Coping with COVID-19 using contact tracing mobile apps

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Abstract

Purpose – To cope with the COVID-19 pandemic, contact tracing mobile apps (CTMAs) have been developed to trace contact among infected individuals and alert people at risk of infection. To disrupt virus transmission until the majority of the population has been vaccinated, achieving the herd immunity threshold, CTMA continuance usage is essential in managing the COVID-19 pandemic. This study seeks to examine what motivates individuals to continue using CTMAs.

Design/methodology/approach – Following the coping theory, this study proposes a research model to examine CTMA continuance usage, conceptualizing opportunity appraisals (perceived usefulness and perceived distress relief), threat appraisals (privacy concerns) and secondary appraisals (perceived response efficacy) as the predictors of individuals' CTMA continuance usage during the pandemic. In the United States, an online survey was administered to 551 respondents.

Findings – The results revealed that perceived usefulness and response efficacy motivate CTMA continuance usage, while privacy concerns do not.

Originality/value – This study enriches the understanding of CTMA continuance usage during a public health crisis, and it offers practical recommendations for authorities.

Keywords COVID-19, Contact tracing, Mobile application, Continuance usage, Coping theory

Paper type Research paper

1. Introduction

At the onset of the COVID-19 pandemic, many countries deployed contact tracing mobile apps (CTMAs) to prevent the spread of the coronavirus (Rowe *et al.*, 2020; Trang *et al.*, 2020). Installed on smartphones, these apps use Bluetooth or GPS signals to detect when two users come into close contact with each other (such as within two meters for 15 min) (Ferretti *et al.*, 2020; Trang *et al.*, 2020). Once an individual has tested positive for infection, these apps can report their case anonymously and alert all other users who had been in close contact with the infected person, allowing exposed users to quarantine or arrange a test and, thus, preventing further transmission (Ferretti *et al.*, 2020). However, such apps' success in controlling the spread of COVID-19 depends on their use by individuals. To sufficiently disrupt coronavirus infection, at least 56% of a country's population, as Hinch *et al.* (2020) estimated, should use such apps. Many European countries (e.g. Germany, Finland and France) and the United States have deployed CTMAs on a voluntary basis (Rowe *et al.*, 2020; Trang *et al.*, 2020). It is

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necessary for authorities to understand how to motivate individuals to keep using CTMAs during the pandemic, which is vital for achieving the goal of a high rate of CTMA use in a country's population to disrupt coronavirus infection, especially if the CTMA use is on a voluntary basis. Therefore, understanding the factors that may facilitate or obstruct citizens' CTMA continuance usage is crucial.

Recent studies have examined individuals' CTMA usage from different theoretical perspectives, such as privacy concerns and diffusion of innovation theory (Lin *et al.*, 2021), unified theory of acceptance and use of technology (UTAUT) (Ojo and Rizun, 2021; Walter Thiée *et al.*, 2021), privacy calculus model and herding heuristics (Wagner *et al.*, 2021), app specifications (Trang *et al.*, 2020) and critical social theory (Rowe *et al.*, 2020). However, these studies focused only on adoption and largely ignored continuance usage, which – unlike adoption's focus on the first-time use of apps – emphasizes the long-term use (Bhattacherjee, 2001). The initial adoption does not always guarantee continuance usage (Bhattacherjee, 2001; Yan *et al.*, 2021). Individual users may stop using CTMAs after using it for some time. For instance, a Corsair study on National Health Service (NHS) COVID-19 App in the United Kingdom has reported that 2% of users deleted the app and 72% of users switched off the contact tracing function in the first two months since the app was launched in September 2020 (Potts, 2020). The reasons for CTMA continuance usage could be different from the ones explaining initial adoption. Users' continuance usage could be influenced by their prior information systems (IS) use experience such that their use experience could lead to their perception change on IS use, such as post-expectation regarding usefulness, confirmation of pre-expectations following actual use and satisfaction with prior IS use (Bhattacherjee, 2001). Thus, recent research findings on the antecedents of CTMA adoption cannot fully explain the continuance usage of CTMA. To disrupt virus transmission until the majority of the population has been vaccinated, achieving the herd immunity threshold, people's continuance usage of CTMA is essential in managing the COVID-19 pandemic (Wymant *et al.*, 2021). Moreover, since global COVID-19 infections keep spreading in the world (World Health Organization, 2021a), understanding how to promote CTMA continuance usage is paramount to managing the COVID-19 pandemic.

Additionally, prior studies have examined CTMA adoption from the view of benefits and threats and highlighted privacy concerns as a threat inhibiting individuals' adoption of CTMA (Chan and Saqib, 2021; Lin *et al.*, 2021) but largely ignored the role of users' assessment of coping options available to respond to privacy issues related to CTMA in explaining their CTMA continuance usage during the public health crisis. The significance of privacy protection regarding CTMA has been highlighted in the literature (Riemer *et al.*, 2020). Privacy-preserving techniques have also been applied in CTMA development to protect CTMA users' privacy, such as anonymity and decentralization (Apple and Google, 2021). However, it is not clear how CTMA users' assessments regarding the coping resources for privacy protection in their CTMA use will affect their continuance usage of CTMA in the public health crisis. Hence, it is necessary to investigate whether users' assessments of coping resources related to privacy protection can predict their continued usage of CTMA, in addition to users' perceived benefits and threats of using CTMAs.

Furthermore, IS researchers have developed an extensive body of knowledge on IS continuance (Bhattacherjee, 2001). Their research contexts mainly focus on normal daily life or work environments. Mobile app continuance usage during a public health crisis might have different causes than IS continuance usage in daily life or work-environment contexts. CTMA continuance usage during the pandemic may be influenced by CTMA as a public good (Rehse and Tremöhlen, 2022; Riemer *et al.*, 2020). A public good is non-rivalrous and non-exclusive; everyone can benefit from it, and one person's use does not obstruct another's (Riemer *et al.*, 2020). Therefore, some individuals may consider more about the social impact of CTMA use rather than their personal costs, thus continuing to use CTMAs during a public health crisis to contribute to the public goods (Campos-Mercade *et al.*, 2021; Riemer *et al.*,

2020). For instance, some people may be willing to sacrifice their private information to help slow the spread of COVID-19 and protect others' health during the unprecedented and emergent public health crisis. The knowledge on IS continuance in daily life or work environment might not explain individuals' CTMA continuance usage during the COVID-19 pandemic. However, research on citizens' CTMA continuance usage during a public health crisis is limited in the literature. Therefore, it is needed to investigate CTMA continuance usage to explain IS continuance usage during unprecedented situations.

To close this research gap, this study examines the factors that determine CTMA continuance usage during the COVID-19 pandemic by developing a research model based on coping theory. According to coping theory, how people cope with a stressful situation depends on a combination of opportunity appraisals (i.e. perceived usefulness and perceived distress relief), threat appraisals (i.e. privacy concerns) and secondary appraisals (i.e. perceived response efficacy) (Beaudry and Pinsonneault, 2005; Lazarus and Folkman, 1984). CTMAs can be an effective coping tool for the pandemic, but it does entail uncertainties; to guide their app use during the pandemic, users cannot draw from or build on their prior knowledge of technology use in daily life and work environments. Thus, CTMA users may appraise the benefits and threats of CTMA use as well as the coping resources for privacy protection over their usage based on first-time use experience to decide their continuance usage of CTMAs. Therefore, to investigate CTMA continuance usage, this study deemed a research model based on coping theory to be appropriate.

The proposed research model was tested using the survey data collected in the United States (n = 551). The findings demonstrate that CTMA continuance usage is determined by users' perceived usefulness (opportunity appraisals) and perceived response efficacy (secondary appraisals). Thus, this study contributes to the extant literature on IS continuance usage by using the coping theory to explain CTMA continuance usage and distinguishing differences between opportunity appraisals (i.e. perceived usefulness and perceived distress relief), threat appraisals (i.e. privacy concerns) and secondary appraisals (i.e. perceived response efficacy) as antecedents that determine individuals' CTMA continuance usage during the COVID-19 pandemic. In doing so, this study offers an in-depth appreciation of how individuals' different appraisals regarding CTMAs determine their continuance usage of CTMAs to cope with the pandemic.

2. Literature review

2.1 Research on the use of contact tracing mobile apps (CTMA) during the pandemic

Recently, CTMA use has attracted considerable research attention in many domains, with researchers focusing on factors that compel individuals to install and use such apps from different theoretical lenses. The determinants of this adoption can be grouped into two main types: (1) usage benefits and (2) threats to usage. Regarding usage benefits, recent CTMA studies have employed traditional IS theories to examine what determines user adoption. For instance, centering the diffusion of innovations theory, Lin *et al.* (2021) found that relative advantage positively influences users' CTMA adoption. Also, the initial research on these apps has highlighted their dual benefit appeal for not only individuals (such as informing them about high-risk contacts) but also society (informing other people about close contact with an infected person), which are important motivations for the adoption of these apps (Trang *et al.*, 2020).

The most significant threats to CTMA adoption—since it involves a compromise between privacy and health—are privacy concerns and risks (Chan and Saqib, 2021; Lin *et al.*, 2021). People are afraid to disclose their private information, such as COVID-19 test results, exposure to infection, location and their communities' or social groups' COVID-19 status; moreover, they worry about potential hacking and data misuse by app service providers or governments (Riemer *et al.*, 2020). Such privacy risks, as Wagner *et al.* (2021) found,

negatively affect individuals' willingness to adopt these apps. To reduce this reluctance, apps that offer a high level of privacy protection and user data confidentiality are crucial (Bhattacharya and Ramos, 2021; Lin *et al.*, 2021; Trang *et al.*, 2020).

Prior CTMA studies in IS fields have principally focused on these apps' adoption (see Table 1), largely ignoring continuance usage despite recent research stating that users' continued app use is important for controlling the pandemic before vaccines achieve sufficient population-level protection (Wymant *et al.*, 2021). Additionally, although recent research has examined the benefits and threats of using such apps, few studies have explored how users' assessment of available coping resources for privacy issues over CTMA use affects their continuance usage of CTMA. It is still unclear what is the role of users' assessments of available coping resources for privacy issues over their CTMA use in explaining their continuance usage of CTMA in the public health crisis. As per previous literature, coping theory may help explain individuals' coping responses to stressful events, based on a combination of opportunity, threat and secondary appraisals (Beaudry and Pinsonneault, 2005; Lazarus and Folkman, 1984). This draws attention to the necessity of exploring what motivates CTMA continuance usage from the coping theory perspective.

2.2 Coping theory

Rooted in psychology, coping theory aims to explain how people cope with stressful situations and perform effective and appropriate coping behaviors. Lazarus and Folkman (1984, p. 141) defined coping as "constantly changing cognitive and behavioral efforts to manage specific external and internal demands that are appraised as taxing or exceeding the resources of the person." Individuals' coping responses, according to coping theory, are based on their cognitive appraisals—that is, their evaluations of whether a stressful event is relevant to them and, if so, how (Beaudry and Pinsonneault, 2005; Lazarus and Folkman, 1984). The cognitive appraisal process comprises two steps: primary appraisals and secondary appraisals. *Primary appraisals* refer to an individual's evaluation of whether an encounter causes potential benefits or harms. It, in turn, comprises *opportunity appraisals* and *threat appraisals*. *Opportunity appraisals* refer to an individual's assessment of whether potential consequences are positive (Lazarus and Folkman, 1984). If they believe an event allows them to achieve beneficial outcomes, they tend to perform such behavioral responses (Bala and Venkatesh, 2016; Gong *et al.*, 2020). Meanwhile, *threat appraisals* refer to an individual's evaluation of whether an event's anticipated consequences are negative (Lazarus and Folkman, 1984). If they believe an event will bring unfavorable outcomes, they will likely perform avoidant behavioral responses (Bala and Venkatesh, 2016; Lazarus and Folkman, 1984). Encounters are complicated and frequently perceived as encompassing both opportunities and threats. *Secondary appraisals* refer to an individual's cognitive assessment of whether coping resources are available to respond to an encounter (Beaudry and Pinsonneault, 2005; Lazarus and Folkman, 1984). Such assessment determines the coping options available to individuals and their sense of control over the encounter (Fadel and Brown, 2010; Lazarus and Folkman, 1984).

Coping theory's three types of appraisals have been used to examine IS adaptation in numerous contexts, such as the use of new IT in work environments (Beaudry and Pinsonneault, 2005), wearable healthcare devices (Marakhimov and Joo, 2017), mandatory IT use (Bhattacherjee *et al.*, 2018) and mobile payments (Gong *et al.*, 2020). For instance, in the context of mobile payment services, Gong *et al.*, (2020) found that opportunity appraisals (measured by perceived value) and secondary appraisals (measured by perceived controllability) positively influence individuals' intentions to use mobile payment services, whereas threat appraisals (measured by perceived threat) negatively influence use intentions. Table 2 summarizes previous studies on the three types of cognitive appraisals in the IS field.

Table 1. Summary of studies on contact tracing mobile apps (CTMA) from the information systems (IS) field

Reference	Focus	Theory	Method	Findings
Bhattacharya and Ramos (2021)	Privacy and confidentiality related to CTMA	/	Qualitative study	CTMA should emphasize privacy protection and data confidentiality
Bitzer *et al.* (2021)	The algorithmic transparency of CTMA	Algorithmic transparency	Experiment	Algorithmic transparency disclosure is positively and significantly related to app selection, user comprehension and trust
Chan and Saqib (2021)	Unwillingness to download and use CTMA	/	Experiment	-COVID-19 concerns decrease intentions to download and use CTMA -Privacy concerns and social conservatism mediate the impact of COVID-19 concerns on intentions to download and use CTMA
Lin *et al.* (2021)	CTMA use intentions	-Diffusion of innovation theory -Privacy concerns	Survey	-Trust beliefs, compatibility and relative advantage positively affect citizens' adoption intentions -Privacy concerns negatively influence trusting beliefs and positively affect risk beliefs
Ojo and Rizun (2021)	CTMA use	UTAUT	Computational grounded theory	The top-five most prevalent topics are the need for tracing apps and mandatory use, tracing apps' launch supported by private-sector organizations, anonymity in reporting positive test results, a new business continuity tracker app for employee safety and apps for tracking symptoms
Riemer *et al.* (2020)	IT governance	-IT governance	Conceptual paper	The selection of approaches to IT governance is influenced by factors regarding health risks to the population, prior pandemic experience, societal culture and values, governments' role in societies and trust in governments and technologies
Rowe *et al.* (2020)	Failure in CTMA design and adoption	-Critical social theory	Critical research methodology	Alienation from the natural and social reality regarding the COVID-19 pandemic leads to inadequate app design and adoption failure
Walter Thiée *et al.* (2021)	CTMA use	UTAUT	Survey	-The factors influencing individuals' intentions concerning CTMA include ethical considerations, social influence, effort expectancy, popular opinions related to COVID-19 and CTMA -Users' behavioral intentions positively affect their actual app use
Trang *et al.* (2020)	CTMA acceptance	-App specifications	Experiment	-Convenience and privacy design positively influence mass acceptance, whereas self-benefit appeal and self-societal-benefit appeal decrease mass acceptance -Mass acceptance varies across groups
Urbaczewski and Lee (2020)	CTMA use	/	Difference in difference	-CTMA are highly and significantly associated with a decreased spread of COVID-19
Wagner *et al.* (2021)	Use intentions and continuance intentions	-Privacy calculus model -Herding heuristics	Longitudinal online survey	-Privacy risks negatively affect use intentions, while perceived benefits and imitating others positively influence use intentions -Updated benefits and imitating others positively affect continuance intentions

Note(s): IT = information technology; CTMA = contact tracing mobile apps; UTAUT = unified theory of acceptance and use of technology;/= no theory applied

We selected coping theory as the theoretical framework for several reasons. First, it highlights cognitive appraisal's role in determining coping responses to stressful situations (Beaudry and Pinsonneault, 2005; Lazarus and Folkman, 1984). This theory can

Table 2.
Summary of studies that used coping theory in the information systems (IS) field

Reference	Context	Method	Appraisals	Outcomes
Bala and Venkatesh (2016)	IT adaptation	Field study	-Primary appraisal -Perceived opportunity -Perceived threat -Secondary appraisal -Perceived controllability	-Avoidance -Exploration-to-revert -Exploration-to-innovate -Exploitation
Beaudry and Pinsonneault (2005)	Information technology (IT) use	Qualitative method (interviews, annual reports and job descriptions)	-Primary appraisal -Opportunity -Threat -Secondary appraisal -IT control	-Minimization of an IT event's negative consequences -Individual efficiency and effectiveness -Restoring personal emotional stability
Bhattacherjee *et al.* (2018)	Mandatory IT use	Interviews	-Primary appraisal -Opportunity -Threat -Secondary appraisal -IT control	-Reluctant response -Engaged response -Deviant response -Compliant response
Chen *et al.* (2019)	Mobile shopping applications	Experiment	-Primary appraisal -Perceived information overload -Perceived intrusiveness -Perceived reward -Secondary appraisal -Perceived information control -Mobile computing self-efficacy	-Discontinuance behavior
D'Arcy *et al.* (2014)	Security-related stress (SRS)	Survey	-Primary appraisal -Secondary appraisal	-Information security policy violation intentions
Christophe *et al.* (2011)	Disruptive IT	Experiment	-Primary appraisal -Opportunity -Threat -Secondary appraisal -IT control	-Benefitsatisficing -Benefitmaximizing -Self-preservation -Disturbance handling

(*continued*)

Reference	Context	Method	Appraisals	Outcomes
Gong *et al.* (2020)	Mobile payments	Survey	-Primary appraisal -Perceived value -Perceived threat -Secondary appraisal -Perceived controllability	-Intentions to use mobile payment services
Liang *et al.* (2019)	IT security	Experiment	-Perceived threat -Perceived avoidability	-Inward emotion-focused coping -Problem-focused coping behavior -Outward emotion-focusedcoping
Marakhimov and Joo (2017)	Wearable healthcare devices	Survey	-Primary appraisal -Challenge -Threat	Extended use
Nach and Lejeune (2010)	IT challenges to users' identity	Qualitative method (narrative synthesis)	-Primary appraisal -Positive emotional response -Negative emotional response -Secondary appraisal -Controllability	-Anti-identity -Reinforced identity -Ambivalent identity -Redefined identity
Wu *et al.* (2017)	New IT systems	Survey and panel data	-Giving-network closure -Seeking-network closure	-Post-adoption IT use -Cognitive adaptation -Behavioral adaptation -Affective adaptation

Table 2.

help explain how individuals appraise stressful situations and how their appraisals form their behavioral responses (Folkman and Moskowitz, 2004; Salo *et al.*, 2020). Second, this theory offers a theoretical framework with which to understand individual behaviors in psychology and post-adoption use in IS (Beaudry and Pinsonneault, 2005; Fadel and Brown, 2010; Salo *et al.*, 2020). This complements this study's aims. Therefore, following the previous literature, coping theory was used in this study to investigate continuous usage of CTMA.

3. Research model and hypothesis development

3.1 Research model development

Users' cognitive appraisals help explain their behavioral responses to stressful events (Beaudry and Pinsonneault, 2005; Lazarus and Folkman, 1984; Salo *et al.*, 2020). The research model was built based on coping theory to study how the three types of cognitive appraisals affect users' behavioral responses to CTMA. Specifically, perceived usefulness and perceived distress relief were conceptualized as *opportunity appraisal*, privacy concerns as *threat*

appraisal, perceived response efficacy as *secondary appraisal* and continuance usage as a *behavioral response*. The definitions of the five constructs are defined in Table 3.

In this study, we adopted variables (e.g. perceived usefulness, perceived distress relief, privacy concerns and perceived response efficacy) from prior studies because the coping theory does not provide specific constructs to measure appraisals. As suggested by prior literature (Bhattacherjee *et al.*, 2018), we accommodated existing relevant variables in the literature to reflect different appraisals and to fit to the CTMA context. Some studies have accommodated the IS continuance enablers (e.g. perceived usefulness) (Bhattacherjee, 2001; Yan *et al.*, 2021) and inhibitors (e.g. privacy concerns) (Zhou, 2016; Zhou and Li, 2014) to reflect users' primary appraisals of opportunity and threat, respectively (Bhattacherjee *et al.*, 2018). Prior studies have also adopted different variables regarding the external resources to deal with IS usage from other theories, such as facilitating conditions, to uncover users' assessments of available resources to respond to IS usage (Bhattacherjee *et al.*, 2018; Venkatesh *et al.*, 2003). Even though these variables (e.g. perceived usefulness, perceived distress relief, privacy concerns and perceived response efficacy) are developed as part of different theoretical paradigms, the prior research applying coping theory shows that they could also be applied in our study to reflect users' different cognitive appraisals under the theoretical framework of the coping theory.

Specifically, in this study, opportunity appraisals reflect the degree to which a user perceives using CTMA to help achieve beneficial outcomes (Bala and Venkatesh, 2016; Beaudry and Pinsonneault, 2005). Past IS literature has used perceived usefulness (Bhattacherjee *et al.*, 2018) and stress reduction (Cheikh-Ammar, 2020; Eisel *et al.*, 2014) to reflect the beneficial outcomes of using an IS. Since CTMA can offer timely alerts and instructions to users who have been near an infected person, CTMA use will instrumentally enhance users' performance in protecting their health. Also, these apps' timely alerts and guidance may relieve the distress caused by infection-related uncertainties and worries (Lin *et al.*, 2020). Thus, perceived usefulness and perceived distress relief are assumed to constitute CTMA-related opportunity appraisal.

Threat appraisals represent the degree to which a user feels that CTMA use disrupts their personal benefits and well-being (Bala and Venkatesh, 2016; Beaudry and Pinsonneault, 2005). Previous IS research has highlighted that privacy concerns are a critical threat to IS users if the IS collects, stores and uses users' private information (Dinev and Hart, 2006; Zhang *et al.*, 2018). This also applies to CTMA since apps collect users' private information—such as their close contacts and COVID-19 testing results—and use it to detect potential exposure. Therefore, privacy concerns can present a key threat for individual users, and app use compromises between health and privacy. Indeed, recent studies have highlighted individuals' privacy concerns as the major threat to CTMA adoption (Lin *et al.*, 2021; Riemer *et al.*, 2020; Trang *et al.*, 2020). In light of this, privacy concerns are assumed to represent threat appraisals regarding CTMA.

Table 3.
Definitions of the five constructs

Construct	Definition
Perceived usefulness	Users' expected benefits from using Contact Tracing Mobile Apps (CTMA) in protecting their health during the COVID-19 pandemic (Bhattacherjee, 2001; Davis, 1989)
Perceived distress relief	Users' perception of relieving their COVID-19-related distress through CTMA (Dholakia, 2006)
Privacy concerns	Users' concerns about opportunistic behavior related to private information collected by CTMA (Dinev and Hart, 2006)
Perceived response efficacy	Users' perception of the efficacy of protection offered by the CTMA providers in successfully attenuating privacy threats in CTMA use (Posey *et al.*, 2015)
Continuance usage	Users' continued use of CTMA during the COVID-19 pandemic (Bhattacherjee, 2001)

Secondary appraisals refer to an individual's cognitive assessment of whether coping resources are available to respond to an encounter (Bala and Venkatesh, 2016; Beaudry and Pinsonneault, 2005; Lazarus and Folkman, 1984). Coping theory has indicated that if users believe there exist adequate and sufficient coping resources, the threat is apt to be minimal or absent (Bhattacherjee *et al.*, 2018; Lazarus and Folkman, 1984). Since privacy issues are one major threat to CTMA use, users' evaluations of privacy protection are particularly critical in this study's context. Indeed, many preventive measures and techniques have been used by CTMA providers to protect private information, such as no location data collection, anonymity and decentralization (Apple and Google, 2021; Sowmiya *et al.*, 2021). These privacy protections provided by CTMA providers offer the coping resource to CTMA users to respond to privacy issues when using CTMA. CTMA users could assess the efficacy of these coping resource for privacy protections in preventing privacy threats in their CTMA use. Thus, perceived response efficacy fits well with the definition of secondary appraisals in our studied context and can be assumed to constitute secondary appraisals regarding CTMA.

In this study, behavioral response was operationalized as continuance usage, which refers to users' continued CTMA use during the COVID-19 pandemic (Bhattacherjee, 2001). Prior literature has adopted continuance usage to represent a behavioral response. For instance, Yang *et al.* (2016) developed *behavioral response* as continuous use when employing coping theory to study users' reactions to mobile shopping channels. Therefore, in this study, continuance usage of CTMA is assumed to reflect users' behavioral responses to the COVID-19 pandemic.

According to coping theory, individuals' opportunity, threat and secondary appraisals jointly determine their behavioral responses to stressful events (Beaudry and Pinsonneault, 2005; D'Arcy *et al.*, 2014; Salo *et al.*, 2020). Aligning with this theory, *perceived usefulness*, *distress relief*, *privacy concerns* and *perceived response efficacy* are proposed as the essential determinants of CTMA continuance usage. Meanwhile, *age*, *gender*, *education* and *coronavirus test status* are moderators in the model (see Figure 1).

3.2 Hypothesis development

Perceived usefulness has been widely considered an important driver of IS continuance usage (Bhattacherjee, 2001). In this study's context, by using CTMA, if users were near a person reported to have been infected with COVID-19, they could use CTMA to be rapidly informed about their potential exposure and receive further instructions on how to self-isolate and protect themselves (Trang *et al.*, 2020) or even quickly access testing and treatment if needed. Consequently, users will likely perceive such apps as useful, improving their ability to protect their health during the COVID-19 pandemic. These usefulness perceptions can facilitate CTMA continuance usage (Bhattacherjee, 2001). Therefore, the following hypothesis is suggested.

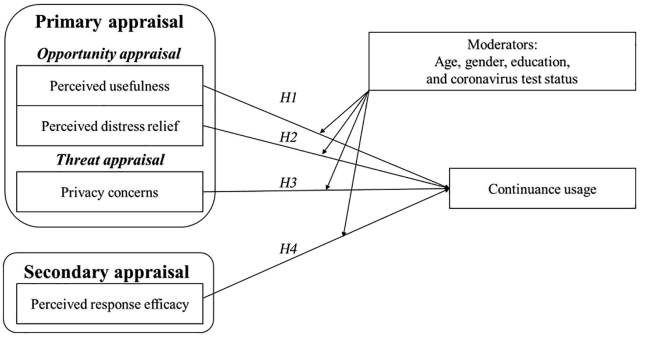


Figure 1.
Research model

H1. Perceived usefulness is positively associated with CTMA continuance usage.

The COVID-19 pandemic has created distress and fear (Li *et al.*, 2021), and one leading cause of this distress is informational uncertainty regarding the pandemic (Lin *et al.*, 2020; Rettie and Daniels, 2021). For instance, people do not know whether they have been exposed to infection, and they are unsure of the correct response to virus exposure or diagnosed infection. Such uncertainties have contributed to intense distress during the COVID-19 pandemic (Lin *et al.*, 2020). Past research has suggested that IS can reduce the distress caused by a specific event by providing information that supports decision-making (Eisel *et al.*, 2014). Similarly, recent research has demonstrated that transparent, timely communication helps reduce COVID-19-related distress (Lin *et al.*, 2020). CTMA can convey such messages by offering timely alerts and clear guidance, so users may perceive such apps as helpful in alleviating distress. Therefore, they would likely continue using these apps. Hence, the following hypothesis is proposed.

H2. Perceived distress relief is positively associated with CTMA continuance usage.

For effective contact tracing, CTMA must collect and process individuals' data (Lin *et al.*, 2021; Riemer *et al.*, 2020; Trang *et al.*, 2020). For instance, a GPS-based tracing app collects users' GPS information, disclosing their precise location. Although some apps rely on Bluetooth techniques and do not collect precise location information, people remain concerned about the use and storage of their sensitive data and possible surveillance (Riemer *et al.*, 2020; Trang *et al.*, 2020). Such CTMA privacy concerns may decrease users' CTMA continuance usage. Privacy concerns, prior literature has indicated, are the primary inhibitor of mobile app continuance intention (Zhou, 2016; Zhou and Li, 2014). For instance, according to Zhou and Li (2014), in the context of mobile social network services, privacy concerns are negatively linked to continuance intentions. Moreover, according to recent CTMA research, privacy concerns are the main reason for unwillingness to download and use CTMA (Chan and Saqib, 2021). Hence, it is reasonable to presume that privacy concerns decrease CTMA continuance usage, yielding the following hypothesis.

H3. Privacy concerns are negatively associated with CTMA continuance usage.

Perceived response efficacy reveals the extent to which users perceive that preventative measures effectively protect their privacy (Boss *et al.*, 2015). To protect users' privacy, many efforts have sought to limit data collection and control data transmission and storage (Sowmiya *et al.*, 2021). Typically, a smartphone app generates and transmits a Bluetooth signal (a series of unique strings of random numbers and letters) that does not contain any personal information (such as names and identities), and when a user is infected, they can report their infection via the app, which will send a unique Bluetooth signal to a central database. The app will automatically check the report for other users and alert them if they have been in close contact with an infected user. Neither app users, the infected person, smartphone operating system developers, nor the government can infer any private information from the data collected by these apps (Apple and Google, 2021). These preventive measures may decrease users' worries about the collection and use of their private information. While users who perceive high response efficacy are more likely to feel secure about their privacy and continue using such apps, users who perceived low response efficacy may continue to feel uncertain and threatened regarding privacy security, avoiding the continued use of such apps. Thus, the following hypothesis is proposed.

H4. Perceived response efficacy is positively associated with CTMA continuance usage.

In this study, age, gender, education and coronavirus test status are considered as moderators to explore the possible effects of user-related characteristics on these proposed

relationships. Such as senior CTMA users might be more vulnerable to COVID-19 than other age groups (World Health Organization, 2021b), they might be more eager to seek interventions to help them to cope with this stressful situation, thus, their cognitive appraisals of using CTMA, such as opportunity appraisals, could exert a stronger influence on their continuance usage than other age groups. Regarding gender, women have been found to be more sensitive to stressful situations than men (Matud, 2004), therefore, women's opportunity, threats and secondary appraisals of using CTMA to cope with COVID-19 pandemic could have different impacts on their continuance usage than men. Considering education background, prior studies found that people with higher education tend to use new technologies more than those with less educational background (Owusu Kwateng *et al.*, 2019). Furthermore, regarding COVID-19 testing status, users who have been tested are obligated to report their test results via the app, particularly when they are diagnosed with an infection, thereby, they might be more concerned about the benefits and threats of using CTMA as well as the privacy protection related to CTMA compared with those who have not been tested. Hence, the effects of cognitive appraisals on continuance usage may be different among users with different characteristics, and it is meaningful to explore the moderating effects of age, gender, education and coronavirus test status in this study.

4. Research method

4.1 Instrument development

We adapted well-established scales from prior research to measure all constructs using a seven-point Likert scale. Specifically, *perceived usefulness* and *continuance usage* were measured with items derived from the work of Bhattacherjee (2001), *perceived distress relief* using items derived from the study of Dholakia (2006), *privacy concerns* using items derived from the research of Dinev and Hart (2006) and *perceived response efficacy* using items derived from the work of Posey *et al.* (2015). More details of these measures can be found in Table 5.

4.2 Participants

Current CTMA users in the USA comprised the target population of this study for the following reasons. First, CTMA use in USA was depended on a voluntary basis among individuals. Second, many individuals had used CTMA for a while before our study. According to a survey on public's attitude toward CTMA use in USA conducted in June, 2020, 42% of respondents supported CTMA use during the pandemic (Zhang *et al.*, 2020). The Amazon Mechanical Turk (MTurk) was used to recruit participants since obtaining a large sample of respondents from various backgrounds who respond fast is easy in USA. A concise explanation of the study's objectives and a link to its online questionnaire were presented with the invitation messages. To investigate CTMA continuance usage, it is necessary that the required respondents have had certain usage experiences. Thus, the two following screening questions were implemented to record respondents' prior CTMA use, including "Have you installed and used a mobile tracing app on your smartphone before?" and if so, "What is the mobile tracing app you are using?". Only those respondents who answer yes to the first question and write the name of a specific tracing app they have used to the second question can proceed with the rest parts of the questionnaire. In addition, two attention-checking questions were incorporated into the questionnaire to ensure sufficient attention by respondents. Each response was checked carefully to eliminate unreliable responses.

The online survey was delivered to prospective respondents at the beginning of December 2020, when mass vaccination efforts had not yet publicly begun in the United States. In total, 783 responses were collected in one week. The 190 respondents who had not installed a contact tracing app on their smartphone or failed to offer the specific names of the contact

tracing app they had used were excluded in this study. Furthermore, we excluded 25 respondents who failed to answer two attention-checking questions correctly and 17 respondents who answered unreliably—such as by providing the same response option for all measurement items. Finally, a valid sample of 551 responses was obtained. Considering the sample size, prior literature suggests that a data sample size of about 10 times the number of items used in a study can be appropriate (Hair *et al.*, 2014). In this study, there are 20 measurement items in total. Thus, the sample size of about 200 will be appropriate for this study. Our sample size (N = 551) is greater than 200 and can be considered as adequate for this study. Among the 551 final respondents, 60.4% were male and 39.4% were female. Most respondents were 20–39 years old (64%), and most had been previously tested for coronavirus (61.3%). Table 4 presents respondents' demographic information.

4.3 Common method bias and collinearity

To assess common method bias, this study employed Harman's single factor test, as recommended by Podsakoff *et al.* (2003). This test revealed that the highest variance explained by a single factor was 39.2%, which was lower than the suggested threshold value of 50% (Podsakoff *et al.*, 2003). Therefore, common method bias was not a serious concern for this study.

The collinearity of each independent variable was measured, as advised by Kock and Lynn (2012), by assessing the values of the variance inflation factor (VIF). The VIF values ranged from 1.189 to 2.416, which was below the recommended threshold of 3.3 (Kock and Lynn, 2012). Therefore, collinearity was not a critical issue for this study.

4.4 Data analysis

This study utilized partial least squares (PLS) to analyze the data. Prior literature suggests that compared with covariance-based structural equation modeling (CB-SEM), PLS-SEM is more suitable for studies when the research objective is for prediction and when the data distribution is lack of normality (Chin *et al.*, 2003; Hair *et al.*, 2019). This study aims to examine what factors predict CTMA continuance usage. Additionally, prior literature suggests that when testing the multivariate normality of the data, if the value of Skewness is between −2 and +2, and the value of Kurtosis is between −7 and +7, data distribution can be considered as normal (Curran *et al.*, 1996; West *et al.*, 1995). Our test results showed that the values of both

Table 4. Respondents' demographic profile

Variable	Items	Count	Percentage (%)
Gender	Male	333	60.4
	Female	217	39.4
	Unwilling to disclose	1	0.2
Age	20–29	172	31.2
	30–39	181	32.8
	40–49	97	17.6
	50–59	70	12.7
	60–69	31	5.6
Education	Basic education	8	1.5
	Upper secondary education (or vocational school)	33	6.0
	Bachelor's or equivalent level	334	60.6
	Master's or equivalent level	170	30.9
	Doctoral or equivalent level	6	1.1
Coronavirus test status	Tested	338	61.3
	Not tested	207	37.6
	Unwilling to disclose	6	1.1

Table 5. Construct measurement and convergent validity test results

Constructs	Reference	Item	Factor loading	CA	CR	AVE
Continuance usage (CU)	Bhattacherjee (2001)	CU1: I continue using CTMA, rather than discontinuing their use in recent days	0.849	0.866	0.903	0.650
		CU2: I continue using CTMA, rather than using any alternative means of tracing in recent days	0.788			
		CU3: I will continue my CTMA use in the following days during the COVID-19 pandemic	0.825			
Perceived distress relief (PDR)	Dholakia (2006)	PDR1: Using CTMA makes me feel self-assured	0.823	0.823	0.883	0.653
		PDR2: Using CTMA makes me feel relieved	0.820			
		PDR3: Using CTMA makes me feel contented	0.820			
		PDR4: Using CTMA makes me feel calm	0.794			
		PDR5: Using CTMA makes me feel tranquil	0.773			
Perceived usefulness (PU)	Bhattacherjee (2001)	PU1: Using CTMA improves my performance in protecting myself during the COVID-19 pandemic	0.825	0.758	0.861	0.674
		PU2: Using CTMA increases my productivity in protecting myself during the COVID-19 pandemic	0.797			
		PU3: Using CTMA enhances my effectiveness in protecting myself during the COVID-19 pandemic	0.825			
		PU4: Overall, using CTMA is useful in protecting myself during the COVID-19 pandemic	0.785			
Privacy concern (PC)	Dinev and Hart (2006)	PC1: I am concerned that my information collected by CTMA could be misused	0.824	0.871	0.911	0.719
		PC2: I am concerned that someone else can access my information through CTMA.	0.855			
		PC3: I am concerned about information collected by CTMA because of what others might do with it	0.871			
		PC4: I am concerned about information collected by CTMA because it could be used in a way I did not foresee	0.843			
Perceived response efficacy (PRE)	Posey *et al.* (2015)	PRE1: The efforts of CTMA providers to keep my privacy safe from information security threats are effective	0.783	0.788	0.863	0.611
		PRE2: The available measures taken by CTMA providers to protect my privacy from security violations are effective	0.773			
		PRE3: The preventive measures available to stop people from accessing my privacy taken by CTMA providers are adequate	0.783			
		PRE4: The preventive measures available to keep people from misusing my privacy taken by CTMA providers are adequate	0.788			

Note(s): CR = composite reliability; CA = Cronbach's alpha; AVE = average variance extracted

Skewness and Kurtosis did not meet the recommended thresholds, indicating that our data is not normal. Thus, PLS-SEM technique is a proper method for this study. The data analysis includes the test of the measurement model and structural model.

4.4.1 Measurement model. Convergent validity and discriminant validity were tested to assess the measurement model. To test convergent validity, this study evaluated the factor loading of each item, Composite Reliability (CR), Cronbach's alpha (CA) and Average Variance Extracted (AVE). As Table 5 shows, all factor loading, CA and CR values met the recommended threshold of 0.70, 0.70 and 0.70, respectively, and AVE values all exceeded 0.5, indicating satisfactory convergent validity for this study (Fornell and Larcker, 1981).

Discriminant validity was evaluated using two means: (1) the criteria proposed by Fornell and Larcker (1981) and (2) the Heterotrait–Monotrait (HTMT) ratio developed by Henseler *et al.* (2015). First, according to Fornell and Larcker (1981), discriminant validity is established when (1) the square root of each construct's AVE exceeds the correlations between the construct and others and (2) the item loadings are higher on their intended construct than on other constructs. Tables 6 and 7 show that this study's results met these criteria. Second, according to Henseler *et al.* (2015), an HTMT of 0.90 is an acceptable threshold for discriminant validity. Table 8 shows that this study's discriminant validity was confirmed.

4.4.2 Structural model. The structural model was tested by measuring not only the significance and size of the path coefficients and the coefficient of determination (R^2 value)

Table 6. Correlation matrix and discriminant validity

Construct	PDR	PU	CU	PC	PRE
Perceived distress relief (PDR)	0.806				
Perceived usefulness (PU)	0.675	0.808			
Continuance usage (CU)	0.632	0.650	0.821		
Privacy concern (PC)	0.395	0.305	0.301	0.848	
Perceived response efficacy (PRE)	0.738	0.649	0.714	0.310	0.782

Table 7. Loadings and cross-loadings

Construct	Construct item	CU	DR	PU	PC	RE
Continuance usage (CU)	CU1	0.849	0.553	0.551	0.259	0.627
	CU2	0.788	0.521	0.513	0.261	0.563
	CU3	0.825	0.482	0.538	0.221	0.567
Perceived distress relief (PDR)	PDR1	0.576	0.823	0.630	0.355	0.628
	PDR2	0.541	0.820	0.562	0.313	0.604
	PDR3	0.501	0.820	0.554	0.323	0.610
	PDR4	0.468	0.794	0.495	0.303	0.576
	PDR5	0.445	0.773	0.456	0.292	0.550
Perceived usefulness (PU)	PU1	0.550	0.555	0.825	0.249	0.561
	PU2	0.519	0.558	0.797	0.247	0.533
	PU3	0.539	0.539	0.825	0.248	0.507
	PU4	0.491	0.530	0.785	0.244	0.493
Privacy concern (PC)	PC1	0.222	0.275	0.224	0.824	0.225
	PC2	0.277	0.350	0.260	0.855	0.290
	PC3	0.290	0.367	0.294	0.871	0.288
	PC4	0.218	0.337	0.249	0.843	0.234
Perceived response efficacy (PRE)	PRE1	0.544	0.602	0.492	0.246	0.783
	PRE2	0.547	0.542	0.512	0.204	0.773
	PRE3	0.580	0.588	0.531	0.251	0.783
	PRE4	0.561	0.574	0.492	0.266	0.788

but also the model's predictive relevance (Q^2 value) and goodness of fit. Figure 2 presents the results using PLS.

The model explains 57.6% of continuance usage variance. Perceived usefulness ($\beta = 0.284$, $p < 0.001$) and response efficacy ($\beta = 0.448$, $p < 0.001$) significantly positively influence continuance usage. In contrast, perceived distress relief and privacy concerns do not significantly influence continuance usage, thus supporting H1 and H4 while not supporting H2 and H3.

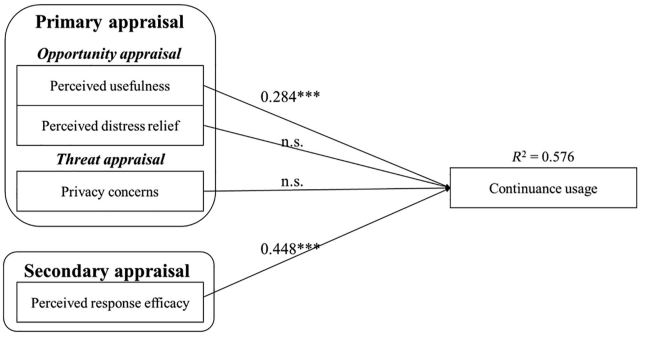
The Stone–Geisser Q^2 was further measured to estimate the predictive relevance of the proposed research model (Geisser, 1974; Hair *et al.*, 2017; Stone, 1974). The results of this test showed that the Q^2 value for continuance usage was 0.363, greater than zero, indicating good predictive relevance (Hair *et al.*, 2017).

The standardized root mean square residual (SRMR) was applied to assess the goodness of fit for the proposed research model (Hair *et al.*, 2017; Henseler *et al.*, 2014). This test's result was 0.061, which is less than the recommended threshold of 0.08, indicating a good model fit (Hair *et al.*, 2017; Henseler *et al.*, 2014; Hu and Bentler, 1998).

4.4.3 Moderation analysis. The moderation analysis was conducted to explore the moderating effects of age, gender, education and coronavirus test status on the proposed relationships. Gender and coronavirus test status was operationalized as a dummy variable. Age and education were operated as a dummy variable that took ordinal values to represent increasing levels of age and education background, respectively. Specifically, respondents were divided into three sub-groups by age: (1) *young*, aged 20–29 years; (2) *middle-aged*, 30 to 49; and (3) *senior*, 50 to 69. Prior research has focused on the young, middle-aged and senior groups to explore how age moderates certain IS relationships (e.g. Czaja *et al.*, 2006; Tams *et al.*, 2014; Zhao *et al.*, 2018). Recent literature also noted there are differences between young, middle and senior people in terms of their vulnerability to COVID-19 (World Health Organization, 2021b; Bhopal *et al.*, 2021). Thus, this study also explores whether there are

Construct	PDR	PU	CU	PC	PRE
Perceived distress relief (PDR)					
Perceived usefulness (PU)	0.792				
Continuance usage (CU)	0.774	0.822			
Privacy concerns (PC)	0.449	0.358	0.365		
Perceived response efficacy (PRE)	0.890	0.804	0.877	0.369	

Table 8. Correlations' heterotrait-monotrait ratio (HTMT)



Note(s): *** = $p < 0.001$; n.s. = not significant

Figure 2. Model-testing results

significant differences among these three user groups. The respondents were also divided into three sub-groups by education following the prior literature (i.e. low, middle and high) (e.g. Cruz-Jesus *et al.*, 2016): (1) *low*, having only completed basic education or upper secondary education (or vocational school); (2) *middle*, having completed a bachelor's degree; and (3) *high*, having completed a master's or doctoral degrees.

Multi-group analysis (MGA) was applied in this study to assess the moderating effect (Hair *et al.*, 2017). Prior to MGA, as recommended by Henseler *et al.* (2016), the Measurement Invariance of Composite Models (MICOM) procedure was used to ascertain whether measurement invariance existed among the different groups. The results showed no measurement invariance among the sub-groups regarding gender and education, so the MGA was not used to analyze differences among user groups in these categories. For age and coronavirus test status, partial measurement was established, so MGA was used to analyze differences among these sub-groups (Henseler *et al.*, 2016).

As Table 9 shows, a significant difference was observed between the young and senior age sub-groups concerning the relationship between perceived usefulness and continuance usage. Specifically, senior group exhibited the most significant effect of perceived usefulness on continuance usage ($\beta = 0.586$, $p < 0.001$), followed by the middle-aged sub-group ($\beta = 0.267$, $p < 0.001$) and young sub-group ($\beta = 0.198$, $p < 0.05$).

As Table 10 shows, a significant difference was observed between the tested and not-tested groups concerning the relationship between perceived response efficacy and continuance usage. Specifically, perceived response efficacy more strongly and significantly influenced continuance usage for the tested group ($\beta = 0.548$, $p < 0.001$) compared to the not-tested group ($\beta = 0.276$, $p < 0.01$). Additionally, distress relief was found to significantly affect continuance usage only in the not-tested group ($\beta = 0.283$, $p < 0.05$).

Table 9.
Testing for age as a moderator

	Comparison by age			Separate structural models' path coefficients		
	Young vs senior	Young vs middle-aged	Young vs senior	Young (n = 172)	Middle (n = 278)	Senior (n = 101)
H1	$p < 0.01$	n.s	n.s	0.198*	0.267***	0.586***
H2	n.s	n.s	n.s	n.s	n.s	n.s
H3	n.s	n.s	n.s	n.s	n.s	n.s
H4	n.s	n.s	n.s	0.464***	0.432***	0.496**

Note(s): *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$; n.s. = not significant

Table 10.
Coronavirus test status as a moderator

	Comparison by coronavirus test status	Path coefficients of separate structural models	
	Tested vs not tested	Not tested (n = 207)	Tested (n = 338)
H1	n.s.	0.325***	0.280***
H2	n.s.	0.283*	n.s.
H3	n.s.	n.s.	n.s.
H4	$p < 0.05$	0.276**	0.548***

Note(s): *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$; n.s. = not significant

5. Discussion

Our findings raised several points of interest. First, our results reveal that perceived usefulness ($\beta = 0.284$, $p < 0.001$) and perceived response efficacy ($\beta = 0.448$, $p < 0.001$) determine CTMA continuance usage. This finding aligns with coping theory, according to which primary appraisals and secondary appraisals predict users' behavioral responses related to new IS (Bala and Venkatesh, 2016; Gong *et al.*, 2020). Generally, when deciding to continue CTMA use, users assess the consequences of their use (primary appraisal) and evaluate the coping resources over this use (secondary appraisal). They tend to continue using these apps during a pandemic when they perceive them as highly useful in protecting their health and highly efficacious in protecting their privacy.

Specifically, perceived response efficacy was found to be a stronger driver for CTMA continuance usage than perceived usefulness. Users' privacy concerns considerably influence their CTMA use during a public health crisis (Chan and Saqib, 2021; Riemer *et al.*, 2020). Using such apps involves a compromise between users' privacy and health. Thus, continuance usage is not only influenced by such apps' perceived usefulness in protecting users' health but also—more importantly—determined by users' evaluation of whether an app's available measures can effectively protect their privacy. If users perceive CTMA's privacy protections as effective and adequate, this study's findings suggest, they will likely continue using these apps—even if they do not fully recognize CTMA's usefulness in protecting their health during a pandemic. This finding highlights the importance of perceived response efficacy in explaining CTMA continuance usage during a public health crisis.

Contrary to our expectations, privacy concerns do not significantly influence CTMA continuance usage. This finding contradicts some prior research findings in normal life contexts. For instance, users' privacy concerns have been discovered to negatively affect their continuance usage regarding social network sites (SNS) (Zhou and Li, 2014) and location-based services (Zhou, 2016). A possible explanation for this research finding is that CTMA users might be willing to sacrifice their privacy for personal and public health benefits during a public health crisis. Privacy calculus theory (Culnan and Armstrong, 1999; Dinev and Hart, 2006) suggests that people may intend to compromise privacy for certain benefits, such as health and security. Prior research has found that, when people perceive a pressing security threat, they will more likely accept a compromise between privacy and personal safety (Davis and Silver, 2004). The COVID-19 pandemic has become a serious public health crisis, threatening individuals' life and health, so users may accept CTMA as necessary for the public benefits. Despite CTMA-related privacy concerns, they may continue using CTMA to help manage the pandemic. Thus, privacy concerns could lose their importance and even have no impact on individuals' CTMA continuance usage during this pandemic.

The finding on the insignificant impact of privacy concerns on CTMA continuance usage is also not consistent with recent research findings on CTMA adoption. For instance, Chan and Saqib (2021) found that privacy concerns can reduce individuals' willingness to download CTMA. A possible explanation is that, if users perceive that preventative measures or designs (such as anonymity and decentralization) of CTMA can protect their privacy effectively based on their prior CTMA use experience, privacy concerns will not obstruct their continuance usage of CTMA (Trang *et al.*, 2020). In addition, Chan and Saqib (2021) focused on initial CTMA acceptance, while this study has focused on continuous usage. When individuals lack experience using CTMA during the COVID-19 pandemic, they are less likely to recognize the extent to which CTMA will protect their privacy and their possible benefits than individuals who have already used CTMA. Therefore, privacy concerns are a critical factor in reducing individuals' initial acceptance of CTMA. After individuals have already used CTMA voluntarily for some time during the COVID-19 pandemic, they can better understand the measures CTMA use to protect their privacy based on their usage experiences, which could enhance their perceptions concerning privacy protection. Thus,

their privacy concerns related to CTMA use become less critical and might not reduce their CTMA continuance usage during the COVID-19 pandemic.

This study also found perceived distress relief has no significant influence on CTMA continuance usage in general. This is not consistent with prior findings in normal life or work contexts. For instance, the findings of Cheikh-Ammar (2020) indicated that distress relief offered by a SNS can motivate users to continue their usage of SNS. A possible reason is that not all CTMA users emphasize the value of distress relief when using CTMA, as we found that perceived distress relief has a significant influence on continuance usage particularly for users who had not been tested for COVID-19 ($\beta = 0.283$, $p < 0.05$). These users worry more about their health than those who have been tested since they do not know whether they have been infected with SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2, the virus that causes COVID-19). These uncertainties can cause distress (Peters *et al.*, 2017), leaving users eager for timely, relevant information from CTMA to help them to release the stress. CTMA can convey such information via timely alerts and instructions. Thus, users who have not been tested might tend to consider CTMA helpful for reducing distress related to COVID-19. Accordingly, when they perceive that these apps can relieve their distress, they will continue using them during the pandemic.

Finally, this study found some differences among the factors determining individuals' continuous CTMA use across different user groups. The results show that age and COVID-19 testing status moderate cognitive appraisal's impact on continuance usage. Specifically, regarding age, perceived usefulness was found to influence continuance usage the most among senior users ($\beta = 0.586$, $p < 0.001$) and the least among young users ($\beta = 0.198$, $p < 0.05$), and significant differences are visible between these two user groups. This significant difference might be due to senior users' vulnerability to COVID-19 than other age groups (World Health Organization, 2021b). Therefore, senior people may eagerly seek effective interventions to prevent infections. In contrast, the risk of severe coronavirus disease and mortality is low among young people in general (Bhopal *et al.*, 2021), so they might worry less about infection than other age groups. Thus, the perception of the usefulness of CTMA will have the strongest impact on their continuance usage of CTMA in the senior group than other age groups.

In examining coronavirus test status, this study found that perceived response efficacy has a stronger impact on continuance usage for users who have been tested for COVID-19 ($\beta = 0.548$, $p < 0.001$) than users who have not ($\beta = 0.276$, $p < 0.01$), and there a significant difference between these two groups. One possible reason for this finding is that users who have been tested are obligated to report their results to the apps if they are diagnosed with infection; therefore, they may be more concerned about disclosing their information and require more privacy protection. Accordingly, when they perceive that these apps can effectively protect their privacy, they may intend more strongly to continue using them.

6. Conclusion

6.1 Theoretical contributions

This study contributes to the research related to CTMA on several fronts. First, it makes contextual contributions to the IS continuance literature by extending the context of IS use from the normal daily life and work contexts to a larger societal public health crisis context and by clarifying cognitive appraisals' role in explaining individuals' CTMA continuance usage in the specific abnormal context of a public health crisis, grounded on coping theory. Investigating cognitive appraisals' role in explaining CTMA continuance usage enriches IS continuance research using coping theory, and it explains how technology can help people cope with public health crises.

Second, this study offers new insights explaining CTMA-related privacy issues. Unlike previous research, which indicated that privacy concerns are one of the key obstacles to IS

continuance in normal life contexts (Zhou, 2016; Zhou and Li, 2014), as well as CTMA adoption (Chan and Saqib, 2021; Lin *et al.*, 2021), this study found that privacy concerns do not inhibit continuance usage of CTMA though privacy concerns have been highlighted to be critical in understanding CTMA adoption. Individuals' appraisal of privacy issues regarding an IS can be different due to context differences (e.g. normal work and life situation and abnormal public health crisis). Specifically, in a public health crisis context, users are willing to compromise their privacy to protect their personal and public health, and their privacy concerns will not hinder them to continue using CTMA during the pandemic. Thus, threat appraisal (such as privacy concerns) is not a hinder for users' CTMA continuance usage, and the second appraisal (such as perceived response efficacy) and opportunity appraisal (such as perceived usefulness) are important appraisals for users' CTMA continuance usage in a public health crisis context.

Third, the theoretical lens of coping theory yields new insights into the mechanisms underlying CTMA continuance usage from a multi-dimension cognitive appraisal view, that is, individuals appraise not only the benefits and threats of CTMA usage but also the coping resources to privacy issues in their continuance usage of CTMA. Unlike recent research on CTMA largely focusing on the initial adoption and ignoring the impact of users' assessment of coping options available to respond to privacy issues on their continuance usage of CTMA (e.g. Chan and Saqib, 2021; Lin *et al.*, 2021), this study's findings show that opportunity appraisals (perceived usefulness) and secondary appraisals (perceived response efficacy) motivate users' continuance usage, indicating that – even during unprecedented situations – coping theory is a powerful tool with which to explain IS continuance usage in a public health crisis.

Fourth, this study has provided new insights specific to emotion-related benefits of CTMAs. The results of this study show that perceived distress relief has a significant influence on CTMA continuance usage only for users who have not been tested for COVID-19. This finding offers further evidence that CTMAs can not only help users protect their health but also reduce emotional distress for specific user groups. This finding indicates that the role of perceived distress relief in predicting continuance usage can change due to the different contexts and user characteristics.

Finally, the moderated-related findings (including age and coronavirus test status) provide a finer-grained understanding of the role of user features in explaining how cognitive appraisals affect CTMA continuance usage during the COVID-19 pandemic. Specifically, the findings highlight the crucial role of user age in explaining how perceived usefulness influences continuance usage, as well as coronavirus test status's role in explaining how perceived response efficacy affects continuance usage. These findings suggest that CTMA continuance usage is a complex and nuanced phenomenon where user-specific factors do matter.

6.2 Practical implications for public policy

This study also provides practical implications for authorities about how to use mobile technologies to manage the ongoing COVID-19 pandemic, as well as future public health crises. First, the findings on CTMAs during the COVID-19 pandemic suggest that authorities should use mobile technologies to manage public health crises. Although individuals will concern about privacy when using mobile technologies to manage public health crises, these concerns will not hinder their continuous use of such technologies if appropriate privacy protection measures are implemented in the design and development of the technologies and if they also help individuals navigate such crises.

Second, in light of the finding that perceived usefulness motivates CTMA continuance usage, authorities are recommended to promote CTMA continuance usage by improving

users' perceptions of these apps' usefulness. For instance, authorities can provide authorized information about how CTMAs have been used to disrupt virus transmission and protect public health in managing the COVID-19 pandemic. Such disclosures can help individuals recognize the benefits of CTMA use. Additionally, authorities can implement promotional or educational programs that clarify these apps' benefits in controlling the COVID-19 pandemic, enhancing individuals' awareness of their utility, which could trigger continuous CTMA use during the COVID-19 pandemic.

Third, motivated by the finding that perceived response efficacy positively influences continuance usage that authorities should adopt strategies to enhance users' perceptions of CTMA's response efficacy during the COVID-19 pandemic. On the one hand, authorities should provide individual users with clear, detailed information about CTMA's privacy protection to demonstrate that sensitive user information is not captured and that collected user data will only be used strictly following data and privacy protection rules. For instance, to protect individuals' privacy, GPS techniques should not be used. On the other hand, authorities should clearly explain how these apps protect user privacy to reduce the negative impacts of rumors or misconceptions related to these apps, such as explaining in detail what data will be captured, stored and used, who owns the data, who can access the data and how user privacy will be protected, following data protection and privacy rules. These strategies will increase individuals' perceptions concerning CTMA's response efficacy, which could lead to continuous CTMA use during the COVID-19 pandemic.

The moderator-related findings inform the fourth recommendation: authorities should consider user-specific factors (including age and coronavirus test status) when promoting CTMA use. Specifically, they could customize promotions or educational programs to specific user groups. For instance, since senior users are more vulnerable to COVID-19 and their usefulness perceptions most strongly influence continuance usage, explaining CTMA's usefulness in protecting their health will more likely motivate continuance usage for this group. For users who have been tested for COVID-19, perceived response efficacy more strongly affects continuance usage, so clearly explaining these apps' privacy protection will likely encourage them to keep using these apps.

6.3 Limitations and future research directions

This study faced some limitations. First, it used an online survey of US users to test its research model. The country's national culture and political atmosphere may affect CTMA continuance usage. Therefore, more empirical evidence from respondents with different cultural and political backgrounds is needed to generalize the findings across countries or regions. Second, due to the survey method's inherent limitations, the collected data may not fully capture the complex nature of how people perceive CTMA. Accordingly, future research should apply qualitative or mixed research methods to explore and comprehensively explain continuous CTMA use. Third, the data collection took place in December 2020, when the United States saw a record number of deaths from COVID-19 (Maxouri, 2020). Individuals' opinions about these apps may have been influenced by this dire situation. Since the pandemic situation keeps changing, future research could investigate CTMA continuance usage via longitudinal research, examining whether changes to the pandemic and coping appraisals related to COVID-19 outbreaks affect continuance usage. Finally, while this study examined how cognitive appraisals directly affect continuance usage, it did not test coping strategies. A user may engage in different coping strategies (such as benefit maximizing and self-preservation) when using apps during the pandemic (Beaudry and Pinsonneault, 2005). Therefore, future research could also examine coping strategies' role in determining IS continuance usage during a crisis.

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