Review

Privacy and Security in Digital Health Contact-Tracing: A Narrative Review

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Abstract: (1) Background: Contact-tracing apps only achieve their aims if the majority of the population installs and actively engages with them. Such acceptance depends on public perceptions and are likely influenced by privacy and security concerns. Therefore, this review evaluates public perceptions towards the privacy and security of contact-tracing apps used during the recent COVID-19 pandemic, with a focus on identifying factors that influence acceptance. (2) Methods: A systematic literature review was performed. A total of 114 articles were retained as per the inclusion criteria, which included quantitative, qualitative, and mixed-methods studies. The data were analysed using thematic analysis. (3) Results: Eight main themes were derived: privacy, data protection and control, trust, technical issues, perceived benefit, knowledge and awareness, social influence, and psychological factors. (4) Conclusions: Improving privacy standards and the awareness of the digital contact-tracing process will encourage the acceptance of contact-tracing apps.

Keywords: contact-tracing; digital contact-tracing; COVID-19; public health; pandemic

1. Introduction

In the fight against infectious diseases, tracing contacts to treat or isolate them, if necessary, is a crucial control strategy [1]. In traditional contact-tracing, health officials manually trace contacts of individuals who have tested positive for an infection. Those individuals are advised to self-monitor symptoms and to quarantine [2]. Reaching out to potential secondary cases is the primary goal of contact-tracing, which is an extreme form of targeted control. When the number of infectious cases is low, contact-tracing has demonstrated effectiveness as a strategy [1], reducing the spread of infectious diseases during epidemics, including severe acute respiratory syndrome-associated coronavirus (SARS-CoV) and Ebola [3,4]. Traditional contact-tracing is labour-intensive and time-consuming, making it infeasible during pandemics [2].

Digital contact-tracing identifies exposed individuals using technology, usually via Smartphone applications [5]. Their availability has enhanced traditional contact-tracing by providing timely and automated notifications, ultimately supporting public health efforts to curb transmission of infectious diseases. Digital contact-tracing was first introduced in March 2020 in Singapore [6] during the COVID-19 pandemic, only being a feasible option due to the wide ownership of Smart devices. In 2011, over 4 billion mobile

device users were identified, and this continues to rise [7]. Digital contact-tracing mechanisms became an integral part of disease prevention during the recent pandemic, mainly due to high transmissibility and fatality rates [8] of the COVID-19 virus. Digital contact-tracing solutions could be more efficient than traditional tracing [8] but acceptance was deterred by numerous challenges. People were reluctant to share their data with an unknown entity and did not feel the newly introduced system was trustworthy and authentic. Digital solutions also inherently suffer from privacy and security issues [9]. It has been reported that data collected by apps could be used in public or private investigations and may break developers' privacy policies [10]. This makes people even more sceptical about using digital contact-tracing apps that collect health data.

Most countries introduced their first version of the contact-tracing app in 2020 during the COVID-19 pandemic period [6]. The low adoption rates directly impacted the app's effectiveness since these apps typically require over 60% of people to utilise them to achieve efficacy [11]. For effective contact-tracing, 80% of smartphone users need to use contact-tracing apps [8]. By December 2020, in the United Kingdom, only 28% had actively used the contact-tracing app [12]. During the pilot study of the first version of the contact-tracing app in the Isle of Wight, 56,000 downloads were observed, accounting for around 40% of the population [13]. In March 2021, Singapore and China reached the 60% threshold, while other countries had an adoption rate of around 15%, including Ireland, Canada, Germany, and Iceland [14].

Many concerns arose over efficacy, battery and data usage, and data management of digital contact-tracing apps, while cybersecurity was also a major concern [15]. People's attitudes toward these technologies were influenced by various factors, including privacy concerns [16–22], technological issues [23–25], and perceptions of effectiveness [25–28]. The aim of this review is to provide a comprehensive overview of the key issues associated with the acceptance of digital contact-tracing, with a primary focus on privacy and security assurances. This paper discusses psychological and behavioural factors that affect individuals' acceptance of digital health contact-tracing reported in the literature.

2. Materials and Methods

2.1. Search Criteria for the Systematic Review

A comprehensive literature search was conducted in the following databases: PubMed, Web of Science, the Cochrane Library, Embase, Scopus, PsycInfo, ArXiv, ProQuest, and CINAHL for studies published from January 2010 up to December 2022. This study was registered in the Open Science Framework (DOI 10.17605/OSF.IO/AE6WD) and is publicly available.

The search query included ('COVID-19' or 'SARS-CoV-2' or 'corona virus' or 'coronavirus' or 'new coronavirus' or 'severe acute respiratory syndrome coronavirus' or '2019-nCoV') and ('digital contact-tracing' or 'digital tracing' or 'digital tracking' or 'contact-tracing apps') and ('security' or 'acceptance' or 'psychology' or 'privacy'). During the second stage, duplicates were removed by the reference manager software and then screened based on titles and abstracts. During the final stage, individual manuscripts were screened, and those not meeting the inclusion criteria were excluded.

Inclusion and Exclusion Criteria

The following inclusion criteria were used: reports on (i) people who practically experienced digital contract-tracing solutions during the pandemic, (ii) people who did not experience digital contact-tracing during the pandemic (before the introduction of the contact-tracing apps), (iii) published in English, and (iv) peer-reviewed, published full

papers. Mathematical models, commentaries, opinion papers, letters, and review papers were excluded from the review.

2.2. Quality Assessment Tool

To mitigate bias, the second reviewer (PE) reviewed ten percent of all decisions made by the primary reviewer (SP) in each phase; screening by title, abstract, and by the full text. Ten percent of articles from each stage were randomly selected. Any discrepancies were resolved through discussion. The critical appraisal skills programme (CASP) tool [29] was used to assess the quality of each article. The checklist included questions related to the study's validity, bias and limitations, result interpretation, and applicability of the study.

2.3. Data Extraction

Data were extracted manually and stored in a Microsoft Excel spreadsheet. The following details were extracted into the spreadsheet: year of publication, authors, main objectives, study period, sample size, sample, country, study design, study type, main findings, privacy findings, and conclusion.

3. Results

A total of 4479 articles were obtained from nine databases after removing the duplicates by the reference manager software. After screening according to the search criteria, the total number of articles included in the study was 114. A detailed description of search results is shown in Figure 1.
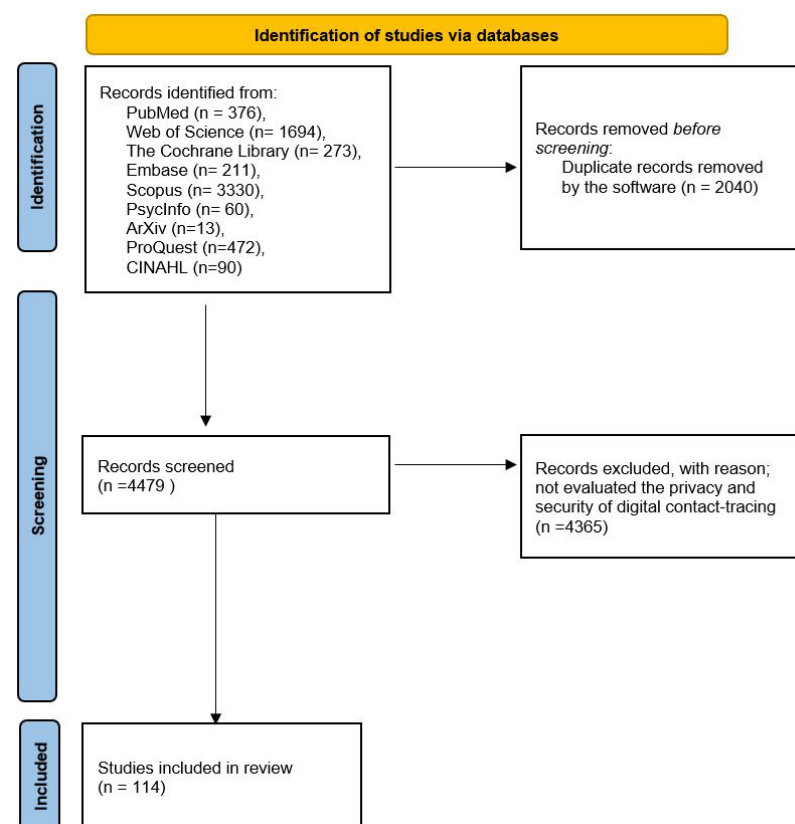

Figure 1. PRISMA flow diagram.

A total of 114 articles were included in the review, and all 114 articles passed the quality assessment criteria. These included 72 quantitative studies, 19 qualitative studies,

20 mixed method studies, and 3 randomised controlled trials. Characteristics of the studies are included in the Supplementary Materials.

A thematic analysis [30] was performed to extract information from the articles. This was achieved using NVivo 12 (Windows). Initial codes were generated after familiarisation with the data set. An inductive approach was followed to create the codes. The subsequent stages of the analysis comprised organising the codes into potential themes, reviewing and refining the themes, and assigning names and definitions to the themes. A total of eight themes were identified from the 114 articles. Those were privacy, data protection and control, trust, technical issues, perceived benefits, knowledge and awareness, social influence, and psychological factors (see Figure 2).
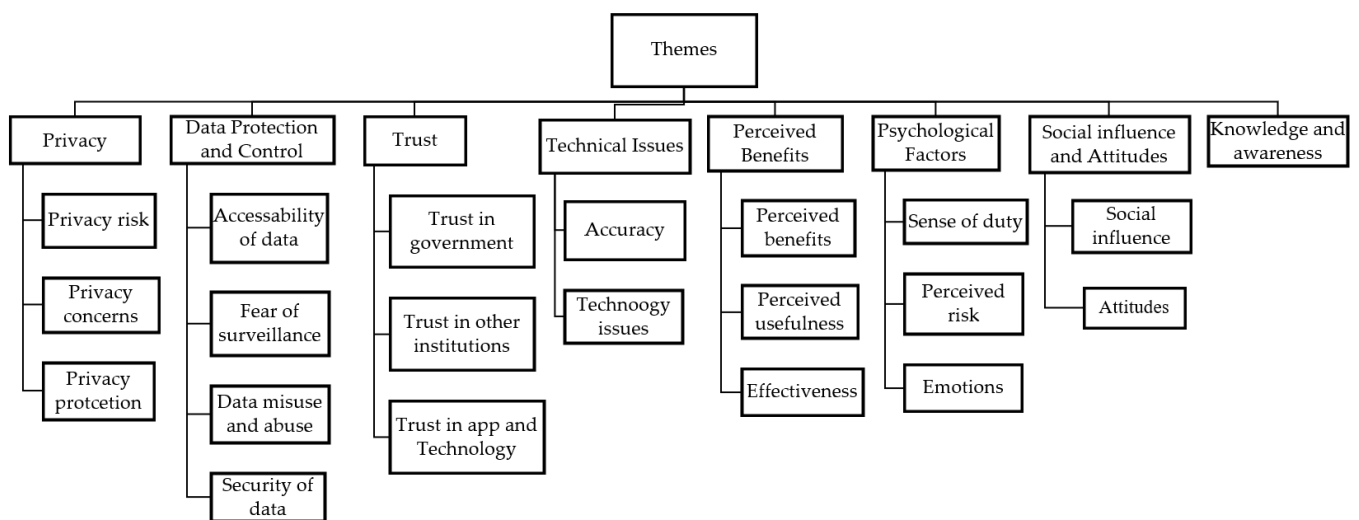

Figure 2. Themes derived from paper corpus.

3.1. Privacy

Digital contact-tracing apps have raised complex concerns, with the main privacy topics mentioned in the literature being risks, concerns, and protection. People are hesitant when they perceive a risk to their privacy primarily related to their sensitive health data. Privacy concerns appeared to be main factor deterring the acceptance of contact-tracing apps [16,17]. On the other hand, the assurance of privacy protection encouraged acceptance.

3.1.1. Privacy Risk

Perceived privacy risk refers to the extent to which an individual believes that using social networking sites will have adverse effects on their privacy [31]. In digital contact-tracing, people believe there are risks related to how their information is being handled. The perceived privacy risk was a significant determinant that negatively impacted the intention to use contact-tracing apps [21,32–35]. Users were less likely to download the app if they believed there was a greater risk to their privacy [34]. Likewise, privacy risks negatively indirectly influenced the actual use of contact-tracing apps [36]. Dooley et al. suggested that clearly communicating how individual data were protected and being transparent about privacy in a collective setting may reduce concerns regarding personal privacy risk [37]. Contrary to the above findings, a study conducted in Saudi Arabia established that privacy risk was not a significant factor influencing behavioural intention to use the contact-tracing app [38].

3.1.2. Privacy Concerns

Privacy concerns refer to issues people have about how their personal data are collected, used, and shared in the contact-tracing process. Privacy concerns were identified as a crucial factor driving the adoption, which acted as a barrier [39,40]. Many studies have reported that privacy concerns were the main reason for not using the contact-tracing app [17–20,22,41–43]. There was a negative relationship between privacy concerns and app usage [44–47]. In several studies, privacy concerns have negatively influenced the intention to use contact-tracing applications as well [42,48,49]. In some studies, the majority of participants had expressed concerns about the privacy and security of personal data [50–52]. Data privacy concerns were strongly associated with adoption intention [46], while app-related privacy concerns had a significant impact on users' intention to adopt contact-tracing apps [53]. Similarly, a European study has reported that information privacy concerns had a significant negative relationship with behavioural intention [54]. Concerns about app information privacy were negatively associated with both the intention to use and attitudes toward contact-tracing apps [55–57].

In line with previous studies, a study in England established that people were less likely to adopt the contact-tracing app if concerned about privacy [58]. In another study in England, among participants who downloaded the contact-tracing app, 47.8% said privacy was extremely important to them [59]. In Ireland, the adoption of digital technology solutions was significantly influenced by privacy and legal concerns related to the use of personal data [60]. In Wales, reluctance to use contact-tracing apps derived from concerns about personal privacy [61]. In New Zealand, suggestions were made that apps should incorporate robust privacy controls for the collected data [62]. In South Africa, some users expressed concerns about the invasion of smartphone privacy, citing a lack of privacy guarantees [63]. In a Twitter analysis, the negative sentiments expressed in India were more focused on privacy issues, while in Brazil they focused more on data misuse [64]. The invasion of privacy is another critical aspect many citizens have raised in their tweets [64].

In a study carried out with registered physicians from the US, UK, and the rest of the world, the majority of respondents (69.8%) believed that potentially relaxing privacy standards to combat the pandemic could result in future privacy violations. In Canada, 17% of users mentioned confidentiality (17%) as a reason for not downloading the app [27]. Notably, respondents willing to install the digital contact-tracing application expressed significantly lower concerns about privacy issues than those unwilling to install the application [65]. Similarly, users were more convinced than non-users that the contact-tracing apps respect users' privacy [66]. Older users were more likely to be influenced by privacy concerns when deciding to disclose information, whereas younger users were not significantly influenced by privacy concerns [67]. A similar finding was recorded in Canada: Privacy concerns related to contact-tracing apps were more prominent in older age groups than in individuals aged 18–29 years [68]. It was reported that a better understanding of safety, security, privacy, and trust plays an essential role in people's willingness to use contact-tracing apps [69]. Some users perceived no assurance of privacy and distrusted the government's guarantees regarding privacy, functionality, and the efforts put into developing the app [63]. Those who did not use the app expressed concerns about privacy violations, and users failed to appreciate the app's privacy-enhancing features. Some believed that the situation demanded that citizens sacrifice privacy (these participants regularly used privacy-invasive apps like Facebook) [70]. In another study, some participants believed that contact-tracing apps violated their privacy, while others had no concerns and considered them secure [25].

An experimental study in the USA detected no relationship between privacy and intention to download. The study revealed no differences in downloads based on privacy

messaging. However, when privacy messaging described how the app kept individuals' data safe and secure, perceptions of data security increased, but privacy concerns did not [71]. Another study in the USA revealed that age and race influenced how people perceived contact-tracing apps and their privacy issues. Furthermore, respondents of Asian descent expressed lower privacy concerns regarding contact-tracing apps, whereas those identified as Black showed more privacy apprehensions [72].

In a German study, privacy concerns did not appear to be the primary factor influencing adoption decisions, with 13% of participants indicating that they were very concerned about privacy violations [73]. Respondents did not consistently prioritise privacy; instead, they preferred a balanced approach that combined human and digital elements in contact-tracing. Surprisingly, privacy concerns did not have as much impact on the choice of the digital app as anticipated in the United Kingdom. Trust in the National Health ervice (NHS) was found to override privacy concerns for many respondents [74]. In China, the users' perception of privacy was positively associated with trust in government institutions [75]. A German study has reported that users' decisions were based on their privacy concerns and the advantages of the contact-tracing app, and their privacy behaviour was situational rather than static [76].

While privacy and security concerns may be significant factors in the initial adoption and use of the app, in the long term, these concerns faded. This shift could be facilitated by the absence of significant data breaches [77]. The expected continued use of the app after the pandemic had a statistically significant negative correlation with privacy concerns [78]. Privacy concerns reduce the likelihood of downloading, but some concerns may decrease over time [79]. However, it is important to note that while privacy concerns significantly impacted current actions and adoption intentions, their influence declined when considering future intentions [44].

3.1.3. Privacy Protection

Research has shown that individuals were more likely to adopt contact-tracing apps if they believed their privacy was preserved [80]. Perceived privacy protection was positively correlated with the use of contact-tracing apps [80]. Perceived privacy protection was a statistically significant predictor of perceived persuasiveness to adopt contact-tracing apps [81].

In an Australian study, most participants agreed that the app design and supporting legislation provided adequate protection. However, they emphasised that privacy and voluntariness should not be compromised [82]. It was reported that users were more inclined to disclose personal information when they believed they had a reasonable level of control over it [83]. The results indicated that most users who trusted the app provider's data protection were using the contact-tracing apps [84]. It was evident that users who read privacy policies more carefully tended to perceive higher levels of privacy protection [75].

In Ireland, 20% of the respondents were highly conscious about reading privacy policies, and 59% read the privacy policy. People may seem more relaxed about privacy, but this might be because they recognised the potential to save lives by sharing data, even though overall awareness of privacy had increased during these times [85]. In the same manner in Scotland, participants found reassurance by reading the privacy statement, considering it to be a fairly standard statement. Additionally, people were reassured by the ability to find a more detailed privacy statement on the government's information site [86]. Paying attention to privacy policies before using the app also positively influenced perceived privacy protection [75].

Consistent with previous results, there was a positive relationship between knowledge of app privacy features and app usage [44]. Furthermore, users highlighted

the significance of privacy policies in building trust in contact-tracing apps [52]. According to an analysis of tweets, users have been consistently tweeting about the lack of strong privacy policies regarding data collection and storage. Users emphasised the necessity for enhanced privacy protections [87].

One study was conducted on Chinese tourists and international students, both of whom did not consider the collection of location information or mandatory usage of the Malaysian contact-tracing app as an invasion of privacy [88]. A similar conclusion was reached in New Zealand; the majority of participants expressed no concerns about the contact-tracing app compromising their privacy. Reasons cited for this lack of concern included having nothing to hide, perceiving themselves as already lacking privacy due to tracking through social media, mobile phone service providers, transaction records, or other means and relying on the app's privacy features [24]. In line with that, a study in Saudi Arabia involving the university community found that users were more inclined to use the app because it was privacy-focused, requiring no sharing of personal information or location. Instead, it relied on Bluetooth to obtain and update IDs randomly, signalling a privacy-centric approach [89].

3.2. Data Protection and Control

Data protection and control issues centred around access to users' data, where those were stored, and how they could be misused. Users were concerned about data-sharing with the government, potential safety risks, and uncertainty about data deletion. The fear of government surveillance, especially tracking through global positioning system (GPS), impacts users' willingness to download apps. Moreover, concerns about data security, potential data leaks, and the misuse of personal information were   prevalent. This theme has been divided into four sub-themes: (1) accessibility of data, (2) fear of surveillance, (3) data misuse and abuse, and (4) security of data.

3.2.1. Accessibility of Data

In digital contact-tracing, the primary considerations revolved around the types of data being collected, the entities with access to those data, the storage location, and the disposal of the data. Particularly, concerns were around the uncertainty about where the data would be stored, who would have access to the data, and for how long [90].

In a study conducted in Europe and the USA, participants expressed concern about their government's use of data and data-sharing without consent [79]. The act of sharing data with the government influenced the willingness to download the app. Additionally, participants expressed concerns about the mechanism of contact-tracing and data usage [79]. People expressed concerns over government access to information [91]. In the USA, in 2020, users lacked clarity regarding who had access to their personal data collected by contact-tracing apps and to what extent their data could be used [52]. It was observed that some individuals planned to uninstall the contact-tracing app once the situation stabilised, expressing a reluctance to continue sharing their data [91]. Concerns were expressed about uncertainty regarding which data had been collected and shared [50]. In New Zealand, a study conducted on healthcare staff emphasised the importance of understanding how technology and data would be utilised and accessed [62]. According to a study conducted in the United Kingdom, the participants overall acknowledged that passive monitoring is valuable in identifying health risks [92]. Similarly, another UK study has reported that people believed using the contact-tracing app would not significantly affect their perspective towards data sharing, indicating a more relaxed attitude towards it, as personal information is already easily accessible [93]. Further, another UK study stated that perceived information transparency significantly influenced the intention to download the contact-tracing app [34].

Participants expressed comfort in sharing their data with researchers in the USA [94]. Participants were more reluctant to share their data with for-profit organisations, acknowledging that entities like Google, Facebook, and Amazon already collect private information about their consumers on their platforms [94]. Similarly, people in the United Kingdom expressed concern about personal data privacy, driven by a lack of clarity about the specifics of the data collection and data-sharing processes [50]. Individuals who expressed concerns about the personal data collected by contact-tracing apps were less likely to adopt their contact-tracing app [95]. Some people feared that their personal information may be used without their authority [22]. In the USA, the top priority among participants for sharing personal information was having precise knowledge about the data being collected and the purpose of such collection [96]. Despite privacy assurances in app design and information detailing the collected data, participants still raised concerns about privacy violations and a perceived lack of data transparency [70], and they perceived the contact-tracing app as privacy-invasive regarding the government's access to the data [70]. In line with previous studies, excessive data collection by the contact-tracing app was cited as the main reason for not downloading the app [18]. Another reported issue in South Africa was disclosing information to other parties [63]. Concerns about negative consequences, particularly with employers (60%) accessing information through contact-tracing apps, were raised [42]. Concerns about contact-tracing apps were frequently related to the exposure of personal data to app providers [97]. A study conducted in Portugal demonstrated a significant positive relationship between willingness to disclose health information through a COVID-19 tracking app and the adoption intention [67]. It was revealed that when the attitude towards contact-tracing apps decreased due to privacy concerns, the willingness to disclose personal information decreased [98]. Further, as trust in the government increased, individuals were more willing to disclose information [98]. Some participants raised concerns about data protection in connection with contact-tracing apps and to ensure the safe storage of their data [90]. Similarly, some individuals expressed concerns about data storage and about the government potentially utilising the app for mass surveillance purposes [99].

3.2.2. Fear of Surveillance

Surveillance by authorities influenced people's willingness to use contact-tracing apps [90]. A survey conducted in Germany and Switzerland before and after the introduction of the contact-tracing apps revealed that the use of contact-tracing apps was negatively impacted by a fear of surveillance [36]. People expressed concerns about the potential for governments to establish long-term surveillance systems [90]. The fear of being geo-located was identified as a concern by respondents [27,100]. They criticised a lack of clarity in communication about how location and movement data were analysed [90]. People strongly disliked the idea of being tracked by the government [101]. According to a study in nine European countries, individuals have expressed their awareness of being monitored through different mediums such as geo-localisation, social media, and web searches; therefore, people felt that using COVID-19 apps could pose a higher threat to their privacy, which was unacceptable [102]. However, in Europe, participants expressed greater comfort with an app that shared location data from tested-positive users instead of sharing location data from all users [79].

In a Canadian study, among the participants, 46% of participants believed that the contact-tracing app located users through GPS, and 29% expressed a fear that it could identify users [27]. In Singapore, respondents expressed a dislike for location-tracing and believed that their data privacy would be violated by contact-tracing apps [103]. In the UK, the participants who had no intention of downloading the contact-tracing app mentioned that reluctance to be tracked was one of the most prevalent reasons [28,104]. In

another UK study, the most chosen concerns for non-adoption were government surveillance and greater surveillance after the epidemic [97].

Twitter analysis showed that most discussions on Twitter revolved around contact-tracing and surveillance among health topics [87]. Notably, an Indian study has reported that concerns regarding government surveillance did not significantly impact resistance towards contact-tracing apps, but such concerns indirectly influenced resistance through distrust [57]. Some participants expressed concerns about government tracking and surveillance due to misconceptions about how the apps operate [68].

In a Malaysian study, the respondents demonstrated a high level of awareness regarding the government's ability to access personal information and location data through the use of a contact-tracing app [105]. Factors such as fear of constant government surveillance influenced negative sentiments about contact-tracing [64,65]. In a US study, most participants believed that contact-tracing via Bluetooth was appropriate, while using additional location data, such as GPS or Wi-Fi, was perceived as less appropriate [106]. In another US study, the use of Bluetooth technology that does not collect location data and clear privacy policies outlining how personal data are handled seemed to enhance users' trust [52]. A study conducted on young adults showed 45.1% were willing to undergo active monitoring, 33.1% expressed willingness for passive monitoring, including tracking location and contacts through their phones, and 25% remained neutral. Young adults were more willing to share personal health information than location or contact data [107].

3.2.3. Data Misuse and Abuse

Data misuse refers to sharing data for purposes other than the main intention, while data abuse refers to a more severe misuse of data for different agendas, which impacts individuals. Concerns about the potential misuse of personal data have emerged as significant barriers to adopting contact-tracing apps. There was a concern among participants that the information collected could be used for purposes other than managing the pandemic [108]. This fear of data misuse has been prominent in the negative sentiments [64,65]. According to a study conducted in the USA, 40% of the participants expressed concern about the purpose of data collection and storage, 28% were worried about the potential sale of data for profit, 24% mentioned security and confidentiality as their main concern, 8% concerned the type of data collected, and another 8% were worried about the possibility of the data being used against them [94].

In Malaysia, respondents acknowledged the potential risk of abuse of their data [105]. In the USA, participants voiced concerns about contact-tracing apps potentially leaking information to third parties. Forty-six percent indicated that this concern would significantly or strongly influence their decision whether to install the contact-tracing app [109]. The public expressed concerns about data theft and the potential for law enforcement to use the information provided against them [110]. There was significant fear about governments using digital contact-tracing to further different agendas [110]. In the US, concerns mainly centred around the misuse of sensitive data [52].

A study conducted in the UK with people from the Black, Asian, and Minority Ethnic (BAME) communities found that many individuals were worried about their privacy due to the possibility of the government or other organisations accessing their data and using it for other purposes as the nature and scope of data collection were not clear [50].

People expressed concerns about sharing their data with other organisations without their consent, which could be used for marketing purposes and to identify the target audience for businesses [108]. In an Irish study, 41% of respondents mentioned that they worried technology companies would use this as an excuse for greater surveillance after the pandemic, 33% worried that the government would do the same, and 22% worried that phones would be more likely to get hacked [111].

The perception of susceptibility to data misuse was negatively correlated with the adoption of contact-tracing apps to the same extent in Singapore and Switzerland. The severity of data misuse was not associated with contact-tracing app adoption in Singapore and was weakly positively correlated with app adoption in Switzerland [112].

3.2.4. Security of Data

Security includes the protection of the data collected from contact-tracing, and it involves implementing the right policies and practices. Security concerns were reported as a reason for not intending to use the contact-tracing app [54,61,100]. Among various concerns, users showed a high level of concern related to data security when using contact-tracing apps [21,113], and people perceived insufficient data transparency and expressed concerns about potential data leaks [103].

Safety concerns, including potential data leaks, are among the frequently cited barriers to adopting contact-tracing apps [113]. Perceived security risks were identified as significant barriers towards adoption in Indian study [114]. Cybersecurity, constituting 18% of the total concerns, was mentioned as another reason [27]. In the USA, participants frequently cited concerns about data security as a primary reason for their reluctance to share data with contact-tracing technology [115]. On the Isle of Wight, some participants conveyed a sense of feeling spied on, emphasising data security concerns [116].

In Scotland, participants raised concerns about the confidentiality of the data they were required to provide, uncertainties about its usage, and potential impact on their contacts [86]. In Scotland, people sought reassurance that their data would remain confidential and not be shared with third parties outside the NHS [86]. In an Australian study, many individuals expressed concern about the security of the contact-tracing app. Some participants believed the app might not be secure enough and could be hacked, leading to unauthorised use of their information [22].

In New Zealand, a minority of participants cited privacy and security concerns that discouraged them from using the app [99]. In a study conducted in the USA, more than 70% of users agreed that they felt their health information was kept private while using contact-tracing apps [26].

In the Netherlands, the likelihood of a participant downloading an app was 3.33 times higher when informed that their data would be protected by law than when no information was provided about how their data would be handled [117]. In Turkey, participants who were presented with information about data protection laws were significantly more willing to download the app than participants who were presented with a COVID-19 call to action that did not mention data protection [117].

3.3. Trust

Trust can be defined as the confidence users have in the system, built upon experience and integrity. Trust is another important factor that has a significant influence on the adoption of contact-tracing apps [33]. From the literature, three sub-themes have been identified: (1) trust in the government, (2) trust in other institutions, and (3) trust in apps and technology.

3.3.1. Trust in Government

As the contact-tracing apps in most countries were implemented by their respective governments, trust in government can be identified as a main factor in adopting contact-tracing apps during the pandemic. People built their trust in the government based on the government's decision-making, policies, and guidelines implemented during the pandemic. During the pandemic period, due to the changing nature of the situation, there were many changes in the guidelines and policies declared by the WHO, which most

countries/governments followed throughout the period. It could be the reason people had less trust towards the government in this regard.

The trust in government [89] and national and local authorities was found to be a crucial factor in the willingness of people to participate in contact-tracing apps. These apps were perceived as a surveillance measure by authorities, making the level of trust towards these authorities an important factor [90]. In a US study, low trust in the government was mentioned as a reason for non-adoption of contact-tracing apps [41]. Similarly, a lack of trust in the government has been mentioned as a reason for the rejection of contact-tracing apps [17,34,118,119]. Further, a significant positive relationship was observed between political distrust and negative attitudes toward digital contact-tracing [120]. They criticised the lack of clarity in communication regarding how location and movement data were analysed, and the role of the Austrian government [90].

In South Africa, users distrusted the government's guarantee of privacy, functionality, and effort in the app's development [63]. Austrian participants expressed their distrust in authorities, calling for more transparent communication about the app.

In Wales, mistrust in the government was among the top ten reasons for a lack of willingness to use contact-tracing apps [61]. In line with previous findings, in the USA, survey respondents identified mistrust in the government (82%) as a barrier to adoption [42]. However, in another study while trust in the UK government did not play a significant role in the initial decision to adopt, it emerged as a predictor for new adoption in the third wave [58]. Studies conducted in Switzerland show that people who have more trust in their government and health authorities are more likely to use contact-tracing apps [23].

In the UK, another factor contributing to reported mistrust in the government was uncertainty regarding the creation of the contact-tracing app and concerns about how the data were collected, stored, and processed [77]. In Canada, the lack of trust in the government's handling of personal data was among one of the most commonly cited reasons for not downloading the app [18].

In the USA, distrust in the government and concerns about the contact-tracing app's security were cited as reasons for refusing to download the contact-tracing app [22]. In Canada, the lack of trust in the government's handling of personal data was among one of the most commonly cited reasons for not downloading the app [18]. In a European study, participants expressed significant distrust in the government conducting digital contact-tracing. However, there was a higher level of trust in government health agencies [79].

3.3.2. Trust in Other Institutions

This includes institutions associated with the digital contact-tracing process. Lack of trust in the public and private institutions was mentioned as a concern for not downloading the app [50].

Respondents expressed the least trust in private companies with their information [107]. Young adult respondents significantly distrusted sharing their data with private companies, including Google, Apple, Microsoft, or Facebook. Only 15.2% agreed to share their information with such entities. This substantial distrust among young adults could potentially interfere with the pandemic surveillance programs developed by these private companies [107]. In contrast, European participants expressed a higher level of trust in Google than in other companies [79]. Similarly, participants expressed a preference for a company known for protecting user data, and creating secure and private apps known to be susceptible to data breaches/leaks in the past [79].

In Germany, Austria, and Switzerland, distrust in authorities was particularly pronounced among Austrian participants, who consistently emphasised the need for more transparent communication about the contact-tracing app [90]. In the Republic of Ireland,

a lack of trust in the Irish health service and distrust in major technology companies were reported as reasons for not downloading the contact-tracing app [20].

In the UK, respondents demonstrated strong trust in the NHS and less trust in the UK government, with the weakest trust towards private contractors [93]. Notably, trust in the NHS was significantly stronger than in any other institution, while trust in private contractors was significantly lower than in any other institution. Individuals who did not plan to download the app exhibited significantly lower trust in the app compared to all other user groups. Additionally, those who initially downloaded but later deleted the contact-tracing app had significantly lower trust than individuals who currently had the app [93]. In the USA, reasons for the non-adoption of contact-tracing apps included low trust in Apple and Google [41].

According to a survey, medical providers (68%) were chosen as the most trusted group to protect the privacy of COVID-19 surveillance data. The second most trusted group was educational/non-profit bodies, and technology companies were considered the least trusted group. Respondents also reported low levels of trust in the government [121]. In the USA, mistrust in the government (82%), tech companies (59%), public health organisations (53%), and corporations (47%) were identified as barriers to the adoption of COVID-19 measures within their communities [42]. In the USA, a survey revealed that when asked about sharing personal information, 62.6% of young adults were willing to share information with their doctor or healthcare provider. Following closely, government agencies emerged as the next-most trusted option, with a comparable number of individuals indicating their readiness to share data with local and federal government agencies and researchers [107]. Similarly, regarding trust in entities associated with tracking apps and tracing apps, users expressed the highest trust in medical providers, followed by health insurers, private companies, public research universities, private research universities, employers, non-profit organisations, local governments, state governments, and federal governments, respectively [96]. People generally expressed their lack of trust in the developers of the contact-tracing app [28,119].

In line with the above finding, a study conducted in European countries and the USA reported that people were reluctant to share their data with private businesses or foreign governments and more willing to share data with medical professionals and academic institutions [122]. It was evident that European participants were more aware of the workings of the contact-tracing apps currently using its data collection mechanism and storage. Thus, users in Europe were more likely than those in the US to have trust in government agencies and research facilities [122].

Participants reported that trust in other stakeholders, such as private contractors, big technology companies, large and small hospitality venues, local councils, and the NHS, varied based on their perceived intentions and competence demonstrated throughout the pandemic [77].

3.3.3. Trust in App and Technology

Many users have expressed concerns about the contact-tracing app's ability to ensure privacy and security. They felt that the app invades the privacy of their smartphones and that there is no guarantee of privacy when using it [63]. There was a positive relationship between distrust in digital contact-tracing and resistance to using the contact-tracing app. It meant that people who had high distrust in the contact-tracing app were likely to resist using it [57]. Perceived trust in the contact-tracing app was one of the positive determinants of intention to use [21,39]. In China, it was reported that people carefully assessed risks, resulting in increased mistrust and doubt about epidemic prevention technologies [83].

In Canada, the perceived trustworthiness of the app was one of the particularly significant factors in its adoption [81]. The functionality and effectiveness of the app mainly determined participants' trust. If participants perceived these aspects to be deficient, then trust was low. Conversely, trust level was higher when the contact-tracing app was considered effective [77]. In the USA, some participants expressed concerns about information being intentionally or accidentally leaked. participant believed that a mobile application database had a higher risk of being hacked than information in a public health department's database. Participants perceived that technology, especially mobile apps, could easily lead to information leakage [115].

In contrast, in Germany, the examination of trust in the contact-tracing app and its developers did not show a significant direct relationship with app adoption [44]. In Vietnam, trust positively influenced the behavioural intention to adopt a certain contact-tracing technology [32]. In Qatar, participants considered contact-tracing apps trustworthy, and there was a significant positive correlation between trust and user satisfaction, which can be defined as the difference between expectations and perceptions [123]. Furthermore, trust had a statistically significant and negative effect on privacy risk, suggesting that higher levels of trust were associated with lower perceived privacy risks [32]. Further, distrust toward human tracers reduced participants' willingness to disclose personal information. Some participants mentioned their reluctance to talk to strangers about their health or lifestyle. Specifically, there was a fear that revealing demographics could potentially lead to racial discrimination. As a result, some participants expressed a preference for contact-tracing technology as a way to mitigate concerns related to racial discrimination [115].

In the USA, many people are hesitant to use contact-tracing technologies because they lack confidence in digital technology [42].This is mainly due to the fact that even when the information is presented in the user's native language on their smartphone, it can still be unfamiliar to those with limited digital skills [42].

In an Italian study, it was found that people in a particular group tended to download more apps on their smartphones, irrespective of the permissions required. This observation was consistent with the higher number of downloads than anticipated. It seemed that individuals in this cluster had more trust in using technology and smartphone apps [124].

A study conducted on Chinese tourists has reported that tourists' trust in health QR codes is affected by knowledge, perceived efficacy, privacy risk, and security. People's trust in digital health applications can increase acceptance of tracing technology [125].

3.4. Technical Issues

Technical issues refer to technology-related problems, including hardware, software, networks that disrupt normal functionality. Several technological factors influence the adoption of contact-tracing apps. Accuracy and reliability were crucial considerations, with concerns about accuracy errors affecting individuals' decisions more than privacy risks in some cases. This has three sub-themes: (1) accuracy, (2) smartphone-related concerns, and (3) technology issues.

3.4.1. Accuracy

The adoption of apps was influenced by factors such as the accuracy and reliability of the contact-tracing app. In the USA, a study revealed that a significant number of individuals indicated that their decision would be influenced more by the degree of accuracy than by the amount of privacy risk [126]. Among those who expressed that they did not intend to use the app, concerns were raised about a perceived lack of accuracy and the potential for false positives [54].

3.4.2. Technology Issues

This includes the problems that arise from the use of technology, including both hardware and software issues. Initially, many participants found the app unusable, struggling with QR code scanning. People reported they had to install and uninstall the app multiple times until a version compatible with their phone was released [24]. Users emphasised that the elderly or individuals with older phones faced difficulties downloading the app and using it correctly [25].

The adoption of contact-tracing apps was also influenced by factors related to the phone, including issues with storage, version compatibility, and battery life. Phone-related issues represented actual or perceived technical difficulties relating to the contact-tracing app [101]. A frequently cited problem was the absence of smartphones compatible with the app [73]. This mainly happened in the earlier versions of the app. In a Belgian study, reasons cited for not installing the app included not having a smartphone (18.5%) or possessing an older smartphone model (9.4%) [66]. The potential adoption rates of contact-tracing apps were reduced to 81.3% and 81.8%, respectively, due to limitations in installing apps and handling Bluetooth functions in Germany [73].

Technical issues were also a significant factor, with almost 20% citing them as a reason in Italy [127]. It was also reported that functional (technical) complexity negatively influenced the intention to adopt contact-tracing apps in India [49]. Technical issues reported included the contact-tracing app not being user-friendly, the inability to download the app on older mobile devices, and older devices having limited space for apps [99]. Certain respondents mentioned that the age or model of their phones prevented them from downloading the app. Another prevalent barrier was the impact on phone batteries due to keeping Bluetooth switched on constantly, which led to quick depletion and made respondents less inclined to download or use the app [17,103,116]. In several studies, the reasons for not installing or stopping using the contact-tracing app were concerns about excessive battery usage and its impact on battery life, among other reasons [20,23,123].

Some users found contact-tracing apps to be less user-friendly and battery-draining, leading to their decision not to use the apps [119]. Problems during installation (4.6%), concerns about difficulties during installation (6.4%), and fear of battery drainage (9.7%) were less frequently chosen as other reasons for not installing the app [66]. In a study conducted in New Zealand, concerns mentioned by respondents included time consumption (17.2%), slow loading (7.3%), bugs and technical errors (7.3%), battery consumption (3.8%), and various technical reasons. Notably, around a third of respondents expressed satisfaction with the app, agreeing that it worked [84].

Battery drainage and the possibility of unwanted notifications were mentioned as negative user experiences limiting individuals' willingness to download the contact-tracing app [50]. The lack of an up-to-date phone (94%) was mentioned as a barrier in the USA [42]. This finding was supported by several studies, as reasons for app non-use included not having a suitable smartphone [23,41] or operating system (22.8%) [23]. Similar findings have been reported in Canada; among participants, factors cited for not downloading the app included not having an appropriate smartphone and a lack of knowledge on how to download the contact-tracing app [18]. People were not willing to invest in a new smartphone, driven by frustration with the government's decision not to develop an app compatible with all mobile phones. This was one of the reasons for being unwilling to use a contact-tracing app in Wales [61]. Barriers to adopting contact-tracing apps include not having a smartphone and potential out-of-pocket costs [113]. In a United Kingdom study, 21.9% mentioned the absence of a smartphone or appropriate device, and 10.9% indicated they did not feel capable of downloading the contact-tracing app as reasons for being unwilling to download it [16]. In an Indonesian study, high memory usage, battery usage, and slow performance of the app were reported as limitations of contact-tracing app [128].

The consumption of too much data [22,54] and limited storage space [22,70], as well as the issue of phones being too old, were cited as reasons for refusal or indecision [22]. Perceived compatibility, the degree to which a contact-tracing app is consistent with a user's past experience, was identified as a determinant of intention to use [21]. Further, users conveyed frustration regarding the ineffectiveness of surveillance through contact-tracing apps due to technical malfunctions [52]. In contrast, a study conducted in Qatar reported that technical experience and privacy were not significant predictors of users' intention towards contact-tracing apps [123].

3.5. Perceived Benefits and Usefulness

The adoption and use of contact-tracing apps were influenced by several factors, among which perceived benefits, usefulness, and effectiveness played significant roles.

3.5.1. Perceived Benefits

This referred to the positive outcome people believe they will gain from using the contact-tracing app. Perceived benefits include keeping oneself healthy, protecting family and friends, safeguarding the community, and helping stop the pandemic [33], the ability to self-isolate early was identified as a perceived benefit of contact-tracing apps, providing peace of mind to individuals [24]. The identified benefits of the app positively influenced the intention to use the contact-tracing app [35,51]. The perceived benefits were the main positive determinant of downloading the contact-tracing app [40]. It was reported that perceived benefits had a statistically significant positive effect on the intention to use contact-tracing apps [33,45].

Further, a positive association was observed between perceived benefits and the app's actual usage [44,47]. In a study conducted in Germany, most of the participants mentioned that there was no reason not to use the app, and they outweighed the benefits over risks, and the app would help in slowing down the pandemic [43].

3.5.2. Perceived Usefulness

This implies the belief that the contact-tracing app would enhance the productivity of the contact-tracing. In a Canadian study, perceived usefulness had the most impact on the choice to use [21]. Perceived usefulness was found to have a positive influence on the intention to use [89,129,130], while perceived lack of usefulness had a negative impact [66]. Concerns about privacy were not found to be a major deterrent, as users believed the app was useful and simple to use [130]. A study conducted in Saudi Arabia found that perceived ease of use and usefulness positively and significantly affected people's behavioural intention to use contact-tracing apps. This study also found that perceived usefulness is the strongest predictor of behavioural intention [38]. In line with this, performance expectancy has been reported as the most important predictor of intention [53,69]. A study in Switzerland with users and non-users reported that the primary reason for not installing the app was perceived lack of usefulness [23].

In the Republic of Ireland, among app users, 76% strongly agreed that it was easy to download and set up, and 67% strongly agreed that the app was easy to use. Only 4% of respondents disagreed with the statement that the app looked professional and of high quality [20]. In a study conducted in Malaysia, effort expectancy or usability had a statistically significant and favourable influence on app adoption [131]. On the other hand, a study conducted in India indicated that effort expectancy did not significantly affect the respondents' adoption of the contact-tracing app. This lack of significance might be because smartphone users are already used to utilise various app-based technologies for messaging, social media, shopping, and news [114].

Among students in the healthcare sector in Italy, those who did not download the contact-tracing app reported that the main reason for not doing so was the belief that it was not useful [127]. In a Dutch study, additional reasons for not using mobile apps included concerns about the expected lack of usefulness of the app [19]. In Italy, the overall usability of the contact-tracing app was perceived as low. Initially, concerns were raised about the volume of push notifications. Subsequently, worries shifted to the lack of feedback. A user mentioned being informed of a risky exposure only after entering the app. Despite reminders to check their status daily, users felt there was no incentive to do so. Moreover, they were not encouraged or reminded to open the app regularly. Users questioned the need to open the app every day, as there was nothing to do once inside [25].

3.5.3. Effectiveness

Effectiveness refers to the degree to which something achieves its intended outcome. It tells how well a process fulfils its purpose. In this context, effectiveness reflects how the contact-tracing apps act to stop the pandemic by timely identification and notification of the infected individuals.

A study conducted in the USA strongly emphasised the importance of the effectiveness of digital contact-tracing, with 42% of users ranking the platform's ability to accurately identify potential contacts as the most crucial characteristic of a contact-tracing tool [26]. In a study conducted in France, the perceived effectiveness of the application was positively associated with the use of contact-tracing apps [80].

In a study conducted in New Zealand, less than half of the respondents agreed that the contact-tracing app was speedy or operated efficiently [84]. Among those who did not download the contact-tracing app (53%), the most frequent reasons that would have motivated them to download it were the desire for more evidence of its effectiveness (23%) [27].

In the UK, among the 27.4% of participants who did not intend to download the app, one of the most prevalent reasons was the belief that the app would not be effective [28]. Similarly, the same reason was cited as one of the two main reasons for non-adoption in Germany [43,118]. The primary reason for not using it was the belief that it was neither effective nor useful (17.6%) [100]. The belief that the contact-tracing app was not effective was cited as a reason for not downloading or lack of download intention in several countries. [18,22,54]. Reasons for being unwilling to use a contact-tracing app included concerns about app efficacy, ranking among the top ten reasons [61]. Regarding perceived efficacy, the contact-tracing app was considered ineffective, primarily due to its low adoption rate [25]. In one of the UK studies, the main concerns about contact-tracing systems were often related to the need for other people to use it rather than privacy concerns [93]. Further, a study conducted in nine European countries revealed that people expressed doubts regarding the ability of existing public health systems to effectively accommodate digital contact-tracing technologies [102].

3.6. Psychological Factors

Various psychological and attitudinal factors influence the adoption and use of contact-tracing apps. There are three sub-themes: (1) perceived risk, (2) sense of duty, and (3) emotions. Psychological factors include individuals' mental states or cognitive processes influencing their behaviour, which could influence how people make decisions.

3.6.1. Perceived Risk

Perceived risk refers to an individual's assessment regarding the potential negative outcomes or uncertainties associated with the situation. Perceived risk is influenced by personal beliefs, emotions, and individual perceptions of a situation.

Perceived risk emerged as the most consistently significant determinant of the intention to use [21]. In a study conducted in Italy, fear of contracting the coronavirus was among (20.0%) the primary reasons for the contact-tracing app's uptake [127]. An Israeli study revealed that the perception of disease risk was positively associated with the use of contact-tracing apps [56]. A study conducted in France mentioned one of the main reasons for downloading the contact-tracing app: protecting one's family, others, and oneself from possible infection [100]. In Germany, across four waves of study, it was consistently observed that the majority of participants expressed equal concern about the risk of infection to themselves and others [118]. Another study reported that the top 10 reasons among individuals willing to use a contact-tracing app included the desire to control the spread of the virus, followed by efforts to mitigate risks for both others and oneself and to increase personal freedoms [61]. A Spanish study has also reported that perceived risk has a positive impact on the behavioural intention to use the contact-tracing apps [130]. Similarly, a study conducted in Australia mentioned the lack of perceived risk of COVID-19 as a reason for not downloading the contact-tracing app [101].

A study in England reported no association between the fear of contracting COVID-19 and downloading the app. However, a weak negative correlation was observed between being in a high-risk group for COVID-19 and downloading the app. Notably, a strong negative relationship was identified between having concerns about the app and the actual act of downloading it [116].

Contrary to the above findings, a study conducted in Ireland has reported that the perceived threat, specifically the concern about getting infected with COVID-19, did not significantly influence the adoption of the contact-tracing app [85]. Perceived severity and susceptibility were not found to be significant among the predictors of intention in Belgium [40]. Similar findings were reported in Portugal: The impact of COVID-19 was not a strong predictor of adoption [69]. In France, the intention to download the contact-tracing apps was reduced by the salient COVID-19 disease concerns. The same pattern was observed in Australia, and the reluctance was mediated by a rise in socially conservative views due to disease concerns. In the USA, the willingness to download the app decreased with salient COVID-19 concerns due to greater personal privacy concerns [132].

3.6.2. Sense of Duty

Several studies have reported that individuals often use contact-tracing apps out of social responsibility, contributing to the collective effort to control the virus for the betterment of their families and friends [111]. Research conducted in the Netherlands revealed that the primary motivation for utilising a contact-tracing app was to help control the spread of the COVID-19 virus [19]. In a study conducted in Italy, the primary reasons for the app's uptake among those who downloaded it included a sense of duty (40.0%) [127]. Similar findings have been reported in New Zealand; a qualitative study found that the most prominent benefit of supporting the contact-tracing app was to control the pandemic [24]. Participants from France and Germany shared a common perspective, viewing the adoption of contact-tracing apps as a way to contribute to a greater societal cause and play a role in preventing the spread of coronavirus [119]. In Italy, some participants decided to download the contact-tracing app as part of a broader concept of pandemic citizenship. Some explicitly mentioned their choice in terms of civic duty and social responsibility [92]. In Scotland, a qualitative study revealed that the public generally considered contact-tracing as a good idea. Some participants viewed the use of these apps as a responsibility to their family, friends, and the broader community, while others saw it as a civic duty [86]. In a UK study, individuals reported a desire to contribute to controlling or ending the pandemic and returning to normalcy as motivating factors for downloading the app [116].

Another reason cited for downloading the app included helping the NHS and safeguarding friends and family [28].

3.6.3. Emotions

Emotions and anxiety towards the contact-tracing system influence the intention to download contact-tracing app. The anxiety of infecting others was identified as a significant factor that positively influenced the intention to use the contact-tracing apps [39]. In contrast, in Belgium, stress was cited as a reason for not using the contact-tracing app [70]. A study conducted in France reported that the main reason for downloading the app was out of curiosity (36.1%) [100], while in Italy, a small percentage (9.4%) of individuals cited curiosity as a reason for adopting the app [127]. In Germany, a study revealed that adoption intentions for a contact-tracing technology were significantly linked to anticipatory anxiety and anticipated emotion [46]. In a UK study, COVID-19 anxiety associated with contact-tracing app installation was identified as a common barrier to the adoption of contact-tracing apps [97]. It was reported that some individuals believe that the entire concept of digital contact-tracing may generate unnecessary panic among citizens [64]. Similarly, in the United Kingdom, some participants expressed concern about the stigmatising potential of the app. They were concerned that the ability to identify individuals with COVID-19 might result in discrimination, including the possibility of hate crimes [104].

Another reason cited for not using contact-tracing apps was the fear of becoming overly aware of the situation and its potential consequences, which may lead to unnecessary stress [19]. A study in Belgium found that people did not want to install an app because they were worried it would stress them out [66]. In Germany, individuals expressed objection to living in fear due to the potential mental stress caused by the contact-tracing app [17]. On the other hand, respondents expressed determination that utilising the app would lower their anxiety regarding COVID-19 infection, driving their decision to install it. Half of the participants mentioned that reducing anxiety would have a strong influence on the decision to install the app. Ten percent of the participants mentioned that the app's potential to amplify anxiety about infection would play a role in their decision [109]. Additionally, some participants expressed concerns that interacting with a human tracer during contact-tracing could raise social anxiety, while some participants felt this could trigger emotional anxiety, especially with people who are sensitive about human interaction [115]. People believed that technology provided a sense of anonymity and could enable positive cases or close contacts to avoid judgment by human tracers for their COVID-19 status or background [115].

3.7. Social Influence and Attitudes

3.7.1. Social Influence

Social influence refers to how people's behaviours are affected by the actions of others. In digital contact-tracing, the adoption decision was seen to be influenced by the people around them. In a study conducted in the United Kingdom across three waves, it was found that individuals who believed that people in their social circles (family, friends, work) supported the use of the contact-tracing app were more willing to adopt it [58]. A study conducted in India found that social influence is a significant positive factor in app adoption, and often seek their approval before considering adopting contact-tracing applications [114]. In a study conducted in France, a significant positive indirect effect of subjective norms on the intention to use was reported through the mediation of perceived usefulness [129]. In the United States, it was discovered that the endorsement of an injunctive norm and a descriptive norm positively impacted both the intention to adopt and actual behaviour [109]. A Singaporean study revealed that both injunctive norms and descriptive norms were significant positive determinants influencing the adoption of

contact-tracing apps [95]. The social pressure and recommendations from influential individuals or groups encouraged users to adopt the contact-tracing app adoption in Malaysia [131]. In Belgium, social influence had a positive impact on intention to adopt contact-tracing apps [53].

In contrast, in a Belgian study, social environment and societal factors did not encourage some people to download the contact-tracing app [70]. In line with this, social risk, social concern, and social interaction were not identified as significant determinants of behavioural intention in Saudi Arabia [38].

3.7.2. Attitudes

Attitude is how people think and act toward something, influencing behaviour, and past experiences and social influences affect attitudes. In digital contact-tracing, the adoption intention was decided by the attitudes towards the digital contact-tracing process. Contact-tracing apps were perceived as more rapid than traditional contact-tracing in detecting and warning infected users [66].

Some respondents believed that using the contact-tracing app might lead people to become more complacent about following strictly the government's advice on social distancing. They anticipated this could result in individuals taking more risks [116]. Other reasons for refusing to download the app included the belief that social distancing was adequate and that the app was unnecessary [22]. The absence of social empowerment was also mentioned as one of the factors that discouraged the intention to download contact-tracing apps [34]. Some participants considered the number of current users of a contact-tracing app and how they perceived its value when making their own decisions to adopt or not adopt the app [119].

Certain participants reported simply forgetting to use the app, citing reasons such as the app usage not yet becoming a habit, and competing priorities due to disruptions in normal routines and hygienic behaviours [99]. A lack of interest (42.9%) was also mentioned as a primary reason for not using the app, and not having time to think about it was reported by 17.6% [100]. Participants also suggested that the pandemic was nearing its end, thinking the app unnecessary [54]. Further, status gain and peer recognition as a result of using the tracing app did not significantly motivate respondents [39].

In Canada, people who infrequently used other common apps were found to be less likely to download the contact-tracing app [27]. Only 56.9% of respondents agreed that digital monitoring would be effective in helping to stop COVID-19 transmission. Furthermore, even fewer young adults (46.0%) agreed that digital tracking would be necessary to return to normal [107]. In a study conducted in England, a significant majority, 64.5%, strongly believed that the app should not be legally enforced on users. These individuals stated that they did not think they should be legally obligated to download the app [59].

3.8. Knowledge and Awareness

Understanding and awareness of contact-tracing apps play a vital role in whether people use them. Participants often expressed concerns about transparency and insufficient details, leading to doubts about government intentions. Knowledge about contact-tracing apps was positively correlated with app use [46]. A lack of information on the contact-tracing app was reported as one of the reasons for not downloading the contact-tracing app [70,104]. Among the students in Italy who did not download contact-tracing apps, 32.7% reported that they believed it was useless, and 23.5% reported that they were not aware they needed to do it [127]. Other reasons, accounting for 18%, included a lack of knowledge about the app [23]. In Canada, the lack of information received about contact-tracing apps was mentioned by 1% of the respondents [27].

Participants raised key concerns regarding insufficient transparency and a lack of adequate information related to the development and planned implementation of the app. Many felt that the government's intentions were not clear due to a general lack of transparency. Participants stated that the information provided about the app's meaning, nature, and scope was insufficient to convince them of the government's intentions. Additionally, participants believed that government agencies had not taken adequate measures to address people's fears and concerns, given the prevalence of COVID-19-related misinformation online [50].

Leaders of community-based organisations (CBOs) in certain communities have noticed that there was considerable misinformation about data privacy. Additionally, an advocate for the LGBTQIA+ community pointed out that many people did not fully understand how contact-tracing apps work, which prevents them from enjoying the full benefits of these apps [42]. The lack of publicly available information about how the contact-tracing app works and the associated privacy protections has raised concerns in Australia. The politicians' failure to provide accurate information and address privacy concerns has contributed to the perception of scepticism and mistrust among the public [82].

In a study conducted in Germany, the results showed a positive correlation between participants' understanding of the app's features and their likelihood of using it [76]. Several issues have been reported regarding the contact-tracing app. These issues include individuals requiring assistance with the app, not receiving initial support, being unaware that the app is available [41], and not knowing how to download it [18]. Poor public communication regarding clarity and outreach has been identified as a challenge [119]. In a study conducted in Indonesia with users of a contact-tracing app, it was found that the purpose of the app, its benefits, and the instructions on utilising its features were not clearly communicated to the users [128]. In line with this, it was reported that understanding the purpose and functionality of the contact-tracing app has significantly increased adoption rates in a cross-country study conducted in European countries and the USA [122].

Several participants appeared uncertain about the function and scope of contact-tracing apps, sometimes using different technologies [90]. Additionally, a lack of consistent information from the government was identified as a major concern [50]. A lower understanding of government advice was linked to less willingness to download the app [16]. Although the contact-tracing app in Germany meets high standards for data privacy, some people were still hesitant to use it due to their lack of trust in the government and their lack of knowledge about the mechanisms in place for data protection [17].

4. Discussion

The literature on digital contact-tracing indicates that while technology has the potential to track and manage pandemics, it also faces significant challenges. The identified issues include privacy, data protection and control, trust, technical issues, perceived benefits, knowledge and awareness, social influence, and psychological factors.

4.1. Privacy and Data Protection

Among the themes identified, privacy emerged as a top concern influencing the adoption of digital contact-tracing technology [21,39]. Most of the studies have shown a negative correlation between privacy concerns and adoption rates [44,45,49,120]. The privacy concerns that resulted in low adoption varied with the nature of the data collected [50,52,62,91,95]. Specifically, there were concerns about data misuse and long-term use of data. In addition, surveillance measures by authorities mainly affected people's willingness to participate in digital contact-tracing [90,101]. However, with time, respondents

showed an increasing likelihood of adopting contact-tracing apps when they believed that their data collected by these apps were secure [95].

Surprisingly, certain studies have reported that there was no relationship or no significant impact on privacy conditions and download intention [71,131]. However, research has shown that individuals are more likely to use contact-tracing apps if they believe their privacy is protected [80]. There was a positive relationship between knowledge about the app's privacy features and app usage [44], and participants value consent as a key privacy protection mechanism [91]. Overall, it was clear from the literature that robust privacy policies and assurances about data handling could create a positive attitude towards contact-tracing applications. In addition, it was evident that people were not fully aware of the contact-tracing mechanism.

Recommendations for government. Governments should establish and enforce strict data privacy regulations with transparent oversight mechanisms to reassure citizens. This is because they are responsible for safeguarding public trust by ensuring personal data are protected, thereby addressing fears of data misuse, and ultimately promoting CTA adoption. Governments should also launch public education campaigns explaining the data privacy features of the apps, including anonymisation and encryption processes. This is because increasing awareness about privacy-preserving technologies can reduce scepticism and increase app adoption.

Recommendations for app developers. App developers should implement privacy-by-design principles, such as anonymised data collection. This is because app developers are directly responsible for ensuring technical measures address privacy concerns. These features reduce the risk of data misuse and demonstrate a commitment to safeguarding user data, thereby promoting adoption. App developers should also provide clear and concise privacy policies in-app, using accessible language and visual aids to explain how data will be protected and used. This is because transparency in privacy practices empowers users to make informed decisions, addressing the negative correlation between privacy concerns and app adoption.

4.2. Trust

Users are more likely to adopt apps from trustworthy sources [79]. If an unknown or untrustworthy entity develops an app, then people may be reluctant to download and use it. Moreover, users distrusted the government's guarantee of privacy [63]. Participants did not like the idea of being tracked by the government [101] and lacked trust in the developers of the app [28], which could leak the information [115]. Throughout the pandemic, the advice provided by governments was often unclear due to the constantly changing guidelines and information. This lack of clarity resulted in a general lack of trust in both governments and software companies. Many people were hesitant to download or use certain apps due to a lack of confidence in the public and private institutions associated with them [50]. Nevertheless, some studies have reported that there was no relationship between trust and app adoption [44], while others found a significant positive correlation between trust on the contact-tracing app and adoption [32,123]. However, no experimental studies have been published about trust in the digital contact-tracing context.

Recommendations for government. Governments should collaborate with independent public health organisations and NGOs to develop and promote contact-tracing apps, ensuring a transparent development process. This is because collaborating with neutral, trusted organisations reduces perceptions of governmental overreach or misuse of surveillance data, thereby building trust. Governments should also consistently communicate the purpose, function, and benefits of the apps through clear and honest messaging and, where possible, avoid contradictions or frequent changes in guidelines. This

is because they are responsible for delivering reliable information, thereby promoting credibility and trust, and ultimately driving adoption.

Recommendations for app developers. App developers should collaborate with trusted third-party organisations to independently audit and certify the app's security and privacy practices and display certification prominently. This is because third-party validation enhances credibility, by addressing the lack of trust in app developers and governments. App developers should also regularly update the app with clear release notes, explaining new features and fixes to build trust in ongoing developer accountability. This is because regular, transparent updates show users that developers are committed to maintaining app quality and addressing concerns, thereby promoting trust.

4.3. Technological Issues

Several technological factors influenced the adoption of contact-tracing apps. Accuracy and reliability were major factors [54], with concerns about errors having a greater impact on decisions even than on the privacy risks [126]. Smartphone-related issues, including compatibility, battery drainage, and technical difficulties [101], were significant barriers to adoption.

Recommendations for government. Governments should provide funding for technical improvements to ensure app compatibility across all smartphone models, optimise battery efficiency, and address accuracy concerns like false positives/negatives in contact detection. This is because they must eliminate usability barriers to ensure inclusivity and reliability, as technical issues significantly impact user experience and adoption rates. Governments should also offer robust technical support, including frequently asked questions, troubleshooting helplines, and tutorials, to assist users in adopting and using the apps effectively. This is because accessible technical support mitigates frustrations and ensures a seamless user experience, making adoption more attractive.

Recommendations for app developers. App developers should develop robust algorithms to reduce false positives and negatives and implement clear error-reporting systems. This is because accurate functionality builds trust, ensuring users perceive the app as reliable, which is essential for widespread adoption. Developers must deliver systems that users can depend on to perform critical public health functions. App developers should also design energy-efficient apps compatible with various devices, minimising battery consumption and technical barriers. This is because high battery use and incompatibility discourage adoption. Developers are responsible for creating apps that integrate seamlessly with users' devices, ensuring accessibility and usability for all.

4.4. Perceived Benefits

Perceived benefits were one of the main positive elements in adopting contact-tracing apps, as highlighted in various studies across different countries [40,44,47]. These perceived benefits include personal health, protection of family and friends, contribution to community safety, aiding epidemic control [33], and providing peace of mind to individuals [24]. Moreover, the perceived usefulness of contact-tracing apps was a significant factor influencing people's intention to use them. In addition, the perceived effectiveness of the application was positively associated with the use of contact-tracing apps [80]. Therefore, it is evident that perceived benefit, usefulness and effectiveness are key elements contributing to the decision to use digital contact-tracing.

Recommendations for government. Governments should highlight genuine success stories where contact-tracing apps contributed to controlling outbreaks, protecting communities, or preventing the spread of disease. This is because demonstrating tangible benefits reinforces an app's perceived value, thereby motivating users to adopt the app through the prospect of personal and societal gains. Governments should also work with

app developers to integrate additional app features, such as local health updates or access to testing facilities, to enhance perceived usefulness. This is because governments can increase the appeal of apps by demonstrating various benefits beyond contact-tracing, aligning with the public's desire for utility and effectiveness.

Recommendations for app developers. App developers should add personalised features, such as risk alerts based on exposure, and integrate health resources like symptom checkers or nearby testing sites. This is because enhancing perceived benefits aligns with users' desire for usefulness and demonstrates the app's value beyond contact-tracing, motivating adoption. App developers should also include gamification elements, such as rewards for consistent app usage or community milestones, to incentivise engagement. This is because gamification makes app use engaging and reinforces positive behaviours, amplifying the perceived value of the technology.

4.5. Knowledge and Awareness

The studies showed that understanding and awareness significantly influence individuals' decisions to accept or reject these apps. Concerns were linked to a perceived lack of information [27], transparency [50], and clarity [82] in the development and implementation of these apps. People felt that the information given by authorities was insufficient to address their worries, emphasising the need for transparency. Misinformation was a significant issue in communities where misconceptions about data privacy arose.

Among other concerns, government communication strategies played an essential role. The lack of consistent information was a major concern. Clear and consistent information was essential to build trust in the government. A lack of a communication strategy is major issue in establishing trust towards the government and assuring individuals' safety for using contact-tracing applications.

Recommendations for government. Governments should implement nationwide educational campaigns to dispel myths and misinformation about digital contact-tracing apps, using multimedia platforms to ensure messages reach diverse audiences, including vulnerable populations. This is because misinformation and a lack of awareness are major barriers to adoption; governments must take a proactive role in correcting misconceptions and providing clear, consistent information. Governments should also ensure transparency in app development and implementation, including open-source code and independent security evaluations, to address concerns about secrecy and foster informed decision-making. This is because transparency builds public confidence, empowering citizens with the knowledge necessary to make informed choices about using these apps.

Recommendations for app developers. App developers should integrate clear, user-friendly explanations within the app about how data are collected, stored, and used. This is because transparent communication promotes trust and combats misinformation. Developers are responsible for addressing user concerns by providing accessible, accurate information directly through the app interface, ensuring users feel informed and secure. App developers should also embed features like frequently asked questions, interactive tutorials, and updates to address misconceptions and provide consistent, reliable information. This is because developers can counter misinformation by equipping users with credible, easily accessible knowledge. These features empower users to make informed decisions, thereby promoting app adoption and sustained use.

4.6. Social Influence

The opinions and behaviours of individuals' social networks, including family, friends, and colleagues, significantly affect people's willingness to adopt contact-tracing apps [58]. It was found that social influence had a positive impact on behavioural intention

to adopt contact-tracing apps [114]. Some people believed that the social distancing was adequate and that the app was unnecessary [22].

Recommendations for government. Governments should collaborate with influential community leaders, public figures, and healthcare professionals to support the use of contact-tracing apps. This is because they can utilise the power of social influence to normalise app usage, particularly in communities where peer behaviour significantly impacts decision-making. Governments should also organise community-led initiatives and group incentives for app adoption, such as workplace or neighbourhood challenges to increase participation. This is because social reinforcement encourages collective behaviour change by utilising community dynamics to drive adoption.

Recommendations for app developers. App developers should incorporate features enabling users to share app usage updates or benefits with their social networks, such as referral rewards or social media integrations. This is because developers can utilise social proof by encouraging peer sharing, thereby amplifying social influence on adoption. App developers should also allow users to see anonymised community-level adoption statistics to reinforce the app's collective benefits. This is because showing how others are participating can normalise usage and create a sense of shared responsibility.

4.7. Psychological Factors

According to the literature, various psychological factors influenced the adoption and use of contact-tracing apps. People often decide to use these apps based on their perceived vulnerability and the severity of the disease [21,56,127]. Similarly, people consider using contact-tracing apps to be a social responsibility; they saw controlling the virus as a collective effort [19,24,61]. Psychological factors such as emotions, anxiety, and perceptions of the entire contact-tracing process influenced the intention to adopt digital contact-tracing [70], while surveillance led to increased anxiety levels among individuals [17,97]. It was also reported that some individuals preferred technology over human tracers for their COVID-19 status [115]. However, Chan et al. have reported that salient COVID-19 disease concerns had reduced the intention to download, while most had stated that disease concerns would increase the willingness to use the contact-tracing [21,56,100,118,127].

Recommendations for government. Governments should frame contact-tracing app adoption as a civic duty and an essential component of collective efforts to combat pandemics. This is because they can appeal to citizens' sense of responsibility and shared vulnerability to create a moral imperative for adoption, addressing psychological motivators like perceived severity and susceptibility. Governments should also minimise surveillance-related anxieties by emphasising that contact-tracing will be temporary and there will be no long-term tracking. This is because alleviating fears of permanent surveillance aligns with citizens' psychological need for autonomy and privacy, thereby reducing barriers to adoption.

Recommendations for app developers. App developers should design the user interface to reduce anxiety, using calming colours, non-intrusive notifications, and reassuring messaging about app security and temporary data use. This is because developers have control over the app's design, which can mitigate psychological barriers such as anxiety and perceptions of surveillance. App developers should also include a feature enabling users to provide feedback or report concerns easily, and visibly address these concerns in updates. This is because giving users a voice and responding to their feedback fosters a sense of control and reduces psychological resistance.

Recommendations for an integrated approach. A national coordination hub for digital contact-tracing should be established. This is necessary, as governments should lead a central hub involving app developers, health services, and privacy experts to

standardise development, share resources, and streamline efforts. This ensures consistent goals, avoids redundant work, and integrates technical, legal, and public health expertise to enhance efficiency and app adoption. A unified communication and deployment strategy should also be developed. This is necessary, as governments, app developers, and health services must collaboratively create a consistent strategy for app promotion, privacy assurance, and technical support. This ensures clear, uniform messaging and coordinated rollout, fostering public trust and reducing confusion, which collectively enhance app adoption and usability.

We acknowledge that this study has few limitations. Only the studies published in English were included in this review, and grey literature was not included. Since retrieving grey literature was a time-consuming task and the review already included a higher number of articles, we did not include grey literature. Further, depending on the topic and the published information we extracted, it was unlikely to significantly alter this study's results by grey literature. In addition, these searches were primarily centred around the privacy and security issues in digital contact-tracing and provide evidence for the role of these issues in the acceptance of contact-tracing apps.

5. Conclusions

In conclusion, the adoption of digital contact-tracing during the pandemic is influenced by following factors: privacy, data protection, trust, technological factors, perceived benefits, effectiveness, psychological factors, social influence, and attitudes. Privacy remains the predominant issue, and other factors centred around this. However, studies have shown that these concerns can be mitigated by clear information about privacy, transparency, and robust communication. Conveying credible information about the mechanism of the digital contact-tracing process is also important, as much misinformation was shared and viewed especially among Internet users. Additionally, addressing technical barriers and emphasising benefits can further enhance user acceptance. While this task is challenging, experimental research on prioritising privacy and transparency could confirm a significant improvement in the public's willingness to adopt digital contact-tracing in future health crises.

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