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Public health

Contact-tracing app predicts transmission risk

Justus Benzler

The risk of catching COVID-19 as calculated by a smartphone app scales with the probability of subsequently testing positive for the coronavirus SARS-CoV-2, showing that digital contact tracing is a useful tool for fighting future pandemics. **See p.145**

The COVID-19 pandemic was the first global outbreak in human history to unfold in a world where many countries had more than 70% smartphone coverage[1]. This generated many initiatives for smartphone applications that could complement or replace established measures to control the spread of infection in pandemics. For instance, apps were developed that could deliver test results, provide proof of vaccination[2] or trace the recent contacts of an infected person. On page 145, Ferretti *et al.*[3] report that data from a smartphone app used for contact tracing can provide valuable epidemiological information.

Contact tracing is a well-established process that public-health authorities follow during outbreaks of diseases that are transmitted directly between humans. The aim is to find people who were in contact with infected individuals, so that those with potential exposures can receive recommendations or interventions, such as quarantine, to prevent further disease transmission. Manual contact tracing is particularly resource-intensive and is not easily scalable[4]. Hence, in a pandemic, it quickly reaches its limits. Digital contact tracing is an alternative solution that relies on data gathered by personal mobile devices. However, it can pose a particular threat to privacy, because it involves collecting sensitive information about an individual's health status and relationships[5].

Various approaches to digital contact tracing were debated at the onset of the COVID-19 pandemic. Ultimately, the public-health authorities in many countries chose to base their contact-tracing apps on an integrated feature of smartphone operating systems provided by Google and Apple, known as the Exposure Notification framework[6]. This feature relies on Bluetooth signals that are exchanged between participating smartphones when they are physically close to each other. The signals transmit unique, randomly generated codes that are then temporarily stored locally on the other phone.

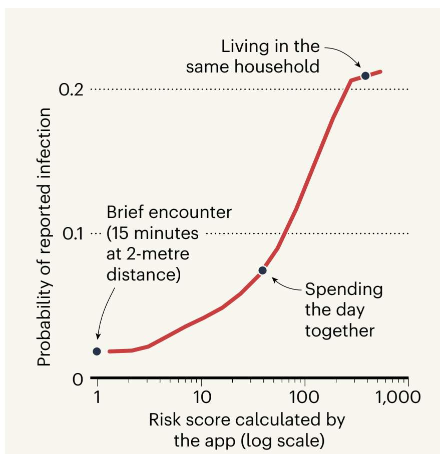

Figure 1 | A smartphone app used for contact tracing during the COVID-19 pandemic can predict the probability of SARS-CoV-2 transmission. Using anonymized data from the NHS COVID-19 app for England and Wales, Ferretti *et al.*[3] show that a risk score for infection – calculated in the app on the basis of the amount of time spent with and proximity to an infected person, and how infectious that person is – scales with the probability of an infection subsequently being reported. A high risk score might result from living in the same household as an infectious person. A brief encounter at a distance of 2 metres for 15 minutes, the threshold for a 'relevant' contact defined in manual contact tracing during the COVID-19 pandemic in most countries, results in a low risk score. In future pandemics, harnessing data from contact-tracing apps might help public-health authorities to understand how infections spread.

If a smartphone user tests positive for SARS-CoV-2, they can opt to upload a set of codes to a server. These codes are renewed daily, and are used to generate the codes that are sent over Bluetooth. The smartphones of other users can then compare the codes on the server to the ones that they had received and stored locally. In the case of a match, the app notifies the second user about past encounters with a potentially infectious person. The threshold for a notification is based on a risk score calculated by the app from the estimated proximity and duration of these exposures, and the infectiousness level of the notifier. This is estimated from the date of the encounter in relation to the notifier's test and the onset of their symptoms.

There is ongoing controversy[7] over the extent to which digital contact tracing – and other non-pharmaceutical interventions – actually contributed to slowing the spread of infections. The aim was to prevent health-care systems being overwhelmed, and to buy time for the development, production and delivery of vaccines. There was little information collected that could address this controversy, mainly because of privacy concerns and the decision to use a decentralized architecture for digital contact-tracing systems, which meant that contact data collected by the apps were not stored in centralized databases. Furthermore, in many countries it was not clear how widely the apps were adopted, because public-health authorities often used downloads as a (poor) proxy for an app's use (see go.nature.com/42q6axc). For the same reasons, the systems also scarcely reached their potential for monitoring key epidemiological indicators for the spread of COVID-19 in the population.

A notable exception is the NHS COVID-19 app rolled out by the National Health Service in England and Wales, which was pioneered by a strong partnership between app developers and academic institutions. Early in the pandemic, the team behind the app created a tool[8] to model the impact of non-pharmaceutical interventions, including digital contact tracing, and published empirical evidence showing that the app helped to prevent COVID-19 cases and COVID-related hospitalizations and deaths[9]. In the current study[3], researchers in the same team analysed data recorded by the app to answer a fundamental question that arose during the COVID-19 pandemic: how is the probability of SARS-CoV-2 transmission from one individual to another related to the proximity and duration of the exposure (Fig. 1)?

Ferretti and colleagues analysed 'packets' of data that each active instance of an app automatically and anonymously sent to a central server. Data packets were sent daily, and on two further occasions: when the app notified its user of an exposure, and when a user submitted a positive COVID-19 test result through the app. From common data points in these packets, the researchers were able to match exposures to actual SARS-CoV-2 infections.

Not all infections resulted from exposures that would have been recorded by the app. By modelling this background 'noise' of infections and removing them, the authors were able to estimate the probability of a notified exposure resulting in a reported transmission. They also further disentangled the risk score into its components, which enabled them to separately analyse the contribution of the instantaneous level of risk (the risk regardless of duration) and the contribution of the duration of exposure. Their main findings are that a clear dose–response relationship exists between the risk score and the probability of reported transmission, and that duration matters even more than proximity. They also confirm that the measurements made by smartphones and the calculations made by contact-tracing apps, despite their limitations, are valid predictors of transmission probability.

Digital contact tracing thus has its place in the toolkit of non-pharmaceutical interventions for future pandemics, and should be part of pandemic preparedness plans. Proximity estimation will probably be improved as smartphones move to using other types of radio technology for signalling, such as ultra-wideband, which enables the distances between devices to be measured more accurately than does Bluetooth. Future smartphones might also be able to take into account other factors that affect the probability of disease transmission, such as being indoors or outdoors.

> **"Digital contact tracing has its place in the toolkit of non-pharmaceutical interventions."**

Furthermore, strategies need to be developed that allow epidemiologically relevant data to be collected while preserving privacy. Such strategies should be discussed with the general public to achieve wide acceptance before the next pandemic, when policy decisions will again need to be made urgently. In future pandemics, analyses such as those presented by Ferretti and colleagues should ideally happen continuously and at the same time as the data are generated. This would enable health authorities to monitor a dynamic pandemic situation with appropriate spatial resolution, and to fine-tune non-pharmaceutical interventions to control the spread of disease.

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