandemic will view and share all sorts of information about the pandemic, including misinformation, to meet their needs for information. On the other hand, in societies where information access is free and unrestricted, respondents who are used to exposing themselves to all sorts of information online will ignore faulty and inaccurate information.

Table 3 Results of Hierarchical Regression Analyses (N = 4,094)

Predictors	EM	SM	MB	AVA	KN
Block 1					
Age	–.11***	–.07**	.03	.03	.14***
Male	.06***	–.01	–.03*	–.02	.14***
Education	.04*	.003	–.04**	–.01	.22***
Income	–.10***	–.08***	–.00	–.12***	.24***
Adjusted R^2	.02	.02	.01	.04	.15
Block 2					
Information accessibility	–.22***	–.09***	.15***	.33***	.04**
Adjusted R^2 incremental	.05	.02	0	.06	0
Block 3					
Misinformation exposure	—	.34***	.51***	.30***	–.05***
Misinformation sharing			.17***	.12***	–.13***
Adjusted R^2 incremental	—	.11	.32	.12	.02
Total adjusted R^2	—	.15	.33	.22	.17

Notes. EM: Exposure to misinformation; SM: Sharing misinformation; MB: Misinformation beliefs; AVA: Anti-vaccine attitudes; KN: Knowledge of COVID-19; All values are standardized regression coefficients. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

H3 stated that the relationship between COVID-19 misinformation exposure and sharing behavior would be positive. As regression results in Table 3 show, exposure to COVID-19 misinformation was positively associated with COVID-19 misinformation sharing (β = .34, p < .001), thereby supporting H3. The result indicates that the more respondents viewed COVID-19 misinformation online, the more they were inclined to share such information with others by virtue of forwarding or reposting it to people in their social media groups.

With regard to the harmful effects of exposure to COVID-19 misinformation on cognitive and attitudinal outcomes, we predicted in H4 that exposure would be positively associated with a) misinformation beliefs, and b) anti-vaccine attitudes, but c) negatively associated with knowledge about COVID-19. To test H4, more regression analyses were performed. As shown in Table 3 (the last three columns), after controlling for demographics and information accessibility, exposure to COVID-19 misinformation was significantly associated with misinformation beliefs (β = .51, p < .001) and anti-vaccine attitudes (β = .30, p < .001). As expected, it was significantly but negatively associated with knowledge of COVID-19 (β = –.05, p < .001). H4 was supported. These results indicate that the higher the level of exposure to COVID-19 misinformation, the greater harms on respondents' cognition and attitudes in terms of having misbeliefs about the pandemic, being anti-vaccine attitudinally, and have less correct knowledge about COVID-19.

Further, to test the mediation effect of COVID-19 misinformation sharing on the relationship between misinformation exposure and cognitive and attitudinal outcomes, the concerns of RQ1, a series of mediation analyses were conducted using PROCESS macro Model 4 (Hayes, 2017), while controlling for demographics. We estimated bias-corrected 95% confidence intervals (CIs) with 5,000 bootstrap samples.

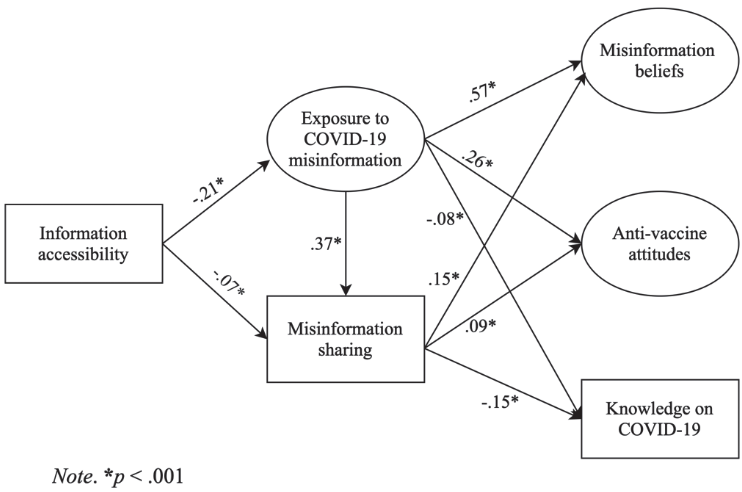
The results showed that misinformation sharing was a significant mediator of the relationship between misinformation exposure and misinformation beliefs (b = .07, SE = .01, 95% CI = [0.05, 0.08]). Specifically, misinformation exposure positively predicted misinformation sharing (b = .49, t = 24.38, p < .001), which in turn enhanced misinformation beliefs (b = .14, t = 10.83, p < .001). Moreover, the indirect effect of misinformation exposure on anti-vaccine attitudes through misinformation sharing was significant (b = .04, SE = .01, 95% CI = [0.03, 0.06]), which means, the increased exposure to misinformation caused by misinformation sharing led to stronger anti-vaccine attitudes (b = .09, t = 5.37, p < .001). Additionally, misinformation sharing significantly mediated the effect of misinformation exposure on knowledge (b = –.09, SE = .01, 95% CI = [–0.12, –0.07]]. The increased level of misinformation exposure resulting from misinformation sharing had a negative impact on respondents' correct knowledge on COVID-19 (b = –.19, t = –8.76, p < .001). Together, these results validated the mediating role of misinformation sharing.

Finally, to uncover the underlying process of how exposure and sharing affected people's beliefs, attitudes, and knowledge of the pandemic across the four societies that differ in information accessibility on digital media, the structural equation modelling (SEM) in Amos 24 was conducted. The model fit was evaluated on the following criteria: For a good model fit, the values for the comparative fit index (CFI) and Tucker-Lewis Index (TLI) should be greater than .95, the value for the root mean square error of approximation (RMSEA) should be less than .06 (Hu & Bentler, 1999), the p-value of chi-square (χ^2) value obtained should be non-significant (p >

.05), and the relative chi-square (χ^2/df) should be less than 2 (Ullman, 2001).

Figure 2 summarizes the SEM results, which showed that although the chi-square for the model was significant, (χ^2 = 2049.76, df =89, χ^2/df= 23.03, $p < .001$), the comparative fit index (CFI = .95), the normal fit index (NFI = .94), the Tucker Lewis index (TLI = .93), and the root mean square error of approximation (RMSEA = .073) indicated that the model fit was acceptable. The model explained 4.20% of the variance in exposure to misinformation, 15.70% of the variance in sharing misinformation, 9.40% of the variance in anti-vaccine attitudes, 41.70% of misinformation beliefs, and 3.80% of knowledge of COVID-19.

Figure 2　Structural Equation Model with Standardized Coefficients (N = 4,094)



Conclusion and Discussion

In responding to the pressing need to understand multi-level factors that influence the diffusion and harm of the widespread infodemic during the COVID-19 pandemic (Chou et al., 2020; Lee & Shin, 2021), this large-scale cross-societal analysis of misinformation on COVID-19 in China, Hong Kong, Taiwan, and Singapore shows that from a stimulus-response perspective, viewing and sharing of misinformation imposed a harmful or negative impact on citizens' beliefs, vaccine attitudes, and knowledge—the greater their exposure to and sharing of misinformation, the stronger were their beliefs about the misinformation and their anti-vaccine attitudes, and the less knowledgeable they were about COVID-19.

These findings expand past research (e.g., Cho et al., 2009; Eveland, 2001) on the positive role of media for citizens to learn about public affairs, especially the facilitating role of social media in gaining health knowledge (Ghalavand et al., 2022). In the context of the global pandemic, widely circulated misinformation about COVID-19 on social media platforms seemed to impede the public's acquisition of factual and accurate knowledge that would help it build the necessary literacy to cope with the disease. Instead of empowering citizens with correct knowledge, misinformation on COVID-19 appears to have a *delearning effect*, a new ground that points the direction for more follow-up research.

Further, more insight is gained from the finding that sharing misinformation on COVID-19 mediates the relationship between exposure and negative cognitive and attitudinal effects. That is, the harm of exposure to COVID-19 misinformation is transmitted through sharing it. The more people shared with others, the greater the harmful effects on misbeliefs, anti-vaccine attitudes, and incorrect knowledge, creating a sort of cascading effect. These patterns reveal the underlying process of how sharing functions as a critical link between encountering misinformation on social media and the negative effects on cognition and attitude. As sharing is a characteristic of social media communication, this finding suggests that the harm of consuming misinformation on COVID-19 diffused on social media platforms was greater than on other media outlets such as e-newspapers. Also, the finding has implications for containing the circulation of misinformation on social media; spotting the super spreader is critical to stopping the spread.

More importantly, the negative effects of misinformation on COVID-19 in society appear to be *differential*, subject to the larger societal context—the greater information accessibility, the less exposure and sharing as well as fewer negative cognitive and attitudinal effects. Conversely, restricted access leads to greater exposure to infodemic. Furthermore, the less information accessibility, the greater exposure and sharing, which in turn is associated with stronger negative cognitive and attitudinal effects. This key finding from the four societies with markedly different media environments underscores the shaping role of digital information accessibility. We conclude that during the on-going public health crisis, the negative effects of misinformation about COVID-19 were less in societies with free access because citizens can access a diverse range of information to stay informed. They are also less likely to share misinformation. On the other hand, in societies with restricted access to digital information, timely and accurate information about COVID-19 outbreaks was scarce. Under the circumstance of information scarcity, citizens tended to seek all the information that they can find and share the limited information to those around them, including misinformation.

Taken together, these findings suggest that societies with free access to digital information provide their citizens with rich information resources to cope with a public health crisis, and they tend to be harmed less by misinformation. Thus, the mantra that "knowledge is power" applies. In comparison, the benefit of online information is less when accessibility is restricted. As our findings show, the harmful effects of misinformation can be greater on citizens in information-poor societies.

What, then, have we learned from this cross-societal study? Access and transparency turned out to be the necessary social condition for understanding the diffusion and consequences of encountering misinformation about COVID-19 on social media. The results of this study strongly support the idea that public health authorities and medical experts should maintain open and transparent communication with the public, especially on digital media platforms. As soon as misinformation about COVID-19 appears on social media platforms, factual and evidence-based information should be presented quickly so that the general public can fact-check user-generated content to sort out inaccurate or false information. Timely and accurate information published from authoritative sources, such as health agencies, should reduce the chance of misinformation that affects the public's beliefs, vaccine attitudes and knowledge.

Theoretically, these key findings contribute to the growing research on the impact of the infodemic in the four societies by integrating environmental social factors (e.g., access to digital information, and media environment) with individual-level social-psychological variables in accounting for the differential harms of misinformation on COVID-19. That is, by situating the relationships of information accessibility, exposure and sharing of COVID-19 misinformation, and cognitive and attitudinal outcomes in the four societies, our findings provide a comprehensive understanding of the underlying societal factors—free flow of digital information—that account for the differential harms of misinformation on citizens' cognition and attitudes in the four societies.

Nevertheless, the links and relationships tested in our SEM model should not be interpreted as causal due to the one-shot design. Hence, a limitation of the study. Future research should attempt a longitudinal design to collect tracking data, which would demonstrate the causal relationships among societal factors, exposure, sharing and the impact of pandemic misinformation. Another limitation concerns the index of information accessibility, which needs to be further tested in societies with greater differences (e.g., Chinese societies vs. Islamic societies) or similarities (e.g., Confucian societies in East Asia) in information accessibility to fully demonstrate its validity and applicability. More multi-cultural and cross-societal comparative studies involving a greater number of societies will be desirable in future research to theorize the role of digital information accessibility in shaping the relationships of exposure to misinformation and its impact on cognition and attitude.

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