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COVID-19 contact-tracing smartphone application usage—The New Zealand COVID Tracer experience

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Abstract

Contact tracing has been a central pillar of the nonpharmaceutical health system response to the COVID-19 pandemic. Countries around the world have devoted unprecedented levels of resources to build up their testing and tracing capabilities, including the development and deployment of smartphone-based applications. Yet despite these nontrivial investments, the body of academic literature evaluating the effects of the smartphone-based applications remains scant and many apps have not delivered the promised benefits (Bano et al. 2021).

We contribute to this body of empirical evidence by analysing data on uptake and usage of New Zealand's QR code-based application New Zealand COVID Tracer (NZCT). Our paper uses descriptive statistics and regression analysis to focus on the likelihood of an individual registering to use the application, the likelihood that a registered user will use the application to scan QR codes, and the extent of that usage, measured as the number of codes scanned daily. In addition, we take advantage of the “natural experiment” offered by the decision in August 2021 following the establishment of endemic community transmission of COVID-19 to make use of the application mandatory from 7 September 2021 to assess the effect of this policy on usage.

We find that despite increasing numbers of individuals downloading the application over time, the number of active devices and scanning activity was very low, even when community outbreaks occurred (i.e. actual infection risk was higher). Mandating use (separate and distinct from increased infection risk) led to an increase in the number of scans in total via an increase in the number of active devices only.

1. Introduction

Contact tracing has been a central pillar of the nonpharmaceutical health system response to the COVID-19 pandemic and remains so even as vaccines have become more readily available (Ferguson et al., 2020; Fetzer & Graeber, 2021; Pierucci & Walter, 2020). Governments around the world have devoted unprecedented levels of resources to build up their testing and tracing capabilities, including the development and deployment of smartphone-based applications that assist in the identification and ongoing management of individuals who may have come into contact with an infected person (Howell & Potgieter, 2021; Li & Guo, 2020). Specific difficulties in establishing critical tracing efficiency, especially for airborne diseases is known from the prior literature (e.g. Eames & Keeling, 2003 or Dhillon & Srikrishna, 2018).
NZ COVID Tracer (NZCT), introduced by the New Zealand government in May 2020, is one example of such an application. Based upon existing New Zealand pandemic management provisions requiring managers of specific premises types to keep records of individuals' presence at their sites, one of its functions is to assist individuals to keep a digital diary of locations visited by scanning a unique QR code displayed at premises entered or other locations visited (e.g. on public transport). Individuals register their contact details in a central health system-managed database when downloading the application. All scanning information is stored on the handset and deleted after 31 days, thereby satisfying local privacy laws. When an individual tests positive for COVID-19, the diary can be uploaded to the contact tracing service, where it assists in the process of identifying known close contacts of the infected individual and places of interest where unknown contacts may have become infected. Application users can be notified electronically of potential exposure, along with instructions on how to proceed (e.g. self-isolation, testing schedule); non-users are notified using other contact tracing processes (e.g. public notifications; liaising with premises managers to identify and notify close contacts). The ability for users to manually enter information when visiting sites not displaying a QR code was added in July 2020; a Bluetooth proximity identification facility was added in December 2020. While use of the application was initially voluntary but strongly encouraged, following establishment of the Delta variant of the virus in late August 2021 scanning was made compulsory for all registered users at all COVID-19 alert levels, effective from September 7 2021.

While considerable resources have been deployed internationally into contact tracing and smartphone applications on the basis that they slow virus growth during a pandemic, empirical evidence of the magnitude of the effects is more limited (Maccari & Cagno, 2021). Nonetheless, the assumption of their positive effects underpins policy interventions such as the August 2021 New Zealand decision to mandate application use. Over time, however, the considerable volumes of data collected on both the course of the COVID-19 pandemic and application use facilitate more detailed analysis of the effectiveness of different interventions. For example, Fetzer and Graeber (2021) took advantage of a temporary failure in the contact tracing system affecting some parts of England in late September 2020 to analyse the comparative effectiveness of that country’s contact tracing system, finding that it reduced subsequent new infections by 63 percent and deaths by 66 percent in the six weeks following the glitch. Further, Urbaczewski and Lee (2020) compared the effectiveness of voluntary usage of smartphone-based contact-tracing applications in Germany, Italy and the United States with mandatory usage in China, Singapore and South Korea, finding that mandatory usage was highly significantly correlated with a reduction in the spread of COVID-19.

In this paper, we contribute to the growing body of empirical evidence by analysing data on uptake and usage of NZCT prior to and following mandating of its use in August 2021. Rather than focusing on the effects of the application on infection rates, we instead examine the effects of the mandate on the likelihood of an individual registering to use the application, the likelihood that a registered user will use the application to scan QR codes, and the extent of that usage, measured as the number of codes scanned daily. Howell and Potgieter's (2021) evaluation of the likely comparative effectiveness of New Zealand's location-based QR code application with Australia’s Bluetooth-based COVIDSafe application suggested that NZCT would likely lead to reductions in the effectiveness of contact tracing activities the higher was uptake and use of the application and the greater were the number of people infected with COVID-19. We take advantage of the natural experiment offered by New Zealand Delta outbreak to also evaluate the validity of this prediction.

The paper proceeds as follows. First, we survey the literature on the factors influencing individuals’ acceptance and usage of QR-based contact tracing applications, and their likely effects in the New Zealand context. Next, we discuss the data collected on New Zealand COVID Tracer usage, and relate it to the patterns of COVID-19 infection and pandemic management in that country. We then discuss descriptive statistics comparing uptake and usage before and after it was made mandatory and undertake several regression analyses to assess the likely drivers of those activities. We find that while the mandate increased the likelihood that a registered user undertook scanning activity, the number of locations scanned per active user did not alter much. However, the percentage of application users active on any given day is low (never exceeding 35 percent). The likelihood of an application user activating the Bluetooth feature was much higher (68 percent) and appears to be driven by infection risk rather than government use mandates. Moreover, we find that as anticipated, the volume of data generated when the infection rate increased quickly overwhelmed both contact tracing and testing operations, leading to changes that render both the mandating and use of NZCT systems highly questionable as to their effect on infection rates. We conclude with some final observations, including the wider effects of application usage on the overall management of contact tracing, in New Zealand and elsewhere.

2. Background

The use of digital surveillance in the combat of disease in general and COVID-19 in particular has been very well developed in East Asia where specific voluntary or compulsory applications as well as intrusive tracking of cell phone signals have been used (Sherstoboeva & Pavlenko, 2021). Privacy concerns, poor adoption rates and low smartphone penetration have been impediments in many jurisdictions. Fortunately, smartphone penetration in New Zealand is very high and privacy concerns were a high priority from the start. Stehlíková (2021) points out that in Austria, for example, the collection of data by a major telecommunications operator (without informing users in advance) and the sharing of anonymised data with the authorities provoked significant distrust in the general population. In Europe the emphasis has been more on contact tracing rather than on tracking and tracking, as in East Asia (Viseur, 2021). NZ’s application is much more in line with the European experience as might be expected because of a common legal and cultural legacy.
2.1. New Zealand COVID tracer

NZ COVID Tracer (NZCT) was introduced on May 20, 2020. Unlike most other smartphone contact-tracing applications using Bluetooth “handshakes” as a proxy for transmission-capable contact between individuals (e.g., Australia’s CovidSafe and Singapore’s TraceTogether), it relies upon individuals scanning QR codes at locations visited to assist (rather than to replace) contact tracing activities. The digital diary kept on the user’s smartphone supplements information obtained in contact tracing interviews to assist in identifying close contacts of the infected person and locations of interest visited when infectious. Supplementary information from the managers of locations of interest can be further perused to identify further close contacts that cannot be identified during the interview process or by the application (e.g., staff present when the infected individual visited). The database of registered individuals, containing their current mobile phone number, additionally assists contact tracers informing those listed as contacts of their exposure and providing instructions for further action (usually instructions to self-isolate and present for testing at intervals following the time of possible infection). Non-users of the application are notified of date and time of likely infection risk via a public notification system.¹

2.2. Effectiveness of automated contact tracing

The use of automated notifications arguably speeds up the time taken (relative to manual systems) to notify close contacts thereby decreasing the time taken to test and isolate newly infected individuals and furthermore, also reducing their propensity to infect others. Hence, infection spread is slowed. Human contact tracer time is freed up to concentrate on working directly with the infected individual (increased contact tracer efficiency). However, as NZCT records only the locations visited and not movement within the location or the time spent there, it can lead to a large number of false positive identifications—individuals who were present at the location but unlikely to be infected because they did not come close enough for long enough for the infection to spread. False positives are especially likely if conservative contact tracers identify long time windows at the locations of interest the infectious individual visited, and include locations visited for only a short time where infection transfer to otherwise unknown individuals is less likely to occur. Excessive false or dubious alerts have occurred elsewhere, including the UK’s “pingdemic” (Rimmer, 2021).

Howell and Potgieter (2021) impute that the critical difference between tracing app performance can be found in the features

1. population adoption rate and actual usage;
2. percentage of actual contacts identified by the app (true tracking positives);
3. percentage of identified contacts who are not actual contacts (false tracking positives); and
4. the ease by which the app allows authorities to reach identified contacts (tracing efficiency).

Kim and Paul (2021) demonstrate that “nearly 75% to 95% of the population need to participate in automated contact tracing for it to be effective”. Their analysis identifies

\[ f_e^{\min} = \sqrt{\frac{f_T}{f_c}} \]

as the minimum fraction of the population to be using a perfectly functioning system for it to be effective. The parameters \( f_T \) and \( p_t \) depend on the disease dynamics but \( f_c \) and \( r_c \) relates to the willingness of individuals to be tested and the effectiveness of the testing procedure, respectively. It is possible if \( f_T r_c < f_c p_t \) that \( f_e^{\min} > 1 \). That means that no feasible minimum effective fraction of the population (which would be an \( f_e^{\min} < 1 \)) exists.

Relatively early in the pandemic, Braithwaite et al. (2020) conducted a survey of automated contact tracing and observed “[n]o empirical evidence of the effectiveness of automated contact tracing” and further concluded that large-scale manual tracing was likely to remain a key tool in combatting the disease. The authors would also suggest that the cost-effectiveness of tracing breaks down when infection is very wide-spread.² This is supported by earlier research (Armbruster & Brandeau, 2010) that suggests that contact tracing becomes more effective than screening as the prevalence of the disease decreases.

Furthermore, while the applications may increase contact tracer efficiency, they risk bottlenecks occurring at other parts of the health system (notably, testing sites) if large numbers of false positive individuals present for testing. This will delay both the time at which a true positive individual is tested and increase the elapsed time taken in laboratory processing for a positive test sample to be identified. The availability of tests became an issue in New Zealand only when widespread community transmission appeared early in 2022 since there had been very few cases up to that point. Although the government had licensed several different rapid antigen tests (RATs), it initially controlled distribution and only scheduled retail availability to the public for March 2022 (Tamihere, 2022). By mid-February, some PCR tests in Auckland were reportedly taking five days to process (Radio New Zealand, 2022). It appeared that the government had miscalculated the overall PCR test capacity by assuming pooling would be feasible and neglecting that this depends very much on the incidence being low (Sachdeva, 2022). It is possible that much earlier and easy availability of RATs to the public would have contributed to the usefulness of NZCT.

¹ https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-health-advice-public/contact-tracing-covid-19/covid-19-contact-tracing-locations-interest.

² Worldometer https://www.worldometers.info/coronavirus/country/chile/ reported nearly 1 m active cases in Chile on 27 February 2022, out of a population of under 20 m.
Howell and Potgieter (2021) also suggest that the information overload and false positive alerts will likely crowd out the benefits of better information for contact tracers, leading to decreased effectiveness of the contact tracing system the higher is the number of application users and scans per user and the greater is the number of new cases identified daily. Nonetheless, it is generally assumed that if smartphone-based applications do indeed improve contact tracing efficiency and effectiveness, then they rely upon widespread acceptance, uptake and usage by the target population. Complex factors influence take-up and use however (Bano et al., 2021).

Early on in the pandemic, NZ’s contact tracing had very limited capacity (Verrall, 2020). New Zealand started with a significantly more poorly developed institutional infrastructure for dealing with disease outbreaks than, for example, Taiwan (Summers et al., 2020). The existing 2017 influenza containment plan was rapidly turned into the 2020 elimination strategy. Digital contact tracing can augment an existing contact tracing system (Plank et al., 2020) but this presupposes good integration with the existing tracing infrastructure (Lee & Kim, 2021) and rapid response once a contact has been identified. There are circumstances in which digital tracing has not proved helpful (Vogt et al., 2022) however.

2.3. Willingness to use contact tracing applications

Chen and Thio (2021) use a MAST (motivation, access skills and trust) model from the digital inclusion literature to explore drivers and barriers to uptake and usage in many jurisdictions (including New Zealand). They find that in most instances, limited uptake or adoption rates have limited the usefulness of the applications. Nonetheless, mandating use has a positive effect on uptake, as does the users’ perceptions of risk (uptake and use of NZCT increased when the rate of community infection was observed to increase—noting that for most of the time examined, New Zealand, practising an elimination strategy chosen at the outset (Baker et al., 2020) rather than suppression, recorded no instances of community transmission of COVID-19). A sense of community inclusion, personal agency and changing behavioural norms can also increase use. By contrast, high costs (e.g. repeated scanning, battery drain due to Bluetooth usage, QR codes absent or hard to find) reduce acceptability and usage. Based upon detailed interviews with 34 experienced NZCT users, Tretiakov and Hunter (2021) found benefits of using the app to society were more salient to the respondents than immediate health benefits to themselves, but that usage was dependent upon the COVID-19 alert level and declined during periods of low perceived risk (low alert levels).

Privacy was not an overriding concern to these users, despite it being cited by Chen and Thio (2021) as one of the possible barriers to uptake and usage. Gasteiger et al. (2021) found using survey data from 373 individuals recruited for a study on COVID-19 stress and health that 31% reported using it frequently, 24% used it sometimes, 21% had downloaded it but not used it and 24% had not downloaded it. The perceived risk of being exposed to COVID-19 was the most important reported determinant of use (high risk was a facilitator; low risk a barrier). Other barriers included forgetfulness, technical issues, privacy and lack of business support. Government communications were perceived as facilitators of use.

3. The New Zealand data

New Zealand has attracted international attention due to the low incidence of COVID-19 infections and deaths recorded (Wilson et al., 2021). While this performance is the outcome of the complex interaction of multiple factors, many of which are outside of government influence and/or control, the New Zealand government’s approach to the pandemic is notable for its stringent border policy restricting entry to only a limited number of residents who must undergo a government-supervised isolation and quarantine process, and harsh lockdowns when community transmission of the virus is identified (New Zealand’s nationwide Level 4 lockdown, entered on August 19 2021, when only a single case of community transmission had been identified, ranked 96.3 – out of 100 – on the Oxford COVID-19 Government Response Tracker. This strategy was implemented very early.

The New Zealand objective was initially to eliminate the virus from the country. Elimination is interpreted as zero transmission of the virus in the community, and the strategy to achieve it was first to trap all new possible infections from offshore in the border isolation and quarantine processes and then at the first identification of community transmission, limiting spread by severely restricting individual contact and movement. Although lockdowns have been stringent, until the August 2021 Delta outbreak they had been used only sparingly. NZCT was introduced in anticipation of the removal of the original 2020 lockdown (removed on 8 June). Community outbreaks in Auckland led to lockdowns in August/September 2020 and February/March 2021. Wellington was moved to a precautionary lockdown for a week in June when an Australian visitor was subsequently (on return to Australia) found to be infected, although no local transmission was identified. The whole country entered lockdown on August 17, 2021, following identification of the Delta variant in the community. This lockdown ended on December 2, when the country moved to a new management regime.5 The elimination strategy has been replaced by a “minimisation and protection” strategy.6

3 As of 2022, the New Zealand government was still making available a contact tracing booklet of which it is possible to order a hard copy or download and print it (in any of 22 languages).
4 https://ourworldindata.org/grapher/covid-stringency-index?time=2021-08-19.
5 https://covid19.govt.nz/alert-levels-and-updates/history-of-the-covid-19-alert-system/.
6 https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-response-planning/covid-19-minimisation-and-protection-strategy-aotearoa-new-zealand.
Since the inception of NZCT, the Ministry of Health has provided data of daily uptake and usage of the application. Data collected in each 24 h period includes the number of new application registrations, businesses registering for the programme, QR codes issued, the number of scans and manual entries recorded, the number of devices active during the period and the number of devices recorded with the Bluetooth application facility activated. Active devices is a count of the number of devices that have either scanned a code or added a manual entry during a 24-hour period. Bluetooth devices active counts the number of unique devices that have checked the server for new exposure notifications in the past 24 h – that is, actively participating in Bluetooth tracing that day.

3.1. Uptake

We first consider the user numbers as well as actual usage of NZCT. Fig. 1 details the number of application downloads (and registrations) from instigation to November 23, 2021. Fig. 2 compares the number of scans and manual entries.

Following an initial surge in downloads, activity was negligible until the August 2020 outbreak led to a surge in registrations (app downloads) and scanning activity. The highest daily level of registration activity was observed at this time (233,200 on August 13) and by the conclusion of this outbreak (mid-September), around 2,250,000 individuals (45 percent of the New Zealand resident population) had joined. A minor uptick in registrations was recorded in conjunction with the February 2021 outbreak and again in August 2021 when the Delta version of the virus became established. By November 23, 2021, registrations stood at 3,395,536 (68 percent of the resident population).

Similarly, the number of scans per day rose during the August 2020 outbreak to a peak of just over 2.5 million on September 9. Scanning rapidly fell off, with fewer than 500,000 per day being recorded in January 2021. Activity increased substantially during the February 2021 outbreak to a peak of just over 2.5 million on September 9. Scanning activity returned to around 2.5 million per day in September 2021 (although with greater daily variability than before), but from a much broader usage base (66 percent of the resident population using the application, compared to 45 percent in September 2020).

After an apparent decline (although not as pronounced as in other outbreaks) a further surge in scanning activity occurred in November 2021 (peaking at just over 3 million on November 19). The sustained (and increased) scanning rate is likely attributable to the extended rate of daily infections (averaging around 200 new cases a day in late November) and changes in lockdown levels, discussed below. Manual entries have typically been low compared to QR code scans, but have peaked at the same time as scans, except for the August 2021 outbreak, where the manual entries increased more than previously, and peaked earlier than the scans (255,338 on August 18, compared to 2.6 million on September 10 for scans).

Fig. 3 shows NZCT business activity. Like individual application registration and downloads, initially businesses were slow to register and obtain QR codes. However, activity increased markedly during the August 2020 outbreak, with a sharp increase in the number of registered businesses (from around 32,000 on August 6 quadrupling to over 120,000 on August 28) and QR codes issued (just over 84,000 (2.6 per business) on August 6 rising to nearly 325,000 (2.8 per business) on August 28). While the number of registered businesses has increased modestly (reaching 145,000 by the beginning of August 2021), QR code issuance has increased more noticeably and steadily, along with the number of QR codes issued to each registered business (reaching 615,000 and 3.2 respectively by August 2021). The pace of both increased again during the most late 2021 outbreak, with just over 842,000 codes (3.6 per registered business) recorded on November 23, 2021. Notably, the number of codes issued per registered business has been increasing at a faster rate during the latest outbreak than observed at any time since August 2020.

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7 https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-data-and-statistics/covid-19-nz-covid-tracer-app-data.
8 https://www.health.govt.nz/our-work/diseases-and-conditions/covid-19-novel-coronavirus/covid-19-data-and-statistics/covid-19-nz-covid-tracer-app-data.
3.2. Usage

While Figs. 1 and 2 show aggregate registration and scanning activity, Figs. 4 and 5 show more detail of individual usage activity. Specifically, while the number of registered users has grown steadily (albeit with slight surges at outbreak events), the number of users actively scanning on any given day is highly variable, and strongly correlated with outbreak events (August 2020, February 2021 and August 2021).

Notably however, the total number of active users, even in the most recent outbreak, has not risen much above 1 million (33.8 percent of total users on November 22, 2021) on any given day. Indeed, usage as a percentage of active users was higher (exceeding 50 percent) during the August 2020 outbreak than at any other time over the whole period examined. The fall-off in active devices closely mirrors the fall-off in scanning activity, indicating that the number of scans is a function of the number of active devices on a given day rather than the number of registered users. This is to a large extent to be expected as the definition of an active device is one that has been used at least once and, furthermore, the average number of uses is low. By contrast, the number of Bluetooth-active devices each day more closely follows the pattern of application downloads (Fig. 4), albeit still at only around 50 percent of registered applications until the August 2021 outbreak, where it climbed sharply to around 68 percent of registered applications by November 23, 2021.

We now turn to the matter of how the number of scans relates to the number of registered and active users—both individuals downloading the application and unique QR codes posted at premises. Fig. 6 shows that when the denominator is taken as the number of applications downloaded, scanning activity peaked in the August 2020 outbreak at a little more than one scan on average per registered user. With the denominator taken as the number of active devices on a given day, scans per active device peaked in the initial period of application availability (2.84 scans per active device on July 17, 2020), when the number of registered users was still very low.
Fig. 4. NZ COVID Tracer–Device activity.

Fig. 5. NZ COVID Tracer–Percentage device activity.

Fig. 6. NZ COVID Tracer–Daily scanning activity.
Presuming that the most committed users were early adopters prepared to scan even when there was no evidence of community transmission, this likely reflects the greatest possible extent of voluntary scanning activity within the New Zealand population. As the number of registered and active users increased during the August 2020 outbreak, average scans per active device stabilised on a lower average (slightly over 2 scans per active device per day, peaking at 2.46 on September 6). As the number of active daily users fell away after the August 2020 outbreak came under control, scanning activity per active user fell away just slightly, averaging around 2 per active user per day consistently for the remainder of the period prior to the August 2021 outbreak. Notably, there was no apparent increase in this rate of usage during the February 2021 outbreak, when the number of active users increased substantially. There was a slight fall early in this outbreak, likely due to the imposition of a strict level 4 lockdown reducing activity, but following relaxation of lockdown stringency, scanning activity per active device resumed at a level not much higher than observed prior to the outbreak: around 2.2 scans per active user per day (maximum 2.39 on November 20): that is, no higher than observed during the peak of the August 2020 outbreak and less than observed in the initial days of application use.

The authors consider the number of around 2 scans per day per active device to be modest and this can be attributed to either (or both) low mobility or lax scanning behaviour. During most of the period of the study people in New Zealand were going to work (where they would have had to scan in) and every trip by public transport also requires scanning in. After app use was made mandatory, Fig. 6 shows a modest increase in the number of scans per active device but a substantial increase in the scans per registered device, indicating that (likely) more people were actually using the scanning function as a result of the mandate. Survey data reported by Ali and Dang (2022) had 39.7% of respondents declaring that they “always” used the app.

3.3. Discussion

The most notable feature of NZCT use from these descriptive statistics is the comparatively low rate of scanning on a daily basis. While the number of active users varied considerably depending upon whether or not an outbreak was in process (i.e. perceived risk of infection was higher or lower), the number of scans per active user remained remarkably stable. There is no evidence to suggest that, on average, more people scanning (i.e. a larger number of active users) leads to more scanning activity by any given individual user. There appears to be an equilibrium level of scans that is determined by the number of places an individual actually visits on an average day and is prepared to scan upon entry. Apart from the brief period when New Zealand was in Level 4 lockdown, when movement was severely restricted, this appears to be on average around only 2 per day. Likewise, increasing the number of QR codes displayed does not appear to lead to any more scanning by individuals; rather it simply appears to distribute scanning activity across a larger number of unique codes. This is possibly because those businesses having registered later are responsible for very few customer visits.

Of course, averages conceal the fact that some individuals may undertake a lot of scanning, and that among different user cohorts different patterns may be observable. However, their high usage means that usage by some others is very low indeed. But as a device is considered active if at least one scan or one manual entry is made on a given day, the descriptive data indicate that on average most users scan very sparingly, if at all on any given day. There are many days when users record no entries (the probability of a registered user making at least one scan or manual entry is at best only 0.35, even when a major infection outbreak is occurring).

The descriptive analysis raises the question of NZCT’s value to contact tracing if average scanning activity even for active users during high-risk periods is so low. The electronic record of the (on average) two places per day an infected individual using the application has, is unlikely to reveal a location that could not be surfaced using other methods, but it does help refine the exact time the premises were entered—something that might otherwise incorrectly recalled or be opaque to the contact tracer. The ability to electronically notify others present at the same location for a duration where infection could have taken place does reduce the burden on contact tracers making individual calls but may also lead to a large increase in the number of “false positives” presenting for testing, especially if contact tracers adopt a cautionary approach and specify wide time bands for alert notifications. This likely occurred during the August 2021 outbreak, where contact tracers did adopt such a conservative approach and long queues were evidenced at testing stations (including individuals waiting for ten hours and still not being able to be tested that day). This necessitated the Minister urging people to stay away from testing unless they were showing symptoms or had been specifically instructed by a contact tracer to seek a test.

Arguably, one of the most significant benefits may lie not in application use per se, but in the registration details recorded when the application is downloaded. In New Zealand’s distributed health system, centrally held records either do not exist or may not include up-to-date contact information. The simple act of registering, and providing current phone and other electronic communication details (e.g. email addresses) in a single central repository likely reduces the time taken to manually contact potentially infected individuals identified by all of the range of contact tracing processes, not just NZCT, relative to out-of-date and dispersed alternatives. Given that close contacts known to an index case (but whose contact details are not necessarily known) are the most likely to become infected, the benefits of up-to-date contact information may be the most significant benefit offered by NZCT.

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9 https://www.stuff.co.nz/national/health/coronavirus/126132021/covid19-fury-over-10hour-waits-at-auckland-testing-centres-only-to-be-turned-away.
10 https://www.newshub.co.nz/home/new-zealand/2021/08/coronavirus-minister-urges-people-to-stay-away-from-covid-19-testing-sites-unless-they-re-a-contact-or-showing-symptoms.html.
4. Analysis: how has mandating NZCT use affected uptake and usage?

In this section we address the question of how the mandating of NZCT has materially affected uptake and usage of the application. When NZCT was introduced in May 2020, its use by individuals was entirely voluntary (although since September 2020 it had been mandatory for businesses and selected other service providers (e.g. public transport and taxi/uber drivers to obtain and display QR codes). In August 2021, community transmission of the Delta variant of COVID-19 was detected in Auckland. The country was moved to Level 4 lockdown – the highest possible level – on 18 August. Unlike past community outbreaks (August 2020; February 2021), this one was not brought rapidly under control. On August 22, the Minister for COVID-19 Response announced that seven days after the current lockdown provisions were relaxed – whenever that might be – it would become mandatory for NZCT (or alternative manual tracking systems) to be used at all business premises and on public transport. Other locations such as churches and community venues not previously included were also required to display QR codes. All of New Zealand except Auckland (where the outbreak first occurred) was lowered to Level 3 on 31 August, triggering the NZCT mandate from 7 September in those regions (covering two thirds of New Zealand’s population). Auckland was lowered to Level 3 on 21 September, when the rest of the country moved to Level 2. Slight relaxations of Auckland’s Level 3 lockdown stringency occurred on October 5 and November 9. The latter is likely influential in total scanning activity because from that date, most retail outlets previously locked down were permitted to operate and serve masked, socially distanced customers. However, restrictions remained in place for hospitality venues, and personal service providers (e.g. hairdressers, beauticians, gyms) remained closed.

4.1. Descriptive data

Figs. 7 and 8 expand Figs. 5 and 6 showing device activity and scanning activity per active device respectively over the period July to November 2021. First, it is noticeable that changes in Bluetooth application usage began prior to mandating coming into effect. Fig. 5 shows that Bluetooth use began increasing when the outbreak began, driven primarily by an increase in the number of applications downloaded and Bluetooth simultaneously activated; by the time mandatory use came into effect (September 7), the percentage of active Bluetooth devices had increased from its pre-August level of 50 percent to nearly 65 percent of registered users. By November 23, this had increased by only a further 3 percent. This suggests that the outbreak (i.e. increased perceived risk), and not the mandate triggered the increase.

Second, it seems that the growth in the number of active devices used for scanning and manual diary entries did not increase as rapidly. While there was a minor increase

- after outbreak was reported, and lockdown began (August 18—from 10 percent to just over 15 percent) and
- another when lockdown was relaxed for the rest of the country except Auckland (August 31—from 15 percent to 24 percent),

the step-change in active devices (from 24 percent to 37 percent) did not take place until after September 7, when usage became mandatory.

The mandate appears to be responsible for only around one half of the observed increase in active devices for scanning and diary entries; increased perceived risk of infection appears to account for at least half of this element of usage increase. However, comparing Figs. 5 to 7 reveals that the rapid drop-off in active devices has not occurred in the outbreak of late 2021. At this stage, it is difficult to know whether this is a consequence of the mandate or the continued perceived high risk of infection. There was no apparent drop in active devices following the relaxation of lockdowns on September 21, unlike in past cases and this relaxation took
place without a concomitant elimination of community transmission. It could be that the relaxation in Auckland while community transmission was still occurring may have led to an increase in risk perception—albeit one that from these data does not appear to have led to a further increase in the number of active devices (something that might have been expected if risk had actually increased).

Third, scanning and manual diary entry activity per active device (Fig. 8) appears to have been affected differently, but once again more in line with the patterns observed for device activity. Although the number of scans per active device increased, this occurred again for the most part after September 7, when usage was mandated. Lockdown on August 18 led to a dramatic reduction in scans per active device, but a less-marked one in the number of manual entries (albeit that manual entries make up only a small percentage of activities – Fig. 2.) Fig. 2 confirms that the increase in total scan numbers appears to be driven by the mandating rather than increased risk perception. However, Fig. 8 indicates that relative to the period before the August outbreak, manual entries have fallen as a percentage of total activities recorded per device, likely because there are more QR codes displayed (Fig. 3). Again, it is noted that there is no perceivable change in activity per device when the Auckland lockdown was relaxed (Auckland comprises approximately one third of New Zealand’s population). As these data are taken against the denominator of active devices, and the number of scans per active device has risen only very slightly above the pre-August number, it is not likely that lower activity in total in Auckland as a consequence of the ongoing relaxed but tighter lockdown obligations relative to the rest of the country, is unduly influencing the average patterns observed. If Auckland users are under-represented because they are not active at all, then they will affect only the percentage of active users, not the number of scans per active user. If Auckland usage is under-represented because active Auckland users are visiting fewer sites under lockdown than other New Zealanders, and this is material, then an increase should equally have been detected on September 21, when the rest of the country and Auckland both stepped down one level in restrictions. That no such increase was observed supports our hypothesis about the limits to individual application use postulated in the previous section.

4.2. Statistical analyses

To address the question of the extent to which variables are the most significant determinants of NZCT usage, we constructed a number of linear regression models with

- first, the number of scans and
- second, the number of active devices

as the dependent variables. Independent variables for the scan regressions included (on a daily basis) the number of active users, and dummy variables for lockdown state (0 if in lockdown a given day, 1 otherwise) and mandated compulsory use (0 if not compulsory, 1 otherwise). For the active devices regressions, the independent variables were selected from total registrations, new cases and the two dummy variables. The results are summarised in Tables 1 and 2.

Table 1 shows that the number of active devices is strongly statistically significant in determining the number of scans (Model 1.1). Adding the two dummy variables (Model 1.2) had negligible effect on the predictive effect (adjusted R Squared increased by just 0.0002), and neither variable is statistically significant at the 5 percent level (although Lockdown is significant at the 10 percent level). Recall that a device is active if it is used to scan at all so this analysis reflects on how much scanning is going on when people are in fact going out.

Table 2 shows that while all of the independent variables are statistically significant at the 0.1 percent level in determining the number of active devices on a given day in all of the models, the predictive power of registrations on their own (Model 2.1) is quite
Table 1

| Model | 1.1 | 1.2 |
|-------|-----|-----|
| Adjusted R Squared | 0.978823 | 0.979019 |
| Significance F | | |
| Independent Variable | Coefficient (P-value) | Coefficient (P-value) |
| Intercept | $-95301.6 \ (1.08E^{-25})$ | $-91276.4 \ (2.47E^{-15})$ |
| Lockdown | $-28584.1 \ (0.065411)$ | $34795.69 \ (0.110982)$ |
| Compulsion | | |
| Active Devices | | |

Table 2

| Model | 2.1 | 2.2 | 2.3 |
|-------|-----|-----|-----|
| Adjusted R Squared | 0.381128 | 0.781211 | 0.85595 |
| Significance F | 5.88E$-$56 | 4.2E$-$171 | 2.1E$-$216 |
| Independent Variables | Coefficient (P-value) | Coefficient (P-value) | Coefficient (P-value) |
| Intercept | $-199600 \ (1.43E^{-06})$ | 311141 \ (4.8E^{-145}) | $-17393.4 \ (0.41275)$ |
| Lockdown | 326466.2 \ (9.48E^{-62}) | 319785.2 \ (4.34E^{-81}) | 319785.2 \ (4.34E^{-81}) |
| Compulsion | 488007.7 \ (2.53E^{-72}) | 361376.9 \ (4.85E^{-56}) | 361376.9 \ (4.85E^{-56}) |
| Registrations | 0.281109 \ (5.88E^{-56}) | 0.140144 \ (8.16E^{-49}) | 0.140144 \ (8.16E^{-49}) |

low (adjusted R Squared 0.3811). The dummy variables Lockdown and Compulsion alone are better predictors of use (Model 2.2 – adjusted R Squared 0.7812); combining all independent variables increases the adjusted R Squared to 0.8599. The coefficients in model 2.3 indicate that an additional app registration has only a very modest effect on the number of active devices (0.14 per additional registration). However, instituting a lockdown increases the number of active devices by 320,000; compulsion adds a further 360,000.

Taken together, the regressions confirm the conclusions from the descriptive statistical analysis. Scanning activity is determined primarily by the number of active devices on a given day. The number of active devices is more strongly influenced by infection risk, which is captured by the Lockdown and Compulsion variables, than by the number of application registrations.

5. Policy implications

The August 2021 Delta outbreak has allowed analysis of the effects of NZCT on contact tracing processes. Howell and Potgieter (2021) proposed that as the number of infections and the number of individuals using the application rose, the rate of false positive contacts identified would rise, resulting in bottlenecks forming in the testing and laboratory analysis processes. Furthermore, the additional information provided from the application would lead to information overload as contact tracers would be required to follow up many more sources of information to identify and follow up with likely contacts. Both of these effects would be exacerbated if contact tracers took a conservative approach and sought to follow up individuals who had been in the same location as the infected individual for a wide time period following the time of the QR code recording. This was in addition to the high false positive identifications arising anyway due to the very coarse filter NZCT uses in identifying the time of entering but not leaving a location and recording neither movement around the location nor interaction with other individuals while there.

As identified above, long queues at testing centres in August 2021 did indeed form, leading the Minister to intervene to request individuals not present for testing unless symptomatic or instructed by a contact tracer to do so. Furthermore, contact tracers did adopt a conservative approach in time definitions, which led to ten times as many close contacts being identified per case than in previous outbreaks. This would have exacerbated the bottlenecks forming at testing and laboratory analysis processes. Contact tracing performance indicators originally specified as the anticipated goals could no longer be maintained, due to the sheer volume of locations of interest indicated. The Minister announced on August 23 that contact tracers would no longer be held to account for the “gold standard” metric of notifying at least 80 percent of potential contacts within 48 h of detecting a new case of COVID-19.

If the vast majority of NZCT users had been only sporadically active, and on average recorded just over two locations of interest on the 35% of days that they did in fact scan, then it begs the question of just how useful the NZCT data was for the contact tracing process, over and above the usual questioning undertaken by contact tracers. It also draws into question the rationale of basing the app on locations of interest in the first place. The limits of the location based NZCT appear to be admitted in the November 5 announcement that the Ministry of Health would no longer be reporting locations of interest identified by contact tracing in Auckland,

11 https://www.stuff.co.nz-national/health/coronavirus/300389323/covid19-who-counts-as-a-close-contact-new-definition-sees-10-times-more-than-previous-outbreaks.

12 https://www.newshub.co.nz/home/new-zealand/2021/08/covid-19-health-officials-no-longer-sticking-to-80pct-contact-tracing-goal-due-to-sheer-volume-of-locations-of-interest-dr-verrall.html>.
(the epicentre of the outbreak). At the time, around 200 new infections per day were being identified. The justification given by the Director of Public Health was that the approach had “shifted” to one focused on “high risk events”. The public health risk posed by being at locations such as supermarkets and drive-throughs was deemed “very very low, due to restrictions of distancing and masking”. But as the vast majority of scans are being taken at these very low risk locations, it is difficult to see the rationale for continuing with the mandatory requirement to scan at them. If the information will not be used, why impose the costly obligation of collecting it? Yet the “traffic light” system due to come into force from December 2, 2021, requires mandatory scanning at all business locations at all levels of activity, including at the very low risk “green” level.

A charitable interpretation may be that when the number of infections is low, and the strategy is to eliminate the virus, then contact tracers may have time to process the smaller amount of information (as was the case in areas outside of Auckland, where locations of interest continue to be publicised, in late 2021), so QR code-based systems such as NZCT have a place. But when infection rates are high, and the strategy is to “manage”, then location-based QR code systems such as NZCT are not helpful, because of the information overload and testing bottlenecks created. However, the question of whether to mandate use at all locations at any infection level is moot if there is such a low risk of infection in the first place, given other tools used to reduce transmission.

The ongoing mandatory requirement to scan also appears somewhat difficult to justify given that NZCT also has a Bluetooth component which is activated by 68 percent of registered users on any given day. It does not appear that this feature has been used at all to identify close contacts during the outbreak of late 2021, despite being used by nearly twice as many users than the QR code scanning feature. The Ministry of Health cited (inter alia) that lack of use of the Bluetooth feature was a reason (refuted by our analysis of the data, above). However, it may be that lack of familiarity with the technology amongst contact tracers, and the fact that the feature’s focus on individuals’ interactions and not locations of interest rendered it incompatible with the existing contact tracing processes, and a location-focused lockdown strategy. It is noted that the “traffic light” system is also location-specific, imposing obligations on business owners (notably those in specific sectors such as hospitality, hairdressing and personal services) and event hosts (e.g. concerts, weddings, funerals, church services—already required amongst others to display NZCT QR codes) to restrict access based on scanning patrons’ QR code-based vaccination passes. It would appear that while the Bluetooth application might miss some true positive cases, it has a far lower false positive rate than the QR code system and the information provided could usefully complement the location-based data to track down individuals at high risk not able to be identified by other interview-based means.

6. Conclusion

In sum, our analysis shows that while uptake of NZCT, represented as downloaded applications, is substantial (68 percent of the resident population), actual use, represented by daily scanning activity, is low. Whereas Gasteiger et al. (2021) reported over 50 percent of their sample population perceive they are active users, we find that even when the risk of infection is high (i.e. during an outbreak) at most 35 percent of the NZCT registered user population (24 percent of the total population) scans at least once on any given day. Furthermore, scanning activity is low, even when the user is active; on average, an active user scans under 2.4 QR codes on average. Scans per active user does not change much when the risk of infection rises; rather increasing risk of infection leads to more individuals becoming active. Mandating use does appear to assist in maintaining a higher level of active users, but again has no material effect on the number of scans per day per active device.

The mandating of the use of QR codes appears to have increased the amount of scanning activity in total, and had a part to play in keeping those numbers high over time, whereas in other outbreaks this has fallen away quickly. However, the changes made to the use of the information collected (principally the decision to focus on identifying events and not locations of interest when assessing infection risk and identifying close contacts) appears to have rendered mandatory scanning at all premises entered redundant in a “maintain” strategy. It may have some role to play in an elimination strategy, so long as the case numbers remain low, but even this is questionable if the low number of locations scanned does not add to the information collected during the initial contact tracer interview.

Data availability

Data will be made available on request.

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https://www.stuff.co.nz/national/health/coronavirus/300447213/covid19-ministry-of-health-scales-back-reporting-of-auckland-locations-of-interest.

https://www.stuff.co.nz/business/126261938/no-straight-answer-from-health-ministry-on-nonuse-of-bluetooth-tracing.
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