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Digital Innovation: A Comparison of Government CovidApps in Australia and China

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Full paper

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ABSTRACT

COVID-19 developed from the end of 2019 and became a fully-fledged pandemic in the years that followed. There were no effective cures or vaccinations during the outbreak early stage. The Chinese Health Code and Australian COVIDSafe systems were introduced for contact tracing purposes and to stop COVID-19 spread. Chinese residents widely adopted and used the Health Code, and the COVIDSafe app initially had a high volume of downloads but few active users. We gathered data from various secondary sources e.g. government documents, government websites, academic papers etc., to better understand the Health Code and COVIDsafe functions and technical features. We adapted the UTAUT model to analyse and understand performance expectancy, effort expectancy, social influence and facilitating conditions as determinants of adoption for the comparison of both apps. We seek to highlight potential reasons for different digital adoption outcomes in differing cultural contexts under mandatory and voluntary conditions.

Keywords

Health Code, COVIDSafe, Mandatory environment, voluntary environment, contact tracing

1 Introduction

At the end of 2019, a COVID-19 outbreak occurred in Wuhan China and quickly spread across the world by March 2020. Up to April 2021, there have been more than 130 million cases and 2.85 million deaths (Worldometers, 2021). The COVID-19 pandemic has similarities to other pandemics in history such as the Spanish Flu (1918), smallpox (1519) and SARS (2002) in that it is highly infectious. The COVID-19 pandemic is significantly different to previous pandemics, however, as so far, it has had a higher transmission but lower mortality rate (Shanks, 2020), and around 60% of infections are mild or asymptomatic (Qiu, 2020). In the COVID-19 pandemic outbreak early stages, there were no effective cures, and vaccinations. The ability to identify infected or potentially infected cases was crucial to prevent COVID-19 spread. Contact tracking/tracing and the quarantining of infected and potentially infected individuals was considered as the most effective strategy to stop the spread of the virus in a pandemic (Eames, 2007).

On 23rd January 2020, Wuhan started to fully lockdown and other cities (within China) also started to quarantine residents from Hubei province especially in the Wuhan area. Many Zhengzhou and Hangzhou citizens travelled to or were working in Hubei, and they tried to return to their hometowns because of COVID-19 outbreak. In order to manage the movement of these citizens more efficiently to stop the COVID-19 spread, Zhengzhou city implemented a QR code system on 2nd February 2020 for residents (who came from other cities) to submit their health status to authorities prior to proposed travel (Health Commission of Zhengzhou, 2020). This was the first instance that a QR code was used for COVID-19 control in China. Zhengzhou's QR code system was implemented to enable citizens to complete a digital record instead of manual paperwork. In addition, there were many Hangzhou residents who drove their cars back home from high-risk areas, which led to a traffic jam, as every resident needed to complete a screening form before they could pass a roadblock. This was very inefficient and placed a lot of processing pressure on the Zhangzhou government employees. The digital screening form, therefore, was a crucial innovation to ensure an efficient and effective system that facilitated travel within China during the pandemic. Moreover, the Yuhang District (one district of Hangzhou city) was a very high-risk COVID-19 area in Hangzhou city and the government needed to urgently track and contact infected or potentially infected individuals. The Yuhang local government started to develop a QR code system for contact tracing purposes (the Health Code prototype) on 4th February (Shi & Ma, 2020), which was then implemented across China, and the health code system then became the main contact tracing process in China.

In Australia, the first case of COVID-19 infection occurred in Melbourne in late February 2020 (18th), By March 2020 COVID-19 infections started to increase where 29 cases on 1st March then jumped to 5048 cases by the 1st April (Worldometer, 2021). By late March the Australian federal government attempted to prevent community spread by limiting gatherings and using behavioural health messaging. As April 2020 passed, household lockdowns were introduced in all State and Territory jurisdictions as well as some border closures. At that time, many other countries were also introducing their own contact tracing apps. The Australia government expressed an interest in Singapore TraceTogether, and then started to develop the COVIDSafe app which uses a similar technological methodology. After COVIDSafe had been launched (April 2020) for one month, there were 6.13 million downloads (Mexiner, 2020), which was nearly 25% of Australia population. The uptake rate then decreased and up to October 2020, there was only 7 million apps (in total) installed (Yang, Heemsbergen, & Fordyce, 2021) and only 17 cases were traced successfully through the app (Clun, 2020). As of August 2021, the COVIDSafe app has been decommissioned by the Australian federal government and has generally been deemed an adoption failure (Department of Health and Aged Care, 2022).

The technical design approach to the Chinese Health Code utilised a QR code system which required users to scan and display their Health Code. Conversely the COVIDSafe app was based on a Bluetooth proximity system which required users to activate Bluetooth in their mobile. Both apps were government funded which included development and ongoing maintenance costs. The Health Code app was initially adopted at a local level government and the adopted across all of China, but the COVIDSafe app was an Australian federal government initiative from the very start.

We adopted the Unified Theory of Acceptance and Use of Technology (UTAUT) which is a research model that explains a user's behaviours of intention to use and usage of new technologies. It has four determinates of intention and usage, and four variables of key relationships. The UTAUT is a popular theory and widely used to assess and explain the drivers of IT acceptance.

It must be noted that China has taken the approach of mandatory adoption of the QR Health Code combined with a COVID-19 infection "zero tolerance" public health policy. Australia on the other hand

has taken a voluntary approach for CovidSafe adoption combined with a series of isolated lockdowns to contain outbreaks. Our research compared the functionality of both apps to determine the facilitators and barriers to adoption and use under both mandatory, voluntary and lockdown conditions.

This paper firstly reviews the literature that deals with contract tracking apps and then summarises characteristics of UTAUT model under mandatory and voluntary conditions. The attributes of both the Chinese Health Code and Australian COVIDSafe apps are then listed and their adoption and performance outcomes compared. This paper then concludes with a summary of potential reasons and impact factors that affected the adoption and performance of both apps.

2 Literature review

2.1 Contact tracing

People who have close contact with someone infected with a virus, generally have a high risk of infection and can then potentially infect others. According to the World Health Organization (2017), the monitoring of close contacts is a process called *contact tracing*, which includes contact identification, contact listing (close contact list), and contact follow-up (contacts status follow up).

Traditional contact tracing relies on public health officials interviewing infected cases and identifying their close contacts (Kleinman & Merkel, 2020). These close contacts are then advised to self-monitor for symptoms, self-quarantine or seek medical treatment. Contact tracing has been implemented successfully to reduce infection transmission in previous epidemics such as Ebola (Kleinman & Merkel, 2020). Kleinman & Merkel (2020) believed digital contact tracing could address the traditional contact tracing limitations of scalability, notification delays, recall errors, and contact identification in public spaces, because exposures to infection cases can be fast and effectively identified via electronic information.

In 2020, Riemer et al., stated that contact tracing could be divided into 3 main approaches: manual contact tracing, surveillance tracing, and proximity tracing. *Manual contact tracing* is manually identifying potential or infected patients via infected patient interviews (Riemer et al., 2020), but manual contact tracing is very labour intensive and time consuming, and information is not reliable and has privacy invasion implications (Ferretti et al., 2020). *Surveillance tracing* requires a range of data collection and surveillance data to retrace infected patients' activities or travel (Riemer et al., 2020). *Proximity tracing* includes *centralized* proximity tracing and *decentralized* proximity tracing. Centralized proximity tracing is where a user registers their ID with a centralized authority (in a database) and where some of this data will be saved in centralised servers. By contrast, decentralized proximity tracing keeps all known infected users' details such as their ID in their own local device i.e. mobile phone (Riemer et al., 2020). In both cases of proximity tracing a user's device is 'pinged' when that user comes into close proximity with an infected person.

We seek to determine which approach (mandatory or voluntary) to contract tracing is the most effective and how contact tracing app functionality (Health code and CovidSafe) supports government efforts to manage an epidemic/pandemic situation.

2.2 Unified Theory of Acceptance and Use of Technology model (UTAUT)

In 2003, Venkatesh et al. developed the Unified Theory of Acceptance and Use of Technology (UTAUT) model to explain user acceptance and usage behaviour determinants. These determinants include performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003) which are moderated by variables such as gender, age, experience and voluntariness of use.

Performance expectancy refers to a system users' belief that using the new system will help them to improve their (job) performance, which can be impacted by a users' gender and age. For *effort expectancy*, Venkatesh et al., (2003) stated that a user can easily identify with the use of the system, which can also be affected by their age, gender and experience. *Social influence* is defined as a user's perception that other important people believe they should use the new system, which can be affected by age, gender, experience, and voluntariness of use. In other words, others' opinions or adoption of a new system will have an effect on an individual's adoption of a system. *Facilitating conditions* refers to the system user's belief that the organization's existing resources or technical infrastructure can support the use of the system. The users' age and experience can have an impact on these facilitating conditions.

Within this conference paper we adapted UTAUT as a 'lens' to identify, analyse and discuss adoption factors of the Health Code and COVIDSafe apps.

3 Methodology

Our research methodology conducts a qualitative analysis of secondary data, using the UTAUT model as a framing device. Our study data or 'accounts of adoption' were gathered from secondary sources such as government reports, academic papers, legislation documentation, websites, etc.

The data was categorized into descriptions of app: features; data sources; technical solutions; operating background rules; and working scenarios in order to outline each app and its adoption trajectory in detail. The UTAUT model was adapted and utilised as a 'lens' to analyse and compare both apps in terms of adoption differences. The variables of gender, age, experience, voluntariness were not considered in this study due to the nature of each implementation approach and environment (mandatory/China and voluntary-anonymous/Australia). Our research model focusses on the UTAUT determinants of performance expectancy, effort expectancy, social influence and facilitating conditions, which are key impact factors on users' behavioural intention and further affect users' behaviour (adoption).

Analysis

3.1 Health Code and COVIDSafe Functions

3.1.1 Health code (QR code) functions

The Health Code originated in Zhengzhou city where the government required residents to complete a digital health status form. It was then further developed by the Hangzhou city government and adopted across China (Shi & Ma, 2020). Each resident has one health code (only) at a city level but around one year later residents' health codes were assigned at a provincial level. The Health Code is divided into 3 different colours (Red, Yellow, Green) which represents different levels of risk (Table 1). The different cities/provinces have different forms of Health code. The State Administration for Market Regulation published a standard format for reference (Figure 1) in 2020.

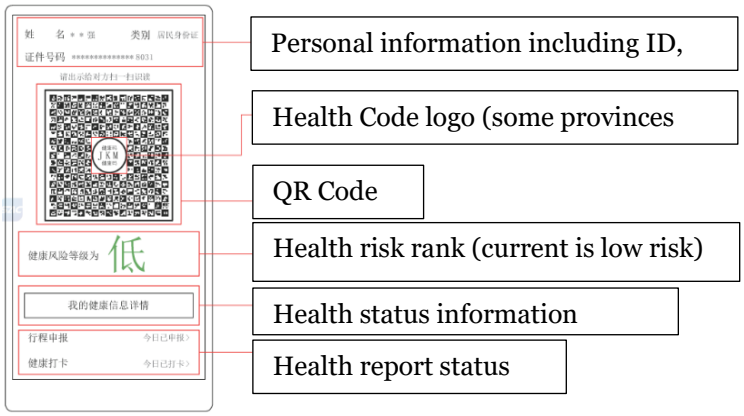

Figure 1: National Health Code standard model (State Administration for Market Regulation, 2020)

Colour	Meaning	Rules	QR Code
Red	High Risk	Close contact with infection patients; travel to high-risk areas (which identified by governments); infection patients	
Yellow	Risk	Under quarantine resident, symptomatic residents such as fever, cough (may get infection of COVID-19)	
Green	Low Risk	No infection	

Table 1. Three colour Health Code (Hangzhou Market Supervision and Administration, 2020)

3.1.2 COVIDSafe functions

After the Australian federal government launched the COVIDSafe App a few million users downloaded

it. COVIDSafe is based on Bluetooth and cloud computing technology (AWS) for contact tracing and data storage.

COVIDSafe could be downloaded online and installed on Android and iOS devices using 8 different languages. After installing COVIDSafe, residents needed to register using their name, age range, mobile number and postcode. For registration, only the mobile number needed to be accurate and verified. To activate the COVIDSafe App, users had to turn on their device Bluetooth and GPS (Figure 2). The COVIDSafe App ran 24x7 if users enabled it, which would ping other devices every 15 minutes (Riga, 2020), creating encrypted records that were saved in the mobile device with date, time, duration and details of the contact device's information. Other information such as the user's mobile number, name etc was encrypted and hosted in the National COVIDSafe Data Store (COVIDSafe, n.d.). According to COVIDSafe (n.d.), the app would not record individual locations and most of the data would be encrypted within the local devices. All stored data was automatically deleted after 21 days. In addition, the COVIDSafe App also provided COVID-19 cases status in different states (Figure 2) which included the number of new cases etc. When users became confirmed cases, the health officials would get a token from users and then contact the close contact directly.

Figure 2: COVIDSafe

3.2 Data Source

3.2.1 Health code (QR code) data source

The Health code draws data from different sources including personal health status and government back-end data. The personal health status statement comes from the individual citizen's submission of information. Firstly, residents need to apply a unique health code that is based on the local province/city information system via WeChat, Alipay, or by downloading the mobile application. The health code application (Chengdu example) includes the different personal information as outlined in table 2 (Bendibao, 2020). Secondly, the residents submit their health status (e.g. temperature) via Health Code.

The other key Health code data comes from government data sources, which include the governments' own companies like telecommunication companies, health information systems. Residents also can scan their Health code in public places, on public transport, and in their communities. Health code data is an important source for swiftly identifying close contacts. Other data sources could be police information systems, government public health risk areas (e.g. high-risk areas), personal location records such as GPS coordinates, and Beidou Navigation Systems which needs an individual's cooperation and is not very commonly used (Xue, 2020).

Questions	Options
Mobile number	Personal mobile number
Address	Home address details
Current residential address	Resident address details
Recently 14 days of close contact with suspected cases or individuals who comes from Hubei, Wenzhou, Chongqing, Guangzhou	Yes/No
Recently 14 days of close contact with COVID-19 patients or suspected cases	Yes/No
Any symptom	Yes/No

Current health status	individual quarantine, centralize quarantine, quarantine treatment, normal, dismiss quarantine

Table 2. Personal Health Status Reporting Information (Bendibao, 2020)

3.2.2 COVIDSafe data sources

COVIDSafe collected limited data from users to protect their privacy. The users' personal information (e.g. name, age range, mobile, postcode) was collected when they registered the app. The Bluetooth handshake information was collected when COVIDSafe was active. The COVIDSafe app also had to be regularly updated/upgraded. When users initially authorized the COVIDSafe app to access location information or other personal information, COVIDSafe versions could directly collect privacy information after each upgrade. In other words, if the COVIDSafe App changed its information collection rules over time, for instance collecting location data, which users authorise then other data could be collected.

3.3 Backend rules

3.3.1 Health Code rules

The Health Code give users a different colour based on rules applied to different data sources and dimensions that have complex computer algorithms automatically applied to them. This is to rate residents' health and subsequently colour code their health status based on their rating. In the most situations, when users first register for the Health Code and submit personal information such as health status, travelling history etc., the Health Code colours will be automatically generated (excluding an international version). In addition, different colours of Health Code can transform from one to another such as Red to Yellow, Yellow to Green, or Green to Red. To transform codes (from high risk to low risk and vice versa), there are different rules applied for different provinces in China. For a high-risk code, such as Red code to be transformed to a low-risk code (e.g. Yellow or Green), all provinces require a government staff member or medical staff member to be involved in the transformation decision. However, for low-risk codes being transformed to a high-risk code this is normally done automatically and is based on the application of big data applications and computer algorithms.

In Hainan Province, the red health code includes confirmed COVID-19 cases including asymptomatic cases, suspected cases, close contacts. When they receive a formal notice of release from quarantine and are approved by the city or country level of headquarters for epidemic control, the patients' Health Code can be transformed e.g. red health code to the green health code (Hainan Health Commission, 2020). In terms of the Yellow health code, if the resident is under normal quarantine, for instance, coming from a potential risk area (not a high-risk area), the resident must continuously report their health status in the health code system for 14 days (must health), to transform their status from Yellow to Green. For other Yellow health code rated individuals, such as people with similar COVID-19 symptoms but that are not COVID-19 positive, they are under self-quarantine, until they are without symptoms. The residents can then get confirmed as COVID-19 free by a doctor and report to government agencies (Hainan Health Commission, 2020). Their Yellow health code would then be transformed to Green.

The transformation code rules are based on different city or provincial rules. Most low-risk code transformation to a high-risk code are done automatically without delay by the health code system algorithm. There are many dimensions to consider when a health code automatically transforms from a low-risk to a high-risk code: close contact; accessing high-risk areas; the time period accessing risk points.

In theory, the health code can be automatically transformed in nearly real-time. According to the State Administration for Market Regulation (2020), the health code expires every 5 minutes, however, the back-end data refresh will depend on different local governments and their processes.

3.3.2 COVIDSafe rules

The COVIDSafe App helped health officials to contact close contacts faster based on mobile Bluetooth handshake records and cloud storage data. Firstly, users downloaded and registered COVIDSafe and their personal information is stored in the National COVIDSafe Data Store which is hosted in the Amazon cloud (AWS). Secondly, the users activated the COVIDSafe App and their mobile device then to broadcast a Bluetooth signal and a digital handshake with other COVIDSafe user mobile devices, to create interaction records. These digital handshake records were then saved on each mobile and encrypted. When a user became a confirmed case, health officials would contact them and provide a

COVIDSafe pin. If the user agreed to upload the digital handshake information to the COVIDSafe AWS servers based on the pin, health officials could then view contact logs and inform close contacts.

3.4 Health code and COVIDSafe technical features

Health Code and COVIDSafe have largely different technical features and technical architectures. In terms of information technical features, the Health Code obviously is more complex and accessible than COVIDSafe. The main differences are in the data sources, access platforms, devices, data recycle, data owner, data access, data collection, data host and the costing of both apps (Table 3).

	Health Code	COVIDSafe
Data Source	Personal submission, telecommunication tower, hospital information system etc.	Mobile Bluetooth
Platform	App/web based across multiple platforms	App (No compatible older than IOS 10 and Android 6)
Device	Multiple devices/paper print out	Smartphone
Data Recycle	Nil	21 days
Data Owner	Governments	Individual and government
Data Access	Governments and individual owner	Only approval by users and US government in theory
Data Collection	Personal details; Government data; Telecommunication companies' data	Mobile Bluetooth contact between devices
Data Host	Government owner servers, cloud computing providers (physical servers in China)	Amazon servers (physical servers in Australia)
Cost	Different levels of governments	Federation government

Table 3. Health Code and COVIDSafe technical features

3.5 Health code and COVIDSafe scenarios

The Health Code and COVIDSafe are used for different purposes. The Health Code can be used in contact tracing and can stop confirmed cases or potentially infected cases from moving around. COVIDSafe was used for basic contact tracing. There are several scenarios to show how Health Code and COVIDSafe work in different situations.

Health Code: Scenario - Resident A comes from a high-risk area or has close contact with infected cases. Resident A's Health Code will be red. If A goes to public places like shopping centres or takes public transport, for example, bus or subway, A is required to scan the access point QR code, which will display a red health code on his/her phone, and A will be barred from public places or public transport.

Scenario - Resident A comes a from potential risk area (not a high-risk area) or has COVID-19 'like' symptoms. Resident A will be under quarantine and their Health Code will be Yellow. During a 14 days quarantine period, if A is confirmed as having COVID-19, A's health code will become Red . While if A has a negative PCR test during the period, A's health code will be displayed as Green. In addition, if A holds a yellow health code and scans the Health Code access point, to go to public places, A will be barred from access to public places.

Scenario - Resident A doesn't come from a high-risk area, does not have any COVID-19 close contacts, and does not belong to any potential risk groups. Their Health Code will be green. Resident A can scan his/her Health Code and access public places or take public transport.

COVIDSafe: Resident A turns on his/her GPS (required by COVIDSafe on IOS and Andriod) and mobile Bluetooth. The COVIDSafe app will record any nearby mobile phone details close to A. If A doesn't have any COVID-19 infection, the data will be deleted in 21 days. However, if A has a COVID-19 infection and he/she agrees to share his/her COVIDSafe data, Health officers can obtain A's COVIDSafe data and access to Amazon Web Services (AWS) servers, and they can then contact A's close contacts. Health officers will do the same step to get A's close contacts' COVIDSafe data to find their close contacts. In theory, if A does not wish to share his/her COVIDSafe data, Health officers are unable to do anything about this.

3.6 Stakeholders

Health Code and COVIDSafe have a variety of stakeholders. The stakeholders of both apps could be categorised into government, organizations including private organizations, app users. The government stakeholders are different levels of Chinese government agencies which implement and manage the

Health Code. The organizational stakeholders of Health Code are business companies, public transport, resident community which provides access checking; telecommunication companies, hospitals which are Health Code data sources; and technical support companies. The government stakeholders of COVIDSafe are the Australian federal government which launched the app, state health officers who notify close contacts, US government (in theory). The organization stakeholders of COVIDSafe include technical support companies that are not relevant to app adoption. The user stakeholders in both countries are individual citizens and residents.

4 Discussion

In applying UTAUT to better understand the adoption of the Chinese Health Code and Australian COVIDSafe contract tracing apps we were able to highlight the following issues.

4.1 Performance expectancy

Both countries citizens and residents believe Health Code and COVIDSafe have benefits for them in terms of COVID-19 infection control. In the Health Code prototype stage, the Health Code was not a compulsory app for residents. It is used for residents to submit their health status, and government officers can easily manage close contacts, which is more efficient than a paper-based submission of details. After Hangzhou city launched the first version of the Health Code system which spread to the whole of China, it then became a compulsory app of all citizens and residents. In this mandatory context, the Health Code app was highly visible for its stakeholders such as resident users and governments. The Health Code is mandatorily used to access public places and transport in China. The red and yellow Health Code mean rejected access to any public places (Health code scenario 1-2). In other words, the green Health Coded residents are at low risk and can return to their normal life. The multiple dimensions of data sources and complex computer algorithms provide a reliable Health Code colour result (section 4.2). The red and yellow Health Code users' information will be auto-sent to government agencies, and residents can receive early treatment (mandated treatment) because of China's "zero" COVID-19 case policy. For the Chinese government, the Health Code helps them to manage contact tracing, identify the potential infections and their health status that directly improving the pandemic's control efficiency. In addition, organization stakeholders such as retailers, bus drivers are responsible for checking residents' Health Code and the barring of potentially at-risk people. To some extent, the Health Code helps organization stakeholders to reduce staff infection risk and keep businesses operating as usual.

The COVIDSafe app was the purely voluntary in its adoption, and its primary function was close contact tracing. Users could not directly benefit from COVIDSafe, because they could still become infected if there were active COVID-19 cases nearby. In addition, as COVID-19 virus could be caught from physical objects such as doorknobs, active cases may not have been detected (within 1.5 m) but infection still spread. Furthermore, COVIDSafe required users to enable Bluetooth, GPS, and broadcast every 15 mins (section 4.1.2), which led to extra battery power impost for mobile power and faster battery drainage. For government, COVIDSafe could assist health officers to quickly and accurately identify close contacts with their contact details providing there was a high level of adoption and activation (which there was not). The organization stakeholders of COVIDSafe are service providers who did not directly impact the COVIDSafe adoption.

4.2 Effort expectancy

Health Code and COVIDSafe have advantages in effect expectancy for individual users, governments and organizations.

In terms of technical features, Health Code can be used to access public places by displaying or scanning access points' QR codes using mobile or printing QR codes. While COVIDsafe has many limits, such as the use of a smartphone with an advanced version mobile operation system (section 4.4). Furthermore, Health code users do not need to install a new app on their mobile because it can be accessed by other apps (Wechat, Alipay) or the web. However, COVIDSafe needed an up-to-date version of the app installed on each user's mobile device. COVIDSafe excluded non-mobile users such as elders and children in its technical solution. Moreover, the COVIDsafe app automatically recorded nearby users contact details, but Health Code users must display or scan their Health Code to record access points. Therefore, COVIDSafe was more user-friendly in terms of the auto-record of close contacts.

Health Code and COVIDSafe are easy to use and facilitate both countries' governments implementation of their COVID-19 policies. The Health Code also centralizes different dimensions of data. The Chinese government can access the Health Code system to identify and contact potentially at-risk residents,

instead of accessing multiple systems. Similarly, Australian health officers could get potentially infected users contact details via user provided token.

According to Chinese COVID-19 policies, organizations such as shopping centers, and public transport companies are responsible for checking resident' access to public places. The Health Code can directly display different colours via scan or display functions so that organizations can quickly identify the potentially at-risk residents and bar them from access. In Australia, only the government and users of COVIDSafe utilised the app, so it is not relevant to organizations.

4.3 Social influence

The Health Code was implemented in mandated environment. The users have been forced to use the Health Code by governments and companies to enable their movement around the country. COVIDSafe was a voluntarily adopted app, and social influence had no significant impact on a users' intention to use it.

In China, higher level of governments has a large impact on local governments, for instance, the central government can directly order or lead province/local level government. The higher-level government promotion of the Health Code had a largely invisible pressure on local governments to adopt the Health Code app for use by their citizens. In Australia, the federal government and state governments are independent. The federal government launched the COVIDSafe, but it does not greatly influence state or territory governments adoption of the app at their local level.

For organizations/companies, the Health Code was supported by organisational senior management teams because it is a compulsory requirement from government for the movement of citizens. COVIDSafe was not supported by organizations as they had no stake in its use.

4.4 Facilitating conditions

Both apps are integrated with existing technologies such as the internet, cloud computing, Bluetooth, operation systems etc., and devices such as mobile, and physical servers.

The Health Code system integrated with WeChat and Alipay, which have more than 1 billion users in China. In addition, the existing systems such as government databases, hospital information systems, telecommunication companies' database are connected to the Health Code system as data sources for supporting the Health Code colour rule. Besides technology and infrastructure resource support, the Health Code also gets supported by the Chinese COVID-19 policy which allows Health Code systems to access personal data from various data sources. The policy can be considered an essential resource for Health Code because it ensures the Health Code can be mandatorily adopted in China.

Excepting the above technologies and devices, COVIDSafe is integrated with existing state government information systems to display COVID-19 case statistics (status). Because of the voluntary adoption environment and independent Australian political systems, COVIDSafe did not receive strong health policy support from state governments which could have had a direct impact on adoption numbers.

5 Conclusion

This research has highlighted the differences between Health Code (China) and COVIDSafe (Australia) contact tracing apps as implemented in their respective environments. The key dimensions of each app include technical solutions such as functions, data sources, features (e.g. technical access etc.), operation rules and stakeholders (Table 4).

Dimensions	Health Code	COVIDSafe
Purpose	Restrict active cases moving	Identify the close contacts
Functions	QR code display and scan	Bluetooth proximity record
Data sources	Various	Bluetooth, GPS
Access	Variety of channels to access	Smartphone only
Platforms	Variety	Android and IOS
Operation rules	Red, yellow and greed Health code for high, potential, low-risk people groups respectively	Close contact records
Stakeholders	Governments, residents, organizations	Governments, residents
Competitors	None	Local contact tracing apps

Implantation environment	Voluntary (early stage only) and mandatory	Voluntary
Benefits for app users	Visible	Invisible
Easy to use	Non-application install; Health Code display and scan	App installation and auto-record
System integration	WeChat, Alipay etc; IT infrastructure; public etc	IT infrastructure; government information systems
Government policy	Significant	Limited

Table 4: The key differences of Health Code & COVIDSafe

This study has also found that digital solution adoption relies on environmental context and the system technical adoption strategies during an emergency situation. Users could not identify visible benefits from COVIDSafe, and it also had technical defects such as high phone battery drainage as well as access limitations. Given the technical issues *and* voluntary app adoption environment, COVIDSafe did not have many active users and so became an adoption failure. On the other hand, Health Code's apps' ease of use, visible benefits and integration with existing systems, ensured that it had many active users in spite of its mandatory adoption environment.

This paper highlights that both the design and development of digital solutions for widespread adoption in crisis situations should be considered from a technical strategy viewpoint. Also, adoption approaches should similarly focus not only on the implementation environment but also on benefits to users, app ease of use, integration with other systems and supporting government policies for adoption.

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