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Without a trace: Is technology the next stage in contact tracing's evolution?

**A thesis submitted in partial fulfillment of the requirement for the degree of Master of
Public Health**

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0.0 Abstract

Contact tracing has become both a buzzword and a priority during the COVID-19 pandemic. Though it was deployed nationwide in the U.S., its success varied regionally. This special project thesis, in the form of a longform journalism article, traces the public health practice back to its roots to explore who contact tracers are, what they do, and what factors contributed to tracing's limited success in 2020–21, centering around concepts of stigma and privacy. With this foundation, it assesses the promise and perils of incorporating technology into contact tracing during the COVID-19 pandemic.

Acknowledgments

Another year, another thesis. My own experience as a volunteer contact notifier inspired many of the topics, as well as the framework, of this project. I would like to thank COVID-19 contact tracers for their dedication to beat on, boats against the current; advisers and professors who listened and provided invaluable feedback; science and public health journalists; editors who have given me a hands-on second education in journalism; Anthony Fauci; friends and family; playing spikeball in Central Park during the summer of 2020; my cat, Maisy; TB; messenger RNA; adenoviral vectors; and vaccine cold chains.

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1.1 Introduction

It may have come as a shock to you when the test came back positive. Maybe you had been at a dinner party where everyone had sworn they'd gotten tested just the other day. Or you decided to sneak in a workout before you picked up your child from daycare, and in your rush to the gym forgot to bring a mask. *I'm standing far enough away from him*, you thought to yourself as you eyed another maskless person. Maybe you were, maybe you weren't. What matters now is that you've tested positive for COVID-19.¹

The next hour is a whirlwind of texts and calls. You cancel the walk with a friend you had planned, and let the group chat know the bad news. Then, you hunker down to isolate. If you get groceries and food delivered, you make sure they leave it at your doorstep, and you come out to claim it once they've left.

You're on FaceTime with your sister — *You were being so safe! You're literally the last person I'd think to get this* — when you get a call from a number you don't have saved. After a few rings you pick up, and the voice on the other line identifies themselves as a contact tracer.

“Hi, this is Julie from the health department. I need to discuss some sensitive information with you.”²

After confirming your name and birth date, Julie asks about when your symptoms started, or, if you haven't experienced any, when you tested positive. Next, she asks if you'd be willing to work with her to list out everyone you were in close contact with up to two days before you started feeling sick. She tells you that you're also free to call your contacts before her team reaches out to them.³

You try to remember what you did in those two days before you first experienced symptoms. You can recall a dinner date at an indoor restaurant, a session with a personal trainer, and a night where a bunch of your friends met up to watch the game. But was that before or after your cough came on? Were you feeling feverish during the date, or could it just have been nerves? You feel yourself choke up, and Julie reassures you, saying, “I know it feels like everything is happening so fast.”

You pull up your Google Calendar to double-check that you've correctly remembered every event and contact you listed. Finally, Julie tells you that your next steps are to isolate: stay home and try not to have contact with other people, unless you have to see a doctor. The interview lasts about an hour, although you've heard from friends that they can last anywhere from 30 minutes to a few hours.^{4,5}

Over the next few days, you might hear from your close contacts that someone had reached out to them as well. They might recall that the notifier said something along the lines of, “I am calling to let you know that you have been identified as someone who was exposed to a person diagnosed with COVID-19, also called coronavirus,” but wouldn't name names.

Your brush with COVID-19 contact tracing isn't unique; in fact, millions of stories that are nearly identical have played out in tandem over the course of the pandemic. As one of the three pillars of "test, trace, and isolate," tracing is an immensely important public health tool. Tracing is a race against the virus, and against the clock.

Tracing, of course, is only one piece of the puzzle. Effective and widespread testing is the backbone to any successful tracing effort, one which was notably absent for most of the U.S. response to the pandemic. But for the sake of this thesis, tracing will be considered in a relative vacuum.

It's crucial to understand where contact tracing came from and how tracing for smallpox and sexually transmitted infections shaped the structure of modern-day tracing, as well as the stigma that historically surrounded the targets and employees of the practice. Tracers played a unique role that required medical and emotional expertise, although the people who conducted tracing were only occasionally doctors. More frequently, they were nurses or other support staff. It's also important to recognize the pressures that led to the effective dissolution of an American contact tracing force, which explains the growing pains associated with rapidly scaling up tracing during the COVID-19 pandemic. Having established this background, we can assess the state of contact tracing during the COVID-19 pandemic more clearly, pointing out what went wrong, what we know, and what we don't. It's within this context that exposure notification apps arrived to "disrupt," promising quicker turnarounds that would reach more people more efficiently than traditional tracing. These hopes, however, were stymied due to problems with the apps themselves and with their underlying premise: that traditional contact tracing could be replaced.

1.1 A brief history of contact tracing

The index case in the outbreak in the city of Chester was a symptomatic child. One day, while at a partially open-air gallery on Northgate Street, a daughter of the late Reverend Harwood passed very close to, but did not touch, this child.⁶ Eleven days later, she fell ill and started displaying the characteristic symptoms of disease: a flat, red rash starting in the mouth and throat. Next, a rash appeared on her skin, and the individual sores filled with a thick, opaque fluid and appeared dented in the center.⁷

This was the late 18th century, and the disease was epidemic smallpox. We know about Rev. Harwood's daughter because of the work of John Haygarth, the physician of Chester Infirmary and the doctor whom many consider to be the father of modern contact tracing.⁸ Haygarth undertook meticulous case counting, interviewing, and documenting of smallpox outbreaks in Chester, a novel approach spurred by an overwhelming desire to reduce the burden of disease in the city.

"In the year 1774, the natural smallpox was so dreadfully fatal to the poor inhabitants of Chester, as to produce a deep impression upon my mind, especially when I considered, that it was possible to prevent such destruction," he wrote in the introduction to a 1784 manual on smallpox prevention.⁶ "Ever since that time, it has been an object of my most anxious wishes to preserve their lives by inoculation."

Haygarth later founded the Smallpox Society in Chester, and he devoted his career to fighting smallpox with the passion of a fanatic. He proposed in his manual the establishment of a team of 500 “inspectors” — analogous to tracers — one per health district in England, managed by a board of 50 physicians.⁹

This hypothetical contact tracing force bore a striking resemblance to that of the Roman legions — and one that may not have been coincidental. Haygarth began his manual with a partial verse from the *Georgics*, a didactic poem by the Roman poet Virgil. The epigram’s initial context was part of an explanation of what to do if a sheep in one’s flock is struck by pestilence: “[C]heck the offence, ere the dread taint spreads through the unwary throng.”¹⁰ Whatever the motivation, Haygarth’s plans were never put into practice, in part due to his support of the French Revolution, an unpopular opinion to hold in Britain at the time.

While contact tracing’s roots stretch back to smallpox (and even before, depending on one’s definition), it did not become a pervasive disease control strategy until it was used in the identification and notification of sexually transmitted infections in the 20th century. Tracing had already become linked with trust and stigma, and this relationship was further cemented by the sensitive and outwardly invisible nature of these diseases.

In 1937, U.S. surgeon general Thomas Parran — who would later champion and approve unethical syphilis experiments in Guatemala and Tuskegee, Alabama^{11,12,13} — created a five-pronged approach to lower the rate of syphilis infections, which he said were costing the country at least \$15 million a year in outpatient care.¹⁴ He called public efforts “scattered, sporadic, and inadequate.” He placed effective contact tracing and notification at the forefront of his plan, referencing its use against smallpox:

“A physician would not consider treating a case of smallpox without investigating fully the source of infection. He would either undertake this himself or report to the health department to make the investigation. On the other hand, one does not feel any such responsibility in cases of early syphilis. Yet the tracing of the source of syphilis is no more difficult than tracing the source of smallpox and is just as important.”¹⁵

Parran’s comparison elides a key difference between the two diseases, namely the degree to which syphilis was associated with sex (particularly with prostitutes) and thus stigmatized. Doctors at the time felt they had to walk a fine line between preserving confidentiality and protecting the “innocent” victims of the disease, mainly spouses and children.¹⁴ And at a time where moral laxity was blamed for an increase in syphilis cases, visiting a brothel was not looked upon kindly.¹⁶

But Parran believed he could use stigma to his advantage: he coined a term to encourage public awareness of the sexually transmitted infection: “syphilophobia,” literally, the fear of syphilis.¹⁵ While that fear-based approach did spread awareness about the disease, it also further stigmatized the disease and, indirectly, the contact tracers at the frontline of the public health effort to treat it. Ultimately, Parran’s plan was enacted, and in 1948, the federal government began training workers known as Public Health Advisers. The role entailed both contact tracing and basic phlebotomy, since syphilis patients were often loath to go into clinics to get tested.¹⁷

The association between prostitution and sexually transmitted infections reaches back before Parran's time and stigmatized positive diagnoses. From the turn of the 16th century until the 19th century, prostitutes were regularly inspected in European cities through a regulatory process called reglementation.¹⁴ In the U.S., similar procedures were implemented by states and within industries. In one instance, the Minnesota Iron Company advised male employees to see a physician if they experienced symptoms of a sexually transmitted infection after seeing a prostitute, whereupon the doctor would take down the names of the brothel and women for further follow-up. Infected women were prevented from seeing clients — though this may have reduced the spread of certain diseases, it may have equally incentivized women to lie about their status or name, or push them further underground.¹⁴

Concurrent to Parran's reforms in the 20th century, contact tracing was employed as a strategy to combat rising rates of sexually transmitted infections like gonorrhea and syphilis not just in the States, but abroad as well.¹⁸ Tracers faced unique — and understudied — burdens. One of the few studies that explored the impact that contact tracing had on tracers themselves summarized the transference of stigma that these tracers, who were predominantly women, endured: “[W]orking as a contact tracer for venereal disease had a distinct impact on a tracer's social life. Tracers' lives were compromised by secrecy, stigma, morality and the demands of public health policy.”¹⁸

Marsha*¹ was a contact tracer for venereal diseases in New Zealand following World War II. Her role, according to an interview with her at the end of her life in 2002, “combined [that] of a public health nurse, a social worker and a kind of detective in one person. This role developed in an erratic fashion, it was uncoordinated and it existed under a cloud of secrecy.” Like 90% of New Zealand contact tracers at the time, Marsha did not have any formal education about STIs or public health. The information she received about contacts could be unhelpful: “She goes to the hotel at Friday nights and she drinks Southern Comforts” was an actual description of a person she was assigned to track down and notify for exposure to a sexually transmitted infection.¹⁸

Marsha never married and described herself as somewhat of an outcast: “I sometimes wonder if I was chosen for the job because I was a loner or if it was the other way around,” she told the interviewer.¹⁸

By the time of the AIDS epidemic, the approach to contact tracing depended both on the disease and the state one was in. Nationwide, there was a mix of provider referral and conditional referral — the latter referring to the practice of allowing either a clinician or the index case himself to contact potential exposures.¹⁴ As with the sexually transmitted infections that predated HIV, privacy was a priority for cases, and a determining factor in whether they'd cooperate with tracers. Laws criminalizing the disclosure of one's HIV status added another risk to testing, disclosure, and cooperation.¹⁹

¹*A pseudonym from the original study that interviewed her.

One small study asked 25 HIV-positive women in New Jersey if they'd disclose sexual partners to a contact tracer: 68% said they would if their own identity were not revealed, but that percentage dropped to 20 if it were not confidential.²⁰

In New Zealand, as with worldwide, a change took place in the mid-1970s that rendered contact tracers like Marsha obsolete. As partner notification became folded into the jobs of clinics, it supplanted traditional tracing efforts. Instead of dedicated contact tracers, the role might be played by a clinician or support staff member.²¹ Full-time disease intervention specialists employed by health departments carried out contact tracing for a number of infections, but on a smaller scale.²² Prior to the COVID-19 pandemic, one official estimated that there were approximately 2,200 full-time contact tracers employed in the U.S., or one for every nearly 150,000 American citizens.²³

1.2 Contact tracing during the COVID-19 pandemic

You didn't have any experience working in public health when you applied for a contact tracing position with your local health department. You learned the basics of case investigation and notification through a 14-hour online course, several of which have cropped up online since the start of the pandemic. Your department staggers 10-hour shifts throughout the week so that tracing is occurring around-the-clock.

At the beginning of a day's shift, you log onto a remote desktop and are assigned a name and phone number — someone who has recently tested positive for COVID-19. You call their number from a Google Voice phone number you've been instructed to use, so that you avoid phone fees and so cases and contacts won't have your personal number.

After verifying the case's identity, you ask questions about their symptoms. Whether you say it or not, the reason you do this is to get a sense of their infectious period — how long they've potentially been spreading the disease to others. Once you've established that period, you work with the case to remember what they did and how many close contacts they might have had. You type these up, including their relation to the case (household, work, or social contact perhaps) and their phone number if the case provides it.

Your next task is to work with the case to develop a plan for how they'll stay isolated until they're no longer infectious. Part of the job might mean defining exactly what isolating means, and troubleshooting any barriers to avoiding contacts, like childcare or workplace responsibilities. You can refer the person to food delivery services if they would otherwise go to a grocery store, for example.²⁴

At the bottom of your checklist, you also have a section labeled "Quick Reminders." They include a list of symptoms requiring emergency care, a metric for calculating a case's infectious period, and two subheaders with "phrases for building rapport" and "active listening techniques." You're advised to say things like "This is a difficult time" and "I hear you," and to paraphrase what you've been told to show the person on the other side of the line that you've been listening.³

Before you hang up, you make a plan to check in with the case to assess their symptoms, likely once a day.²⁵ After the call, you'll write up a report and pass it along to contact notifiers, whose tasks are to reach out to every close contact based on the information provided to them. Or, depending on where you work and what policies they've decided on, you might serve double duty as both the investigator and the notifier. At least some of the contacts you call won't pick up, and you or a colleague will try again the next day. Several nonanswers and you'll mark the contact as a nonresponse and move on.

After calling the case, you take a few minutes to collect yourself. Then it's on to the next call, and the next one after that for the rest of your shift. Multiply that experience by tens of thousands each day, and you've got a picture of what contact tracing looks like in the U.S.

Both hypothetical scenarios — the one in which you were called by a contact tracer, the other where you were the contact tracer — are based on a composite of CDC, media, and official training sources, but the realities of contact tracing are varied and hard to pin down. Because there is no national force of contact tracers in the U.S., and there have been no published studies looking at what contact tracers actually do, the contact tracing interview is a kind of black box.

But probing what goes on beneath the formalized structure of an interview is critical to understanding how tracing might be improved, and comparing human tracers with automated tracing programs. Here's what we do know about the state of contact tracing during the COVID-19 pandemic in the U.S.

First: the outcome of these phone calls, measured in the number of contacts disclosed and contacted. As defined by the CDC, a close contact is someone who was within 6 feet of an infected person for a total of 15 minutes or more starting from 48 hours before illness onset until the time the patient is isolated.⁵ The number of close contacts for a given positive case can vary significantly depending on factors like a person's household, their risk-taking behaviors, or the level of lockdown of a particular region. Still, we know that for most people, the number of close contacts is much greater than one. In a study that used data from Singapore, a country with particularly intensive contact tracing and notification processes, a cohort of 1,114 people with lab-confirmed cases of SARS-CoV-2 listed 7,770 close contacts, or roughly seven contacts per person.²⁶ Another study in Taiwan identified 2,761 close contacts from 100 cases.²⁷

How many contact tracers does a country like the U.S. need? 100,000 was an oft-cited number, taken from a report out of Johns Hopkins Bloomberg School of Public Health.²⁸ To answer the question, the report factored in tracing efforts used in previous coronavirus outbreaks (SARS and MERS) and the particulars of how SARS-CoV-2 is spread. The 100,000 professionals they recommended would consist of a mix of health department staff, community members, already trained contact tracers, and social workers.²⁹

Without a starting infrastructure, such an investment was costly. Tracers earn on average \$35,000 a year.²³ Put another way, estimates of the cost of the 100,000 tracing force came to around \$3.6 billion.³⁰ That cost, of course, was not distributed evenly across states: New York City alone spent \$600 million on its contact tracing initiative,³¹ and Boston spent at least \$94 million.³²

Some argued that even that would not be enough to slow the spread of the virus before the development of vaccines. Using mathematical modeling, one study concluded that as two variables increased — the R0, or number of secondary infections stemming from a single primary case in a totally susceptible population, and the proportion of transmission events occurring before symptom onset — effective contact tracing became close to impossible.³³

These models of contact tracing, thus far, have assumed a semi-ideal world, in which people remember their close contacts from the previous days perfectly, and are transparent and honest in disclosing them. That, of course, is not always the case.

It is difficult to ascertain just how often people lie or consciously omit when being interviewed by contact tracers. A study in the CDC publication *Morbidity and Mortality Weekly Report* found that 35% of positive coronavirus cases interviewed by North Carolina contact tracers reported 0 close contacts (those who did report contacts listed three, on average).³⁴ At least a quarter of the contacts listed could not be reached. In New Jersey, half of cases reached refused to provide contacts.³⁵

Trust is an integral part of contact tracing, but it's not always a given. Contact tracers during the pandemic faced hurdles in convincing Americans that they were who they said they were. It can be unnerving to pick up the phone and talk to a stranger who knows personal information about you, like your name, birthdate, and address. And in a year where scam calls are on the rise³⁶, people are justified in being skeptical of calls from unknown numbers; in May, the Federal Trade Commission warned Americans about scammers impersonating tracers over text message.³⁷

Cooperation is a separate question entirely. A Pew survey from late October 2020 found that 28% of U.S. adults polled would not share the names of close contacts with public health officials as part of a contact tracing program.³⁸

Distrust can come from a few places. Not only may cases worry about confidentiality, but by reporting contacts as also having attended large indoor gatherings, they may also feel like they are implicating those friends in bad behavior.

“You would think if you might cause another person to become ill, you would have an interest in that person being notified. But some worry they are snitching on other people,” Marcus Plescia, the chief medical officer for the Association of State and Territorial Health Officials, told Kaiser Health News.³⁹ Those worries aren't justified: public health officials technically have the authority to mandate quarantine, but they almost always choose gentle persuasion instead.⁴⁰ Additionally, while violating some states' stay-at-home orders incurred fines, contact tracers are not the group enforcing those policies, and reporting a gathering that violates public health guidance to a contact tracer would not get a person in legal hot water.

Marginalized communities may also be particularly fearful of talking to a contact tracer.⁴¹ Undocumented immigrants may fear that interacting with public health officials may lead to their deportation — a problem that current-day contact tracers for tuberculosis have also encountered.^{42,43} Instructions and questions may be misinterpreted by people for whom English is

not their first language, and a contact tracing corps may not have enough translators to step in. And according to one survey, those facing social and economic hardships said they would be less likely to participate in testing programs including contact tracing than those not facing the same challenges.⁴⁴

Stigma and shame are driving factors in people's reluctance to cooperate.⁴⁵ One study found that people who lied about not having COVID-19 symptoms (34% of survey respondents) said they were afraid of stigma and social judgment.⁴⁶ But the contact tracing call isn't just stressful for the person on the receiving end of the line. Full-time tracers work in shifts to call positive cases — one contact tracing supervisor in California described how the process added up over the course of a shift:

“If you look at the number of interviews that you have to call in a day and you figure out that each one ... is about a 30-minute interview with a 15-minute prep, and then a 15-minute summary just to make sure the data is accurate. You've got really one heck of a day ahead of you. You're doing nothing but calling people and trying to convince them to do something they'd rather not do. They don't want to hear from you because it involves the illness It just doesn't let up.”⁴⁴

Surges in case numbers make the job even more overwhelming: the supervisor said that during a surge in the winter of 2020, he assigned 1,000 positive cases to a staff of five people in one night.

Other times, tracers may be the first to tell a person about their positive diagnosis, or track outbreaks where one or more people have died from coronavirus infection.⁴⁷

“It's emotionally devastating for them and for us,” said one Nevada contact tracer.⁴⁸ Another tracer said he spent most of his nights after shifts ended “lying on the floor” of his home.⁴⁸

Some researchers believe contact tracers may be at risk for compassion fatigue, a type of stress that has been documented in the medical staff who work in Intensive Care Units.⁴⁹

At the same time, contact tracers have faced death threats and been the subject of conspiracy theories.⁵⁰ According to a June 2020 report, YouTube videos with names like “Beware the Contact Tracers” had racked up over 300,000 views each and were being shared tens of thousands of times on Facebook before being removed by the platforms.⁵¹

Even so, there are no formal protocols in place to support the emotional health of contact tracers. One tracing force organized a “pep rally” featuring a Zoom visit from NIAID director Anthony Fauci.⁴⁹ Organizers of other forces said that being understaffed amid surges led to increased stress and burnout, but there's been little research into interventions to help contact tracers cope with the emotional burden of their jobs.⁵²

When Haygarth was investigating epidemic smallpox in Chester, he relied on personal interviews and patient visits, along with reports from other local physicians. That's not coincidental: it was common in the early days of contact tracing for the tracers to be medical

officers, health commissioners, or other health department workers.⁵³ Since then, however, contact tracing corps have comprised fewer full-time medical professionals and a greater proportion of volunteers. This trend can be explained by the specialization of medicine and public health professions, as well as the erratic demand for dedicated contact tracing.

The temporary nature of modern contact tracers raises an issue: namely, we don't know who they are. No published studies have sought to figure out the demographic makeup of contact tracing teams, and we have no large-scale knowledge of their ages, races, occupations, genders; whether they are predominantly paid or volunteer; whether they work full- or part-time; whether they have a background in public health.

It matters who contact tracers are because their make-up can influence who feels most at ease cooperating with them. It's known, for instance, that LGBTQ-identified individuals have better health outcomes and are more forthcoming with LGBTQ providers.⁵⁴ Contact tracing involves empathy, but also language and cultural competency. Knowing who contact tracers are could also aid organizers in developing large-scale programs to support them. The lack of such initiatives coupled with glaring gaps in information about contact tracers points to areas of research that, for whatever reason, have yet to be explored.

Knowing little about contact tracers isn't a new issue, either. The researcher who interviewed Marsha about contact tracing noted that her account was one of two that exist of New Zealand contact tracers from WWII and right after. We can look to newspaper articles for small-scale answers about who some contact tracers are, but they are in no way representative of this broader, unknown population.

Still, we can surmise several things. First, it's likely that contact tracers come from a range of backgrounds and levels of experience with public health. Said one Vermont contact tracer, "It's like everybody, from the most entry level jobs in the Department of Health, up to the deputy commissioner level ... have been in the ranks of contact tracers. I remember a moment when I was looking at the list of cases for the day, and it shows who is assigned to that investigation, seeing [Vermont deputy health commissioner] Tracy Dolan assigned to cases. It's like, 'Wow! Tracy Dolan's doing the same job I am? How cool is that?' I love the mix of professions and ages and stages of career that makes up the pool of contact tracers."⁵⁵ At another extreme, the director of UCSF's contact tracing program said that a majority of his contact tracing workforce were librarians.⁴⁹

Measured through average turnaround times, response rate, and proportion of people who listed no contacts, contact tracing in the U.S. was an abject failure, much more so than in other countries.⁵⁶ The U.S. never approached 100,000 contact tracers — as of August 2020, an NPR survey found the total was less than half that, or 41,122.⁵⁷ At the time of the survey, nine states reported that case surges and testing delays forced them to adjust their contact tracing programs. In Nevada during August 2020, for example, a health investigator said that tracing was "impossible" due to the volume of cases and shortage of staff.⁵⁸ Health officials made similar statements about Texas over the same period.⁵⁹ Part of the problem was that though some states' tracing workforces were adequate, surges and lulls in cases produced pressure points around the nation that were not easy to predict. Leaving contact tracing up to state and regional health

departments made those workforces immobile and resistant to change — a Vermont tracer could not just switch to California, even if cases in Vermont were under control and those in California were surging, because a Vermont tracer works for Vermont’s health department, a completely separate entity from California’s.

Traditional contact tracing during the COVID-19 pandemic in the U.S. was hindered by design and execution. The variability of every conversation between a tracer and case or contact is variable by nature, which can help effective tracers build trust but makes the practice difficult to standardize or study. A major limitation to tracing has been its demand on time and manpower, not to mention cost. Speed is paramount in minimizing new infections spread by a case’s close contacts and their contacts, especially when there’s a significant proportion of asymptomatic infection. Technology for contact tracing and notification, not a novel concept but never used at this scale, arrived in the midst of this strained system.

1.3 The role of contact tracing apps during the COVID-19 pandemic

You test positive for COVID-19. But this time, instead of a person calling you up to ask about your close contacts, your phone does the job for them. The process is streamlined and automated. It takes only seconds from the time your positive test result is processed to notify your close contacts that they’ve been exposed to coronavirus and should quarantine. Here’s how it’s supposed to work.

A positive test is reported to an app. If a case has already consented to having their cellular data shared with the app, it will calculate a period of infectiousness and triangulate their location at all times throughout that period. It does that in one of a few ways: you can get a general idea of a person’s location based on what cell phone towers their phone pings as it connects to the Internet or makes and takes calls; however, this method can be inaccurate.⁶⁰ Instead, apps may take these location data from a few nearby cell towers. Another option is to make use of a phone’s GPS capabilities. Finally, an app may use Bluetooth beacons, which are fleeting connections created when two devices with Bluetooth capability are in proximity to one another. A particular flavor, called Bluetooth Low Energy, doesn’t drain a user’s battery as quickly and was seen as a more promising alternative to standard Bluetooth.¹⁷

Outside the U.S., countries like Singapore and India developed their own technology tracing programs based on Bluetooth Low Energy and GPS tracking and in some cases mandated that citizen participate in them. In America, as in most countries, most technological tracing is based on the Google/Apple Exposure Notification system, or GAEN. The purpose of the GAEN system is to keep users’ personal information — i.e., fine-grain location data — private from public health personnel.⁶¹ Of course, there are exceptions to GAEN’s seeming ubiquity: North Dakota, South Dakota, and Wyoming, for example, adapted their exposure notification app, Care19 Alert, from a preexisting Bluetooth-powered app used to track bison.⁶²

The technology companies that have created these apps say their role is to support traditional contact tracers.⁶³ In some health departments and organizations where they’ve been used, apps have served as a way to double-check the information gleaned from a case interview. In others, it means leaving traditional case finding or exposure notification up to the apps, freeing up an

otherwise understaffed contact tracing workforce. Initial models appeared promising, concluding that even in the absence of widespread adoption, apps that could notify contacts immediately and skip an assumed 3–4 day delay of traditional contact notification would significantly reduce downstream infections.⁶⁴

Google and Apple anticipated that individual states would develop their own apps using their application programming interface (API), but only six states did.⁶⁵ In early September 2020, they pivoted: Google designed custom apps for each state, while Apple offered states an app built into its operating system.⁶⁶ The branding also changed: what Google and Apple first called “contact tracing” apps back in April 2020 became “exposure notification.”

One of the drawbacks of traditional contact tracing was its cost — were exposure notification apps any cheaper? The limited data we have suggest that in the U.S. at least, the answer was no. New York state spent \$700,000 on their GAEN-based app, and Virginia spent nearly \$230,000.⁶⁷ The added costs didn’t seem to translate to increased adoption, either: as of December 2020, only 5% of New York’s population downloaded the state-specific app.⁶⁸

Touted as an alternative to human error, Bluetooth Low Energy tracking isn’t actually foolproof. One’s signal gains and loses strength depending on where they are — in an open field, in a crowded city, or underground, perhaps.⁶⁹ Depending on how one encodes a threshold over which two signals are considered to be “close contact,” the apps may read out results that vary in accuracy and precision. Bluetooth signals can travel through walls, for example.⁷⁰ One study found that when tested on a commuter tram, Swiss and German thresholds triggered 0 close contact notifications, while Italian rule generated 50% false positives.⁷¹ A GAEN-based system also has the potential to be spammed by repeating the ID code of a true positive over a wider area to deliberately create false positives.⁷²

Contact tracing apps’ access to and use of personal data were a concern for many, given that they were used in countries such as Russia and China to surveil citizens, in some cases involuntarily.⁷³ GAEN systems purposely decentralized and encrypted user information into unique, anonymous strings of numbers.⁷⁰ It is surprisingly easy to identify a person based on their location data, and there are ways, albeit involved, to reverse engineer GAEN identifiers and deanonymize data.⁷⁴ Some state’s apps that have used the GAEN platform also ask for optional demographic information; a user’s answers to these questions undermines the anonymity of the system by making it possible for state officials who have access to the data to draw inferences about individuals.⁷⁵ Not only that, metadata generated by apps built on a GAEN platform could unintentionally reveal a user’s IP address.

The drawbacks explored so far highlight problems with the apps when they are used — since no one must download any of the apps, adoption is a problem in and of itself.²³ Modeling studies suggested that up to 80% of all smartphone users would have to opt in to an app for it to be effective at ending the pandemic.⁷⁶ While other studies found that lower adoption rates would still decrease case rates, it’s mathematically intuitive that only a fraction of exposures would be notified. After all, if only 15% of users download an app, the chance that two people who have both downloaded the app will encounter one another is even lower.⁷⁷

Furthermore, apps built on a GAEN platform exclude people who do not own smartphones — around 17% of North Americans.⁷⁸ People who have smartphones (and reliable internet and cell service) and are digital natives are more likely to be younger, whiter, and richer.⁷⁹

In the same Pew survey in which the majority of U.S. adults asked said they would cooperate with contact tracers, only 49% said they would feel comfortable sharing cellphone location data with a public health official for contact tracing.³⁸

Outcomes for tracing apps have been preliminary and mixed. A non-peer reviewed evaluation of Britain’s GAEN-based exposure notification app found that those who opted-in to it starting in September 2020 were less likely than those contacted by traditional tracers and notifiers to eventually test positive for SARS-CoV-2.⁸⁰ The difference, they concluded, prevented over 200,000 cases of coronavirus, perhaps due to reaching out to contacts sooner than traditional tracers would have. However, in a review that looked at all published instances of manual and automated contact tracing between 2000 and April 2020, researchers found no evidence that automated contact tracing was effective.⁸¹

In the U.S., little research has been published on the effectiveness of exposure notification apps. Instead, studies have focused on more basic metrics, like usability and participation rate, before tackling the question of efficacy. One small study measured adoption of a GAEN-based app at the University of Arizona. The study, which was published as a preprint, found that less than half of people who tested positive for coronavirus and were interviewed by university contact tracers used the app; however, among those who used it, over half reported their positive diagnosis to it prior to their case interview.⁸² Searching for research about digital contact tracing apps in two popular directories for peer-reviewed and non-peer-reviewed literature yielded no other results for trials in the U.S., but media reports have largely characterized the apps as not living up to their promise.

1.4 Discussion and conclusion

Contact tracing for infectious diseases began long before the COVID-19 pandemic, but its implementation at a never-before-seen scale and efforts to automate the process through technology has made for a novel field of study, full of potential and pitfalls.

There is so much we do not know, from who contact tracers are to a systematic way of seeing what it is they do. It is inevitable that with time, more empirical studies will be published that assess the impacts of human and automatic contact tracing, comparing outcomes in the U.S. with those of other countries.

But right now, we can conclude that traditional contact tracing was not set up to succeed in the U.S., from historical links to stigma and shame to the lack of resources with which tracing organizations had to make do. The promise of exposure notification apps — to relieve human tracers of some of the burden in a fast, cost-effective way — proved neither cost-effective nor particularly relieving, instead diverting even more resources and attention away from human-based tracing.

Mary Gray, a social scientist at Microsoft Research, summarized the main issue with apps this way: “technology can’t solve the problem of convincing someone they should pick up the phone when a contact tracer calls....It is the reason we are failing—because we keep searching for something else we can buy or put into place. We have not conceded how deeply human this process is.”⁴²

The problem with automated exposure notification apps is that they remove the human element from tracing.⁸³ Traditional contact tracing encompasses much more than building a list of exposures and relaying a message to them. Rather, it emphasizes listening and identifying barriers to care and cooperation, which apps cannot replicate.

Some researchers feel that the way contact tracing apps have been conceptualized is all wrong. Instead of using them for individual-level notification, GAEN platforms could alert public health officials to superspreader locations, or give insight into demographics and networks at risk.⁸⁴

Aside from its shortcomings, contact tracing apps forced the reevaluation of what contact tracing is for and brought the practice into the vernacular. As the outcomes of contact tracing during the COVID-19 pandemic are investigated and published, this reevaluation is bound to continue. The story of contact tracing is still being written.

1.5 Supporting materials for a special project thesis

My reasons for attending public health school were always to use the master’s degree to inform my reporting on science and public health. To that end, I was most concerned with creating a thesis that I could in some way apply to a future reporting project, and less concerned with publishing my thesis as a scientific paper in a peer-reviewed journal. I decided that a longform journalism article would be most suited to my strengths, and most useful to my professional aspirations. I hope to eventually publish this thesis in a popular science outlet as a feature — having accrued bylines in CNN, Vice, Popular Science, Inverse, and other outlets, I believe this to be a reasonable and achievable goal. I have already soft-pitched this story to editors at Scientific American, where I will be working this summer, and they have expressed interest in seeing the final product. My target audience with this article, therefore, is not public health professionals, scientists, or researchers, but rather general members of the public without a recent science background or STEM education beyond high school.

A key reason that I chose this format for the presentation of my master’s thesis is the severe lack of published, peer-reviewed literature when it comes to contact tracing. I go into this in the thesis itself, but the majority of written work about who contact tracers are and what they do comes from the realm of media reports and personal narratives — in other words, grey literature. One of my goals was to synthesize the dozens of narratives I’ve read while researching this thesis and attempt to generalize the experiences of contact tracers in a way that revealed information about their jobs and outcomes, and pointed to areas for future research.

Based on the subject matter and my knowledge of print and digital media, I decided to research and write a longform journalism article. These articles are typically between 4,000 and 10,000 words and contain a mix of reporting, research, and analysis. One of the key differences between analytic and academic writing is journalism’s reliance on a writer’s voice and point of view — there are points throughout this thesis that I write in my own voice, from my own opinion. I use

studies and sources, but it is important to note that uncited statements are typical of this form of writing, by intent a mixture of op-ed and reportage.

Based on the format for this product, I imagine it is quite different from literature reviews or original research theses typically graded; instead, it combines aspects of historical research, literature review, analysis, and opinion writing. As a Yale undergraduate, I enrolled in several science writing courses. Here is a rubric taken from “Writing about Science & the Environment,” an upper-level seminar taught by New York Times science journalist Carl Zimmer:

“A (95)= For a story that could appear in a publication with minor rewriting.

B (85)= For a story that has a strong core (good reporting, presents a clear idea of what it’s about, and so on) but requires some significant revising before being published

C (75)= A story in serious need of work on all aspects: reporting, organization, attention to language, etc., before it could even be considered for publication

D (65)= A story that is poorly reported and unacceptably written.”

I understand that a grader who is not an editor at a newspaper or magazine may find this grading scheme difficult to replicate, but it the metric by which I judge this thesis. I looked through the syllabi of three other science writing classes I took while at Yale and failed to find any other sort of rubric. I believe this speaks to a wider principle that professors generally grade papers without a formal rubric. I am happy to have this thesis assessed on that scale.

Because of the audience for this project, I was unable to go into technical detail in the same way as a traditional thesis would have. The studies cited are also not a comprehensive review of all literature on contact tracing, but rather a synthesis of the body of research on contact tracing in the U.S. supplemented by studies conducted in other countries when data from the U.S. were lacking.

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