COVID-19 DIGITAL CONTACT TRACING BETWEEN PRIVACY ISSUES AND CO-PRODUCTION WHY SOME HAVE WORKED AND SOME HAVEN'T

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Abstract
With the first outbreak of COVID-19, governments in the world adopted various policies to contain its spread. Major policies are: social distancing; identify and isolate who diagnosed with COVID-19; contact tracing and quarantine them; mass testing and quarantine those who are positive; and lockdown. Among these methods, contact tracing is used for contagious diseases and was used during the Ebola virus outbreak, as well as in the SARS outbreak. As COVID-19 has gone global, some countries have aggressively used digital contact tracing in an attempt to control outbreaks and they have been successful.

When contact tracing is performed manually, it needs staff interviewing people who have been diagnosed with the disease to figure out who they may have recently been in contact with. Then, they have to contact and tell those people they may have been exposed. This procedure needs well trained staff and is time-consuming. Thus, with the outbreak of COVID-19, this method became unrealistic to perform, opening the way to develop digital contact tracing methods.

This paper analyses various types of digital contact tracing developed and used in different countries and tries to understand why some worked, while others haven't, focusing on the issue of privacy and co-production, which are important issues in using new digital technology.

1. Introduction: COVID-19 outbreak as digital laboratory

Governments in the world adopted various policies to contain the spread of COVID-19. Major policies are: social distancing; identify and isolate who diagnosed with COVID-19; contact tracing and quarantine them; mass testing and quarantine those who are positive; and lockdown.

Among these methods, contact tracing is typically used for contagious diseases and was recently used during the Ebola virus outbreak (2013-2016: [27]), as well as in the Severe acute respiratory syndrome (SARS) outbreak (2002-2004: [3] [13]). As COVID-19 has gone global, some countries have aggressively used contact tracing in an attempt to control outbreaks and they have been successful, while some failed [1].

When contact tracing is performed manually, as in most previous cases, it needs trained staff interviewing people who have been diagnosed with the disease to figure out who they may have recently been in contact with. Then, they have to contact and tell those people they may have been

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exposed. This procedure needs well trained staff and is time-consuming. Thus, manual tracing was performed only at the very early stage of this pandemic and with the outbreak of COVID-19, this method became unrealistic to perform (Barret et al., 2020), opening the way to develop digital contact tracing methods in various countries, with the support from private sector as well as the civil society. The digital contact tracing, which includes contact tracing apps [8]; however, varies in its methodology as well as in its performance [4].

The effectiveness of contact tracing has been confirmed by many previous cases of contagious diseases [3] [27] [13]; although it is difficult to isolate the effectiveness of contact tracing strategy from other measures, as various measures have been introduced together in different combinations in various countries and regions.

For example, New Zealand is one of the countries in the world with less number of COVID-19 contagion and has aggressively performed contact tracing; however, it also performed other measures [21]. Indeed, New Zealand introduced short city-wide lockdown, when three cases of the variant B.1.1.7, so-called UK variant, were detected in Auckland on 15 February 2021 [18]. When the new strains emerged, many countries have adopted the dual approach of closing borders and increasing domestic surveillance, while some banned travellers from countries where cases of the new strains have been reported. New Zealand too, adopted selective travel bans and its borders were effectively policed and monitored, also thanks to its geographical characteristics; however, it reported the presence of new variants within their borders, confirming that short of total isolation, importation of the virus is almost inevitable. The country has lower community transmission rates, reducing the risk of an indigenous mutation. Therefore, it is the efficient implementation of domestic protocols rather than selective travel bans that ultimately provides protection. According to Menon [18], closing borders will not stop the new or future variants from finding their way in. The evidence suggests that countries that can implement domestic surveillance efficiently are managing the original and new strains better, with the additional protection from selective travel bans likely to be low or redundant. Improving domestic protocols or surveillance will be less costly and more effective than continuously increasing or prolonging border restrictions and the case of New Zealand seems to confirm this.

As the effectiveness of a certain measure to contain the spread of virus cannot be isolated from the other measures and strategies, although, the evidences suggest that some are more effective than others, and as the aim of this research is to analyse various digital contact tracing systems, not in terms of how they are effective in containing the virus, but in terms of effectiveness as a digital instrument, the paper focuses on digital contact tracing strategies of various countries independently from other measures and strategies adopted by them.

The paper, thus, analyses various types of digital contact tracing systems and tries to understand why some have worked and some others haven't, focusing on two issues: first, technical and legal issues of privacy and personal data protection [16] [14]; and second, citizens and civil society's co-production, which is essential in contact tracing, and depends highly on cultural and emotional aspects of the society [4].

2. Methodology and Design of the Research

Given the objectives of the research and the characteristics of the topic, the paper uses case studies to identify the common issues as well as case specific characteristics of these digital contact tracing methods, through analyses of secondary data and information, provided by the official channels, such as documents of government institutions of the selected countries, media sources, such as articles of newspapers and magazines, and academic literatures, such as papers in scientific journals.

The paper first explores the contact tracing as a consolidated method, typically used to contain the spread of contagious diseases. It especially considers the recent cases, in which the technique was employed and consolidated Ebola virus outbreak [27], and the SARS outbreak [3] [13]. In the past, including these cases, contact tracing was performed manually, which requires trained staff interviewing people who have been diagnosed with the disease to figure out who they may have recently been in contact with. Then, they have to contact and tell those people they may have been exposed. This procedure needs a significant number of well trained staff all over the territory in question and is very time-consuming.

During the outbreak of COVID-19, however, initially utilise manual contact tracing methods were substituted by digital contact tracing systems. The scale and speed of contagion of COVID-19 were completely different from the previous contagious diseases outbreak, which required new approach substituting manual contact tracing; however, more importantly, the technological as well as societal conditions were significantly different from the previous periods, especially in terms of the use of digital devices. Indeed, the number of smart phone users worldwide grew from 2012 to 2021 from 1.06 billion to 3.8 billion [24]. There are 5.22 billion unique mobile phone users in the world today, in other word, 66.6% of the world population own mobile phone, the latest data from Ericsson show that the number of mobile subscriptions associated with smartphones now exceeds 6 billion, accounting for more than three-quarters of the mobile handsets in use around the world. The number of smartphones in use is growing at an annual rate of 7%, with an average of more than 1 million new smartphones coming into use every day [6]. Furthermore, now roughly 4.66 billion people around the world use the internet, which is 59.5% of the world's total population. Internet users are growing at an annual rate of more than 7.3%, equating to an average of 875,000 new users each day. 92.6% of internet users use mobile devices to go online at least some of the time. And the average global internet user spends almost 7 hours online each day. These show that the conditions were met to introduce digital contact tracing using smartphones.

Second, the paper examines three cases of digital contact tracing systems, from two points of view; first, technical and legal issues of privacy and personal data protection [16] [14], which is an important aspect in using digital technology; and second, citizens and civil society's co-production, which is essential in contact tracing, and depends highly on cultural and emotional aspects of the society [4]. The cases are; South Korea, Taiwan, and Japan. The first two countries are considered successful in containing contagion, thanks not only to digital contact tracing systems, but also to the combination of various measures adopted by their government. For example, South Korea adopted unique strategy: it never imposed country-wide lockdown, only short and local ones when necessary and many activities remained open, even big sport events [5]. In this paper; however, other strategies and measures are not analysed, neither the effectiveness of digital contact tracing system [2] in containing the contagion. The last case of Japan is a failure case, both in low penetration, which is fatal for the effectiveness of digital contact tracing system, and in various technical issues, including Android-linked bug, which caused malfunction of the app in registering contacts as well as in communicating to those exposed to the person tested positive [20], which, in turn, raised doubt on the effectiveness of the app among the users and distrust towards the app and government institutions in general.

The aim of this research is to investigate why some digital contact tracing systems have functioned, while others have failed, especially from the points of view of technology, privacy, and co-production with the civil society. The first two strongly relates each other; countries with more authoritarian approach were able to involve most population and centralised data to government institutions, while, for example, Japanese app does not allow the government to centralize data, use GPS to track people, or harvest information such as phone numbers and names and downloading the app is strictly optional [20]. Among the cases examined in this research, indeed, technology adopted by countries is strongly conditioned by the privacy concern of the society. The last point, co-production with the civil society [9], is influenced by the trust of the citizens towards government institutions as well as towards technology, and results in the effectiveness of the system.

This research adopts case study [28]. Data were collected from secondary sources, provided by the official channels, such as announcements and documents available in the public domain, that of government institutions of the selected countries, media sources, such as articles of newspapers and magazines, and academic literatures, such as papers in scientific journals. Case study research is appropriate for this research as it makes use of multiple sources of evidence in order to create a picture of the phenomenon under investigation and is methodologically appropriate when exploring complex issues like this or when researchers have little or no influence on the event being studied [28] such as in this research. Document analysis is appropriate, as documents are a rich source of data and in this instance they provided valuable primary data. Document analysis of policy documents and government reports contributed to the understanding of the case study in two ways: first, the document analysis allowed the context for the case study to be understood; second, it also provided a basic information of the government policies in relation to COVID-19.

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3. Contact Tracing Technique for Contagious Diseases

What is contact tracing?

One of the recent, still previous example can be found during the outbreak of Ebola virus disease. Contact tracing is an integral component of the overall strategy for controlling an outbreak of contagious virus. It is defined as the identification and follow-up of persons who may have come into contact with an infected person. Contact tracing is an important part of epidemiologic investigation and active surveillance [27]. During the Ebola virus disease outbreak with established person-to-person transmission, new cases were more likely to emerge among contacts. For this reason, it was critical that all potential contacts of suspect, probable and confirmed Ebola cases were systemically identified and put under observation. Immediate evacuation of potentially infectious contacts with signs and symptoms of the disease to designated treatment centres or to the nearest healthcare facility prevented high-risk exposure. Contact tracing was therefore one of the most effective outbreak containment measures and must have been implemented prudently.

During the Ebola virus disease outbreak in West Africa between 2013 and 2016, contact tracing posed serious challenges, in part as a result of the wide geographical expanse of the outbreak, insufficient resources (human, financial and logistical), and limited access to affected communities. From these experiences, it was noted the importance to set up a functional system for conducting systematic contact tracing, through standardisation and scaling up coordinated contact tracing activities.

Major elements of contact tracing are: the procedures for conducting contact tracing up to the point of discharging the contacts; precautions to be taken by the contact tracing teams; data management; and a guide to estimate the resources needed for an effective system. The stages of contact tracing are: identification; listing; follow-up; managing contacts with signs and symptoms; supervision of contact follow-up; and finally discharge of contacts. Below are the standardised stages of contact tracing, used for various contagious diseases in various places around the world.

3.1. Contact Identification

Contact identification is an essential part of epidemiologic investigation for all cases meeting the standard/surveillance case definitions of the disease. These cases are classified as suspected, probable or confirmed. The epidemiologist/surveillance officer conducting the epidemiologic investigation should complete case investigation forms for all the cases and deaths meeting the standard/surveillance case definition. After completing the case investigation form, the officer should systematically identify potential contacts.

Contact identification therefore begins from a case. Identification of contacts is done by asking about the activities of the case and the activities and roles of the people around the case since onset of illness. Although some information can be obtained from the patient, much of the information will come from the people around the patient. Information, such as persons who lived with the case in the same households, persons who visited the patient, all places and persons visited by the patient, all health facilities visited by the patient and all health workers who attended to the patient without appropriate infection prevention and control procedures, would be collected and processed.

The exposure information should be verified and double-checked for consistency and completeness during re-interview in later visits to ensure that all chains of transmission are identified and monitored for timely containment of the outbreak.

3.2. Contact Listing

All persons considered to have had significant exposure should be listed as contacts. Efforts should be made to physically identify every listed contact and inform them of their contact status, the actions that will follow, and the importance of receiving early care if they develop symptoms. The contact should also be provided with preventive information to reduce the risk of exposing people close to them. Advise all contacts to: remain at home as much as possible and restrict close contact with other people; avoid crowded places, social gatherings, and the use of public transport; report any suspicious signs and symptoms immediately (by providing contact of follow-up team and/or hotline/call centre numbers). It was advised that contact identification and listing, including the process of informing contacts of their status, should be done by the epidemiologist or surveillance officer, not by the local surveillance staff/community health worker performing the daily follow-up.

3.3. Contact Follow-up

The officer responsible for contact tracing should assemble a competent team to follow-up all the listed contacts. This could include surveillance staff/health workers from health facilities, community health workers, volunteers and community leaders. An efficient contact tracing system depends on a relationship of trust with the community, which in turn fosters optimum cooperation. Communities should have the confidence to cooperate with contact tracing teams and allow the referral of symptomatic contacts to designated isolation facilities. Involving appropriate community members in contact tracing is critical in cultivating this good relationship, trust and confidence. The local surveillance staff and community health workers should be closely supervised by trained officers.

The contact follow-up teams and their supervisors should be trained with basic information on the disease, procedures and tools for contact tracing, and the required safety precautions. On this regard, SARS and MERS outbreaks served as an occasion to train health workers with contact tracing techniques as well as to prepare for an outbreak of contagious diseases in several countries and regions, especially in Asia.

3.4. Managing contacts with signs and symptoms

The contact tracing/follow-up team is usually the first to know when a contact has developed symptoms. This may be volunteered by the contact in a phone call, or the contact tracing team makes the discovery during a home visit. If a contact develops signs and symptoms, the responsible team should immediately notify the supervisor and/or the alert management desk/call centre. The alert management desk/call centre will immediately inform the case management team leader. The ambulance team is then dispatched to conduct an assessment and/or evacuation of the symptomatic contact to the treatment centre.

3.5. Supervision of contact follow-up

Close supervision and monitoring of contact follow-up is necessary to ensure that the local surveillance/community workers visit and observe contacts daily. Supervisors should join contact follow-up teams for home visits on a rotating basis to ensure that home visits are done correctly. Conduct regular meetings with all contact tracing teams to address any issues that might have an impact on the effective functioning of contact tracing. Other strategies may be needed to address non-compliance and the management of uncooperative contacts.

3.6. Discharge of contacts

While contact identification, listing and follow-up should start as soon as a suspected case or death has been identified, follow-up of contacts for suspect cases that test negative for the disease should stop and the contacts removed from the contact list. Contacts completing the follow-up period should be assessed on the last day. In the absence of any symptoms, the contacts should be informed that they have been discharged from follow-up and can resume normal activities and social interactions. The team should spend time with the contacts' neighbours and close associates to assure them that the discharged contacts no longer poses a risk of transmitting the disease. The contacts should ensure that they are not re-exposed to symptomatic contacts or probable/confirmed cases of the disease.

These steps were developed during the past outbreak of contagious diseases such as SARS (2002-2004) and Middle East respiratory syndrome (MERS) (2012-), and consolidated during the Ebola outbreak (2013-2016); however, various conditions, in particular the use of internet through mobile devices, especially smartphone, are completely different today under COVID-19, which opened the way to digital contact tracing.

4. Case Studies

Digital contact tracing systems follow exactly the same logic of manual contact tracing; however, the technologies employed for the apps and the management systems varies among cases. In this section, three cases of digital contact tracing systems would be explored and analysed from two aspects: technical and legal issues of privacy and personal data protection [16] [14]; and citizens and civil society's co-production [4].

4.1. South Korea

According to many researches, South Korea learned a lot from the previous experience of MERS, and people knew how to physical distance and how to wear masks [17]. South Korea performed aggressive testing from the very early stage of COVID-19 and contact tracing. Contact tracing has the manual part, but it has enhanced by facial recognition through closed-circuit television (CCTV) and also traces people via credit card transactions. CCTV, credit card transactions, and mobile phone data are used to retrospectively track the movements of people who have tested positive. The routes taken by people confirmed as infected are published online, while an alert is pushed to the phones of people who visited the same locations. South Korean authorities use data-surveillance techniques to get around the problem of people being unwilling to disclose, or unable to recall, close contacts. A law passed in response to an outbreak of MERS in 2015 allows authorities to use data from credit cards, mobile phones and CCTV to trace a person's movements and identify others they might have exposed to the virus [15].

In the early days of the outbreak, public-health officials treated each case more or less individually, with contact tracers compiling detailed histories of a patient's recent whereabouts and screening others accordingly [5]. However, with the first outbreak in February 2020, the authorities introduced systematic digital contact tracing. Restaurants, cafes, and even nightclubs and gyms have stayed mostly open, but often with limited capacity, and patrons must scan a QR code linked to a national contact tracing system before clients entering.

Contact tracing team gets involved immediately once someone tests positive. Public-health workers interview patients, asking them to list where they've been, when, and with whom. That information is fed back to the staff of contact tracing team, who are given access to GPS and transaction records as well as information from the QR code system in use in restaurants and other high-traffic locations. That information allows tracers to verify a person's movements and to find connections between cases. Tracing team tries to identify the likeliest path of transmission through suspected movement of the virus and possible superspreader. The goal is to have all contacts identified within a few hours, or a day at most, and ideally to trace infections back to their source [5]. When a person tests positive, their city or district might send out an alert to people living nearby about their movements before being diagnosed. A typical alert can contain the infected person's age and gender, and a detailed log of their movements down to the minute, in some cases traced using CCTV and credit-card transactions, with the time and names of businesses they visited. South Korean residents have been receiving flurries of emergency text messages from authorities, alerting them to the movements of local people with the virus. Epidemiologists say that detailed information about infected people's movements is crucial for tracking and controlling the epidemic, but some question whether it's useful to make those data public [29].

Smart data-management systems can ease the workload of contact-tracers. Other tasks typically managed by contact-tracers can also be delegated to technology. The South Korean government says the public is more likely to trust it if it releases transparent and accurate information about the virus, including travel histories of confirmed patients. However, the specificity of the publicly available data has raised privacy concerns. The data trails released about some of the infected people have been so detailed that they could be identifiable [29]. In March 2020, Choi Young-ae, chair of the National Human Rights Commission of Korea, expressed concern that the "excessive disclosure of private information" could cause people with symptoms to avoid testing. In response, South Korea's Centres for Disease Control and Prevention announced that such detailed location information should be released only when epidemiological investigations could not otherwise identify all the people with whom an infected person had been in contact before their diagnosis. No other country has released data as detailed as in South Korea.

The public broadly supports the government publishing individuals' movement and the government sharing travel details of people with the virus. Furthermore, most seemed "prefer the public good to individual rights", according to several surveys [29].

Thus, it is fair to conclude that previous experiences, open and transparent data [19] [26], reliable technology, and trust in government are the major reasons of success of South Korean digital contact tracing system, although there are several concerns, namely, privacy violations, social sorting and abuse of power [22]. Regarding the privacy issue, Korea has stringent privacy protection laws, such as its 2011 Personal Information Protection Act (PIPA), which bans the collection, use and disclosure of personal data without the prior informed consent of the individual whose data are involved. PIPA was altered after the MERS outbreak to allow authorities to override some of these provisions in future epidemics. The government realised that the strict criteria found within PIPA were a barrier to their response to the MERS. As a result, Korea established a clear legal basis for collecting personal data during disease outbreaks that align with general data protection regulation guidelines. With digital contact tracing, the authority may directly access digital movements, thus, creating concerns around consent. Furthermore, the information published on the government's website from digital contact tracing is detailed and has the potential for privacy infringements [22]. In relation to abuse of power, there are concerns that digital contact tracing will be misused to implement unnecessary surveillance on citizens. There is the potential that digital contact tracing will be repurposed for other activities that it was not originally designed for. Thus, it is important to identify what the government can do with the technology, the data retrieved and how citizens are protected from abuses of power as a result of its use [22].

4.2. Taiwan

Taiwan is an example of effectively containing the virus employing various digital technologies.

According to Summers et al. [25], there are several reasons for the success. Taiwan established a National Health Command Centre (NHCC) in 2004 following the SARS epidemic. The agency, working in association with the Centres for Disease Control (CDC), was dedicated to responding to emerging threats, such as pandemics, and given the power to coordinate work across government departments in an emergency. Taiwan's pandemic response was largely mapped out through extensive planning as a result of the SARS pandemic, and was developed in such a way that it could be adapted to new pathogens. It also has a very proactive policy of supporting production and distribution of masks to all residents, securing the supply and providing universal access to surgical masks from February 2020 onwards. The mask distribution system was co-created with civil society using digital technology, but also uses conventional channels such as convenience stores in the neighbourhood.

Taiwan's pandemic measures, with extensive contact tracing through both manual and digital approaches, and access to travel histories, meant that potential cases could be identified and isolated relatively quickly. This ability to track individuals or identify high-risk contacts resulted in fewer locally acquired cases.

Summers et al. [25] suggest that relying on identifying symptomatic cases and contact tracing may not be sufficient as methods for containing the virus. A subsequent analysis in Taiwan based on empirical data provided further evidence that case-based interventions (contact tracing and quarantine) alone would not be sufficient to contain the COVID-19 pandemic; however, many other studies suggest the systematic digital contact tracing has certainly contributed to the containment.

Taiwan strengthened its public health response through developing real-time surveillance methods pre-COVID-19 and already had a national alert system in place. Surveillance does not only mean contact tracing, but also national and regional disease and outbreak surveillance systems including sentinel surveillance and more specialised systems, such as wastewater testing. Development of both conventional and digital solutions to contact tracing has been effectively accompanied by isolation/quarantine monitoring. Taiwan is well-known for having developed an effective means of face mask distribution. This digital solution, such as the name-based mask distribution system, and distribution and sales controls implemented by the Taiwan Central Epidemic Command Centre, avoided hoarding and enabled distribution to those most at need. This could also be applied and extended to medicine distribution [25].

The Taiwanese approach is a combination of bottom up and top down as Kluth [11] puts "participatory self-surveillance". Taiwan enforces quarantines with mobile phone tracking and has stitched together various government databases, such as travel and health records. But, the whole country voluntarily partnered with the government to create a protean network of databases in which information flows both from the bottom up and from the top down. To make new online and offline tools for fighting the virus, "hacktivists," developers and citizens have been collaborating with the government on vTaiwan, a kind of online town hall and brainstorming site. One tool, indeed, prevented a run on face masks by mapping where the stocks were and allocating them wherever they were most needed. By involving people in the solutions, rather than just dictating policies to them, the process is transparent and inspires trust, even civic pride.

The case also shows the importance to establish cultural, societal and legal acceptability for these pandemic response measures. There are legitimate concerns regarding the use of big data analytics, particularly with the use of digital methods in public health responses. Other populations may also be less inclined than Taiwan's citizens to accept the imposition of stringent interventions that limit personal rights and liberties [25].

In order that digital tools being developed to work, people must actually download and use them. That means people must trust these apps. Digital surveillance must be in harmony with social values and must be proactively accepted by the population. Various opinion polls show that the health minister Chen Shih-chung have been receiving a higher approval rating than any other top official, including President Tsai Ing-wen, who enjoys high approval rating herself with the COVID-19 measures taken by her administration. Taiwanese are particularly reassured by Chen's swift response, timely orders and candid communication style [30], confirming the importance of communication, transparency, and trust building. This case also shows the importance of co-production with the citizens, not only in terms of participating in digital contact tracing, but also in co-creating apps, such as digital mask mapping tool.

4.3. Japan

Japan is a unique case. It is generally regarded as rather successful in terms of containment of the virus, despite its rather “soft” approaches. Some points out two factors: a unique contact-tracing strategy [10] and early awareness that brought a positive reaction from the public. Without any official instruction, the public began hand sterilising, wearing masks and social distancing of its own accord. Everyone wore masks to protect themselves but the real effect was to reduce spreading by asymptomatic carriers of the virus. Japan used a particular approach to contact tracing [10]. While most countries adopted prospective tracing, Japan introduced the cluster-based approach, thorough retrospective contact tracing to identify common sources of infection. Japanese approach tries to find out where they were infected and then monitor people who visited that site. Four out of five coronavirus patients do not infect anyone else, so finding the superspreaders was a more efficient way to control the virus [10].

When it comes to digital contact tracing; however, Japanese app, named COCOA for Contact-Confirming Application, has had a malfunction since September 2020 and has failed to deliver notifications of suspected contact with people infected with the virus. In February 2021, the Minister of Health, Labour and Welfare publicly apologised for this problem and promised to fix the bug; however, so far, the various issues have not been resolved. The app has been downloaded almost 24 million times (approximately 20% penetration) since its launch last summer and has recorded 9,736 positive coronavirus cases [20], which are very few, suggesting structural problems. Figures suggest willingness among the public to download and use the app has been lukewarm at best.

Touted as minimally intrusive and with its use remaining voluntary, the app has added to Japan’s reputation as one of the most privacy-savvy nations in Asia. Now, the very emphasis COCOA has placed on privacy is attracting fresh scrutiny, with some critics saying protections in the app prevent the government from collecting data essential to gauging its effectiveness. The app is based on what is known as an “exposure notification system”, co-developed by Google and Apple, in which smartphones equipped with the app use Bluetooth signals to automatically exchange and log one another’s randomly generated codes whenever they are within a proximity of one meter for 15 minutes or longer. If a user tests positive and agrees to confirm their infection status via the app, users whose smartphones swapped codes with theirs in the preceding days will be identified as possible close contacts, and notified by the app. Those who receive such notifications are then instructed to self-quarantine and consult nearby public health authorities, where it may be possible to arrange a test for free [20]. The privacy-first ethos has its downside. Officials say the way encryption has been used makes it all but impossible for the government to grasp the actual number of notifications sent via the app.

The Japanese case suggests three issues: first, manual contact tracing might have functioned to a certain extent, but it didn’t guarantee the success of its digital version; second, digital contact tracing would not automatically function by voluntary participation of citizens, but needs to be supported by professional manual work, as confirmed by Korean case and shows that co-production of citizens is a necessary condition, but not a sufficient condition; third, privacy-savvy system has a limitation in terms of effectiveness, confirming the original sin of digital tools; that an effective digital systems have privacy and/or data protection issues, while privacy-savvy digital systems are not effective.

5. Findings, Limitations, and Future Research

This paper aims to explore the digital contact tracing systems for COVID-19, thus, analyses various types of systems and tries to understand why some have worked and some others haven't, focusing on technical and legal issues of privacy and personal data protection; and citizens and civil society's co-production.

The findings from three case studies contributes to theoretical discussions, as they highlight empirical issues, such as the relationship between technology employed, privacy concerns, trust in government, and co-production with citizens, many of which are not explored in existing literatures. The cases contribute to the discussion of digital co-production of public service delivery [7] [12] as well, since they are examples of co-production.

Given the limitation of the number of case studies chosen, the further research would explore more cases, such as New Zealand [21], Singapore [23], and Germany and the United States, in order to include some other successful digital contact tracing systems, yet with some controversies like the Singaporean case, as well as failure cases with different characteristics.

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