Engineering 6 (2020) 1061–1063

Contents lists available at ScienceDirect

Engineering

journal homepage: www.elsevier.com/locate/eng

News & Highlights

COVID-19 Fight Enlists Digital Technology: Tracking an Elusive Foe

Mitch Leslie

Senior Technology Writer

In March 2020, a Finnish businessman who had just returned from a skiing trip noticed something strange in the output from his Oura ring, the fitness tracker he had been wearing on one of his fingers for a year [1]. Although he did not feel sick, the device detected that his body temperature was 1 °C above normal, and it rated his overall condition as subpar. Concerned, the man saw a doctor and found out he was infected with the coronavirus disease 2019 (COVID-19) coronavirus. His experience helped spark several studies involving thousands of Oura wearers to test whether data collected by the tracker can allow early diagnosis of COVID-19 [2].

As more and more people become infected and die from COVID-19, the world is looking to new technologies that may help fight the spread of the new pathogen. "There is a lot of opportunity here," said Jeffrey Klausner, a professor of infectious diseases at the David Geffen School of Medicine at the University of California, Los Angeles. Cell phone tracking, the Oura ring, and smart thermometers are three high-profile examples of technologies already in use or being tested to determine whether they can speed diagnosis, illuminate the spread of the virus, and uncover or possibly predict outbreaks of the disease.

Privacy issues aside, a person's cell phone can provide a detailed itinerary of their life [3]. Many apps capture location information through Global Positioning System (GPS), connections to wireless fidelity (Wi-Fi) networks, and other means [4]. Telecom companies record customers' movements based on cell phone tower pings [5]. Facebook, Google, and Apple have also amassed troves of data on user mobility from cell phones that they have released to help illuminate the scope of the pandemic [6,7].

Analyses of these location data, pooled from thousands and even millions of phones, are proving useful for tracking the disease trends and guiding public policy [8]. One way in which this data has been enlightening is by providing "epidemiologic insights on mobility," said Alain Labrique, a professor of global disease epidemiology and control at Johns Hopkins University in Baltimore, MD, USA. For example, scientists have used pooled cell phone location information to gauge the effectiveness of stay-at-home regulations. Data from 15 million US phones showed that the lockdowns that many states and cities began to adopt in mid-March made a dramatic impact [9]. On average, users in counties with lockdowns reduced the distance they traveled by about 84% between late February and late March 2020. In contrast, the decrease in counties that did not have these regulations was only 67%, suggesting that the restrictions were curbing travel [9].

A different analysis of cell phone data for 86 million people found that decreased mobility appears to help limit the virus' spread. In the 25 US counties with the most COVID-19 cases, the study determined, residents began to stay home before government officials required it, and the reductions in movement correlated with declines in the rate of growth in new coronavirus infections starting 9–12 days later [10].

Not everyone can stay home, however, and cell phone records have elucidated factors that might influence whether people shelter in place. Data from the company Cuebiq (New York City, NY, USA) pinpointed the phones of 15 million users across the United States between mid-February and late March 2020, allowing comparisons of movement patterns in different areas [11]. By 16 March 2020, residents of high-income areas had cut their movement by 50%. However, residents of low-income areas did not reach a 50% reduction until three days later, and in some cities the delay was a week or more [11]. These findings may help explain why COVID-19 has disproportionately affected low-income people, said Labrique.

Another analysis of location data from around 18 million phones showcased their potential for helping to monitor compliance with shelter-in-place regulations. By late April 2020—before many US states began to officially loosen shelter-in-place restrictions—the percentage of people remaining home had declined by 13% from its peak, a drop said to be possibly related to "confinement fatigue" [12].

Cell phone location data has also helped document events that may have spread the virus. In March 2020, for instance, the data companies X-Mode (Reston, VA, USA) and Tectonix (Columbia, MD, USA) probed location records for about 5000 phones that had been on one Florida beach during the annual US "spring break" holiday. Their widely publicized findings showed that after spring break ended, the phones' owners scattered throughout much of the United States, potentially carrying the virus with them [13]. And cell phone-based analyses of mobility have led to policy changes. In early April 2020, such evidence showed that rural residents in Tennessee were not curtailing their travel, prompting the governor to order a lockdown for the state [14].

As every smart phone user knows, location information can be imprecise, but that is not an impediment for tracking population

https://doi.org/10.1016/j.eng.2020.08.006

movements, said Swarun Kumar, an assistant professor of electrical and computer engineering at Carnegie Mellon University in Pittsburgh, PA, USA. GPS, for example, is usually accurate to within tens of meters outdoors, but it can be off by more than a hundred meters indoors. "Based on the assumptions with which these studies are performed, these errors are not of significant concern," Kumar said. But an important limitation of this approach, he added, is that it overlooks certain population groups, such as children and adults who do not have smart phones. Moreover, location data cannot reveal whether people are taking other measures to curtail viral transmission even if they are moving around, such as maintaining social distancing and wearing face masks, and its value for predicting the disease's spread remains uncertain [15].

Instead of tracking users' movements, devices such as the Oura ring and internet-connected thermometers capture biometric data that may provide more direct evidence of infection and the pandemic's spread. Asymptomatic and pre-symptomatic people with COVID-19 may be contagious [16]. As in the example of the Finnish businessman, devices like the Oura ring could help uncover such hidden or early infections, possibly prompting individuals to get tested and self-isolate. The US National Basketball Association (NBA) bought into the idea, making the ring part of its plan to monitor players' health so that it could resume its disrupted season [17].

Invented by the Finnish company Oura Health (Oulu, Finland), the ring, which costs 299 USD, registers heart and respiration rate, body temperature, and movement (Fig. 1). Several studies are now testing whether patterns in these records might be useful for identifying people with COVID-19 infections. In one such study, researchers at the University of California, San Francisco, and colleagues are following 2000 doctors, nurses, and other healthcare workers in San Francisco who are at high risk of exposure, as well as other Oura wearers [18]. A similar study conducted by scientists at West Virginia University is investigating whether the ring can help forecast when 600 health care workers and first responders will develop symptoms [19]. Both studies have announced positive preliminary results, including evidence that the ring can help predict COVID-19 symptoms as much as three days in advance. However, the findings have not been published in peer-reviewed journals [2].

The smart thermometers (Fig. 2) made by the San Francisco-based company Kinsa already have more than two million users in the United States [20]. The thermometers automatically send body temperature measurements to the company, which has charted the data to establish baseline levels of fever throughout the country. An increase from these baseline levels can signal that the flu or a similar disease is spreading.

A study conducted before the COVID-19 pandemic indicated that including data from the thermometers led to better predictions of flu outbreaks [21]. Kinsa also suggests that the information can help locate surges in COVID-19 infections. The company now publishes a county-by-county map online that shows where in the United States flu-like illnesses—which could include COVID-19—are above their established baseline [22]. In March 2020, Kinsa announced that its data suggested that lockdowns were reducing the incidence of COVID-19 [23]. And in June 2020, the company reported that increases in fevers predicted spikes in cases in states such as Arizona that had begun reopening [24].

Klausner and Labrique, however, said that the Kinsa thermometer data has only limited value. Although the thermometers could identify some outbreaks of illness that need to be investigated, because of their spotty adoption—less than 1% of the US population uses them—they will miss other outbreaks, Labrique said. Klausner noted that fever is not a specific symptom, and people with COVID-19—including many of the elderly people who are at greatest risk from the virus—often do not have a fever. As a result, "temperature monitoring is going to miss a lot of people with infections," said Klausner, adding that the Oura ring is more promising because it measures other variables. Even so, a significant fraction of people who are infected but do not have symptoms will escape detection. The NBA's reopening plan also included regular testing for the virus, and that is a better way to find out if any players are infected, Klausner said.

As the pandemic continues, researchers are investigating whether additional technology can help inform efforts to contain the crisis. One approach, which builds on equipment and procedures already in place, attempts to detect COVID-19 outbreaks by monitoring sewage for the coronavirus [25]. Another approach, discussed in the second article of this News and Highlights column,

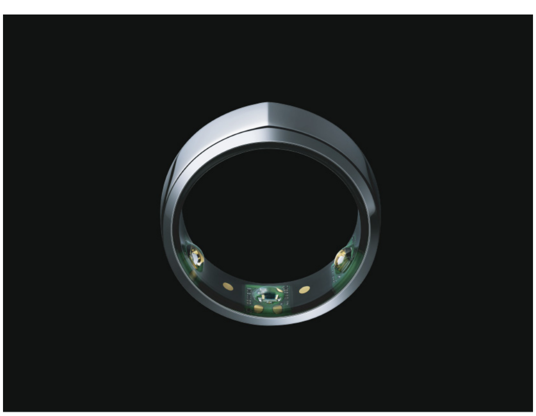

Fig. 1. The Oura ring captures three kinds of data about wearers. Infrared sensors measure heart rate by detecting when arteries in the finger become more opaque, a sign that the heart has just pumped blood through the vessels. A negative temperature coefficient sensor, which gauges electrical resistance, measures skin temperature. And a three-dimensional accelerometer detects movement. An algorithm in the linked cell phone app then profiles the user's sleep, activity, and readiness, a general measure of physical condition. The hope is that alterations in users' scores will reveal whether they are asymptomatically or pre-symptomatically infected by the COVID-19 coronavirus. Credit: Oura Health (public domain).

Fig. 2. The 30 USD Kinsa smart thermometer works with a cell phone app that records the users' temperature history and transmits the values to the company for public health forecasting of the spread of flu and flu-like illness, including COVID-19. Readings from the more than one million Kinsa thermometers in use have allowed Kinsa to establish baseline levels of fever across the United States. The company's HealthWeather maps, available to the public on the company's website, show where fever is above the expected levels, a possible indicator of a coronavirus outbreak. The map for 31 March 2020, for example, revealed an increased level of fevers in the New York City area, where COVID-19 cases were surging. Credit: Wikimedia Commons (CC BY 2.0).

involves using cell phones to facilitate contact tracing of COVID-19-infected individuals.

References

[1] Oppenheim S. Consumer data to the rescue? How tech and researchers are illuminating the spread of COVID-19 [Internet]. Jersey City: Forbes; 2020 Apr 6 [cited 2020 Jul 8]. Available from: https://www.forbes.com/sites/serenaoppenheim/2020/04/06/consumer-data-to-the-rescue-how-tech-and-researchers-are-illuminating-the-spread-of-covid-19.

[2] Fowler GA. Wearable tech can spot coronavirus symptoms before you even realize you're sick [Internet]. Washington, DC: Washington Post; 2020 May 28 [cited 2020 Jul 8]. Available from: https://www.washingtonpost.com/technology/2020/05/28/wearable-coronavirus-detect/.

[3] Thompson SA, Warzel C. Twelve million phones, one dataset, zero privacy [Internet]. New York: New York Times; 2019 Dec 19 [cited 2020 Jul 8]. Available from: https://www.nytimes.com/interactive/2019/12/19/opinion/location-tracking-cell-phone.html.

[4] Valentino-DeVries J, Singer N, Keller MH, Krolik A. Your apps know where you were last night, and they're not keeping it secret [Internet]. New York: New York Times; 2018 Dec 10 [cited 2020 Jul 8]. Available from: https://www.nytimes.com/interactive/2018/12/10/business/location-data-privacy-apps.html.

[5] Pegoraro R. Apple and Google remind you about location privacy, but don't forget your wireless carrier [Internet]. McLean: USA Today; 2019 Nov 23 [cited 2020 Jul 8]. Available from: https://www.usatoday.com/story/tech/columnist/2019/11/23/location-data-how-much-do-wireless-carriers-keep/4257759002/.

[6] Nield D. How Apple and Google's social distancing maps work [Internet]. San Francisco: Wired; 2020 Apr 19 [cited 2020 Jul 8]. Available from: https://www.wired.com/story/apple-google-social-distancing-maps-privacy/.

[7] Waltz E. How Facebook and Google track public's movement in effort to fight COVID-19 [Internet]. New York: IEEE Spectrum; 2020 Apr 16 [cited 2020 Jul 8]. Available from: https://spectrum.ieee.org/the-human-os/telecom/wireless/facebook-google-data-publics-movement-covid19.

[8] Oliver N, Lepri B, Sterly H, Lambiotte R, Delataille S, De Nadai M, et al. Mobile phone data for informing public health actions across the COVID-19 pandemic life cycle. Sci Adv 2020;6(23):eabc0764.

[9] Glanz J, Carey B, Holder J, Watkins D, Valentino-DeVries J, Rojas R, et al. Where America didn't stay home even as the virus spread [Internet]. New York: New York Times; 2020 Apr 2 [cited 2020 Jul 8]. Available from: https://www.nytimes.com/interactive/2020/04/02/us/coronavirus-social-distancing.html.

[10] Badr HS, Du H, Marshall M, Dong E, Squire MM, Gardner LM. Association between mobility patterns and COVID-19 transmission in the USA: a mathematical modelling study. Lancet Infect Dis 2020. In press.

[11] Valentino-DeVries J, Lu D, Dance GJX. Location data says it all: staying home during coronavirus is a luxury [Internet]. New York: New York Times; 2020 Apr 3 [cited 2020 Jul 8]. Available from: https://www.nytimes.com/interactive/2020/04/03/us/coronavirus-stay-home-rich-poor.html.

[12] McMinn S, Talbot R. Mobile phone data show more Americans are leaving their homes, despite orders [Internet]. Washington, DC: NPR; 2020 May 1 [cited 2020 Jul 8]. Available from: https://www.npr.org/2020/05/01/849161820/mobile-phone-data-show-more-americans-are-leaving-their-homes-despite-orders.

[13] O'Sullivan D. How the cell phones of spring breakers who flouted coronavirus warnings were tracked [Internet]. Atlanta: CNN; 2020 Apr 4 [cited 2020 Jul 8]. Available from: https://www.cnn.com/2020/04/04/tech/location-tracking-florida-coronavirus/index.html.

[14] Kelman B. Cellphone data convinced Gov. Bill Lee to shut down Tennessee. This is what he saw [Internet]. Nashville: Tennessean; 2020 Apr 3 [cited 2020 Jul 8]. Available from: https://www.tennessean.com/story/news/health/2020/04/03/coronavirus-tennessee-gov-bill-lee-shelter-in-place-cell-phone-data/5102643002/.

[15] Timberg C. The limits of smartphone data are on display as the country seeks to reopen [Internet]. Washington, DC: Washington Post; 2020 May 14 [cited 8 July 2020]. Available from: https://www.washingtonpost.com/technology/2020/05/14/location-data-covid-predictions/.

[16] Shukman D. Coronavirus: the mystery of 'asymptomatic' silent spreaders [Internet] London: BBC; 2020 May 31 [cited 2020 Jul 8]. Available from: https://www.bbc.com/news/uk-52840763.

[17] Pickman B. The story behind the ring that is key to the NBA's restart [Internet]. New York: Sports Illustrated; 2020 Jul 1 [cited 2020 Jul 8]. Available from: https://www.si.com/nba/2020/07/01/oura-ring-nba-restart-orlando-coronavirus.

[18] Peters J. New study aims to use health data from a smart ring to identify coronavirus symptoms [Internet]. New York: The Verge; 2020 Mar 23 [cited 2020 Jul 8]. Available from: https://www.theverge.com/2020/3/23/21191225/coronavirus-smart-ring-oura-ucsf-san-francisco-general-hospital-tempredict.

[19] Etherington D. Researchers use biometrics, including data from the Oura ring, to predict COVID-19 symptoms in advance [Internet]. San Francisco: TechCrunch; 2020 May 28 [cited 2020 Jul 8]. Available from: https://techcrunch.com/2020/05/28/researchers-use-biometrics-including-data-from-the-oura-ring-to-predict-covid-19-symptoms-in-advance/.

[20] Bloudoff-Indelicato M. This company claims its smart thermometer could help detect coronavirus hot spots faster than the CDC [Internet]. Englewood Cliffs: CNBC; 2020 Apr 2 [cited 2020 Jul 8]. Available from: https://www.cnbc.com/2020/04/02/this-smart-thermometer-could-help-detect-covid-19-hot-spots.html.

[21] Miller AC, Singh I, Koehler E, Polgreen PM. A smartphone-driven thermometer application for real-time population- and individual-level influenza surveillance. Clin Infect Dis 2018;67(3):388–97.

[22] HealthWeather [Internet]. San Francisco: Kinsa Inc.; [updated 2020 Jul 8; cited 2020 Jul 8]. Available from: https://healthweather.us.

[23] Kopf D, Ossola A. Social distancing is slowing not only COVID-19, but other diseases too [Internet]. New York: Quartz; 2020 Mar 25 [cited 2020 Jul 8]. Available from: https://qz.com/1824020/social-distancing-slowing-not-only-covid-19-but-other-diseases-too/.

[24] Young R, McMahon S. Kinsa smart thermometer data predicts new COVID-19 spikes weeks before CDC [Internet]. Boston: WBUR; 2020 Jun 25 [cited 2020 Jul 8]. Available from: https://www.wbur.org/hereandnow/2020/06/25/covid-19-kinsa-smart-thermometer.

[25] Begley S. Wastewater testing gains traction as a COVID-19 early warning system [Internet]. Boston: STAT; 2020 May 28 [cited 2020 Jul 8]. Available from: https://www.statnews.com/2020/05/28/wastewater-testing-gains-support-as-covid19-early-warning/.