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Beyond TAM: The impact of trust, privacy control and reliability on an individual's intention to use a coronavirus contact tracing App

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Más allá de TAM: el impacto de la confianza, el control de la privacidad y la confiabilidad en la intención de un individuo de usar una aplicación de rastreo de contactos de Coronavirus

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Résumé de l'article

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ABSTRACT

Few empirical studies have explored the factors that influence the intention to use Coronavirus contact-tracing apps. Building on previous literature on technology acceptance, trust, privacy control and reliability, we propose an integrated model. The hypotheses are tested on a representative sample of 1000 citizens in France who installed a contact-tracing app. Trust was found to play a central role: it directly and strongly influenced use intentions and mediated the relationship between perceived ease of use and behavioral intentions. Reliability was found to be a major antecedent of perceived ease of use, and privacy control influenced perceived usefulness.

Keywords: Technology acceptance model, Coronavirus contact-tracing apps, trust, privacy, reliability, ease of use, usefulness, ehealth

Résumé

Peu d'études empiriques ont exploré les facteurs qui influencent l'intention d'utiliser les applications de traçage de contacts liés au coronavirus. Nous proposons un modèle intégré, basé sur la littérature sur l'acceptation de la technologie, la confiance, le contrôle de la confidentialité et la fiabilité. Les hypothèses sont testées sur un échantillon représentatif de 1000 citoyens en France ayant installé une telle application. La confiance influence directement et fortement les intentions d'utilisation et constitue le médiateur de la relation entre la facilité d'utilisation et les intentions. La fiabilité influence la facilité d'utilisation perçue, et le contrôle de la confidentialité influence l'utilité perçue.

Mots-Clés : Modèle de l'acceptation de la technologie, Applications de traçage des contacts, confiance, confidentialité, fiabilité, facilité à utiliser, utilité, esanté

Resumen

Pocos estudios empíricos han explorado los factores que influyen en la intención de usar aplicaciones de rastreo de contactos de Coronavirus. Proponemos un modelo integrado centrado en la confianza, basado en la literatura sobre la aceptación de la tecnología, la confianza, el control de la privacidad y la fiabilidad. Las hipótesis se prueban en una muestra representativa de 1000 ciudadanos en Francia que instalaron tal aplicación. La confianza afecta directa y fuertemente las intenciones de uso y media en la relación entre la facilidad de uso percibida y las intenciones. La fiabilidad influye en la facilidad de uso percibida, mientras que el control de la privacidad influye en la utilidad percibida.

Palabras Clave: Modelo de aceptación de tecnología, aplicaciones de rastreo de contactos de Coronavirus, confianza, privacidad, confiabilidad, facilidad de uso, utilidad, e-salud

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In an effort to control the spread of the COVID-19 epidemic, at least 47 countries launched applications to trace the contacts of those infected with Coronavirus (Morley, Cowls, Taddeo, & Floridi, 2020). Such applications, or apps, are installed on mobile phones and inform users when they come into contact with an infected person. Their objective is to restrict contagion (Ferretti *et al.*, 2020; Trang, Trenz, Weiger, Tarafdar, & Cheung, 2020). Coronavirus contact-tracing (CCT) apps are usually downloaded and installed by users on a voluntary basis, thus making mass acceptance (Trang *et al.*, 2020) a main concern for policy makers. CCT apps are the first mobile applications used to address health issues in the general population, without targeting users according to age or preexisting pathology (Kim & Koo, 2016).

Not surprisingly, the acceptability of these apps has been the object of increasing scholarly attention (Altmann *et al.*, 2020; Bengio *et al.*, 2020; Dowthwaite *et al.*, 2021; Sharma *et al.*, 2020; Touzani *et al.*, 2021; von Wyl *et al.*, 2021; Walrave, Waeterloos, & Ponnet, 2021). A number of factors have been shown to influence the intention to adopt a CCT app including self-efficacy (Sharma *et al.*, 2020; Walrave *et al.*, 2021), subjective norms (Sharma *et al.*, 2020), trust in government (Altmann *et al.*, 2020; Oldeweme, Märtins, Westmattelmann, & Schewe, 2021; von Wyl *et al.*, 2021), social influence (Oldeweme *et al.*, 2021; Walrave *et al.*, 2021), perceived benefits (von Wyl *et al.*, 2021; Walrave *et al.*, 2021), performance and effort expectancy, innovativeness and facilitating conditions (Walrave *et al.*, 2021) and application quality (Kahnbach *et al.*, 2021). However, few studies (e.g., von Wyl *et al.* (2021)) have investigated the drivers of CCT app adoption and intention to adopt in contexts where the app is already installed, tested and in use.

How individuals adopt and use new technologies has been a continuous and crucial question in the IS field (Benbasat & Barki, 2007). In health care, while numerous authors have studied the adoption by health professionals of technologies such as electronic health records or hospital information systems (e.g. Aggelidis & Chatzoglou, 2009; Chau & Hu, 2002; Chen & Tseng, 2012; Vitari & Ologeanu-Taddei, 2018), few studies have explored the factors that influence technology acceptance by patients for health issues (e.g. Kamal, Shafiq, & Kakria, 2020; Lin & Yang, 2009). Further research is required to improve the acceptance and intention to use "citizen centered digital health" systems (Värri *et al.*, 2020) such as personal health record (PHR) systems (H. Li, Gupta, Zhang, & Sarathy, 2014), especially in real use situations.

The Technology Acceptance Model (TAM) (Davis, 1989; Dinev, McConnell, & Smith, 2015; Venkatesh & Davis, 2000) has been successfully employed by many scholars over the past three decades to study the question of individual adoption and use of new technologies such as enterprise systems, websites, recommender agents and mobiles applications. TAM models two main constructs that influence behavioral intention to use a technology (BI): perceived ease of use (PEOU) and perceived usefulness (PU). There are growing calls in the literature for further research into the antecedents of these constructs (Benbasat & Barki, 2007; Y. Lee, Kozar, & Larsen, 2003). In a healthcare setting, where health data are considered to be more sensitive than other kinds of personal data, two such factors are privacy and trust (F. Li, Zou, Liu, & Chen, 2011; Sajid & Abbas, 2016; Xing Zhang *et al.*, 2018). A growing body of literature has emphasized the influence of trust on BI (Carter & Bélanger, 2005; Lu, Yang, Chau, & Cao, 2011; Nicolaou & McKnight, 2006; Venkatesh, Thong, Chan, & Hu, 2016). While the role of trust in the patient-doctor relationship is well-established, recent literature in healthcare has also underscored the importance of trust in telemedicine and e-health acceptance and adoption (Duggal, Brindle, & Bagenal, 2018; Tuckson, Edmunds, & Hodgkins, 2017). For example, Duggal *et al.* (2018) found that distrust among clinicians, patients, and healthcare providers leads to situations of technology ignorance or abandonment. Scholars have recently highlighted the central role trust plays in a citizen's decision to adopt CCT apps (Horvath, Banducci, & James, 2020).

As new digital technologies record an increasing amount of personal data, privacy has also been identified as an antecedent of intentions to use a technology (Princi & Krämer, 2020; H. L. Yang & Lin, 2015). Achieving mass acceptance is notably challenged by such data privacy concerns (Altmann *et al.*, 2020; Fox, Clohessy, van der Werff, Rosati, & Lynn, 2021; Janssen & van der Voort, 2020; Sharma *et al.*, 2020; Trang *et al.*, 2020; von Wyl *et al.*, 2021; Walrave *et al.*, 2021). For example, in a recent qualitative study conducted in Germany, Zimmerman et al (2021) show that CCT apps may be undermined by privacy risks that are not compensated by potential benefits. Rowe *et al.* (2020) found that a lack of transparency and coercion to use a CCT app reinforces stakeholder alienation and skepticism about the reality of the pandemic. In addition, using a situational privacy calculus perspective, Hassandoust *et al.* (2021) showed that initiatives related to privacy protection influence trust beliefs which in turn influence the intention to adopt a CCT app.

Technical reliability and performance have also been found to influence technology acceptance and use continuance by a small number of studies (Carayon, Hundt, & Wetterneck, 2010) and recently for CCT apps (Howell & Potgieter, 2021; Islam, Islam, Munim, & Islam, 2020; Lohar *et al.*, 2021; Zastrow, 2020). CCT app acceptance and use is notably influenced by issues relating to battery consumption (Lohar *et al.*, 2021), software bugs (Pereira, 2020), and smartphone compatibility (Osman *et al.*, 2020).

Our paper integrates trust, privacy and technical reliability into the TAM to study CCT app adoption. By doing so, we respond to exhortations in the literature (e.g. Benbasat & Barki, 2007; Goodhue, 2007; Venkatesh, Davis, & Morris, 2007) for more research using TAM in specific contexts and to answer unique problems that are relevant to practice. In addition, we follow the recommendation made by Benbasat & Barki (2007) to investigate antecedents of existing TAM belief constructs. By exploring the antecedents of PEOU, PU and BI for a CCT app our work may help both designers and managers successfully implement m-health applications.

We propose the following research question: *To what extent do trust, privacy and technical reliability influence the intention to use a mass health mobile app?* The paper theoretically develops and empirically validates a research model that both extends and revises the TAM in healthcare settings. The TAM is extended by the inclusion of three main antecedents of its main constructs: trust, privacy control, and reliability. While these variables have been previously highlighted in the literature and notably in a healthcare context, they have not yet been modelled together. Our empirically validated model questions the core relationship in the original TAM between PEOU and PU and between PU and BI, opening avenues for new conceptualizations of the determinants of PEOU, PU and BI for general public voluntary digital health technologies. Our paper makes two main contributions to the extant literature: First, it emphasizes the role of privacy and trust as antecedents of PU, and of technical reliability as a determinant of PEOU. Our results also suggest that trust is central to the model through its direct and mediating effects on BI. Thirdly, our paper provides a contextual model for analyzing the specific acceptance of PHR technologies including CCT apps.

The paper is structured as follows. First, we present the conceptual development with a focus on TAM, trust, privacy and technical reliability. We then present the research model and hypotheses. Finally, we present the results, the discussion, and then conclude with the limitations of the study and directions for future research.

Conceptual development

Acceptance factors

TAM asserts that two main constructs (PEOU and PU) influence behavioral intention to use a new technology (Davis, 1989). PEOU is "the degree to which a person believes that using a particular system would be free from effort" (Davis, 1989, p. 320); PU is "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). PU and PEOU both influence BI directly or through the mediation of attitude towards a technology (Venkatesh & Davis, 1996).

TAM has proven reliable in predicting continued IT use based on users' beliefs, even after they are exposed to the system for a short period of time (H. Yang & Yoo, 2004). A meta-analysis of 88 TAM studies by King and He (2006) found the TAM to be a robust model and that the main measures (PEOU, PU and BI) were highly reliable and may be used in a variety of contexts.

While we accept that TAM has been "overworked" (Goodhue, 2007, p. 220) and that other longitudinal and multi-stage models are also needed to assess influences throughout the implementation process (Benbasat & Barki, 2007), we believe that the explanatory power and parsimony of TAM allow researchers to focus on the reasons why individuals use new technologies (Goodhue, 2007). Furthermore, the model's implicit assumption that "more use is better" (Goodhue, 2007, p. 220) which may be inaccurate for most systems, is appropriate for technologies requiring mass acceptance such as CCT apps.

We follow Benbasat & Barki (2007) recommendation to model other salient beliefs such as trust as well as antecedents of the existing TAM belief constructs. We extend the TAM to better reflect the influences on m-health use.

Therefore, we propose the following hypotheses which are consistent with core TAM relationships:

- H1. PU has a positive effect on BI.
- H2. PEOU has a positive effect on BI.
- H3. PEOU has a positive effect on PU.

Trust

There is a significant body of literature on the influence of trust on adoption intention (Carter & Bélanger, 2005; Lu *et al.*, 2011; McKnight, Choudhury, & Kacmar, 2002; Nicolaou & McKnight, 2006; Venkatesh *et al.*, 2016). This concept has been investigated in IT enabled contexts such as e-commerce (Kim & Koo, 2016; W. Wang & Benbasat, 2005), digital markets (Du & Mao, 2018) and knowledge management systems (Thatcher, McKnight, Baker, Arsal, & Roberts, 2010). The underlying assumption is that, because IT related environments are often associated with higher levels of uncertainty and complexity (Chandra, Srivastava, & Theng, 2010; Luhmann, 1979; McKnight *et al.*, 2002; Pavlou, 2003; W. Wang & Benbasat, 2005), trust can overcome user concerns related to those aspects.

Several studies have extended the TAM with trust constructs (Gefen, Karahanna, & Straub, 2003b, 2003a; Venkatesh *et al.*, 2016; W. Wang & Benbasat, 2005). Accordingly, in addition to the well-known antecedents (PU and PEOU) of behavioral intention, trust also contributes to explaining user acceptance of IT (e.g. Chandra *et al.*, 2010; Gefen *et al.*, 2003b, 2003a; W. Wang & Benbasat, 2005).

Table 1 displays a sample of studies which measure the role of trust on PU, PEOU and the intention to use an information technology in TAM models.

TABLE 1
The role of trust and the intention to use an IT in the TAM extant literature

Study	Trust	Context
Gefen *et al.* (2003b)	Antecedent of PU and BI Consequence of PEOU	Online shopping
Wu & Chen (2005)	Antecedent of PU Consequence of PEOU	Online tax
Tung *et al.* (2008)	Antecedent of PU and BI Consequence of PEOU	Logistics health information system
Alsajjan & Dennis (2010)	Antecedent of PU	Internet banking
Chandra *et al.* 2010	Antecedent of PU and PEOU Antecedent of BI	Mobile payment systems
Wang & Benbasat (2005)	Antecedent of PU and BI Consequence of PEOU	Online recommendation agents
Li *et al.* (2014)	Antecedent of PU and BI	Personal health record system
Pavlou (2003)	Antecedent of PU and PEOU Antecedent of BI	E-commerce
Ortega Egea & Roman Gonzales (2011)	Antecedent of PU and PEOU Antecedent of BI	Electronic health care records
Gefen *et al.* (2003a)	Antecedent of BI	Online stores
Gefen (2004)	Antecedent of PU Antecedent of BI	Electronic Resource Planning

Trust can be defined as a state of favourable expectation regarding other people's actions and intentions (Möllering, 2001). Definitions of trust usually highlight the "willingness to depend" on one another (e.g. Gefen *et al.*, 2003b; McKnight *et al.*, 2002; Vance, Elie -Dit-Cosaque, & Straub, 2008). One of the most cited definitions is provided by Mayer, Davis, and Schoorman (1995), who suggest that trust is "*the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party.*" (p 712). Therefore, trust involves both risk control based on a rational assessment of the other party's interests and competence, and risk taking. McKnight *et al.* (2002) propose a conceptualization of trusting beliefs that encompass three dimensions: competence (i.e., the ability of the trustee to do what the trustor needs), benevolence (i.e., the trustee's motivation to act in the trustor's interests), and integrity (i.e., the trustee's honesty and promise keeping). This conceptualization has been widely used to examine the role of trust in technology adoption in IT-enabled contexts such as e-commerce (e.g., W. Wang & Benbasat, 2005) and e-government services (Venkatesh *et al.*, 2016). Wang & Benbasat (2005) propose an integrated trust-TAM conceptualization according to which trust influences both intention to adopt and usefulness, in addition to the well-known TAM effects. The authors validated their model for online shopping recommendation agents using a laboratory experiment. This conceptualization is important because it is the first to focus on trust in IT instead of the broader conceptualization of trust in a vendor (e.g., a vendor in the context of e-shopping).

Thus, trust has been conceptualized and empirically validated as an antecedent of PU (Chandra *et al.*, 2010; Gefen *et al.*, 2003b; Pavlou, 2003; Tung, Chang, & Chou, 2008; W. Wang & Benbasat, 2005). In the health care sector, Li *et al.* (2014) show that trust in a provider of a PHR software application had a positive impact on both perceived benefits and usage intentions. The main assumption behind the relationship between trust and PU is that if users do not trust the IT artifact then they will not perceive the potential benefits derived from the use of the artifact (W. Wang & Benbasat, 2005). In the context of CCT, this means that if citizens think that the CCT app is not able to fulfill their needs (e.g., the CCT app fails to capture the right data about an infected person), to work in their best interests (i.e., rather than for government surveillance goals) and to keep its promise (e.g., give accurate notifications about infections), then they may consider that the CCT app is not useful for them.

We therefore posit that:

- H4. Trust has a positive effect on PU.

A small number of studies model trust as a consequence of PEOU (Gefen *et al.*, 2003b; Tung *et al.*, 2008; W. Wang & Benbasat, 2005). Gefen *et al.* (2003b) and Wang & Benbasat (2005) argue that PEOU increases trust because when users perceived that an IT is easy to use, they feel that the IT provider cares about users which in turn generates trust. Therefore, we propose the following hypothesis:

- H5. PEOU has a positive effect on trust.

Trust has also been shown to influence behavioral intention in various IT-enabled contexts, and using different conceptualizations (Fang *et al.*, 2014; Kim & Koo, 2016; B. Q. Liu & Goodhue, 2012; Vance *et al.*, 2008). These studies included both TAM extended models (Awad & Ragowsky, 2008; Gefen *et al.*, 2003b, 2003a; Suh & Han, 2003; Tung *et al.*, 2008; N. Wang, Shen, & Sun, 2013; W. Wang & Benbasat, 2005) and studies of intention to use PHR systems (H. Li *et al.*, 2014). According to this body of research, trust can overcome user' risk and uncertainty concerns and lead them to express an intention to adopt an IT (Gefen *et al.*, 2003b; W. Wang & Benbasat, 2005). If users do not trust the IT artifact, they may not use it and instead switch to other systems (W. Wang & Benbasat, 2005). Moreover, trust creates more positive attitudes (Chandra *et al.*, 2010). In the context of CCT app adoption, Altmann *et al.* (2020) conducted a survey in five countries and showed that the probability of installing a CCT app increases with trust in the government. Using a panel survey conducted in Switzerland, von Wyl *et al.* (2021) showed that trust in government is correlated with trust in a CCT app. In addition, Dowthwaite *et al.* (2021) conceptualized and empirically validated the role of trust in a CCT app on adoption intentions.

Trust is particularly important when users interact with an IT for the first time and thus have limited understanding of agent behavior as they have no previous experience with the IT nor have assessed its quality (McKnight *et al.*, 2002; W. Wang & Benbasat, 2005). This is the case for a CCT app for which the intention to adopt is investigated in this paper in the early months after its implementation. Therefore, we posit the following hypothesis:

- H6. Trust has a positive effect on BI.

Information privacy

Previous literature has highlighted the importance of information privacy and privacy concerns in technology adoption (Dinev *et al.*, 2015; Malhotra, Kim, & Agarwal, 2004; Trang *et al.*, 2020; Wu, Huang, Yen, & Popova, 2012). While the influence of privacy on mobile health acceptance has not been addressed, scholars such as Li *et al.* (2014) have argued that privacy-related risks are the primary reason why many people hide their medical information.

Authors have defined privacy in various ways, including general privacy concerns (i.e., the importance of privacy), willingness to display personal information, and privacy control. Clarke (1999) distinguishes four dimensions of privacy: privacy of a person, personal behavior privacy, personal communication privacy, and personal data privacy. Bélanger and Crossler (2011) argue that as most communications are digitized and stored as information, personal communication privacy and data privacy can be merged into the construct of information privacy. Information privacy is the ability of an individual to control when, how, and to what extent their personal information is exchanged with and used by others (Bansal, Zahedi, & Gefen, 2015; Belanger, Hiller, & Smith, 2002; H. Li *et al.*, 2014). This concept is strongly related to control over information about oneself (Taddei & Contena, 2013). As a loss of information privacy renders users vulnerable to various types of privacy risks, they tend to evaluate information sensitivity and loss of information control before sharing their data (Malhotra *et al.*, 2004).

An app's privacy design can differ according to the amount and type of sensitive information required from a user and the extent of control over access to it, including where the data is located and who has access to it (Cavoukian, 2009; Trang *et al.*, 2020). Recent research on mobile devices and apps has found that different types of IT designs influence privacy concerns and user acceptance (Venkatesh, Aloysius, Hoehle, & Burton, 2017), that users prefer control to direct information access (Sadeh *et al.*, 2009), and that app permission requirements decrease installation intentions (Gu, Xu, Xu, Zhang, & Ling, 2017).

As privacy concerns are a main inhibitor for app acceptance (Dinev *et al.*, 2015), it stands to reason that an app's privacy design affects adoption (Trang *et al.*, 2020). As contact tracing apps require access to sensitive data, a citizen's decision to install the app may depend on the app's privacy design in terms of sensitivity (e.g., geolocalisation tracking vs. Bluetooth tracing) and control (e.g., centralised vs. decentralised data processing; restricted vs. extended data usage), and on the trust in the app provider to develop appropriate privacy safeguards (Trang *et al.*, 2020).

Perceived privacy control is defined as the perceived level of control over the disclosure and subsequent use of one's personal information (H. Li *et al.*, 2014). The concept of privacy control is inspired by the concept of self-efficacy and trust in one's own abilities. According to Bandura (1997) self-efficacy is "an individual's conviction (or confidence) about his or her abilities to mobilize the motivation, cognitive resources, and courses of action needed to successfully execute a specific task within a given context" (Stajkovic & Luthans, 1998, p. 66). Individuals may consider that having control over their health information disclosure and usage allows them to assess the benefits and potential privacy risks involved in using a mobile health app (H. Li *et al.*, 2014). A high level of perceived control over information practices could reassure users that the mobile health app provider is likely to behave responsibly, leading them to form more favorable judgments about the benefits of the app (H. Li *et al.*, 2014). Li et al (2014) has shown in the context of PHR that privacy control positively influences PU.

We therefore hypothesize that:

- H7. Privacy control influences PU.

Technical reliability

Reliability has been defined as the dependability of system operations (Nelson, Todd, & Wixom, 2005; Shaw, 2002; Srinivasan, 1985; Wixom & Todd, 2005) or, more specifically "*the technical availability of the system.*" (Nelson *et al.*, 2005, p. 205). More recently, McKnight, Carter, Thatcher, and Clay (2011) defined reliability as the belief that the specific technology will consistently operate properly. Carayon, Hundt, and Wetterneck (2010) conceptualized reliability as a dimension of technical performance together with speed, and accuracy, and found that reliability most influenced system acceptance and continued use. Reliability has also been shown to be an antecedent of system quality (Wixom & Todd, 2005).

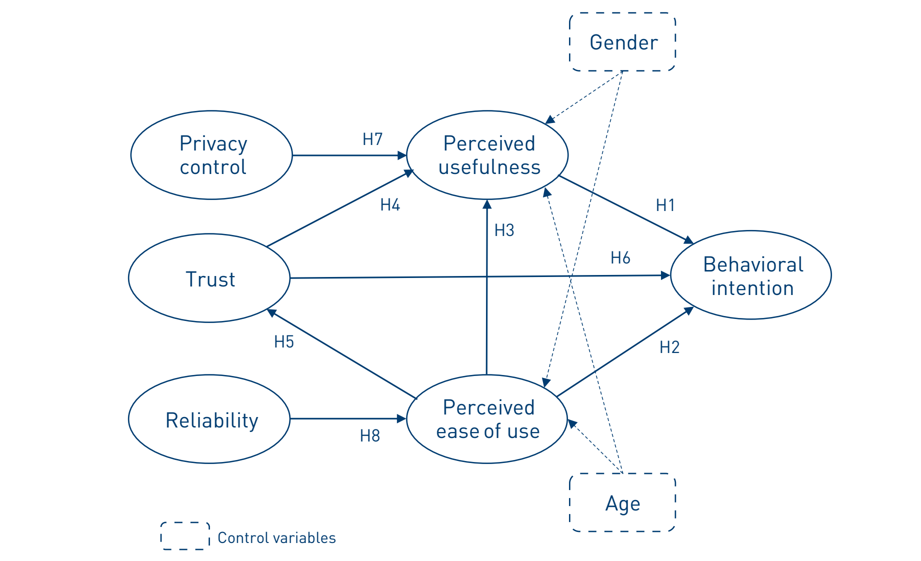
In one of the few studies that have examined the influence of reliability on technology acceptance, Liao & Landry (2000) show that system reliability has a direct effect on PEOU, assuming that a performant IT (e.g., which does not breakdown) is perceived as being more easy to use than a less performant IT.

Therefore, we propose the following hypothesis:

- H8. Reliability has a positive effect on PEOU.

In line with previous studies, we added control variables to PU and PEOU for gender (Gefen & Straub, 1997; X. Zhang & Prybutok, 2003) and age (Burton-Jones & Hubona, 2006; Gomez, Egan, & Bowers, 1986). Our conceptual research model is presented in Figure 1.

FIGURE 1
The conceptual research model



Methodology

Development of a questionnaire

A questionnaire was developed (Appendix 1) to test the research hypotheses and model. All constructs of the conceptual model were operationalized based on the extant literature (Lai & Li, 2005; H. Li *et al.*, 2014; Nelson *et al.*, 2005; Venkatesh *et al.*, 2016). The questions were translated following a forward and backward translation procedure as recommended for this kind of study (Bullinger, 1995) and a five-point Likert scale was used (i.e., 1 very strongly disagree to 5 very strongly agree) to measure each item. Following Li *et al.* (2014), we adopted the concept of "perceived benefits" to measure PU as it is more appropriate in a healthcare setting. Perceived benefits are the useful and desirable effects that are expected to accrue from using a technology. A pilot test was conducted with ten individuals to ensure that items were easy to understand.

Context of the french contact tracing app

Stop Covid was a French Coronavirus contact-tracing app that was designed by a consortium of French companies led by the National Institute for Research in Computer Science and Automation (INRIA) and implemented by the French Government in June 2020. Its use was voluntary and the government developed a promotion strategy to increase its adoption (Rowe *et al.*, 2020). The aim was to alert users who may have been in contact with someone infected by the Coronavirus. The app was available for Android and iOS compatible telephones, was free to download and used a wireless Bluetooth protocol. The app used Bluetooth to identify nearby users rather than geolocalisation which is considered more intrusive. When a telephone identified a nearby user who also had the StopCovid app installed and activated, user codes were exchanged via Bluetooth. The codes were designed to change regularly so that users remained anonymous. If a person developed symptoms which were confirmed by a laboratory test, the laboratory provided the patient with a QR code to flash with their phone. This information was centralized on a server which sent alerts to anyone who had been within one meter of the infected person for more than 15 minutes within the previous 14 days. The consortium launched a Bug Bounty program with French startup YesWeHack before launching the app, to enhance the security of the StopCovid application. This initiative mobilized a community of cybersecurity experts to search for potential vulnerabilities within the application and its infrastructure. The app was modified to improve data protection following a request from the national committee in charge of data protection rights (Commission Nationale de l'Informatique et des Libertés, CNIL). The consortium also published the source code of the app on GitHub.

When the app was launched, a computer science researcher reported that the app collected more data than claimed, including the data of all persons in proximity to a user for less than 15 minutes. Facing criticism from several rights groups about individual privacy and the relevance of collected data, the consortium made several modifications to the app. Beyond privacy concerns, technical performance was also reported as problematic as the first version of the app proved to be incompatible with Apple's operating system and the Bluetooth settings used by iPhones.

According to the data published by the government, three weeks after launch the app had only been downloaded by 2.7% de la population and 14 notifications of suspected contacts had been sent to users. This raised public criticism about the app's lack of efficacy, as its design requires it to be used by most of the population in order to accurately track suspected contacts.

Sample and data collection

A web-based questionnaire was used for data collection in July 2020 by a leading market research provider, Panelabs. The survey was administrated to a sample of 1000 individuals from the French population of over 20 years of age that was quota-controlled according to gender, age, geographic area and occupation to ensure that it was representative. Our study focuses only on individuals that installed the application, in order to measure the influence of the reliability and perceived ease of use constructs following our conceptual model. Table 2 presents the principal characteristics of the sample, broken down according to whether they installed and then actually used the application or not. This smaller sample of "installers" is also representative of the general French population for age, geographic area and occupation. It differs along the variable gender; a greater percentage of men installed the app than in the general population[1]. The influence of gender was controlled for in the model.

1. A Chi-squared test was conducted to compare the "installer" sample distribution with that of the general French population. The results are as follows: Gender χ^2= 13.55, df = 1, p > 0.05; Age χ^2= 2.98, df = 5, p < 0.05; Occupation χ^2= 3.06, df = 5, p < 0.05; Geographical area χ^2= 1.03, df = 4, p < 0.05.

TABLE 2
Demographic profile of the sample

Dimension	Actual use		Total	%
	Yes	No		
Gender				
Male	98	33	131	59.8%
Female	62	26	88	40.2%
Age				
20–24	13	10	23	10.5%
25–34	22	10	32	14.6%
35–44	27	11	38	17.4%
45–54	29	11	40	18.3%
55–64	28	6	34	15.5%
65+	41	11	52	23.7%
Occupation				
Self-employed workers (e.g. farmers, traderperson)	11	1	12	5.5%
Executives, intellectual and liberal professions	21	8	29	13.2%
Intermediate professions, middle management	20	8	28	12.8%
Employees, workers	44	24	68	31.0%
Retaired	48	10	58	26.5%
No work activity	16	8	24	11.0%
Living area				
Ile-de-France	34	16	50	22.8%
North-West	32	14	46	21.0%
North-East	39	10	49	22.4%
South-West	15	6	21	9.6%
South-East	40	13	53	24.2%

Data analysis and results

Measurement model

The study used SmartPLS 3.0 (Ringle, Wende, & Becker, 2015) in line with similar studies in healthcare (Zobair, Sanzogni, & Sandhu, 2019) to estimate the measurement properties of our model. Specifically, the study applied nonparametric bootstrapping (Chin, 2010; Efron & Tibshirani, 1994) with 5000 replications to obtain the standard errors of the estimates (Hair, Hult, Ringle, & Sarstedt, 2016) and a path weighting scheme to estimate the structural model relationships.

Reliability and validity analyses were first conducted to evaluate the quality of the measures used. The Cronbach alpha statistics that were computed to evaluate the internal consistency reliability for each construct are presented in Table 3. All values are above 0.70 indicating adequate internal consistency.

TABLE 3

Quality criteria of the measurement model

Latent constructs	Indicators	Standardised loading	AVE	Composite reliability	Cronbach's Alpha	R^2	Adjusted R^2
Trust	TRUST1 TRUST2 TRUST3	0.885 0.729 0.810	0.657	0.737	0.851	0.288	0.285
Privacy control	PRICT1 PRICT2 PRICT3 PRICT4	0.851 0.875 0.901 0.897	0.776	0.904	0.933		
Reliability	RELI1 RELI2 RELI3	0.921 0.912 0.877	0.817	0.888	0.930		
Perceived usefulness	PU1 PU2 PU3 PU4 PU5 PU7	0.854 0.869 0.945 0.928 0.912 0.843	0.797	0.949	0.959	0.472	0.459
Perceived ease of use	PEOU1 PEOU2 PEOU3	0.902 0.905 0.940	0.839	0.904	0.940	0.399	0.390
Behavioral intention	BI1 BI2	0.986 0.985	0.971	0.970	0.985	0.545	0.539

Note: TRUST = Trust; PRICT = Privacy control; RELI = Reliability; PU = Perceived usefulness; PEOU = Perceived ease of use; BI = Behavioral intention

The convergent validity of each construct was evaluated by inspecting the outer loadings of each individual item and the average variance extracted (AVE). The individual item loadings are all above 0.7 on their respective constructs and the average variance extracted of each construct is above the 0.5 threshold (Fornell & Larcker, 1981) indicating the convergent validity of the instrument items.

The discriminant validity of each construct was assessed using two separate measures. Firstly, an inspection of the cross loadings of the indicators revealed that loadings on the associated construct were greater than loadings on other constructs (Table 4). Secondly, the square root of each construct's AVE value was greater than its highest correlation with any other construct (Table 5). These findings support the discriminant validity of the constructs.

A full collinearity test was conducted following the procedure outlined by Kock & Lynn (2012) to test for common method bias. This is particularly important in our study as TAM constructs (Straub & Burton-Jones, 2007) and self-reported usage in particular (Y. Lee *et al.*, 2003) may be subject to bias. All variance inflation factor (VIF) statistics were below 3.3 confirming that the model was free of common method bias.

Once we confirmed that construct measures were reliable and valid, we then assessed the predictive capabilities and the relationships between constructs in our structural model.

TABLE 4

Cross loadings of all indicators

Variable	TRUST	PRICT	RELI	PU	PEOU	BI
TRUST1	**0.885**	0.478	0.509	0.527	0.486	0.700
TRUST2	**0.729**	0.366	0.383	0.376	0.420	0.508
TRUST3	**0.810**	0.415	0.591	0.604	0.399	0.519
PRICT1	0.406	**0.851**	0.346	0.476	0.208	0.399
PRICT2	0.448	**0.875**	0.417	0.452	0.255	0.436
PRICT3	0.488	**0.901**	0.409	0.477	0.225	0.520
PRICT4	0.491	**0.897**	0.397	0.530	0.239	0.484
RELI1	0.511	0.362	**0.921**	0.376	0.588	0.530
RELI2	0.582	0.411	**0.912**	0.463	0.587	0.562
RELI3	0.573	0.439	**0.877**	0.491	0.521	0.587
PU1	0.518	0.489	0.408	**0.854**	0.258	0.411
PU2	0.521	0.431	0.442	**0.869**	0.322	0.407
PU3	0.610	0.546	0.482	**0.945**	0.286	0.502
PU4	0.545	0.531	0.410	**0.928**	0.273	0.464
PU5	0.593	0.517	0.473	**0.912**	0.268	0.507
PU7	0.551	0.425	0.389	**0.843**	0.275	0.447
PEOU1	0.443	0.196	0.495	0.247	**0.902**	0.404
PEOU2	0.486	0.256	0.592	0.280	**0.905**	0.478
PEOU3	0.538	0.263	0.623	0.325	**0.940**	0.518
BI1	0.716	0.524	0.614	0.521	0.493	**0.986**
BI2	0.697	0.507	0.603	0.491	0.520	**0.985**

Note: TRUST = Trust; PRICT = Privacy control; RELI = Reliability; PU = Perceived usefulness; PEOU = Perceived ease of use; BI = Behavioral intention

TABLE 5

Correlations of the latent variables

Variable	TRUST	PRICT	RELI	PU	PEOU	BI
TRUST	**0.811**					
PRICT	0.521	**0.881**				
RELI	0.613	0.445	**0.904**			
PU	0.625	0.551	0.488	**0.893**		
PEOU	0.537	0.263	0.627	0.313	**0.916**	
BI	0.717	0.523	0.617	0.514	0.514	**0.985**

Note: TRUST = Trust; PRICT = Privacy control; RELI = Reliability; PU = Perceived usefulness; PEOU = Perceived ease of use; BI = Behavioral intention

Square root of AVE in bold on the diagonal

Structural model

Prior to interpreting path coefficients, we checked for collinearity between predictor constructs. All VIF statistics are below 5 indicating acceptable levels of collinearity (Hair, Ringle, & Sarstedt, 2011). We next examined the magnitude and strength of the paths of the structural model and then its overall explanatory power. Standardized paths should be around 0.20 and ideally above 0.30 and be directionally consistent with expectations to be considered meaningful (Chin, 1998). The loadings on all significant structural paths were close to or above 0.20 indicating that the model had sufficient predictive power. The results of the structural model are presented in Table 6.

TABLE 6
Results of the structural model

Paths	Path coefficient (β)	Standard deviation	t statistic	p-value	Decision
PU à BI	0.114**	0.057	1.991	0.047	Supported
PEOU à BI	0.184***	0.063	2.946	0.003	Supported
PEOU à PU	-0.031	0.060	0.455	0.649	Not supported
TRUS à PU	0.481***	0.069	6.922	0.000	Supported
PEOU à TRUST	0.539***	0.058	9.213	0.000	Supported
TRUST à BI	0.547***	0.062	8.871	0.000	Supported
PRICT à PU	0.287***	0.066	4.278	0.000	Supported
RELI à PEOU	0.629***	0.048	13.158	0.000	Supported
Control variables					
Age à PEOU	0.061	0.054	1.145	0.252	
Age à PU	0.071	0.057	1.256	0.209	
Gender à PEOU	-0.033	0.053	0.588	0.556	
Gender à PU	0.091	0.050	1.816	0.069	

Note 1: TRUST = Trust; PRICT = Privacy control; RELI = Reliability; PU = Perceived usefulness; PEOU = Perceived ease of use; BI = Behavioral intention

Note 2: *p < .10; **p < .05; ***p < .01 (two-tailed) confidence intervals for significance testing.

The path between PU and BI was weak but significant at the 5% level (β = 0.114, p = 0.047), thus supporting hypothesis H1. The PU of the CCT app weakly influences intention of use.

The path between PEOU and BI (β = 0.184, p = 0.003) was significant at the 5% level, thus supporting hypothesis H2. The perceived ease of using the contact tracing application influenced use intentions albeit with a weak path coefficient. PEOU did not significantly influence PU (β = 0.-0.031, p = 0.649) at the 5% level (H3).

The path between trust and PU (β = 0.481, p < 0.001) was significant, supporting hypotheses H4. Trust was strongly influenced by PEOU (β = 0.539, p < 0.001), thus supporting H5. In turn, trust significantly influenced BI (β = 0.547, p < 0.001) (H6).

Privacy control positively influenced PU (β = 0.287, p < 0.001), albeit with a moderate path coefficient, lending support to hypothesis H7. The relationship between reliability and PEOU was also found to be strong and significant (β = 0.629, p < 0.001), upholding hypothesis H8.

The coefficient of determination (R^2) was computed to assess the model's overall explanatory power. The analysis revealed that the structural model explained 54% and 46% of the variation in BI and PU respectively, suggesting that the structural model provided adequate explanatory power of these constructs (Hair *et al.*, 2016). The model explained less variation in the trust (R^2 = 29%) and PEOU (R^2 = 39%) variables. The inclusion of the two control variables (age and gender) did not significantly influence the explanatory power of the model.

In addition to evaluating the model's predictive accuracy with the R^2 statistic, we also calculated Stone-Geisser's Q^2 value to assess the model's predictive relevance. Predictive relevance measures how well the path model can predict the originally observed values. The Q^2 values of our model are all between 0.18 and 0.52 indicating medium to strong predictive relevance of our model (Hair *et al.*, 2016).

Discussion

We proposed and validated a model that includes three antecedents of the main TAM constructs that are relevant in a healthcare context. Firstly, the trust variable was found to play a central role by virtue of both its direct and mediated effects. Trust was confirmed as an influence of PU and BI, in line with the extant literature (Alsajjan & Dennis, 2010; Gefen *et al.*, 2003b; Pavlou, 2003; W. Wang & Benbasat, 2005). Trust was also found to be a consequence of PEOU, with the latter accounting for over one quarter of the variance in the trust variable (R^2 = 0.285). This result is also consistent with the existing literature (Gefen *et al.*, 2003b; W. Wang & Benbasat, 2005). To further explore the role of the trust variable in our model, post hoc exploratory analysis (Hollenbeck & Wright, 2017) was undertaken and revealed that trust mediates the relationship between PEOU and PU (β= 0.257, p < 0.001) and between PEOU and BI (β = 0.293, p < 0.001).

Secondly, privacy control was confirmed as an antecedent of PU, underscoring the role of data privacy as a predictor of BI. This result is consistent with previous studies (H. Li *et al.*, 2014) that emphasize the importance of this relationship within a healthcare context. Moreover, it contributes to the recent literature on the determinants of CCT app acceptability, which has found privacy concerns to be main adoption barriers (Altmann *et al.*, 2020; Dowthwaite *et al.*, 2021; Fox *et al.*, 2021; Janssen & van der Voort, 2020; Sharma *et al.*, 2020; Trang *et al.*, 2020; von Wyl *et al.*, 2021; Walrave *et al.*, 2021).

Thirdly, reliability was found to be an antecedent of PEOU. Post hoc analysis revealed that reliability indirectly influenced the trust variable through PEOU (β = 0.337, p < 0.001).

Surprisingly, our study does not support the main TAM relationship between PEOU and PU (β = -0.031, p = 0.649). In addition, the influence of PU on BI is weak (β = 0.114, p = 0.047). We suggest that this unexpected result may be explained by the central role trust plays in a healthcare context (H. Li *et al.*, 2014). Trust was found to both directly influence BI and mediate the relationship between PEOU and BI. While this result is consistent with the extant literature (Alsajjan & Dennis, 2010; Gefen *et al.*, 2003b; Pavlou, 2003; W. Wang & Benbasat, 2005), no previous studies have questioned the TAM in this way. This unexpected result requires further investigation.

Our findings also open four new and interesting research perspectives. The first is related to the link between privacy control and trust. Altmann *et al.* (2020) have suggested that privacy concerns play a role in the negative relationship between trust in government and the probability of installing the app. Hassandoust *et al.* (2021) have already found that initiatives related to privacy protection influence trust beliefs which in turn influence the intention to adopt a CCT app. The situational privacy calculus conceptualization that they propose could be investigated further in different empirical settings.

The second perspective involves the investigation of the determinants of trust, such as the roles of rational cognitive beliefs based on previous experience, competence and testing (McKnight *et al.*, 2011), and of emotional attitudes (Komiak & Benbasat, 2006). In addition, further research could investigate the role of non-experiential antecedents in the formation of trust as well as privacy control and perceived usefulness. We suggest that the discourse in both broadcast and social media may influence people's beliefs and intentions to use CCT apps especially in such a highly publicized context as the Coronavirus pandemic. Recent research has notably highlighted the role of media in influencing public health awareness and preventive behaviors (e.g., Al-Dmour, Masa, Salman, Abuhashesh, & Al-Dmour, n.d.; L. Liu, Xie, Li, & Ji, 2020) during the pandemic. Another non-experential antecedent that could be further investigated is the social norm. Indeed, Sharma *et al.* (2020) and Fox *et al.* (2021) have previously shown that social influence has an effect on intentions to adopt a CCT app. Future research could consider these non-experiential influences.

A third perspective may consider different levels of trust. Indeed, the IT artifact cannot be considered as isolated from other stakeholders in the eHealth ecosystem (Kohli & Tan, 2016), such as the IT provider, IT governance and management (i.e. the national government in the case of most CCT apps (Kahnbach *et al.*, 2021)), and doctors.

While previous studies have insisted on the importance of trust in the relationship between patient and healthcare provider (especially doctors) (Petrocchi *et al.*, 2019), some surveys (e.g., Digital Health Consumer Survey in US, Accenture, 2020[2]) have shown that individuals rely on healthcare providers rather than software companies to adopt health applications. Independently, scholars have also demonstrated that citizens' trust in government has eroded (Parent, Vandebeek, & Gemino, 2005; Spire, 2020). In the context of CCT, von Wyl *et al.* (2021) show that trust in government is correlated with trust in the CCT app. Similarly, Dowthwaite *et al.* (2021) found that citizens who did not download the CCT app had significantly lower trust in the app as well as in other users and stakeholders involved in app design and implementation.

In addition, van Velsen *et al.* (2021) show that trust between patients and doctors can be transferred to eHealth services (more specifically to an eHealth portal for telerehabilitation). This transfer has not been conceptualized in the management field although Lee, Kang, & McKnight (2007) found that trust in an offline bank transfers (i.e., influences) perceptions about that company's online bank. The conceptualization of this trust transfer in an eHealth ecosystem is an interesting avenue to extend TAM or to propose a new adoption model. Considering the CCT context, it is interesting to note that the implementation of most CCT apps, including the French CCT app has been decided and managed by governments (Kahnbach *et al.*, 2021), who are not historically a major actor in the health ecosystem. It would be interesting to investigate the transfer of trust in government to trust in a CCT app beyond correlations which have already been documented in the literature (Dowthwaite *et al.*, 2021). A promising research area is the role of ecosystem trust in the intention to adopt a CCT app, according to a new approach that highlights different levels of trust (e.g. trust in the care organization, trust in the care team and trust in the treatment (van Velsen *et al.*, 2021), trust in the IT artifact (W. Wang & Benbasat, 2005) and institution-based trust (McKnight *et al.*, 2002).

According to a fourth perspective, the dimensions of trust, competence, benevolence and integrity (McKnight *et al.*, 2002) could be investigated further using more detailed scales than the one used in this paper (Venkatesh *et al.*, 2016). This may allow for a finer understanding of how the different dimensions of trust individually influence intentions to adopt a CCT app. For example, an IT artefact may be considered competent but lacking in benevolence. In addition, while reliability influences BI, this concept and similar constructs such as technical performance should be extended to also consider technical issues related to an individual's device (e.g., storage). To date, no model nor instrument exists to measure these issues. Further research could propose a new conceptualization of this construct.

Our study makes several significant contributions to the literature. Firstly, it is one of the few studies that measures the antecedents of intention to use a CCT app, and by extension of a citizen centered health app in a real-world context in which the app was installed, thus allowing users to test the app and to form perceptions such as PEOU and technical reliability. Indeed, existing studies have investigated antecedents in experiments (e.g., Trang *et al.*, 2020) or in contexts in which apps were not installed by respondents (e.g., Altmann *et al.*, 2020). As the use of such apps is expected to increase in the future, understanding the predictors of acceptance and actual use is useful for policy makers and app designers. Secondly, our study offers practical guidelines for policy making about potential antecedents of citizen health apps. Finally, while the current literature on the determinants of adoption and intention to adopt contact tracing apps to combat COVID-19 have focused mostly on potential benefits and privacy issues, our study highlights the importance of trust in those applications.

Our study also informs policy intervention. Indeed, the French government has emphasized the technical transparency of the app in relation to data privacy and security (e.g., by publication of the code source on GitHub), but our results show that these technical and rational arguments may not influence citizens as expected since most individuals chose to trust or not and form their beliefs prior to evaluating technical aspects.

Prior to concluding the paper, it is important to acknowledge its limitations. Firstly, the study employs a cross-sectional design which involves the collection of data at one moment in time. Future research could use a longitudinal approach to observe changes in the model over time, or a mixed-methods approach that uses both qualitative and quantitative research techniques (Venkatesh, Brown, & Bala, 2013). These approaches

2. https://www.accenture.com/_acnmedia/PDF-130/Accenture-2020-Digital-Health-Consumer-Survey-US.pdf

may be particularly relevant in times of a pandemic as consumer sentiment has been shown to change over time (Mehta, Saxena, & Purohit, 2020). Secondly, unobserved heterogeneity was not assessed in this study (Becker, Rai, Ringle, & Völckner, 2013) and future research could consider this issue during the data collection process.

Conclusion

In this article, we have theoretically developed and empirically validated a research model anchored in the TAM that integrates trust, privacy control and reliability as antecedents of the perceived ease of use, the perceived usefulness and intention to use a Coronavirus contact tracing app. The study is based on a survey conducted on a representative sample of French citizens and data were analyzed using structural equation modelling with PLS software. Trust was found to be the strongest predictor in the model, as it directly and indirectly influences perceived usefulness and intention to use a Coronavirus contact tracing app. Surprisingly, core TAM relationships between perceived ease of use and perceived usefulness, and between the perceived usefulness and use intentions were insignificant or weak suggesting that the TAM should be revised to integrate the trust variable in healthcare settings. While our findings validated the role of privacy control, trust and reliability as antecedents of perceived usefulness (for trust and privacy control) and ease of use (for reliability), more research is needed to further validate this model and to further investigate the role of trust and its dimensions.

Our paper extends the body of knowledge on digital health acceptance and use at the individual level of population wide health apps such as Coronavirus contact tracing apps, identifies promising research opportunities into the antecedents and consequences of citizen centered digital health and contributes to informing policy making in this domain.

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APPENDIX

Constructs and items used in the model

Construct	Source	Items	Adapted items
Trust	Venkatesh *et al.* 2016	1. I believe that government websites would act in my best interest. 2. I expect government websites to be sincere and genuine. 3. I believe that government websites perform their roles very well	1. I believe that StopCovid would act in my best interest. 2. I expect StopCovid to be sincere and genuine. 3. I believe that StopCovid perform their roles very well
Privacy control	Li *et al.*, 2014	If I use a standalone PHR ..., 1. I believe I have control over who can access my personal health information stored in the standalone PHR. 2. I think I have control over what my personal health information in the standalone PHR is shared with other parties such as my healthcare providers. 3. I believe I have control over how my personal health information is used by vendors of standalone PHRs. 4. I believe I can control my personal health information provided to a standalone PHR	If I use StopCovid ..., 1. I believe I have control over who can access my personal health information stored in StopCovid. 2. I think I have control over what my personal health information in StopCovid is shared with other parties such as my healthcare providers. 3. I believe I have control over how my personal health information is used by the government though StopCovid. 4. I believe I can control my personal health information provided to StopCovid.
Perceived benefit[3]	Li *et al.* 2014	1. Using a standalone PHR would improve my access to my health information. 2. Using a standalone PHR would improve my communication with physicians. 3. Using a standalone PHR would improve my ability to manage my health. 4. Using a standalone PHR would improve the quality of my healthcare. 5. I would manage my health more effectively using a standalone PHR.	1. Using StopCovid would improve my access to my health information. 2. Using StopCovid would improve my communication with physicians. 3. Using StopCovid would improve my ability to manage my health. 4. Using StopCovid would improve the quality of my healthcare. 5. I would manage my health more effectively using StopCovid. 6. Using StopCovid would improve the quality of healthcare for all.
Perceived ease of use	Lai & Li, 2005	1. Learning to use Internet Banking is easy for me. 2. It is easy to use Internet Banking to accomplish my banking tasks. 3. Overall, I believe Internet Banking is easy to use.	1. Learning to use StopCovid is easy for me. 2. It is easy to use StopCovid to record/visualize data. 3. Overall, I believe StopCovid is easy to use.
Reliability	Nelson *et al.*, 2005	1. [system] operates reliably 2. [system] performs reliably 3. The operation of [system] is dependable.	1. StopCovid operates reliably. 2. StopCovid performs reliably. 3. The operation of Stop Covid is dependable.
Behavioral Intention	Venkatesh *et al.* 2016	1. I intend to use government websites to access government information in the next four months. 2. I predict I would use government websites to access government information in the next four months. 3. I plan to use government websites to access government information in the next four months.	1. I intend to use StopCovid in the next four months. 2. I predict I would use StopCovid in the next four months. 3. I plan to use StopCovid in the next four months.

3. The concept of "perceived benefits" was used to measure PU as it was considered to be more appropriate in a healthcare setting.