THE LANCET
Public Health

Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplement to: Vogt F, Haire B, Selvey L, Katelaris AL, Kaldor J. Effectiveness evaluation of digital contact tracing for COVID-19 in New South Wales, Australia. *Lancet Public Health* 2022; published online Feb 4. https://doi.org/10.1016/S2468-2667(22)00010-X.

Supplementary material

Appendix 1: Protocol

Rapid evaluation of effectiveness and utility of the COVIDSafe app as a contact tracing tool for the COVID-19 response in NSW

Background

The COVID-19 pandemic is an unprecedented global health emergency.[1] In the absence of a vaccine or effective treatment, high levels of testing linked to contact tracing and quarantine of exposed people underpin a critical control strategy.[2] Widespread community quarantine measures ('lockdowns') are highly effective in limiting exposure and transmission, but are unsustainable in the long term.

To enhance contact tracing capacity, particularly as community quarantine measures are reduced, the Federal Government has developed and promoted the COVIDSafe app. This app, when installed and registered on a mobile phone will use digital 'handshakes' using Bluetooth technology to record contacts with other phones held by people who also use the app. Details of encounters meeting a pre-specified threshold (currently defined as exposures of at least 15 consecutive Bluetooth encounters with at least one encounter rated as a medium to high probability of being within 1.5 metres) can be uploaded by the user to a web portal at the request of public health authorities in the event that the user is diagnosed with SARS-CoV-2 infection. The COVIDSafe app is available to Australian mobile phone users, and as of 24 May had been downloaded by over 6 million people. Jurisdictions have started integrating the app into their contact tracing procedures.

Contact tracing in NSW, as elsewhere in Australia, has previously relied on phone interviews with people confirmed to have SARS-CoV-2 infection, to identify others who were in close contact during the infectious period of the person newly diagnosed case. The COVIDSafe app automatically generates a list of potential contacts that can supplement the list elicited from the case. Regardless of the source of potential contact information, a multi-stage assessment process is then undertaken involving the index case and potential contacts, to identify the contacts at high risk of infection who are then requested to quarantine for 14 days from the time of their last exposure to the case. Alternative approaches to app-based contact tracing include the omission of the potential resource-intensive risk assessment process to automatically issue quarantine directions to all app-identified contacts meeting the pre-defined threshold on notification of a case.

Establishing a comprehensive and ongoing monitoring and evaluation mechanism from the earliest implementation stage of the COVIDSafe app will guide evidence-based adjustments to app, to maximize its effectiveness and utility as an additional contact tracing tool for COVID-19.

Overall aim

To determine a) the benefit and utility of the COVIDSafe app, as integrated into existing contact tracing processes, for identifying contacts of COVID-19 cases in NSW and b) hypothetical public health utility of fully automated app-based contact tracing

Methods

Design

This evaluation will use a mixed methods approach and cover the early implementation period (Phase 1) as well as the following full-scale implementation period (Phase 2). It is planned to transition from Phase 1 to Phase 2 after about 20 COVID-19 cases with active app use have been processed.

The evaluation will comprise three linked components:

A. Output
B. Process
C. Qualitative

Each component will be addressed during both phases, with lessons learnt during Phase 1 incorporated into Phase 2. The evaluation processes may involve some re-framing of evaluation questions and indicators depending on changes in implementation strategies and processes.

Definitions

'Contact' refers to a person who meets the criteria for a close contact as defined in the COVID-19 Series of National Guidelines (SoNG)[1].

'Potential contact' refers to a person who has been identified through contact tracing as having been in contact with a confirmed case during the case's infectious period, but who has not yet been assessed against the criteria of the SoNG.

'Automated app-based contact tracing' refers to a hypothetical approach whereby all potential contacts identified by the app are automatically considered close contacts and directed to self-quarantine, without any further risk assessment by public health staff.

Objectives and evaluation questions

A. (Output)

- Objective 1: To assess the uptake of the COVIDSafe app in NSW
  - Evaluation question 1: What is the uptake of the COVIDSafe app in NSW?

- Objective 2: To assess the utility of the COVIDSafe app for initial contact identification
  - Evaluation question 2: To what extent does the COVIDSafe app assist in the initial contact identification process?

- Objective 3: To assess the impact of the COVIDSafe app on contact risk assessment
  - Evaluation question3: To what extent does the COVIDSafe app impact risk assessment of contacts?

- Objective 4: To assess the additional yield of the COVIDSafe app
  Evaluation question 4: What is the additional yield of the COVIDSafe app?

- Objective 5: To assess the reduction in potential public exposures to COVID-19 through the COVIDSafe app
  - Evaluation question 5: To what extent does the COVIDSafe app help prevent potential public exposures to COVID-19?

- Objective 6: To assess the hypothetical public health utility of fully automated app-based contact tracing in comparison to combined interview and app-based contact tracing.
  - Evaluation question 6: Among cases using the app, to what extent would automated app-based contact tracing be able to identify true close contacts?

B. (Process)

Process evaluation questions and the mode of data collection will be further developed in collaboration with public health staff involved in case interviews and contact tracing. Data collection for some of these questions may be via the qualitative interviews described under C below.

- Objective 6: To assess how the COVIDSafe app is being operationalized within NSW Health
  - Evaluation question 6: What steps take place following notification of a case, for cases using the app and those who are not?

  Indicative process evaluation questions under this objective may include the following:
  - Time from notification to case interview; Information sought about contacts;
  - Process for contacting contacts; Prioritisation of contacts; Data management on contacts; Time to reach contacts; Means of contacting contacts (phone call, SMS)
  - Follow up process with case and contacts after the initial contact; Duration and variation according to risk factors for severe COVID-19 and/or workload
  - Map of the movement of information and outputs/outcomes) by public health unit

- Objective 7: To identify inefficiencies in the contact tracing process (with and without the app), and how they might be addressed

  - Evaluation question 7: What are the processes following notification of a case, for cases with and without the app?

  Indicative process evaluation questions under this objective could include the following:

[1] https://www1.health.gov.au/internet/main/publishing.nsf/Content/cdna-song-novel-coronavirus.htm

- For all participating public health units, describe/map the process from the receipt of case notification to identifying and contacting all contacts, including transfer of information between individuals.
- Identify bottlenecks in the contact identification and contact tracing processes for cases with and without the app.
- Describe the additional time and workload in documenting/cross-referencing contacts identified via the app

C. (Qualitative)

The qualitative aspect of the evaluation will investigate how COVID-19 contact tracing is understood by NSW Health staff to operate, and how they view the contribution of the COVIDSafe app to contact tracing.

- Objective 8: To document the views and perceptions of contact tracers and relevant public health authorities on how the COVIDSafe app impacts on contact tracing processes and their effectiveness, both hypothetically (Phase 1) and in practice (Phase 2).

  Phase 1:
  - Evaluation question 8a: What questions or concerns do staff have about the usefulness of the COVID-Safe app?
  - Evaluation question 8b: What are the perceived benefits of the COVID-Safe app for contact tracing?
  - Evaluation question 8c: What are the perceived flaws of the COVID-Safe app and its integration into the NSW Health contact tracing process?
  - Evaluation question 8d: On balance, do staff perceive that the COVID-Safe app will improve contact tracing processes?
  - Evaluation question 8e: How have changes in the development and functionality of the app, and communications about these, affected implementation plans

Phase 2:
- Evaluation question 8f: What are staff experiences of working with the COVID-Safe app?
- Evaluation question 8g: How does the experience of working with the COVID-Safe app compare with expectations of its usefulness?
- Evaluation question 8h: Describe the contact tracing process in your unit. How does it differ when the case has a lot of contacts and when the case has a few? What are the bottlenecks?
- Evaluation question 8i: How does the use of the app affect timeframes for contact tracing?
- Evaluation question 8j: How does the app impact on workflow within and between NSW Health units and individual staff?
- Evaluation question 8k: What changes could be made to the app and contact tracing processes more generally to optimize their utility?
- Evaluation question 8l: What are the views of public health staff regarding automated app-based contacts tracing in terms of public health benefits and acceptability?

<u>Data collection</u>

A. (Output)

This component will be quantitative, based on data derived from the app or collected during case and contact management. The majority of the data will be captured in the NSW Health Notifiable Conditions Information Management System (NCIMS). A set of indicators derived from these data sources will be used to address each evaluation question. The indicators are descriptive summary statistics stratified by source of contact identification (app, interview or both), cumulatively over time and per case as relevant.

Table 1

Objectives	Indicators	Data Sources
1	Indicator 1.1: Number and percentage of NSW residents who have downloaded the app, if available by location and age group.	Commonwealth data (availability tbc)
	Indicator 1.2: Number and percentage of all cases who had downloaded and activated the app for at least part of their infectious period.	NCIMS
	Indicator 1.3: Number and percentage of demographic and contact pattern characteristics separately for app-using and non-app using cases.	NCIMS

2	Indicator 2.1: Number and percentage of all cases reporting app use where data were released by the case and accessed by NSW Health staff. Indicator 2.2: Number and percentage of reason for failure to release or access data (per 2.1)	Not currently captured Not currently captured
3	Indicator 3.1: Median number and percentage of app-identified close contacts that were identified or considered close contacts based on interview-derived information per case (i.e. "additional yield")	Not currently captured
4	Indicator 4.1: Median number and percentage of contacts by source of identification (e.g. app-only, interview-only, app-and-interview) per case Indicator 4.2: Median number and percentage of contacts by setting of exposure per case, by source of identification (e.g. app-only, interview-only, app-and-interview)	NCIMS NCIMS
5	Indicator 5.1: Median number and percentage of contacts who started quarantine after being contacted by NSW Health staff, by source of identification per case Indicator 5.2: Median number of days between time of last contact with the case and time of quarantine start of contacts, by source of identification per case Indicator 5.3: Median number and percentage of contacts that were lost to follow-up by source of identification per case Indicator 5.4: Cumulative number and percentage of contacts who became secondary cases by source of identification per case, and percentage in quarantine at start of their infectious period	NCIMS NCIMS NCIMS NCIMS
6	Indicator 6.1: Cumulative number and percentage of true close contacts among app users who would have been identified using automated app-based contact tracing only Indicator 6.2. Cumulative number and percentage of all app-identified potential contacts who would have been erroneously considered close contacts using automated app-based contact tracing only	NCIMS/additional data collection NCIMS/additional data collection

Some of the data required for these indicators are already captured in NCIMS, and can be exported for analysis. Where this is not the case, the feasibility of additional data collection will be assessed and implemented during Phase 1 to ensure that indicator data are comprehensively captured during Phase 2. If key indicators cannot be readily obtained through NCIMS, additional, evaluation-specific data collection tools hosted outside NCIMS may be considered. Data available to public health staff through the contact tracing web portal will undergo consolidation, assessment, and interpretation in the context of interview-derived information prior to being documented for the purpose of public health action and evaluation. The timing of data collection and extraction for analysis during Phase 2 will be determined by future case load, agreed in collaboration with NSW partners.

B. (Process)

The data for the process review will be obtained by interviewing and observing case investigators and contact tracers while they are undertaking their work. This will involve observations within the Ministry of Health as well as in public health units located within local health districts. This observation and interview process may generate additional questions for inclusion in semi-structured interviews and a survey if necessary. It would be ideal also to conduct this component of the evaluation in more than one public health unit, in case their operating procedures differ.

Descriptive analysis of the data obtained will be undertaken. Process diagrams will be drawn with possible inefficiencies highlighted. The data will be collated and analysed separately for cases who used the app and those who did not.

C. (Qualitative)

This component will use semi-structured in-depth interviews and small (up to three person) focus groups. Data collection will be conducted by video conferencing or telephone, and led by a person experienced and qualified in qualitative research processes of this kind.

The semi-structured interview guide and the focus groups questions will be co-designed by the research team and collaborators at NSW Health. Drafts of the questions will be provided, discussed and amended until consensus is reached. As data are generated, the research team may recommend further amendments to the interview and question guides. Any proposed changes will be fed back to collaborators at NSW Health and the consensus process continued.

Semi-structured interviews provide a framework that ensures that key data are collected, while allowing richness and flexibility. It is important to build flexibility into the data collection to allow participants involved in novel circumstances to raise issues not anticipated by the researchers. Data richness means that the perspectives and experiences of participants can be explored without being constrained by any pre-formulated expectations of the research team. Interviews and focus groups will be audio recorded and transcribed verbatim by a professional transcriber who has signed a confidentiality agreement. Interviews will take between 30 and 60 minutes, and focus groups between 60 and 90 minutes.

Focus groups and interviews on small scale will be undertaken during Phase 1 to gain insight into expectations, and on an expanded scale during Phase 2. Data will be thematically analysed drawing on the process of iterative categorisation, [3] a systematic technique for the analysis of qualitative data, and framework analysis.[4] Analytic categories will initially be structured by the evaluation questions 8a-e above. Analysis of responses to the process evaluation questions (6 and 7 above) will include developing process maps and identifying bottlenecks that may require further investigation. The data analysis for the process component of the interviews will largely be descriptive.

All staff identified by NSW Health as having a substantive role in contact tracing activities will be invited to participate, with decisions about which who participates in focus groups versus in-depth interviews being negotiated with NSW Health and the staff concerned. Participants will have the option of signing a participant information and consent form, so that data arising from their involvement in focus groups or interviews could be reported in external scientific reports.

Data protection and ethical approvals

All data collected made available to external researchers will be held in secure electronic environments, following Kirby Institute best practice. Identifying details of interviewees including consent forms will be stored separately from data on their responses.

NSW Health has advised that this project is a quality improvement activity as defined in "GL2007 020 Human Research Ethics Committees - Quality Improvement & Ethical Review: A Practice Guide for NSW"2, and that formal ethical approval is therefore not a requirement for its conduct. The Kirby Institute research team will nevertheless seek approval for the project from the UNSW Human Research Ethics Committee, to allow for the possibility of using findings in external scientific reports. Individual informed consent will be obtained from NSW Health staff prior to their involvement in evaluation-related interviews and focus groups.

John Kaldor will be the lead representative of the external members of the research team, and ensure compliance with commitments to data protection, confidentiality and appropriate dissemination of evaluation findings.

Timeline and milestones

- Fri 19 June 2020 CHO/PHEOC expedited approval obtained
- End of June 2020 Protocol finalised and submitted for UNSW ethics review
- June/July 2020 Ethics approval obtained, Phase 1 initiated[3]
- Mon 31 August 2020 Interim report submitted to NSW Health
- TBD Final report submitted to NSW Health[4]

Publications and reports

[2] https://www1.health.nsw.gov.au/pds/ActivePDSDocuments/GL2007_020.pdf

[3] Initiation of phase 2, i.e. full implementation of the app for contact tracing by individual PHUs state-wide, is contingent on (a) the Commonwealth making key improvements to reliability and usability of contact data and the web portal and (b) a sufficient number of cases using the app having been followed up centrally to support implementation of the state-wide roll out.

[4] Date may change depending on case load, in agreed in collaboration with NSW partners.

The final report to NSW Health will be the main deliverable. The research team may propose external scientific presentations, including peer-reviewed publications. The content, format and authorship of any such presentations will be determined via a consensus negotiation between all members of the research team, both NSW Health and external. There will be no external scientific presentation of findings prior to the acceptance of the final report by NSW Health, unless there has been an explicit agreement by NSW Health to do so.

INDICATIVE PROCESS INDICATORS

Objectives	Indicators (to be finalised during Phase 1 in consultation with relevant public health staff. Data collection to include observation, semi-structured interviews and possible survey)	Data Sources
	Description of the contact identification and contact tracing processes including bottlenecks in the process and the particular processes that take longer time. This will involve processes for cases that use the app and those that do not. Potential processes of interest would include: • Initial contact identification • Comparing interview and app contact lists • Verifying app-only identified contacts with the case and with the contacts • Finalising the contact list • Number and duration of phone calls with the case Number and proportion of NSW Health public health staff involved in contact tracing who are trained in and able to access contact information from the app. Process of recording information/data management by site/individual.	
	How does the app affect work flow for contact tracers? How does the app impact on the time taken in case interviews and contact tracing? What are the advantages of the app for contact tracing? What are the disadvantages of using the app? How does working with the app compare to working without the app	Qualitative data

Semi-structured questionnaire

The questionnaire content and question framework for focus groups will be developed in consultation with NSW Health colleagues. It will include questions relating specifically to the processes involved in contact identification and tracing as defined above.

References

1. Fauci, A.S., Lane, C.L.& Redfield, R.R. Covid-19 — Navigating the Uncharted. *New England Journal of Medicine*. 2020; 382:1268-1269.
2. Ferretti, L.,et al., Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing. Science. 8 May 2020; 368 (6491).
3. Neale, J. Iterative categorization (IC): a systematic technique for analysing qualitative data. *Addiction*. 2016; 111: 1096–1106. doi: 10.1111/add.13314.
4. Gale, N.K., Heath, G., Cameron, E. *et al.* Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Med Res Methodol 2013;* **13 (**117).

Appendix 2: Qualitative evaluation component

Qualitative Methods

The qualitative component of the evaluation used semi-structured interviews and focus groups as data collection tools. Interviews and focus groups were conducted through video conferencing platforms, audio recorded and transcribed verbatim by a professional transcriber who signed a confidentiality agreement. Interviews took between 20 and 60 minutes, and focus groups between 60 and 90 minutes.

There were two phases of data collection: Phase 1 which involved staff who had been trained in the use of the app but had little if any actual experience; and Phase 2, which involved staff involved in contact tracing who had experience with the app.

All staff (n=119) who had undertaken training on the use of the app were invited to participate in a Phase 1 interview, regardless of whether they had any hands-on experience using the app. Staff were invited initially via a group email sent by the researchers, and then followed up via a reminder from NSW MoH staff. Six individual interviews and one focus group discussion of three participants were conducted. The six interviews and the focus group discussion were conducted by video conferencing (Zoom), audio recorded and transcribed. Data were analysed thematically using a coding framework constructed to address the evaluation questions, and managed using the software package NVIVO v.12.

Following discussion with the COVIDSafe app Evaluation Working Group, we proceeded with Phase 2, which targeted staff with hands-on experience of working with the app from August 2020 after reporting the data from Phase 1.

To recruit for Phase 2, an email was sent to all contact tracing staff, this time asking for those with experience to self-nominate for interviews. This received no response. A second email was sent by NSW MoH staff that targeted individuals known to be experienced with the app (n=10), and a follow-up was sent by the research team. This resulted in six staff with app experience volunteering to be interviewed, including one who responded to interview questions in writing rather than orally. One interview from Phase 1 (participant 6) was re-classified to Phase 2, as they had experience with using the app in more than two instances. This interview was therefore analysed as part of Phase 2 data.

The following semi-structured interview guide was used:

1. How has it been for you working with the COVIDSafe App?
2. Is this what you expected?
3. How is it different to what you expected, and how is it similar?
4. Has anything surprised you about the app's functionality?
5. Are you finding it more or less useful than expected?
6. Can you give me some examples of how long it takes to trace the contacts of case (maybe think of a relatively simple recent case in the last week or so)
7. Can you give me an example of a really complex case – someone with a lot of contacts, or contacts who were a challenge to find?
8. Do you get bottlenecks in the contact tracing process? If so, what are the causes of these? Can you give me an example?
9. How does using the app affect the time it takes to trace contacts?
10. Thinking again about the app, how does it affect workflow?
11. Can you tell me how the app affects work in your PHU?
12. Having a look at this picture, are all the steps right in terms of your workflow? Is there anything you'd add or change?

Qualitative Results

Evaluation questions 9a-9e were addressed by responses from Phase 1 interviewees who were trained in using the app but not experienced with it. In some instances, relevant responses from Phase 2 participants addressing this set of questions have been included.

Evaluation question 9a: What questions or concerns do staff have about the usefulness of the app?

Phase 1 respondents had some concerns both with the user interface of the app from their perspective as workers, and also with the steps required of community members to download, install and register for the app. These concerns included:

- Whether the app system would work reliably for public health officials – one respondent had an experience where they could not get into the system, and the Commonwealth did not respond to calls for assistance (this case was passed on to the NSW MoH);
- Whether sufficient people would go through the steps necessary to make the app functional – download the app and register and keep it open on their phones;
- Concerns about reported conspiracy theories that could be debunked with more information about how the app works, in particular the fact that it only retains 21 days of data and that it does not record geolocation information.

Phase 2 respondents had more significant concerns about the usefulness of the app, which are reported under questions 9f-i.

Evaluation question 9b: What are the perceived benefits of the app for contact tracing?

Phase 1 respondents were generally optimistic about how the app could enhance contact tracing work, viewing it as a tool that could potentially assist, particularly if the case had been in crowded public spaces.

- Respondents thought that app data could help cases who have poor recall, noting that when people have just been diagnosed with COVID-19, they are distressed, and it can be hard for them to think clearly about their actions and contacts. Data from the app could help with this process, as staff involved in contact tracing could prompt the case's memory by referring to app data.
- Respondents expressed the belief that the app could be useful in contexts where the case might have been on public transport or in venues where it is otherwise difficult to tell whether a contact is classified as 'close' or 'casual'.
- Several rural based respondents thought that its uptake might be most pronounced in metropolitan settings.
- Most respondents were clear that the app could not replace conventional contact tracing processes, but that it could expedite some aspects.
- One respondent related the example of a case in a non-verbal disabled person who did not have the app (or indeed a phone) and where a close contact with an ambulance officer was not known for several days. This situation would not have occurred if the case had had a phone and both case and contact had used the app.
- Respondents considered that the time stamp element on the app would be especially useful for venues, because sign in sheets were often missing information such as time in or time out. This response predated the requirement for electronic sign-in with QR codes.
- Respondents observed that there are careful consent processes involved in utilising app data, and that these are important for privacy and public confidence.

Evaluation question 9c: What are the perceived flaws of the app and its integration into the NSW MoH contact tracing process?

Phase 1 respondents were concerned that the app did not work reliably on all phones, that its interface was not user-friendly enough for app-inexperienced contact tracing staff, and that members of the public did not understand exactly what information it collected and what it did not. Importantly, the app was not well integrated into NSW contact tracing processes at the time of these interviews. For almost all cases with the app there was a reliance on the expertise of a few highly skilled NSW MoH staff to interpret the data and manage the process of follow-up. Even when PHU staff managed the app element, they frequently had to call upon NSW MoH staff for advice, assistance or even to hand the process over

to them. In Phase 2, some PHU staff had managed the app-based component, but still called upon support from the NSW MoH staff.

- Respondents were concerned that the app did not work reliably on iPhones;
- The one respondent who had tried to use the app could not log in;
- Respondents suggested that more health promotion in the general community about how the app works would be useful, including information about legal aspects such as the exclusion of app data as a source of evidence in prosecutions related to breaches of public health orders.

Evaluation question 9d: On balance, do staff perceive that the app will improve contact tracing processes?

Phase 1 respondents could see a role for the app as an adjunct to traditional contact tracing processes, particularly as restrictions relax and people resume more active socially engaged lives. The optimism of Phase 1 respondents contrasted with responses from Phase 2 respondents, who generally viewed the technical problems with this app (under-registering potential close contacts on iPhones and over-registering them on Android phones) as being too significant to make the app a useful tool.

- Respondents noted that the usefulness of the app depended first on whether the case used it – and had their phone with them, with the app running, and whether their contacts did.
- Respondents speculated that event-specific app use could work well, for example having a downloaded the app as a condition of entry to particular events, at a time when mandatory QR codes had not been introduced for venues.
- Several respondents said that they would like to have further training using a 'dummy' app, to get a better hands-on feeling of how it works.
- Generally, respondents were open to the benefits of an app that assists with contact tracing and saw it as complementary to their work, as an adjunct rather than a replacement for in-person contact tracing.

Evaluation question 9e: How have changes in the development and functionality of the app, and communications about these, affected implementation plans?

This question was not well- addressed by Phase 1 participants as they did not have the experience to answer it. From the perspective of Phase 2 participants, the changes to the app improved sensitivity on iPhones, but this corresponded with greatly increased sensitivity and reduced specificity on Android phones, in that 'pings' were recorded for proximity well outside the prescribed 'close contact' distance of 1.5 metres, and led to a lot of 'noise' that staff then had to sift through.

- Respondents had been trained on the changes to the functionality of the app, but no respondents really remembered these changes.
- There was a strong sense that more and better promotion of the app – including details about what it does and doesn't collect – could really help its acceptability and thus its uptake in the general community and therefore its usefulness.

Evaluation question 9f: What are staff experiences of working with the app?

Only a small number of staff members had extensive experience of working with the app, due to most of the app-based data retrieval having been handled centrally by NSW MoH staff. The overwhelming response from those who worked with the app, including those from the NSW MoH, was that it did not produce much usable data.

> *I haven't identified any new venues* [using the app] *and the contacts that I, some, some contacts that I've seen on the COVIDSafe app were people who'd already been identified as close contacts as part of the interview process, who were like family members. P7*

One respondent estimated that in only about 5% of instances of app use did it provide data that warranted a follow-up phone call to establish whether there may be close contacts beyond those elicited from conventional procedures. This was due to several factors:

- Some cases were already in isolation during their infectious period, as they had been identified as a close contact of a previous case;
- Close contacts had often already been identified in the initial case interview;

- No interactions were recorded on the app (more often with iPhones); or
- No interactions were recorded during the relevant timeframe, i.e. the infectious period.

Respondents who were highly experienced with the app recommended viewing app data as 'part of the picture' that should be explored alongside information gleaned from the case interview and venue information from QR codes and manual lists.

Evaluation question 9g: How does the experience of working with the app compare with expectations of its usefulness?

Respondents generally rated their expectation of the app as high, in that they thought it would be targeted to detecting close contacts and that it would help to pick up more contacts, even if many had already been identified through an interview. While some respondents were clear that an automated device alone could not be relied upon to accurately assess a 'close contact' (given the importance of context, such as whether apparently close contacts were separated by a wall, for example), they were nevertheless surprised by how little the app yielded.

> *I suppose we didn't have a clear idea how much the technology could actually be targeted towards capturing what we define in public health as a 'close contact'. I think we went into it not being sure to what extent those two things overlapped and how much they overlapped, but I do think we probably had the idea that it might be [more] targeted than it turned out to be. P9*

The lack of reliability of app-based data was mentioned frequently by Phase 2 respondents – how in some instances, with Android phones, there might be many 'pings' registered which upon examination turned out to be from people who were well outside the defined 'close contact' range. Conversely, and particularly with iPhones, the issue was too few or no 'pings' registering, even in instances where a case was with a person who they knew had the app.

> *We know it's missing people all the time. Cos you know, I can only really think of two occasions that we had to follow up so many contacts, and generally, there's a few, and we know sometimes that some of their contacts have the app because they tell us. "My wife's got the app". But there's no pings. Like, so we know that it's not helping us. P8*

There were two examples of situations in which the app had played a useful role. In one instance involving a complex case who had been to many venues during their infectious period, a pattern of 'pings' helped identify a venue that the case had not recalled (this same example was raised three times by different respondents). The second was regarding a workplace in which contacts had been assessed as casual, but a pattern of 'pings' caused this assessment to be revised.

Evaluation question 9h: What changes could be made to the app and contact tracing processes more generally to optimise their utility?

Respondents had a range of suggestions as to how the app could be improved. These included addressing the problems with sensitivity and specificity described above. It was noted that half the population has an iPhone, so not working well on these devices was problematic. While this problem could be ameliorated by increased training of app users to ensure that the app was on and working, user failure was only a small part of the more general problem.

> *A lot of things have to happen before a signal can be picked up. So the case has to have the app on, I understand, in the background [and] the contact has to have it on in the background…If either of those things don't happen, you won't detect it. So, the vast majority of interactions someone has, won't be detected by the app, so it's not very sensitive in that respect. P10*

Other implementation issues were related to security features and protocols, including requirements that prescribed the questions that staff involved in contact tracing could ask potential contacts identified from app data, and the lack of geolocation. Respondents argued that geolocation would mean that cases and their app-identified potential contacts would not have to remember where they were at particular time points.

> *Once you upload someone's data, the easiest thing to do to be able to say to the case "do you know someone called Bob Smith, do you know someone called Jane, who you saw on Saturday?" It would just make it so much quicker and easier. But we can't use it like that because we can't disclose the app data to the case themselves. P10*

The views expressed with regard to app improvement support the premise that contact tracing staff should be actively involved in the development and testing of technologies that are intended to assist their work.

Evaluation question 9i: What are the views of staff involved in contact tracing and other relevant public health staff regarding automated app-based contacts tracing in terms of public health benefits and acceptability?

Phase 2 respondents had detailed critiques of the app's failure to provide a user-friendly, reliable tool for assisting in contact tracing, given its issues with sensitivity, lack of geolocation and the security protocols that impede flows of communication both between staff units managing a case and between the staff involved in contact tracing and the case.

> *… So, you might have three names that you think are from the person's workplace, but if that workplace is in another Public Health Unit area, they will have been following up that workplace. And so, the easiest thing to do would be to just put those three names in an email and say, "just checking that these people are on your workplace list". But you can't do that. You have to get them to log into their app and sort of say "see the three people halfway down on your list" … P10*

Respondents understood that geolocation was sensitive from a privacy perspective, but believed that it would greatly increase the usefulness of app data.

> *At the moment we just get the time of an interaction and the two names. Whereas if you had the geolocation data and it had a dot for where that interaction was, it would just make things so much easier.*

Phase 2 respondents questioned the size of the investment in the app, in relation to what it had yielded in terms of useful data. The combination of technical difficulties with the app, and the security protocols that governed how app data were cross-checked against data from interviews and venue lists, were perceived as significant barriers to usefulness.

Several respondents also reported that many cases and contacts who had the app mistakenly believed that there was a geolocation element, and that this had been acceptable to them, raising the issue of whether an app with geolocation capacity might in fact be feasible.

> *Lots of people think that …, their locations are being monitored. P8*

The compulsory use of QR codes in venues was contrasted with the opt-in principle of the app.

> [QR code use] *is not an option, it is an obligation. We see the app as an opt-in. So it's always going to be partial, technological issues aside. P9*

Respondents were open to the concept of technologies that could support their work, so their criticisms of the app were specific to the current version of the technology and not indicative of negative attitudes towards such technologies in general.

Overall, respondents in both phases of the qualitative research were receptive and even excited by the idea of a technological tool that would assist with contact tracing. In particular, staff involved in contact tracing with no app experience imagined that the app could be very useful when cases had been in crowded places, to help identify close contacts unknown to the case.

User experience with the app punctured this enthusiasm, however. Although experienced public health staff did not expect that an app could replace contact tracing processes such as the case interview, there was an expectation that it could (or should) have been able to provide more usable data. The technological issues with the app were a key barrier, particularly the discrepancy between iPhones and Android phones. The iPhone issue may also have been amplified by user failure to have the app running at the appropriate times.

A further barrier to app utility was the security protocols, which prevented some forms of direct triangulation of data, which could have facilitated the process of cross-checking contacts across lists. This was a particular issue when app data were managed centrally and cases locally. The lack of uptake of app management by PHUs may be attributed to a lack of confidence, both in the ease of integrating app data into routine processes, and the ultimate value in doing so. The first issue could be addressed by training, using some form of 'dummy' app to build user confidence. The second is more complex, in that the evidence suggests that the app does not yield much useful data, at least in the circumstances under which it has been used in NSW so far.

Appendix 3: RECORD checklist

The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	Page 2 Page 2 n.a.
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			Page 5
Objectives	3	State specific objectives, including any prespecified hypotheses			Page 5,6
Methods					
Study Design	4	Present key elements of study design early in the paper			Page 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection			Page 6,7

Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case		RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	Page 7 n.a. n.a.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.		RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Page 7
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group			Page 7,8
Bias	9	Describe any efforts to address potential sources of bias			Page 12
Study size	10	Explain how the study size was arrived at			Page 8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			Page 8

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			Page 8
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population. RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	Page 15 Page 8
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	n.a.
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed)		RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.*, study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	Figure 1

		(b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram			
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)			Table 1 Page 8,9
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures			Page 9,10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period			Page 9,10
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses			n.a.
Discussion					
Key results	18	Summarise key results with reference to study objectives			Page 10

Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	Page 12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence			Page 13,14
Generalisability	21	Discuss the generalisability (external validity) of the study results			Page 13
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based			Page 2,8,15
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	Annex 1 Page 15

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.