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The more the merrier! Barriers and facilitators to the general public's use of a COVID-19 contact tracing app in New Zealand

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Objective

Contact tracing for infectious diseases can be partially automated using mobile applications. However, the success of these tools is dependent on significant uptake and frequent use by the public. This study explored the barriers and facilitators to the New Zealand (NZ) general public's use of the COVID-19 contact *NZ COVID Tracer* app.

Participants

Adults (≥18 years, N=373) in NZ.

Materials and Methods

Qualitative and quantitative data were gathered from a nation-wide online survey. App use and frequency of use were presented as descriptive statistics. Qualitative data were analyzed thematically.

Results

31% reported using the app frequently, 24% used it sometimes, 21% had installed but not used it, and 24% had not installed it. Barriers to use include technical issues, privacy and security concerns, forgetfulness and a lack of support from businesses. The perceived risk of contracting COVID-19, government recommendations and communications, and the importance of contact tracing facilitated use.

Conclusion

Technical, user, business, and government factors influenced the public's use of a COVID-19 contact tracing app. The development of apps requiring minimal user effort and initial user testing may improve uptake. Enabling environments and better risk communication may improve uptake of similar community-driven contact tracing apps during future pandemics.

Keywords: coronavirus; contact tracing; public health; mobile apps; perceptions

Introduction

Contact tracing is a crucial process for controlling and containing infectious diseases such as Ebola, sexually transmitted diseases and now the novel coronavirus 2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1-3]. Contact tracing is a method of identifying individuals who may have been exposed, as well as in revealing how and where a disease is spreading [4].

Once a positive diagnosis has been made, government and public health professionals begin a process of proximity tracking (contact tracing) - identifying and locating anyone who may have been exposed to the infected individual [1]. This process often involves reviewing CCTV footage, credit card transactions or GPS location data from smartphones [4]. Potential (exposed) cases are then contacted, to be interviewed on their whereabouts, provided with health-related (e.g. symptom self-management, testing, vaccinations) and, if needed, self-isolation information [5]. This process may take up to three days per infected person, with each call taking approximately 20 minutes [4,5].

In cases such as COVID-19, pre-symptomatic individuals may still be infectious [6,7], with some not presenting symptoms for up to 14 days after initial exposure [8,9]. This can result in fast and unknown spread. The transmissibility of COVID-19 means that manual contact tracing methods are too slow [10]. Aside from being both time and resource-intensive, this method depends on an individual's ability to recall not only their exact whereabouts, but also the time they were there. Further, some people may not be truthful about their whereabouts, in order to protect their contacts (i.e., friends and family) from needing to self-isolate.

The contact tracing process can be partially automated by using mobile technologies [5]. One common avenue is through mobile applications (apps), which may be considered ‘passive’ or require active and intentional ‘check-ins.’ Passive Bluetooth-enabled contact tracing apps act as a ‘digital handshake,’ when multiple users come into proximity of one another. Data on contact is

then stored, to hasten future contact tracing efforts. In contrast, check-in apps simply act as digital diaries to record location and time. This may include manually entering details on whereabouts (e.g., location and time) or scanning a QR code. While check-in apps require intentional effort by users, the precision and accuracy of passive apps has been critiqued. In some cases, passive apps released false positives (e.g., [11]), meaning that people had to unnecessarily self-isolate. Research also found that the type of device, absorption (i.e., by human bodies in a crowd or when carried in a bag) and the environment (e.g., walls or furniture) significantly impacts Bluetooth signals [12].

Further differences are evident in the means of data storage and retention. Within centralized systems, the data is stored and processed on a central server that is operated by public health authorities, while in decentralized systems the data is stored on a user's device [13]. Ongoing discussions revolve around privacy, security, interoperability across countries and potential for misuse of data [13], with decentralized approaches better accepted by the public [14]. Regardless of the method employed, contact tracing apps may allow for storage and easy sharing of data with contact tracers.

Contact tracing apps have been widely implemented by governments, globally. Singapore and Australia both introduced Bluetooth-enabled contact tracing apps *TraceTogether* and *COVIDSafe,* respectively [15]. India's app *Aarogya Setu* uses Bluetooth in addition to location data, while the Qatari *Ehteraz* app also has access to a user's photos and videos. Passive apps are also used in Europe and the United States of America (USA). Austria was among the first in Europe to introduce an app (*Stopp Corona-App,* launched March 25, 2020), with countries like Germany and Switzerland following lead in June, 2020 (*Corona-Warn-App* and *SwissCovid-App*) [16-19]. It is important to note that these German-speaking countries have been using the apps to simply support containment, compared to countries like Singapore which use them to enforce quarantine [16]. COVID-19 tracing apps in the USA tended to be launched later in the pandemic, such as Virginia's *COWISE* app, launched in August, 2020 [20].

In New Zealand (NZ), the Ministry of Health introduced the *NZ COVID Tracer* app in 2020, using a check-in method and decentralized data management system [21]. The early version of the *NZ COVID Tracer* app was unique, as unlike *COVIDSafe,* it depended on QR codes and so failed to capture brief interactions between strangers away from establishments [15]. Unlike in some passive apps, users also had to register, by creating profiles that contain their personal details (e.g., name and address). When entering establishments such as shops, restaurants, universities and supermarkets, users manually scan QR codes located on posters. In environments where QR codes are unavailable, such as parks and playgrounds, users can complete a manual entry in their 'digital diary.' They input information such as their location, date, time and names of other people who accompanied them. Entries older than 31 days are deleted automatically. If a user has been in contact with an infected individual, they receive a push notification. Contact tracers may also contact them through the app to request information from the digital diary. This can be shared, using a unique code [21]. An option to enable Bluetooth contact tracing was introduced in December, 2020, but depended on users to change their settings and was recommended to be used in addition to the QR codes.

Many COVID-19 contact tracing apps are optional, but free-of-cost to download and use [22,23]. However, adoption has been stunted in many countries, due to technical and privacy-related concerns [1,4,5,24]. Slow uptake has resulted in inefficient and ineffective automated contact tracing efforts, as the success of the app is dependent on the majority of the population being willing to use, and frequently use the app. In the UK, experts have stated that 80% of people with smartphones, or 37 million people would need to use the contact tracing app, for it to be effective [25]. Other studies estimate population-wide uptake of 75-90% [26] and 90-95% [27].

Although previous research has compared different contact tracing apps [15], predicted adoption [28], evaluated intention to use [29] and explored ethical and privacy-related issues associated with use [30,31], few directly explore why the public chooses to (or not) use a COVID-

19 contact tracing app after implementation (e.g., [32]) and no research on this topic has been conducted in NZ. Abuhammad et al. [32] explored use in a sample of 2,000 Jordanian adults, finding that although 71.6% were accepting of the app, only 37.8% had installed it. Similar findings were evident in Germany and Switzerland [33,34]. In a Swiss study 72% stated they would be willing to install a contact tracing app [35], but only one in three citizens had actually installed the *SwissCovid* app [33]. Some possible reasons for low uptake include ethical concerns such as privacy and voluntariness of use [32,33,35].

The present study builds on this previous work, as it considers wider barriers and facilitators to uptake beyond ethical issues, and in more detail by also using qualitative methods. Further, WHO [36] highlights the need for an understanding of the feasibility of contact tracing apps, and considerations for mass implementation, while Wensing et al. [37] call for more empirical research on interventions implemented during the pandemic.

The aim of this paper is to explore the barriers and facilitators to the general public's use of the COVID-19 contact tracing *NZ COVID Tracer* app. It also makes recommendations for engaging the public and in designing future digital contact tracing tools.

Materials And Methods

The data presented in this article were collected as part of a larger nation-wide COVID-19 Stress and Health prospective cohort study in NZ. The Auckland Health Research Ethics Committee approved the study (Ref: AH1326). The COVID-19 Stress and Health Study is a collaboration between the University of Auckland, the University of Nottingham and King's College London [38,39]. A similar study is being conducted in the United Kingdom to make comparisons with the NZ cohort. In NZ, a cohort of residents are followed, to explore their mental health status during the first 10 weeks of the COVID-19 pandemic, 12 weeks later and again once restrictions are removed. The data presented in this article is from the second survey, collected from 31 July to 14

September 2020. The app available at this time only offered a check-in option, as Bluetooth tracing was not enabled until December, 2020.

Sample and recruitment

All adults in NZ (over 18 years) were eligible to participate in the COVID-19 Stress and Health Study, if they spoke English, could provide informed consent and could access the Internet to complete the survey. Participants were recruited via a media campaign whereby the study website (www.covidstressstudy.com) was distributed on digital media, radio and social media (Facebook, Twitter and Instagram). Organizations (e.g. district health boards, councils, universities, general practices and retirement villages) and community groups across NZ also shared the website with their networks.

Procedure

Interested participants read an information sheet and gave consent to participate on the study website. They could then access the first survey, which was implemented via Qualtrics. To maintain participant anonymity and privacy, Qualtrics generated a random and unique identifying ID number for each participant. The second survey was emailed directly to participants.

In this survey, participants were given the opportunity to answer optional questions on their use of the COVID-19 contact tracing app and factors that influenced their choice whether or not to use the app (see Table 1). The first question was multiple-choice and asked, "Do you use a COVID-19 tracing app?" A second question asked: "What informed your decision to use (or not use) a contact tracing app?" Participants provided text-based responses to this open-ended question. These questions were not asked in the UK study as the NHS COVID-19 contact tracing app had not yet been released.

Data analysis

Data pertaining to the contact tracing app questions were downloaded from Qualtrics into Excel. The data on use of the app were described as descriptive statistics (number and percentages). Qualitative data were analyzed through an inductive thematic analysis [40]. Two researchers coded the data. This ensured independent and reliable interpretations of patterns within the dataset and resulted in the development of clear themes [40]. Discussion between the researchers ensued until consensus was reached on the themes and on the strongest quotes to support each theme.

Results

Participant characteristics

A total of 380 adults participated, with 373 individuals responding to the COVID-19 tracer app questions. On average, participants were aged 43.5 years (18-87 years). The sample mostly consisted of females (90%), reflecting a gender bias that is often evident in both traditional (paper-based) and online surveys [41,42]. This bias may have been exacerbated further by making the questions on the contact tracing app optional. Participants resided across NZ with the largest proportion from Auckland (41.6%) and most identifying as NZ European (73%). Table 2 reports the participant characteristics.

Frequency of use

Participants were asked how often they use the contact tracing app. One hundred and seventeen (31%) participants reported using it frequently, and 89 (24%) reported using it sometimes. Seventy-eight (21%) stated that they had installed it, but not used it and 89 (24%) reported not using it. Evidently, 55% of the participants were using the app frequently or sometimes, and 45% had not used it.

Themes

Seven main themes emerged from this study: risk of COVID-19, forgetfulness, technical issues, privacy and security, business support, government recommendations and communications and the importance of contact tracing. These can be categorized into barriers and facilitators to using the contact-tracing app, with the risk of COVID-19 acting as both (see Figure 1).

Risk of COVID-19

The majority of participants initially reported not using the app, as they perceived their risk of being exposed to COVID-19 to be minimal. They explained that NZ citizens have likely become complacent in their use of the app and preventive behaviors, as the government has dealt with COVID-19 well. As there was no community transmission, there was no perceived benefit or purpose in tracking their whereabouts.

> By the time it was released, the risk of Covid was gone, so it felt unnecessary to install it.

> There is probably quite a bit of complacency now as well, given that New Zealand has been doing so well with the virus.

However, the nature of responses changed after COVID-19 re-emerged in the Auckland community. Participants cited a nation-wide change in restrictions and the associated increased risk of contracting COVID-19 as the primary reason why they used the app. During this time, the Auckland region moved to level 3 (partial lockdown and restricted social interaction) and the rest of NZ moved to level 2 (reduced interaction). Some participants also reported a return of COVID-19 in Australia.

> Felt like Covid was 'gone.' As soon as we got community transmission in NZ I downloaded the app and intend to use it.

A sub-theme of environments was evident in the theme of risk, whereby risky environments were reported to influence use of the app. Participants stated that they did not perceive themselves to be in risky situations, where they might be exposed to COVID-19, as they avoided crowded environments, were self-isolating or mostly stayed at home. Due to this, they did not use the app. Conversely, those in risky environments, such as university students and travelling individuals chose to use the app, as they were aware of being at risk of being infected.

> Have been self-isolating since I downloaded it, so have not yet used it.

Forgetfulness

Some participants reported simply forgetting to use the app. Reasons include use not yet being habitual, bad memory and competing priorities related to a disruption of normal routines and hygienic behaviors (e.g. wearing a mask, using hand sanitizer and social distancing).

> Memory - have simply forgotten to use it - It has not become a habit.

> Forget to enter manually- So many things to think about - masks, hand sanitizer, hand washing, distancing, disruption to normal routines.

Technical Issues

Many participants identified technical issues that created barriers to their use. Accordingly, the app could not be downloaded on older mobile devices. Older devices were also reported to have limited space for apps, so some participants chose not to use it. The app was also reported to often be

unreliable, as it could not always scan QR codes. Participants stated that technical issues experienced during their first time using it deterred them from trying again.

> I don't have a fancy phone and enough storage to download the app without removing other things like messenger which I use daily.

> Tried to download the app but my phone is too old and is not compatible with the app.

> I tried to use it wherever I was able but it would not recognize any QR codes so I got frustrated and deleted the app.

The app was also criticized to not be intuitive or user-friendly. Instead, participants reported that setting up a profile, remembering their password and scanning QR codes requires substantial effort and is a *'hassle'* and *'inconvenient.'* Many participants stated that they were not tech-savvy, and did not feel confident using it nor figuring out how to use it. A small minority of participants disagreed, and stated that the app was *'quick and easy to use'*.

> I saw a place to use it today but I wasn't sure how to do it and felt shy trying to figure it out.

The purpose of the app was sometimes reported as unnecessary, as participants were already using other tracing methods. Additionally, due to technical issues and difficulty in using the app, many participants preferred to use other methods. These included Google location services on their smartphones, Google Maps, bank transactions (EFTPOS records), calendars, physical diaries and notebooks, paper-based forms provided by businesses, notes on smartphones or hospital letters.

> I downloaded the app, however I use EFTPOS virtually everywhere I go (shops, cafes etc.) so already have a digital trace.

> I saw it on a news article and tried to install it, but found it too clunky. I instead write down everywhere I go and when.

Privacy and security

A minority of participants reported privacy and security concerns, which deterred them from using the app. Fear of hackers and misuse of data to record movements or monitor individuals was reported. Others reported concerns regarding the storage of data and the government using the app for mass surveillance purposes. This was likened to 'Big Brother.' Some participants reported hearing about these privacy concerns from their family members and the general public.

> I do not trust that this surveillance data will not be misused.

> Family swayed my thinking a bit in terms of the app potentially being used inappropriately by some to record my movements.

Lack of business support

An absence of available QR codes was reported before the 19thAugust 2020, when it became mandatory for NZ businesses to display QR COVID-19 tracking posters. Participants initially stated that only *'dominant'* businesses displayed the posters when the app was first released and that very few businesses provided the QR codes. This meant that although many people had installed the app, they were not able to use it.

> Places I have been do not have the barcode available at entrance.

The change in regulations was reflected in some participants' responses. A minority reported that the QR codes were becoming more widespread and that businesses were enforcing and encouraging the use of the app. Some staff members reported that their workplaces required them to install and use the app. However, many participants stated that the availability of the posters was still inconsistent and that the posters were not always visible, easy to see and easy to access.

> It's now more widespread, so easier to use- so why not?

> The posters are not always visible/easy to see...

Government recommendations and communications

Government communications and recommendations encouraged use. Participants reported that communications and advice from the NZ Director-General of Health Dr Ashley Bloomfield, and Prime Minister Jacinda Ardern facilitated their choice to use the app. Likewise, advertising on TV, online and the radio from the Ministry of Health prompted use. Importantly, the app was perceived as a public health strategy.

> Ashley said to…

> I downloaded it weeks ago but didn't really use it. Media reminders prompted me to begin using it now.

Importance of contact tracing

Many participants reported that contact tracing methods are important for monitoring and containing community transmission. Participants stated that they use the app as they have a

collective responsibility to help with contact tracing efforts. They often cited being part of a team, their responsibility as citizens to help, and working together to protect their own health, their families health and the health of the wider community. The *NZ COVID Tracer* app was perceived as an effective and accurate contact tracing tool to hasten and support contact tracing methods.

> I know fast contact tracing is our best bet of containing an outbreak.

> It's about working together as a team.

> My decision is based on the principles of common human decency to ensure I mitigate any harm I may do [to] another person, to ensure if I am placed at risk I am aware of that risk, to reduce the overall risk of undetected spread of a pathogen and just because I am a responsible citizen.

Discussion

The success of digital contact tracing efforts depends on high uptake, whereby the more people frequently use the apps, the better the contact tracing procedure and associated health benefits. This study has therefore uncovered important factors that influenced the general public's use of a contact tracing app during the COVID-19 pandemic. Reasons included technical issues, privacy and security concerns, forgetfulness and a lack of support from businesses. Facilitating factors included the risk of contracting COVID-19, government recommendations and communications, and understanding the importance of contact tracing.

To our knowledge, this is one of the first studies to directly explore perceptions related to using COVID-19 contact tracing apps after implementation. Previous literature has focused on technical issues and privacy-related concerns as primary barriers to use [1,4,5,24]. As consistent with this literature, technical issues were often reported as barriers to use in our study. One of the most common issues reported by participants was mobile device compatibility. Osman et al. [1]

highlights compatibility as a key consideration when designing digital contact tracing methods for the public. Other important considerations include digital literacy and usability. As with any technology, contact tracing apps must be effortless, easy to use, remember to use and easy to learn to use [15,43], especially for older adults and those with poor digital literacy, who may experience lower self-efficacy and comfort with using technologies [44].

Interestingly, in our study, only a small number of participants reported privacy concerns. This may be because trust in the NZ government may be higher than in other countries or because differences exist in the authority of the government or consequences of privacy breaches. For example, this is evident in the USA, whereby a lacking coordinated national approach combined with low levels of trust in the government and the health system's ability to cope undermines the success of contact tracing apps [45]. More broadly, NZ citizens have previously reported a higher level of trust in their national government and media, when compared to the USA and an OECD average [46].

Strategies to uphold privacy and security must be considered, as health and personal data require protection. COVID-19 tracing apps that require users to share their location-based data may reveal unintentional information as to who they have been spending time with, and sensitive places they have visited [5]. Bluetooth-enabled apps have been perceived to be more secure, as they do not collect location data. However, they emit longitude and latitude readings, making it possible to track users. If this is triangulated with personal information it can reveal anonymous identities. As with any app, misuse of data by third parties [1] and hacking are possible, but are minimized through encryption [5]. In the *NZ COVID Tracer* app, data is encrypted and sent to the Ministry of Health via the Amazon Web Services cloud-based system. Two-factor authentication also adds a secure additional layer. These procedures ensure that data is managed securely.

Unsurprisingly, many participants reported forgetting to use the app. This issue could be overcome with passive apps, that are able to collect data without input from the user, or with

further support and enforcement from businesses, whereby customers may only enter premises after signing in. Tibbett et al. [5] highlight ethical issues with mandatory use of contact tracing apps as this is a form of mass surveillance and also excludes individuals without compatible mobile devices. Instead, for widespread contact tracing efforts to be successful, alternative contact tracing methods must be provided (e.g. paper-based booklets and sign-in sheets). These can also help to overcome technical barriers associated with apps.

This study also provides insight on factors that may promote uptake of contact tracing apps. Some participants appeared to understand the importance of contact tracing to contain and monitor the pandemic. They also appeared to respond well to government recommendations, including formal communications through mass media formats, as evidenced by referencing the message of teamwork and uniting against COVID-19. This may be due to the government's daily updates and transparent reporting of COVID-19 cases and containment approach.

The most commonly reported reason for use was perceived increased risk of contracting COVID-19. The importance of risk perceptions in influencing behavior change have been widely documented in literature, whereby increased perceived risk can significantly increase health behaviors, including inconvenient preventative behaviors [47-49]. Additionally, research conducted across 10 countries with 6,991 participants during the COVID-19 pandemic highlighted a significant correlation between risk perception and adoption of preventive behaviors [50]. Our study also revealed the opposite, whereby low perceived risk acted as a deterrent to using the app, as contact tracing was deemed unnecessary.

According to van der Linden's [51,52] risk perception model, risk perception includes cognitive tradition (knowledge and understanding of risk), emotional/experiential tradition (experience), individual demographic factors (education) and the social-cultural paradigm (values, trust and social amplification of risk). Dryhurst et al. [50] suggest that engaging perceived risk of contracting COVID-19 through risk communication may be a successful means to support uptake

of contact tracing methods, but should include evidence on how effective measures are, both on a personal and a societal level. Risk communication for COVID-19 should also incorporate the elements of Linden's risk perception model.

Implications

Future development of contact tracing and general health-promoting behavioral apps should focus on minimizing user-effort. For example, apps should not require users to create lengthy profiles, use email addresses to log in each time and depend on users remembering to use the app. In this sense and for contact tracing purposes, solely passive Bluetooth apps may be superior to those using QR codes.

Initial user-testing and thorough implementation are also crucial to the design, acceptance and uptake of technologies. User testing helps to identify technical and use-related issues, while also identifying common concerns that the public may experience during implementation. Issues such as privacy concerns should be transparently addressed early during the implementation process, by reinforcing processes related to the secure storage, deletion and sharing of user data.

Enabling environments, risk communication, and an overall increased understanding of the importance of contact tracing by the public may also lead to better uptake of similar community-driven contact tracing apps during future pandemics. Governments, trusted figures of authority and businesses are also vital to ensuring that environments enable and encourage use (i.e. providing easily accessible QR codes and alternative paper-based methods) and to educating the public on the importance of contact tracing.

Strengths and Limitations

A key strength of this study is participation from a diverse and large group of people across NZ both during and after a local lockdown, thus representing a range of perspectives from the general

public and during different times of the pandemic. The findings can also be transferred to similar contexts overseas, where COVID-19 contact tracing apps are used. Having two independent researchers code the data also enhanced inter-coder reliability, consequently ensuring that interpretations were both consistent and reliable [53]. The anonymous nature of the survey may have reduced the possibility for social desirability bias and therefore encouraged more honest responses. However, text-based responses may have limited the depth of the data provided, as follow-up questions (as in interviews) could not be asked.

This study was also limited to NZ, a country with much lower cases of COVID-19 and associated mortalities. Another limitation of the study includes self-selection bias and excluding those who could not participate in an online survey, due to technology-related reasons (e.g. unstable/no Internet connection, poor digital literacy, no device ownership). These individuals experience obvious barriers to using contact tracing apps. We also did not explore differences across sub-groups, such as between people living rurally or in the city, which may impact their perceived risk of contracting COVID-19.

Conclusion

In this study, we investigated the use of and subjective perceptions of the *NZ COVID Tracer* app, a COVID-19 contact tracing app. Data showed that 55% of the participants were using the app frequently or sometimes, and 45% had not used it. The qualitative data uncovered seven factors that influenced the general public's use of the app- the risk of COVID-19, forgetfulness, technical issues, privacy and security concerns, lack of business support, government recommendations and communications and the importance of contact tracing. These findings illuminate the need for the development of apps with minimal user effort and initial user testing. Enabling environments and risk communication may also lead to better uptake of similar community-driven contact tracing apps during future pandemics.

Declaration of Interests

The authors declare that there are no conflicts of interest.

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Contributors

EB, KV and NG designed the study and collected the data. NG and CG analyzed the data. NG wrote the first draft of the manuscript. All of the authors participated in the interpretation of the study findings and the preparation of the manuscript.

Ethics Approval

The Auckland Health Research Ethics Committee approved the study (Ref: AH1326)

References

1. Osman M, Fenton N, McLachlan S, et al. The thorny problems of Covid-19 Contact Tracing Apps: The need for a holistic approach. *Journal of Behavioral Economics for Policy* 2020;4(COVID-19 Special Issue):43-59
2. Radcliffe K, Clarke J. Contact tracing-where do we go from here? *Sexually Transmitted Infections* 1998;74:313-15
3. World Health Organization. Implementation and management of contact tracing for Ebola virus disease. 2015. https://www.who.int/csr/resources/publications/ebola/contact-tracing/en/.
4. Baraniuk C. Covid-19 contact tracing: a briefing. *The BMJ* 2020;369:m1859
5. Tibbetts J. Researchers Continue Quest to Contain Spread of COVID-19: Digital technologies aim to accelerate contact tracing. *BioScience* 2020;70(8):633–39
6. He X, Lau E, Wu P, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nature Medicine* 2020;26:672–75
7. Wei W, Li Z, Chiew C, et al. Presymptomatic Transmission of SARS-CoV-2 - Singapore. *Morbidity and Mortality Weekly Report* 2020;69(14):411–15
8. Lauer S, Grantz K, Bi Q, et al. The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases: Estimation and Application. *Ann Intern Med* 2020;172(9):577-82

9. Yu P, Zhu J, Zhang Z, et al. A Familial Cluster of Infection Associated With the 2019 Novel Coronavirus Indicating Possible Person-to-Person Transmission During the Incubation Period. *The Journal of Infectious Diseases* 2020;221(11):1757-61
10. Ferretti L, Wymant C, Kendall M, et al. Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing. *Science* 2020;368(6491):eabb6936
11. Manthorpe R. Coronavirus: NHS contact tracing app to stop sending 'false alarms' after update. 2020. https://news.sky.com/story/coronavirus-nhs-contact-tracing-app-to-stop-sending-false-alarms-after-update-12117882.
12. Leith D, Farrell S. Coronavirus contact tracing: evaluating the potential of using bluetooth received signal strength for proximity detection. *ACM SIGCOMM Computer Communication Review* 2020;50(4):66-74
13. Ciucci M, Gouardères F. National COVID-19 contact tracing apps: Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament, 2020.
14. Zhang B, Kreps S, McMurry N, et al. Americans' perceptions of privacy and surveillance in the COVID-19 pandemic. *PLOS ONE* 2020;15(12):e0242652
15. Howell B, Potgieter P. A Tale of Two Contact-Tracing Apps – Comparing Australia's COVIDSafe and New Zealand's NZ COVID Tracer. *SSRN* 2020
16. Amann J, Sleigh J, Vayena E. Digital contact-tracing during the Covid-19 pandemic: An analysis of newspaper coverage in Germany, Austria, and Switzerland. *PloS ONE* 2021;16(2):e0246524
17. German Federal Government. Die Corona-Warn-App: Unterstützt uns im Kampf gegen Corona. 2021. https://www.bundesregierung.de/breg-de/themen/corona-warn-app.
18. Swiss Federal Office of Public Health. SwissCovid App. 2021. https://bag-coronavirus.ch/swisscovid-app/
19. Austrian Red Cross. Questions and answers about the Stop Corona app. 2021. https://www.stopp-corona.at/faq_stopp_corona_app/.
20. Muoio D. US' first Apple-Google COVID-19 tracing app goes live in Virginia. 2020. https://www.mobihealthnews.com/news/us-first-apple-google-covid-19-tracing-app-goes-live-virginia.
21. Ministry of Health. NZ COVID Tracer app. 2020. https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-novel-coronavirus-resources-and-tools/nz-covid-tracer-app.
22. Anderson R, Heesterbeek H, Klinkenberg D, et al. How will country-based mitigation measures influence the course of the COVID19 epidemic? *The Lancet* 2020;395(10228):931–34
23. Dubov A, Shoptaw S. The Value and Ethics of Using Technology to Contain the COVID-19 Epidemic. *The American Journal of Bioethics* 2020:1-5
24. Urbaczewski A, Lee Y. Information Technology and the pandemic: a preliminary multinational analysis of the impact of mobile tracking technology on the COVID-19 contagion control. *European Journal of Information Systems* 2020
25. Kelion L. Coronavirus: NHS contact tracing app to target 80% of smartphone users. 2020. https://www.bbc.co.uk/news/technology-52294896.
26. Bulchandani V, Shivam S, Moudgalya S, et al. Digital herd immunity and COVID-19. *ArXiv (preprint)* 2020
27. Xia Y, Lee G. How to return to normalcy: fast and comprehensive contact tracing of COVID-19 through proximity sensing using mobile devices. *ArXiv (preprint)* 2020
28. Jonker M, de Bekker-Grob E, Veldwijk J, et al. COVID-19 Contact Tracing Apps: Predicted Uptake in the Netherlands Based on a Discrete Choice Experiment. *JMIR Mhealth Uhealth* 2020;8(10):e20741
29. Altmann S, Milsom L, Zillessen H, et al. Acceptability of App-Based Contact Tracing for COVID-19: Cross-Country Survey Study. *JMIR Mhealth Uhealth* 2020;8(8):e19857

30. Bengio Y, Ippolito D, Janda R, et al. Inherent privacy limitations of decentralized contact tracing apps. *JAMIA* 2020:ocaa153
31. Lucivero F, Hallowell N, Johnson S, et al. COVID-19 and Contact Tracing Apps: Ethical Challenges for a Social Experiment on a Global Scale. 2020;Journal of Bioethical Inquiry:1-5
32. Abuhammad S, Khabour O, Alzoubi K. COVID-19 Contact-Tracing Technology: Acceptability and Ethical Issues of Use. *Patient preference and adherence* 2020;14:1639-47
33. von Wyl V, Bonhoeffer S, Bugnion E, et al. A research agenda for digital proximity tracing apps. *Swiss Medical Weekly* 2020;150:w20324
34. Kozyreva A, Lorenz-Spreen P, Lewandowsky S, et al. Public Perceptions of COVID-19 Digital Contact Tracing Technologies During the Pandemic in Germany. *PsyArXiv* 2021
35. Hargittai E TF. Weite Teile der Bevölkerung sind bereit, eine Tracking-App zu nutzen – wenn diese von Bund und Kantonen herausgegeben wird. *Neue Züricher Zeitung* 2020.
36. World Health Organization. Digital tools for COVID-19 contact tracing. 2020. https://apps.who.int/iris/bitstream/handle/10665/332265/WHO-2019-nCoV-Contact_Tracing-Tools_Annex-2020.1-eng.pdf.
37. Wensing M, Sales A, Armstrong R, et al. Implementation science in times of Covid-19. *Implementation Science* 2020;15(42)
38. Gasteiger N, Vedhara K, Massey A, et al. Depression, anxiety and stress during the COVID-19 pandemic: results from a New Zealand cohort study on mental well-being. *BMJ Open* 2021;11:e045325
39. Jia R, Ayling K, Chalder T, et al. Mental health in the UK during the COVID-19 pandemic: cross-sectional analyses from a community cohort study. *BMJ Open* 2020;10:e040620
40. Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative research in psychology* 2006;3(2):77-101
41. Kwak N, Radler B. A comparison between mail and web surveys: response pattern, respondent profile, and Data quality. *Journal of Official Statistics* 2002;18(2):257-73
42. Underwood D, Kim H, Matier M. To mail or to Web: Comparisons of survey response rates and respondent characteristics. 40th Annual Forum of the Association for Institutional Research. Cincinnati, OH, 2000.
43. Davis F. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *Management Information Systems Quarterly* 1989;13(3):319-40
44. Czaja S, Charness N, Fisk A, et al. Factors predicting the use of technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychol Aging* 2006;21(2):333–52
45. Barber G, Knight W. Why Contact-Tracing Apps Haven't Slowed Covid-19 in the US. 2020. https://www.wired.com/story/why-contact-tracing-apps-not-slowed-covid-us/.
46. The Organisation for Economic Co-operation and Development. Trust in government, policy effectiveness and the governance agenda. Government at a Glance 2013. OECD Library: OECD, 2013.
47. Becker M. The health belief model and sick role behavior. *Health Education Monographs* 1974;2(4):409–19
48. Brewer N, Chapman G, Gibbons F, et al. Meta-analysis of the relationship between risk perception and health behavior: the example of vaccination. *Health Psychology* 2007;26:136
49. Rogers R. A Protection Motivation Theory of Fear Appeals and Attitude Change. *The Journal of Psychology* 1975;91(1):93-114
50. Dryhurst S, Schneider C, Kerr J, et al. Risk perceptions of COVID-19 around the world. *Journal of Risk Research* 2020

51. van der Linden S. The Social-Psychological Determinants of Climate Change Risk Perceptions: Towards a Comprehensive Model. *Journal of Environmental Psychology* 2015;41:112-24
52. van der Linden S. Determinants and Measurement of Climate Change Risk Perception, Worry, and Concern. In: Nisbet M, ed. Oxford Research Encyclopedia of Climate Science. Oxford, UK: Oxford University Press, 2017.
53. Thomas J, Harden A. Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology* 2008;8(45)

Table 1. Questions asked about the COVID-19 contact tracing app.

Question	**Responses**
Do you use a COVID-19 tracing app?	Multiple-choice options: 1) Yes, I use it frequently 2) Yes, I sometimes use it 3) I have installed it, but not used it 4) No
What informed your decision to use (or not use) a contact tracing app?	Open-ended text

Table 2. Participant characteristics (N= 373)

Characteristic	**Mean, range**
Age	43.5 (18-87)
	Number, %
Gender	
Female	337 (90.3%)
Male	31 (8.3%)
Prefer not to say/other	5 (1.4%)
Ethnicity	
New Zealand/European	273 (73.2%)
Māori	6 (1.6%)
Chinese	10 (2.7%)
Indian	12 (3.2%)

Samoan	2 (0.5%)
Other	70 (18.8%)
Place of residence	
Northland	6 (1.6%)
Auckland	155 (41.6%)
Waikato	41 (11.0%)
Bay of Plenty/ Gisborne	10 (2.7%)
Hawkes Bay	15 (4.0%)
Taranaki	10 (2.7%)
Manawhatu- Whanganui	12 (3.2%)
Wellington	31 (8.3%)
Nelson/ Tasman/ Marlborough	27 (7.2%)
West Coast	9 (2.4%)
Canterbury	31 (8.3%)
Otago	7 (1.9%)
Southland	5 (1.3%)
Other	14 (3.8%)

Figure 1. Image showing barriers and facilitators experienced when using a contact tracing app.