COVID-19 Spatial Contact Tracing

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When future epidemic waves of COVID-19 occur, near-instantaneous contact tracing will be essential to lower the transmission growth rate. The recently released Google Apple Contact Tracing (GACT) system only traces device-to-device proximity for users of its app and neglects other crucial spatial-and temporal-aspects of disease transmission. We solve this problem with a simple idea: a Spatial Contract Tracing (SCT) system that tethers static devices (“SCT devices”) to specific spaces.

This idea improves the precision of exposure risk estimates by providing more accurate measures of environment (type of room), distance (between individuals), time (duration and contemporaneity of exposure), and location (horizontal and vertical coordinates). In the immediate term these metrics enable rapid and comprehensive contact tracing. In the near term they provide an essential natural experiment if transmission models are to be refined and more efficient responses developed.

In the baseline GACT system, mobile devices act as proxies for people, and thus one may speak of devices that are “infected” with COVID-19. GACT detects contact between an infected device and another device when they are within each other’s Bluetooth range. SCT devices mounted on the ceiling of rooms will better detect the presence of all GACT devices. More importantly, these detect contact in five additional situations: app users beyond the GACT detection range; app users occupying the same space at a later time; users holding low-cost Bluetooth beacons; and those reachable by managers of these spaces for users who do not have the app installed or do not own a mobile device.

Alerted contacts could then decide on the relevant level of response to take, which is especially pertinent to those with preexisting health conditions or for contacts who live with or frequently visit individuals at higher risk. Further, because SCT devices run an app following GACT, they inherit the security and privacy features of the GACT system. Lastly, data collected through SCT could be used by epidemiologists to refine the transmission model, thereby enabling more effective contact tracing.
To keep the COVID-19 pandemic from overwhelming healthcare systems, half the world remained at home. But, the world cannot remain at home forever.

Half the World is Under Stay-Home Order; White House Debates Face Masks.
(Adapted from The New York Times, 2020)

Source:
Retrieved from https://www.nytimes.com
The economic costs are simply too high.

Securing Justice, Health, and Democracy against the COVID-19 Threat. (Adapted from Allen et al., 2020)

Mitigating without destroying the economy and society

The economic costs of these policies are already clear: disruptions in global and local supply chains; massive job loss; market illiquidity; a corporate debt crisis; asset price declines (loss of home values and retirement security); personal bankruptcy; and financial system stress (as creditors face default from borrowers). There are also supply bottlenecks (masks and ventilators most urgently) and the problem of hoarding and profiteering. The war analogy is especially salient for supply bottlenecks and the need to redirect industrial production. The potential social costs include all those typical of a major recession or depression—deaths of despair and other negative health impacts (Case and Deaton 2020); degradation of human skills and resources; mental health harms; and political unrest.

Source:

Source research team and affiliations:
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However, intermittent social distancing may continue until 2022 or even until 2024.

Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period.
(Adapted from Kissler et al., 2020)

Abstract
It is urgent to understand the future of severe acute respiratory syndrome–coronavirus 2 (SARS-CoV-2) transmission. We used estimates of seasonality, immunity, and cross-immunity for betacoronaviruses OC43 and HKU1 from time series data from the USA to inform a model of SARS-CoV-2 transmission. We projected that recurrent wintertime outbreaks of SARS-CoV-2 will probably occur after the initial, most severe pandemic wave. Absent other interventions, a key metric for the success of social distancing is whether critical care capacities are exceeded. To avoid this, prolonged or intermittent social distancing may be necessary into 2022. Additional interventions, including expanded critical care capacity and an effective therapeutic, would improve the success of intermittent distancing and hasten the acquisition of herd immunity. Longitudinal serological studies are urgently needed to determine the extent and duration of immunity to SARS-CoV-2. Even in the event of apparent elimination, SARS-CoV-2 surveillance should be maintained since a resurgence in contagion could be possible as late as 2024.

Source:

Source research team and affiliations:
Stephen M. Kissler (1), Christine Tedijanto (2), Edward Goldstein (2), Yonatan H. Grad (1), Marc Lipsitch (2)
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To prevent a future epidemic wave from growing exponentially, manual contact tracing will not work. It is too slow.

**Quantifying intervention success.**
(Adapted from Ferretti et al., 2020)

![Graph showing the exponential growth rate of the epidemic and the success rate of contact tracing](image)

**Fig. 3. Quantifying intervention success.** Heat map plot shows the exponential growth rate of the epidemic $r$ as a function of the success rate of instant isolation of symptomatic cases ($x$ axis) and the success rate of instant contact tracing ($y$ axis). Positive values of $r$ (red) imply a growing epidemic; negative values of $r$ (green) imply a declining epidemic, with greater negative values implying faster decline. The solid black line shows $r = 0$ (i.e., the threshold for epidemic control). The dashed lines show uncertainty in the threshold due to uncertainty in $R_0$ (see figs. S15 to S17). The different panels show variation in the delay associated with the intervention, from initiation of symptoms to case isolation and quarantine of contacts.

**Source:**

**Source research team and affiliations:**
Luca Ferretti (1), Chris Wymant (1), Michelle Kendall (1), Lele Zhao (1), Anel Nurtay (1), Lucie Abeler-Dörner (1), Michael Parker (2), David Bonsall (1,3), and Christophe Fraser (1,4).

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Contact tracing needs to be instantaneous because the number of transmissions per day significantly increases after day 2.

**Model of infectiousness.**
(Adapted from Ferretti et al., 2020)

![Model of infectiousness diagram]

**Source:**

**Source research team and affiliations:**
Luca Ferretti (1), Chris Wymant (1), Michelle Kendall (1), Lele Zhao (1), Anel Nurtay (1), Lucie Abeler-Dörner (1), Michael Parker (2), David Bonsall (1,3), and Christophe Fraser (1,4).

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“Google and Apple Privacy-Preserving Contact Tracing” is instantaneous, but it uses the Bluetooth Received Signal Strength Indicator (RSSI) to determine the distance for the Exposure Risk Level. RSSI measurements are not a reliable way to calculate distances because they fluctuate greatly under different conditions, and this uncertainty is inherent to all wireless signals.

Although transmission risk for COVID-19 is commonly measured in terms of distances (for instance, “to remain 2 meters apart”), it is difficult to determine if the two phones pictured below are 2 meters or 8 meters apart. Therefore, Google and Apple Contact Tracing lacks the necessary spatial context required to calculate the Exposure Risk Level accurately, potentially leading to many missed detections.

Adapted from https://www.apple.com/covid19/contacttracing
Outdoors, where the transmission risk from COVID-19 is lesser, Bluetooth RSSI values make people appear much closer than they really are because there are fewer obstacles and fewer bodies to absorb the signal.

Indoors, where the transmission risk from COVID-19 is greater, Bluetooth RSSI values make people appear further apart because furniture and people’s bodies absorb the signal.
Adding a static Bluetooth device, which participates in Google and Apple Contact Tracing, to a room allows for Spatial Contact Tracing. Mounted on the ceiling of the room, the device will receive the RSSI signal more clearly. Additionally, people who attend an event but do not have the app installed can be notified by the Spatial Contact Tracing system. Data collected through Spatial Contact Tracing could also be used by epidemiologists for refining transmission models and hence refine both the conditions that trigger contract-tracing user alerts and the severity of those alerts.
A building with multiple static devices and a manager, who has a comprehensive view of the severity of contact between positive-testing traces in the building, could send different levels of warning. For example: one notification for recipients within the same room as the positive-testing user; another notification for recipients occupying the same floor; and a third notification for recipients occupying the same building. Alerted contacts could then decide on the relevant level of response to take, which is especially pertinent to those with preexisting health conditions or for contacts who live with or frequently visit individuals at higher risk.
Spatial Contact Tracing will significantly increase the number of people notified instantaneously when a COVID-19 case is confirmed. In the diagram of traced contacts below, each icon represents one case in Singapore. A cluster of cases often occurred at a single location, such as the preschool in the figure below.

Source: https://againstcovid19.com/singapore/cases
But when a sudden exponential rise in cases overwhelmed the people manually tracing the contacts, they could no longer identify all the contacts within the crucial two-day window and details of the cases were not recorded.

Source: https://againstcovid19.com/singapore/cases
Hundreds of cases were then not adequately traced.

Adapted from https://againstcovid19.com/singapore/cases
The Google and Apple system only traces device-to-device proximity and will therefore have a limited impact.

Alice and Bob meet each other for the first time and have a 10-minute conversation.

Bob is positively diagnosed for COVID-19 and enters the test result in an app from a public health authority.

Their phones exchange anonymous identifier beacons (which change frequently).

A few days later...

With Bob’s consent, his phone uploads the last 14 days of keys for his broadcast beacons to the cloud.

Apps can only get more information via user consent.

Source: https://www.apple.com/covid19/contacttracing
Spatial Contact Tracing maintains the location- and identity-privacy of the app users while adding spatial and temporal awareness to the system. Following Google and Apple’s specifications, the low-cost USD $25 Spatial Contact Tracing devices inherit the security and privacy features of the Google and Apple Contact Tracing system. Since only the managers of spaces with these devices have knowledge of the devices’ locations, the Spatial Contact Tracing system is decentralized and privacy-protecting, and this infrastructure self-disassembles when COVID-19 infections cease being reported.
For users who do not own a mobile phone, using USD $12 Bluetooth beacons with “Ephemeral Identifiers” (a unique rolling ID system that helps preserve privacy) allows such users to receive exposure notifications. These users could then choose when and where to carry the beacon, further preserving their privacy. Spatial Contact Tracing significantly extends the effectiveness of the Google and Apple Contact Tracing system through low-cost devices, protecting billions of people whether or not they have an Apple or Android mobile phone.

Source: https://www.blueupbeacons.com/index.php?page=bangle

Source: https://www.thetileapp.com/en-us/store/tiles/pro