DIGITAL CONTACT TRACING: ASSESSING EFFECTIVENESS AND PRIVACY TRADE-OFFS IN SINGAPORE AND INDIA

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KEY TAKEAWAYS

- Under pressure to act swiftly, governments around the world hastily launched digital contact tracing mobile applications as COVID-19 began overwhelming their public health infrastructures. In Asia, two early adopters were Singapore, which launched TraceTogether in March, and India, which launched Aarogya Setu in April.

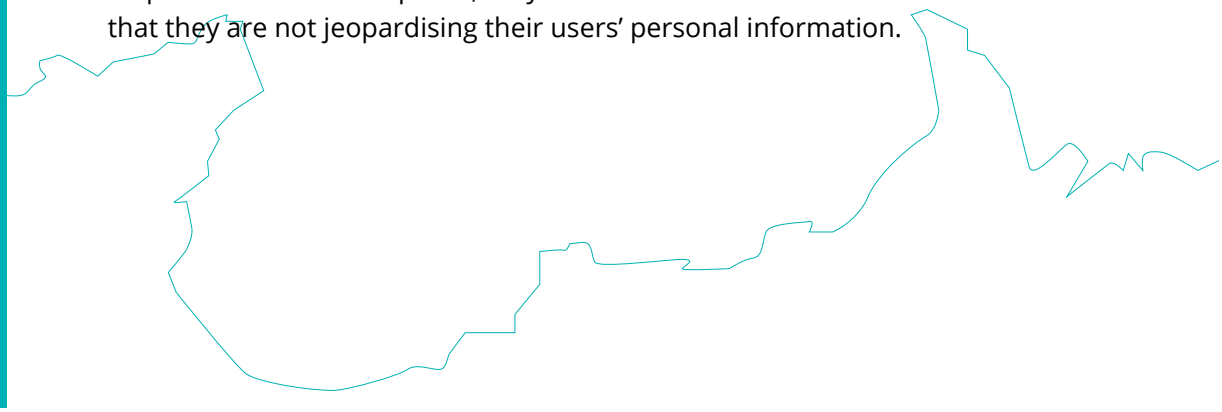
- While there is a broad consensus among the scientific community that digital contact tracing has the potential to curtail the spread of COVID-19, early results have varied. Both applications have, to varying degrees of success, aided public health authorities in their efforts to identify proximity contacts, but these modest gains have come at a cost.

- India's Aarogya Setu, due in part to joint development with the private sector, has underlying conflict of interest issues. For example, the application is overly intrusive in its data collection, as it requires its users to divulge their demographic information while lacking proper privacy safeguards.

- In Singapore, the use of TraceTogether was, until recently, optional for everyone except for foreign migrant workers living in dormitories. Although high rates of adoption are necessary for the success of digital contact tracing solutions, they should not be achieved through force or coercion. Discriminatory rules for marginalised segments of the population should be scrutinised closely, as they can easily set the foundation for further unequal encroachments on civil liberties.

- Because contact tracing requires identifying infected people, individuals must tolerate greater invasions of privacy than they would accept in normal times. Their willingness to surrender personal data depends on what they receive in return.

- Without transparency and accountability regarding these intrusions, policymakers are implicitly paving the way for potential abuses. Since policymakers cannot guarantee that their applications will help control the virus' spread, they should – at minimum – ensure that they are not jeopardising their users' personal information.



From the moment governments understood the severity of the COVID-19 pandemic, they turned to technology for solutions that could dampen its impact and slow its spread. One of the most promising interventions has been digital contact tracing, which uses technology to identify and inform users when they have been in close contact with an infected individual. Bolstered by this promise, countries around the world have rushed to release their own versions of digital contact tracing applications.

In Asia, two early adopters were Singapore and India. Singapore launched its mobile application, TraceTogether, in late March 2020, while India released its application, Aarogya Setu, in early April. Singapore leads the region in terms of smartphone penetration, with more than 90% of its adult population using smartphones.[1] By contrast, in India, estimates suggest that only roughly 30% of the adult population owns smartphones.[2] Although the two countries appear to share little when it comes to technological penetration, data from Johns Hopkins University indicates both have witnessed similar COVID infection rates. As of early November, Singapore had witnessed 58,000 cases (roughly one percent of the total population), while India had just over eight million confirmed cases (~0.6% of the population), although the true extent of the disease's spread is likely greater.[3] Despite their differences, this paper focuses on these two case studies as the juxtaposition of their starting conditions can be instructive for policymakers in similar circumstances.

The paper begins by briefly defining an understanding of the term 'contact tracing' and what digital contact tracing seeks to accomplish. It then considers why it became such a favoured technologically-driven response before reviewing whether the actual implementation has lived up to expectations in India and Singapore. Finally, the paper seeks to explore and analyse some of the privacy designs that have been associated with the frameworks used in both Singapore and India.

1 *"New Report Reveals Singapore Has the Highest Smartphone Penetration in the Region." REBL, 20 March2019. (https://rebl.sg/new-report-reveals-singapore-has-the-highest-smartphone-penetration-in-the-region/).*

2 *Rai, Subhash. 2020. "Aarogya Setu: The Bridge to Nowhere." Janata Weekly, 14 June 2020 (https://janataweekly.org/aarogya-setu-the-bridge-to-nowhere/).*

3 *Johns Hopkins Coronavirus Resource Center. 2020. "COVID-19 Map." (https://coronavirus.jhu.edu/map.html).*

Contact Tracing Goes Digital

The World Health Organization defines contact tracing as "the process of identifying, assessing, and managing people who have been exposed to a disease to prevent onward transmission."[4] Digital contact tracing promises to overcome some key limitations of manual contact tracing, such as reliance on human memory and the reach of human contact tracers, by leveraging the ubiquity of Bluetooth and GPS-enabled smartphones to assist public health officials in scaling up their efforts.

Researchers have studied the potential effectiveness of contact tracing applications and whether they can successfully stem the spread of the virus. In mid-April, a group of epidemiologists from Oxford University published what would become one of the most widely cited studies on this issue. After demonstrating that roughly half of the transmissions occurred before anyone showed symptoms, they generated a scenario where a mobile application is rolled out in a city of one million inhabitants. They concluded that "a digital contact tracing app, if carefully implemented alongside other measures, has the potential to substantially reduce the number of new Coronavirus cases, hospitalisations and ICU admissions".[5] Under pressure to act swiftly, many countries in Asia, including Singapore and India, had already begun to roll out contact tracing apps for their citizens.

The promise afforded by contact tracing technologies even paved the way for a rare collaboration between Apple and Google in May of 2020. The two technology giants jointly developed a Bluetooth framework that allows for contact tracing on devices running either one of their operating systems. Given that the two operating systems collectively account for 98% of smartphones worldwide, the announcement was met with a mixture of hope and scepticism. At a time when big technology companies are often suspected of violating their users' privacy, Apple and Google pledged that no location data or personal data

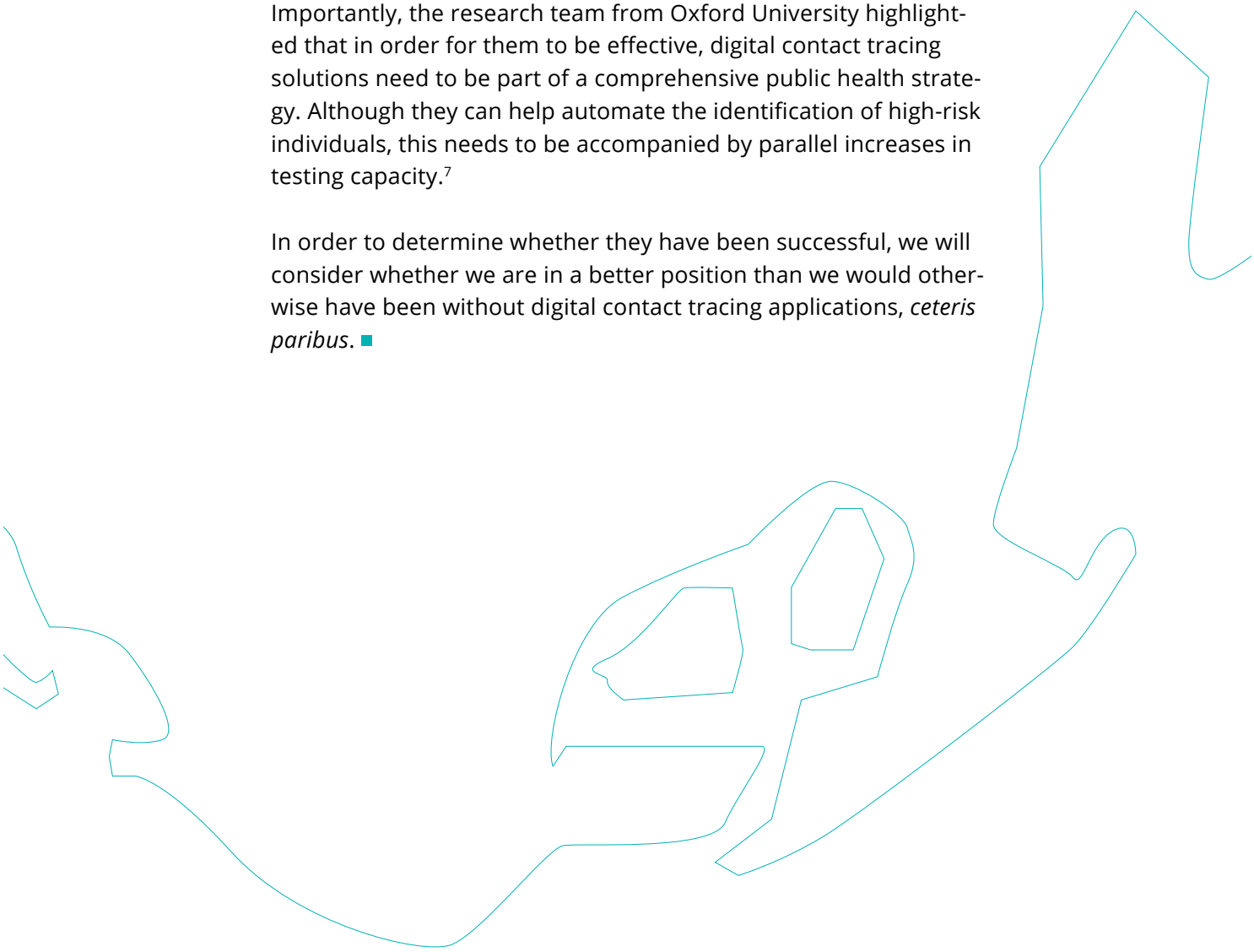
4 *World Health Organization. 2020. "Contact Tracing in the Context of COVID-19." (https://www.who.int/publications/i/item/contact-tracing-in-the-context-of-covid-19).*

5 *Fraser, Christophe. 2020. "Digital Contact Tracing Can Slow or Even Stop Coronavirus Transmission and Ease Us out of Lockdown." University of Oxford Research, 16 April. (https://www.research.ox.ac.uk/Article/2020-04-16-digital-contact-tracing-can-slow-or-even-stop-coronavirus-transmission-and-ease-us-out-of-lockdown).*

would be recorded.[6] To date, a number of countries, including Germany and Japan, have used this framework to develop their own contact tracing applications.

While a broad consensus regarding the potential effectiveness of digital contact tracing exists among the scientific community, there is also an understanding of this technology's limitations. Importantly, the research team from Oxford University highlighted that in order for them to be effective, digital contact tracing solutions need to be part of a comprehensive public health strategy. Although they can help automate the identification of high-risk individuals, this needs to be accompanied by parallel increases in testing capacity.[7]

In order to determine whether they have been successful, we will consider whether we are in a better position than we would otherwise have been without digital contact tracing applications, *ceteris paribus*. ■



6 *Kelion, Leo. 2020. "Coronavirus: Apple and Google Team up to Contact Trace Covid-19." BBC News, 10 April 10. (https://www.bbc.com/news/technology-52246319).*

7 *Wetsman, Nicole. 2020."Google and Apple's COVID-19 Tracking System Can't Save Lives All on Its Own." The Verge, 15 April. (https://www.theverge.com/2020/4/15/21222161/apple-google-bluetooth-contact-tracing-system-coronavirus-health).*

Aarogya Setu in India

India's official contact tracing application, Aarogya Setu, was launched by the Indian Ministry of Electronics and Information Technology in April 2020. With more than 127 million downloads as of July 2020, it is the world's most downloaded COVID-19 tracing application.[8] This rate of adoption can be explained by the fact that the Indian government made its app mandatory for millions of people, including government employees, although it has since reneged on the mandatory adoption. As such, the high number of downloads should not necessarily be taken as a popular endorsement.[9]

Since its launch, Aarogya Setu has witnessed some modest success in aiding authorities with the public health imperative. As of late May, the platform had contacted almost a million users who had been flagged as close contacts of infected individuals, advising them to quarantine or get tested. Among this group, 24% tested positive for COVID-19, as compared to less than five percent amongst the population as a whole, highlighting its effectiveness at detecting proximity contacts.[10] Further, the Health Ministry was able to use data from the app to identify over 600 'hotspots' where the virus had been spreading, making recommendations to its users to avoid such areas.[11] Aarogya Setu has also helped frontline workers take adequate precautions in their line of work.

It is difficult to identify or assess the true efficacy of Aarogya Setu and its role in limiting the spread of COVID-19, and so far, the only information available originates from the government's own, non-independently verified data. The Indian Council of Medical Research (ICMR) looked at contact tracing data for over a million administered COVID-19 tests, of which over 40,000 were positive. The research, released in late

8 *Verma, Shubham. 2020. "Aarogya Setu Now World's Most Downloaded Covid-19 Tracking App." India Today, 16 July. (https://www.indiatoday.in/technology/news/story/aarogya-setu-now-world-s-most-downloaded-covid-19-tracking-app-1701273-2020-07-16).*

9 *Howell O'Neill, Patrick. 2020. "India Is Forcing People to Use Its Covid App, Unlike Any Other Democracy." MIT Technology Review, 7 May. (https://www.technologyreview.com/2020/05/07/1001360/india-aarogya-setu-covid-app-mandatory/).*

10 *Indian Government, Ministry of Electronics & Information Technology. 2020. "Aarogya Setu Is Now Open Source." (https://static.mygov.in/rest/s3fs-public/mygov_159050700051307401.pdf).*

11 *KJ, Shashidhar. 2020. "Aarogya Setu App and Its Many Conflicts." MediaNama, 8 June. (https://www.medianama.com/2020/06/223-aarogya-setu-app-and-its-many-conflicts/).*

May, concluded that the mode of transmission of the virus was not known for over 44% of those who tested positive. In South Korea, by contrast, contact tracers have successfully uncovered the source of transmission for over 90% of cases.[12] This research is all the more alarming considering that the ICMR noted that the proportion of unresolved cases had *increased* with time, even as Aarogya Setu's adoption rate grew.

One of the reasons that digital contract tracing has failed to fulfil its potential in India may be put down to its low adoption. High adoption rates were highlighted as an important success criteria in the Oxford University study, which calculated that 56% of the population needed to download a given contact tracing application in order for it to be effective.[13] Yet others believe that adoption by as little as a third of the population may positively contribute to the public health effort.[14] Although Aarogya Setu leads the world in number of downloads, as a percentage of India's 1.3-billion-person population, only 10% of Indians have the application on their smartphones. Even if the lower threshold is taken, in India this presents an unattainable utopia.

There are roughly 400 million smartphone users in India, representing approximately 30% of the total population. Although certain parts of more densely populated cities may have a higher density of smartphone users, for the country as a whole, smartphone penetration is simply too low. Therefore, even if we hypothetically imagine that *all* of India's smartphone users were to download Aarogya Setu, it would *still* not be enough to have any meaningful impact on the overall contact tracing efforts.[15]

12 *S, Rukmini. 2020. "ICMR Data Shows India's Covid Testing Is Not in Right Shape – 5 Things That Need Fixing." The-Print, 1 June. (https://theprint.in/opinion/icmr-data-shows-indias-covid-testing-is-not-in-right-shape-5-things-that-need-fixing/433077/).*

13 *Abeler-Dörner, Lucie, et al. 2020. "Effective Configurations of a Digital Contact Tracing App: A report to NHSX." (https://cdn.theconversation.com/static_files/files/1009/Report_-_Effective_App_Configurations.pdf?1587531217).*

14 *Howell O'Neill, Patrick. 2020. "No, Coronavirus Apps Don't Need 60% Adoption to Be Effective." MIT Technology Review 5 June. (https://www.technologyreview.com/2020/06/05/1002775/covid-apps-effective-at-less-than-60-percent-download/).*

15 *Rai, Subhash. 2020. "Aarogya Setu."*

TraceTogether in Singapore

Singapore was the first country to adopt contact tracing technology, launching its contact tracing application in March 2020. As of early September, TraceTogether had been downloaded by 2.4 million people, or roughly 42% of the country's population.[16]

In its public communications the Singaporean government has extolled TraceTogether's virtues. The Ministry of Health has used TraceTogether to identify close contacts of positive COVID-19 tests, who are then typically contacted by human contact tracers. Thanks to digital contact tracing technology, 118,000 close contacts have been identified since its implementation. It has also helped the government reduce the time it takes to identify and quarantine a close contact from four days to less than two days.[17]

While it has been a helpful tool in Singapore's battle against the pandemic, there are indications that it has not been as useful as anticipated. Initially hailed as one of the few countries that was able to ward off high caseloads, Singapore experienced a prolonged spike in cases in April and May.[18] Even though the spike was predominantly driven by heightened infection rates amongst migrant workers living in dormitories, TraceTogether, whose adoption rate at the time was lower than at present, was still unable to outpace the disease's spread.

Unlike India, Singapore has among the highest internet and smartphone penetration rates in the world. Yet despite TraceTogether's relatively high rate of per-capita adoption, there are signs that it may still be insufficient. In mid-September, the government launched 'wearable' TraceTogether tokens and QR code check points in designated hotspots or venues providing essential services. These have helped to expand the scope and the reach of the contact tracing efforts, by targeting segments of the population that may not own

16 *Co, Cindy. 2020. "Low Community Prevalence of COVID-19, 0.03% of People with Acute Respiratory Infection Test Positive: Gan Kim Yong." Channel News Asia, 4 September. (https://www.channelnewsasia.com/news/singapore/covid-19-singapore-low-community-prevalence-testing-13083194).*

17 *Co, Cindy. 2020. "Low Community Prevalence."*

18 *Bainbridge, Amy. 2020. "When a Second Wave of Coronavirus Reached Singapore, They Hit the 'Circuit Breaker'." ABC News, 31 July.. (https://www.abc.net.au/news/2020-07-31/victoria-can-learn-from-singapores-second-wave-of-coronavirus/12502404).*

smartphones or who do not wish to download an application. These recent developments may amount to a tacit admission that TraceTogether's Bluetooth based contact tracing has not worked as initially hoped.[19]

TraceTogether has undoubtedly been a useful tool in Singapore's response to the COVID-19 pandemic. However, its recent efforts, and the associated difficulties with boosting user adoption, suggest that it may not have lived up to its promise. This case study, from a small country with a relatively high level of trust in the government, provides a harsh reality check for other countries that expect digital contact tracing to be a sort of silver bullet. ■

19 *Asher, Saira. 2020. "TraceTogether: Singapore Turns to Wearable Contact-Tracing Covid Tech." BBC News, 4 July. (https://www.bbc.com/news/technology-53146360).*

Having considered the varying degrees of effectiveness of the contact tracing solutions deployed in India and Singapore, the paper now turns its attention to evaluating the privacy-preserving safeguards present in each application. Indeed, if policymakers cannot guarantee that their applications will help control the virus' spread, they should at the minimum ensure that they are not needlessly jeopardising their users' personal information.

Aarogya Setu in India

Aarogya Setu's development lacked transparency from the very beginning, and involved the private sector in ways that were not entirely clear. The application was developed through a joint public-private partnership, and, as a result, there remains some ambiguity and some concern over design decisions. For example, it recently emerged that a number of members of a Bengaluru-based technology lobbying group, iSPIRT, contributed to Aarogya Setu's development.[20] Understandably, many fear that certain design choices may have been made by those who have a conflict of interest, such as "a desire to access user data through the app".[21] Partially as a result of these controversial beginnings, Aarogya Setu has, so far, failed to assuage the public's fears.

When downloading the application, users are asked to share demographic data, including their age, travel history and whether they smoke. As a general rule, all personal data (aside from one's phone number), can be considered superfluous for tracing solutions whose purpose is exclusively to alert a user if they may have been exposed to the virus. Indeed, as Chinmayi Arun, a leading Indian privacy lawyers points out, "if the government had been concerned about being able to monitor the number of infected people in particular areas [...], it could have designed a system that flagged trends without identifying individuals".[22]

While the government claims that all the information it collects is being used solely in the interest of public health, it uploads the

20 *Agrawal, Aditi. 2020. "Untangling the Web That Is Aarogya Setu's Creation." MediaNama, 29 October. (https://www.medianama.com/2020/10/223-aarogya-setu-creation/).*

21 *Arun, Chinmayi. "India's Contact Tracing App Is a Bridge Too Far." Council on Foreign Relations, 2 September. (https://www.cfr.org/blog/indias-contact-tracing-app-bridge-too-far?utm_source=tw).*

22 *Arun, Chinmayi. 2020. "India's Contact Tracing App."*

data to a central government-owned server. Privacy best practices established by other contact tracing technologies dictate that sensitive data should be stored on an individual's phone as opposed to central servers that may be more prone to hacking and misuse by authorities.[23]

Furthermore, after collecting its users' personal data, the government reserves the right to share it with "persons carrying out medical and administrative interventions necessary in relation to COVID-19".[24] This ambiguous language is troubling. It relies solely on the government's interpretation of who should be entitled to data that would, in regular times, be considered confidential. If any data or information is made available to a government agency or public health authority through an application, the extent of their ability to use this data and share it with third parties should be clearly defined.[25] Personal data collected through Aarogya Setu can be shared with "Indian government ministries, public health institutions, and, after anonymisation, universities and research institutions for academic research".[26] This large pool of potential recipients invites the possibility, likely to be exploited, that the information may be shared with third parties seeking to profit from it.

Aarogya Setu uses a combination of Bluetooth and GPS data to track its users' movements and proximity contacts. This is another point of concern, as GPS location data is widely believed to be unnecessary for contact tracing purposes. Aside from being less precise than Bluetooth technology with regards to gauging short distances between devices, it also comes with more privacy trade-offs, as GPS location data is harder to anonymise than Bluetooth data.[27]

23 *Howell O'Neill, Patrick, Tate Ryan-Mosley, and Bobbie Johnson. 2020. "A Flood of Coronavirus Apps Are Tracking Us. Now It's Time to Keep Track of Them.," MIT Technology Review, 23 June. (https://www.technologyreview.com/2020/05/07/1000961/launching-mittr-covid-tracing-tracker/).*

24 *Clarance, Andrew. 2020. "Aarogya Setu: Why India's Covid-19 Contact Tracing App Is Controversial," BBC News, 15 May. (https://www.bbc.com/news/world-asia-india-52659520).*

25 *Amnesty International. 2020. "Joint civil society statement: States use of digital surveillance technologies to fight pandemic must respect human rights." (https://www.amnesty.org/download/Documents/POL3020812020ENGLISH.pdf).*

26 *Arun, Chinmayi. 2020. "India's Contact Tracing App."*

27 *Cantrell, Bethan, et al. 2020. "Outpacing the Virus: Digital Response to Containing the Spread of COVID-19 while Mitigating Privacy Risks." Harvard University Edmond J. Safra Center for Ethics, 3 April. (https://ethics.harvard.edu/files/center-for-ethics/files/white_paper_5_outpacing_the_virus_final.pdf).*

The risk of revealing private data acquired through GPS logs was confirmed when the 'ethical hacker' who goes by the pseudonym Elliot Alderson decided to test the application's privacy-preserving features. Aarogya Setu allows its users to know how many individuals are infected within a given radius surrounding their location, all while supposedly keeping identifying information confidential. However, Alderson was able to modify his location on the application. While this may not sound like a consequential privacy threat, thanks to triangulation, a cyber attacker would be able to pinpoint precise latitude and longitude coordinates to uncover a specific user's health status.[28] This example further demonstrates the heightened security risks posed by centrally stored GPS data, as well as the lack of appropriate privacy safeguards.

Application developers and the governments who contract them should be transparent about how their digital tracing solutions operate. Transparency is critical – it allows the public to scrutinise the application's workings and provide feedback for modifications that are in line with their privacy expectations. This is especially important if these applications and the governments that deploy them are truly interested in achieving widespread adoption of their technology. Transparency can take the form of clear, publicly available policies and design, such as an open-sourced code base or other measures that clearly demonstrate their commitment to open dialogue.[29] Unfortunately, Aarogya Setu has fallen short on this count, too. At the time of its release, "neither the privacy policy nor the terms of service were publicly available".[30] After mounting pressure, the authorities released the source code in late May, only for activists to notice that it was not the one that was being actively developed by authorities, and was unusable by the open-source community.[31] Despite opportunities to prove that it was operating with public health in mind, Aarogya Setu's developers have regrettably failed to seize them.

Finally, the government has avoided mentioning what might be done with Aarogya Setu after the pandemic is over. Digital contact tracing solutions that are

28 *Alderson, Elliot. 2020. "Aarogya Setu: The Story of a Failure," Medium, 7 May. (https://medium.com/@fs0c131y/aarogya-setu-the-story-of-a-failure-3a190a18e34).*

29 *Howell O'Neill, Patrick, Tate Ryan-Mosley, and Bobbie Johnson. 2020. "A Flood of Coronavirus Apps."*

30 *Howell O'Neill, Patrick. 2020. "India Is Forcing People."*

31 *Rai, Subhash. 2019. "Aarogya Setu."*

privacy-preserving often include a *sunset clause*, a provision that states when surveillance activities end, and confirms that any remaining data will be destroyed after this date.[32] The Indian government has neglected to specify what will happen to the data it collects after the pandemic, and it is not mentioned in the application's Terms of Service.[33] Many people are worried, with good cause, that the app may not be withdrawn in the wake of the pandemic, and may instead be repurposed for surveillance purposes.

As the coronavirus pandemic continues to ravage countries around the world, including India, citizens may be willing to sacrifice some privacy in exchange for an assurance that it will be worthwhile in aiding the public health effort. Unfortunately, the privacy sacrifices associated with using Aarogya Setu outweigh the potential upside of an unproven application. Aarogya Setu is overly intrusive in its data collection, lacking in safeguards regarding data usage and insufficiently transparent.[34] Before it can count on the buy-in of more users, the application's developers must address these issues.

TraceTogether in Singapore

TraceTogether was developed by the Singaporean Government Technology Agency (GovTech). From the beginning, the GovTech team favoured building a contact tracing application that used Bluetooth protocol to identify proximity contacts, given its greater accuracy. Unlike GPS systems, Bluetooth will only pick up signals from devices within a certain radius, instead of all devices that share the same GPS coordinates, which may include devices that are on different floors or in distant parts of the same building. This avoids flooding the system with false positives. Instead, public health authorities can focus their attention on plausible cases of disease transmission.[35] It is, however, worth noting that Bluetooth technology is not a cure-all, as it requires fine-tuning on the back end to ensure that it is picking up signals from devices that are close enough for their users to transmit a virus.

32 *Mauro, Aaron. 2020. "Coronavirus Contact Tracing Poses Serious Threats to Our Privacy." The Conversation, 10 May. (https://theconversation.com/coronavirus-contact-tracing-poses-serious-threats-to-our-privacy-137073).*

33 *Rai, Subhash. 2020. "Aarogya Setu."*

34 *Shahane, Girish. 2020. "Opinion: Does Aarogya Setu Really Work?" Mint, 28 May. (https://www.livemint.com/mint-lounge/features/opinion-does-aarogya-setu-really-work-11590636898864.html).*

35 *Cantrell, Bethan, et al. 2020. "Outpacing the Virus."*

Bluetooth protocols do not only provide greater accuracy; they also offer fewer privacy trade-offs than location tracking alternatives. When two phones come into close contact with one another, the information that is shared between them only consists of the anonymous tokens that register the interaction. These tokens can be cryptographically secured in a way that makes them less vulnerable to de-anonymisation than GPS location histories.[36] Thanks to this system, a user is incapable of knowing who the tokens stored in their app belong to. These tokens also provide a higher level of protection than those that run on GPS protocols as the data is encrypted and stored on a user's device, instead of a central server.[37]

When downloading and signing up for the app, users must only share their phone number. No other personal information is collected, meaning that it is only collecting the minimum data necessary for contact tracing purposes. The app creates temporary IDs that change regularly, meaning that the lack of a consistent identifier makes it nearly impossible for third party snoopers to identify or track individuals. Furthermore, the data collected through TraceTogether is only stored locally on users' devices for 21 days before being automatically deleted.[38] Of course, data detailing potential exposure to a source of contamination becomes useless once the window for testing has passed. By automatically destroying data at regular intervals, the Singaporean government is signalling that it will not be using the data at a later date for purposes other than contact tracing.

GovTech also sought to create a transparent solution. TraceTogether's source code is open-sourced, inviting outside scrutiny.[39] In its privacy statement, the government clearly states that the data it collects through the application will be used solely for contact tracing purposes. It also clarifies that usage of the application is timebound; once contact tracing activities cease in the wake of the pandemic, users will be prompted to disable its functionalities and dispose of their tokens.[40] While all of the privacy safeguards de-

36 *Cantrell, Bethan, et al. 2020. "Outpacing the Virus."*

37 *Cantrell, Bethan, et al. 2020. "Outpacing the Virus."*

38 *Singapore Government Technology Agency. 2020. "Press Release: Launch of New App for Contact Tracing." (https://www.smartnation.gov.sg/whats-new/press-releases/launch-of-new-app-for-contact-tracing).*

39 *Singapore Government Technology Agency. 2020. "Press Release."*

40 *"TraceTogether Privacy Statement." TraceTogether. gov.sg. (https://www.tracetogether.gov.sg/common/privacystatement).*

scribed above are steps in the right direction, TraceTogether has still come under attack for failing to respect its users' civil liberties in certain cases.

Although high rates of adoption are a precondition for digital contact tracing solutions to be effective, they should not be achieved through force or coercion.[41] Instead, citizens should feel an obligation to download a digital contact tracing solution in the interest of the public good, under the assurance that all necessary safeguards are in place and that their personal information will not be jeopardised. For the majority of the duration of the pandemic, all Singaporean residents could voluntarily choose whether to download TraceTogether, *except* for foreign migrant workers living in dormitories.[42] The government justified this distinction by stating that these dormitories are the perfect breeding ground for the disease to spread. Although TraceTogether will become mandatory for the *entire* population by the end of December 2020,[43] in general, imposing disparate rules for different segments of the population should be monitored closely, as it may be setting the foundation for further encroachments on civil liberties.

Another privacy concern arises when a TraceTogether user is suspected of having been exposed to the virus. By law, they must share the tokens that are locally stored on their phone with the Ministry of Health (MOH), or risk prosecution.[44] Such anxiety-provoking regulations may partially explain why Singapore has struggled to push the app's user adoption past the 50% threshold. Fear should not be used as a motivator during public health efforts. Instead, the government should clearly communicate the benefits of sharing this information and the risks associated with keeping them on one's phone. If this barrier is removed and the benefits of cooperating with the MOH in its contact tracing efforts are clearly enumerated, user adoption will likely increase.

41 *Howell O'Neill, Patrick, Tate Ryan-Mosley, and Bobbie Johnson. 2020. "A Flood of Coronavirus Apps."*

42 *Wong, Lester. 2020. "All Foreign Workers Have to Download and Activate TraceTogether App by June 19: MOM." The Straits Times, 16 June. (https://www.straitstimes.com/singapore/all-foreign-workers-have-to-download-and-activate-tracetogether-app-by-june-19-mom).*

43 *Wong, Lester. 2020. "Use of TraceTogether App or Token Mandatory by End Dec." The Straits Times, 12 November.. (https://www.straitstimes.com/singapore/use-of-tracetogether-app-or-token-mandatory-by-end-dec).*

44 *Hwa, Ang Peng. 2020. "The More We TraceTogether, the Safer We Will Be." The Straits Times, 16 June. (https://www.straitstimes.com/opinion/the-more-we-tracetogether-the-safer-we-will-be).*

Finally, it has been noted that while the necessary safeguards have been adopted to protect users from one another and from malignant hackers, that privacy protection does not extend to the government. After a user is diagnosed and shares their tokens with the MOH, the government retrieves the phone numbers of all contacts a user has been near. Therefore, "neither the diagnosed user, nor the exposed contacts, have any privacy from the government", and potentially uninfected users are no longer in control of their data.[45] The Singaporean government claims that this is a necessary price to pay to protect the health of its citizens, and that the myriad security precautions it has taken elsewhere make up for this infringement. Nevertheless, this is another area that presents plenty of potential for abuse and should be surveyed closely.

The Singaporean government has taken many proactive steps to assuage its citizens' security and privacy concerns. Its commitment to transparency, minimal data collection and regular data destruction are laudable and represent important steps to protecting its users' privacy, especially given that the application's effectiveness remains unproven. Notwithstanding these advances, it has struggled to increase user adoption, perhaps in part because certain privacy questions still remain unanswered. ■

45 *Cho, Hyunghoon, Ippolito, Daphne, and Yun, William Yu. 2020. "Contact Tracing Mobile Apps for COVID-19: Privacy Considerations and Related Trade-offs." Cornell University, 30 March. (https://arxiv.org/abs/2003.11511).*

CONCLUSION

As mobile digital contract tracing applications were hastily deployed around the world in an effort to control the spread of COVID-19, a lot of questions have arisen regarding their effectiveness. Case studies from India and Singapore demonstrate that these applications have yet to live up to their promise. Both India and Singapore have failed to reach the adoption rates that experts agree are necessary for these interventions to be effective. Contact tracing applications may still play a role in a government's COVID-19 mitigation strategy, but it would only be as one part of a broader healthcare response. Based on the findings laid out in this paper, the contact tracing solutions deployed in both India and Singapore have aided the public health effort by uncovering proximity contacts more effectively than would have been possible in their absence. The question remains, however, as to whether the opportunity cost of investing in digital contact tracing, and away from other public health resources has been worth it.

Regardless of efficacy, at a minimum, policymakers have a duty not to violate their users' privacy. Given that the fight against COVID-19 is a public health emergency, individual rights need to be balanced with the greater good. Because contact tracing requires identifying infected people, tracing their contacts and quarantining them, individuals are having to grow accustomed to greater invasions of privacy than they would accept in normal times. The willingness of individuals to surrender personal data depends on what they receive in return. Since there is no assurance that downloading a contact tracing solution aids the public health effort, they should only give up the minimum amount of data necessary to be able to help authorities conduct contact tracing. It is imperative for there to be transparency and accountability regarding these intrusions, or else policymakers are implicitly paving the way for potential abuses. If the necessary safeguards are not implemented, increased adoption of contact tracing technology will fail to materialise, as will its potential to help abet the disease's spread. Ultimately, all public health initiatives rely on trust between a government and the people it serves. Establishing and maintaining that trust may be the difference between a successful contact tracing solution and a futile one. ■

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