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Research

Stemming the flow: how much can the Australian smartphone app help to control COVID-19?

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Key points

- We assessed the potential contribution of the COVIDSafe contact tracing app to the sustained control of COVID-19 following successful suppression of the pandemic in Australia during March–May 2020
- If a high level of community uptake can be achieved, the COVIDSafe app, combined with testing and social distancing, could have a valuable mitigating effect on a new wave of COVID-19 through enhanced and expedited case detection

Abstract

Objectives: Our objective is to assess the potential contribution of the Australian Government's mobile smartphone tracing app (COVIDSafe) to the sustained control of coronavirus disease 2019 (COVID-19).

Study type: Development and analysis of a system dynamics model.

Methods: To define the pandemic context and specify model-building parameters, we searched for literature on COVID-19, its epidemiology in Australia, case finding processes, and factors that might affect community acceptance of the COVIDSafe smartphone app for contact tracing. We then developed a system dynamics model of COVID-19 based on a modified susceptible–exposed–infected–recovered compartmental model structure, using initial pandemic data and published information on virus behaviour to determine parameter values. We applied the model to examine factors influencing the projected trends: the extent of viral testing, community participation in social distancing, and the level of uptake of the COVIDSafe app.

Results: Modelling suggests that a second COVID-19 wave will occur if social distancing declines (i.e. if the average number of contacts made by each individual each day increases) and the rate of testing declines. The timing and size of the second wave will depend on the rate of decrease in social distancing and the decline in testing rates. At the app uptake level of approximately 27% (current at 20 May 2020), with a monthly 50% reduction in social distancing (i.e. the average number of contacts per day doubling every 30 days until they reach pre-social distancing rates) and a 5% decline in testing, the app would reduce the projected total number of new cases during April–December 2020 by one-quarter. If uptake reaches the possible maximum of 61%, the reduction could be more than half.

Conclusions: Maintenance of a large-scale testing regimen for COVID-19 and widespread community practice of social distancing are vital. The COVIDSafe smartphone app has the potential to be an important adjunct to testing and social distancing. Depending on the level of community uptake of the app, it could have a significant mitigating effect on a second wave of COVID-19 in Australia.

Introduction

Australia adopted a rigorous policy of suppressing coronavirus disease 2019 (COVID-19) early in the pandemic. Strong national leadership and coordination, prompt interventions in all states and territories to restrict travel and human interaction, and an actively engaged population minimised COVID-19 incidence and mortality throughout Australia by mid-May 2020. In the absence of immunisation, relaxation of restrictions creates a risk of new waves of COVID-19, arising from either infected individuals in communities or travellers. An immediate goal is to find an allowable level of human interaction that supports continuation of social and economic activity.

Until now, most of the known cases in Australia either have been associated with clusters from circumscribed environments (e.g. cruise ships, aged-care facilities, workplaces) or have spread from infected travellers. Contact tracing and follow-up of most known cases have been achieved by Australia's well-organised public health services using conventional methods.[1]

Any future waves of COVID-19 in Australia will eventually spread from cases distributed throughout the population. Contact tracing for community cases is difficult. Infection may spread during encounters with individuals not known to the index case, who may be unaware of, or not remember, these encounters. Because individuals may be infectious while asymptomatic or presymptomatic, they can be unaware of the infective hazard they pose.

A smartphone app that can register other nearby smartphones has the potential to enhance case detection. A large proportion of Australian adults, particularly those moving about in the general community, use smartphones. The Australian Government introduced a smartphone contact tracing app (COVIDSafe) on 26 April 2020[2], relying on voluntary uptake.

Our aim is to assess the potential contribution of COVIDSafe to the sustained control of COVID-19. We developed a dynamic aggregate-level model that could be used to project trends in COVID-19 occurrence, and we applied the model to examine the factors that influence the projected trends.

Three features of COVID-19 are pertinent in assessing the app. First, individuals with COVID-19 may experience disease at all levels of clinical severity. Second, asymptomatic and presymptomatic individuals, as well as those with mild, moderate and severe disease, are infectious, and evidence suggests that presymptomatic cases may be highly infectious.[3] Third, the disease is easily spread by respiratory droplets, disseminated by exhalation, sneezing, coughing, hand-to-hand contact, or contamination of surfaces (e.g. handles, doorknobs, armrests). Voice projection, such as singing, may promote viral spread by aerosolisation of respiratory secretions.[4]

Most individuals with COVID-19 are symptomatic but have mild to moderate disease, often with coryza or influenza-like symptoms.[5] Those affected may therefore not be aware they could be infected and may not undergo testing. The clinical presentation can be surprising[6], and this may lead to delayed diagnosis, increasing opportunities for spread.

It is not clear whether infected individuals develop immunity to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), or whether the antibody response differs according to the severity of the clinical syndrome.[7] Vaccine development is in progress, but efficacy and safety testing and worldwide delivery of a vaccine may take at least a year.

Control of the COVID-19 pandemic relies on case finding, testing for infection and isolation of infected individuals. Case finding requires a capacity to detect infectious individuals in whom the illness may be covert or develop insidiously, as well as those with a variety of clinical syndromes.

COVIDSafe app

The Australian COVIDSafe app uses Bluetooth[8] sensing technology to recognise other smartphones on which the app has been downloaded, provided that the respective apps are switched on and the smartphones come within a set distance of each other for a set minimum time. Each user's app records the unique reference code of other nearby users and data necessary for contact tracing, including the date, time and duration of the encounter, and the distance between the smartphones. If any of the individuals carrying a smartphone with the activated app is found to have COVID-19, the others can be notified as contacts.[8] This does not depend on the index case knowing the others or remembering situations. Data generated by the app can only be decoded by designated state or territory health authorities that manage contact tracing. Whether decoded or not, the stored data are deleted from the smartphone after 3 weeks.

Early versions of the COVIDSafe app did not function reliably and, with some smartphone operating systems, the app tended to switch off when the device was locked.[9] Testing of recent software upgrades shows considerable improvements, and the affected smartphones can now be locked without switching off the app.[10]

Promotion of the app has stimulated debate on public health ethics and personal privacy.[11] The potential benefits of the app, which might be realised only if a second wave of COVID-19 occurs in Australia, must be weighed against the risk of breaches of privacy, which may be realised whether or not a second wave occurs. Privacy and security concerns are among the many factors affecting individuals' willingness to download the app.[12,13] The Australian Government has attempted to maximise data security and system integrity with legislation that restricts data transfer, storage, use and disposal.[14] Data from the app are relayed to and stored on a secure cloud site located in Australia.

Evaluation of security, and analysis of ethical and privacy considerations are beyond the scope of this paper, which concentrates on assessing the efficacy of the app.

Methods

Development of the system dynamics model

We developed a system dynamics model of COVID-19 based on a modified susceptible [S]–exposed [E]–infected [I]–recovered [R] (SEIR) compartmental model structure. To determine parameter values for the model, we used sociodemographic data that were current at the start of the pandemic in Australia, as well as published information on the behaviour and epidemiology of COVID-19 in Australia, the novel use of technology for contact tracing, community acceptance of contact tracing using a mobile phone app, and issues affecting community participation in epidemic control measures. Our search concentrated on the period November 2019 – May 2020.

The model primarily accounts for numbers of individuals of different infectious status, called stocks (e.g. the number of people infectious with COVID-19), and numbers transitioning between infectious states, called flows (e.g. the number of people becoming infectious). A flow rate is determined by probabilities of transitions, and in some cases also the time taken for the transition to occur (e.g. duration of the incubation period). Stocks and flows are summarised in Figure 1.

We modified the conventional SEIR structure to allow for the proportions of infectious cases at each stage of the disease who are either diagnosed with COVID-19 and isolated, or placed in 14-day quarantine after being in contact with a diagnosed case(s). We expanded the part of the model structure relating to infected people to account for transmission by asymptomatic infectious individuals[3], as well as for differences in care-seeking behaviour among symptomatic people in the early and later stages of disease.[15]

We calibrated the model using publicly available COVID-19 case counts in Australia up to 16 May 2020[16], stratifying the cases as locally acquired or coming from outside Australia. The calibrated model was then used to project future COVID-19 case counts under five scenarios. In these scenarios, we examined the effects of varying community participation in social distancing, tapering the amount of testing, and varying the uptake of the COVIDSafe smartphone tracing app by the Australian population. Variables relating to the introduction and effects of social distancing, overseas travel restrictions, test availability, contact tracing and the introduction of the tracing app were calibrated to match the actual dates of these initiatives in Australia (Table 1). For model construction and analysis, we used Stella Architect (Lebanon, NH: isee systems; Version 1.9.5), and we defined the modelling period as being from 1 January to 31 December 2020. A detailed description of the model structure and parameters is provided in the Technical Supplement (available from: www.saxinstitute.org.au/how-much-can-the-smartphone-help-control-covid19-supplement/).

Table 1. Significant Australian dates in the COVID-19 pandemic[17]

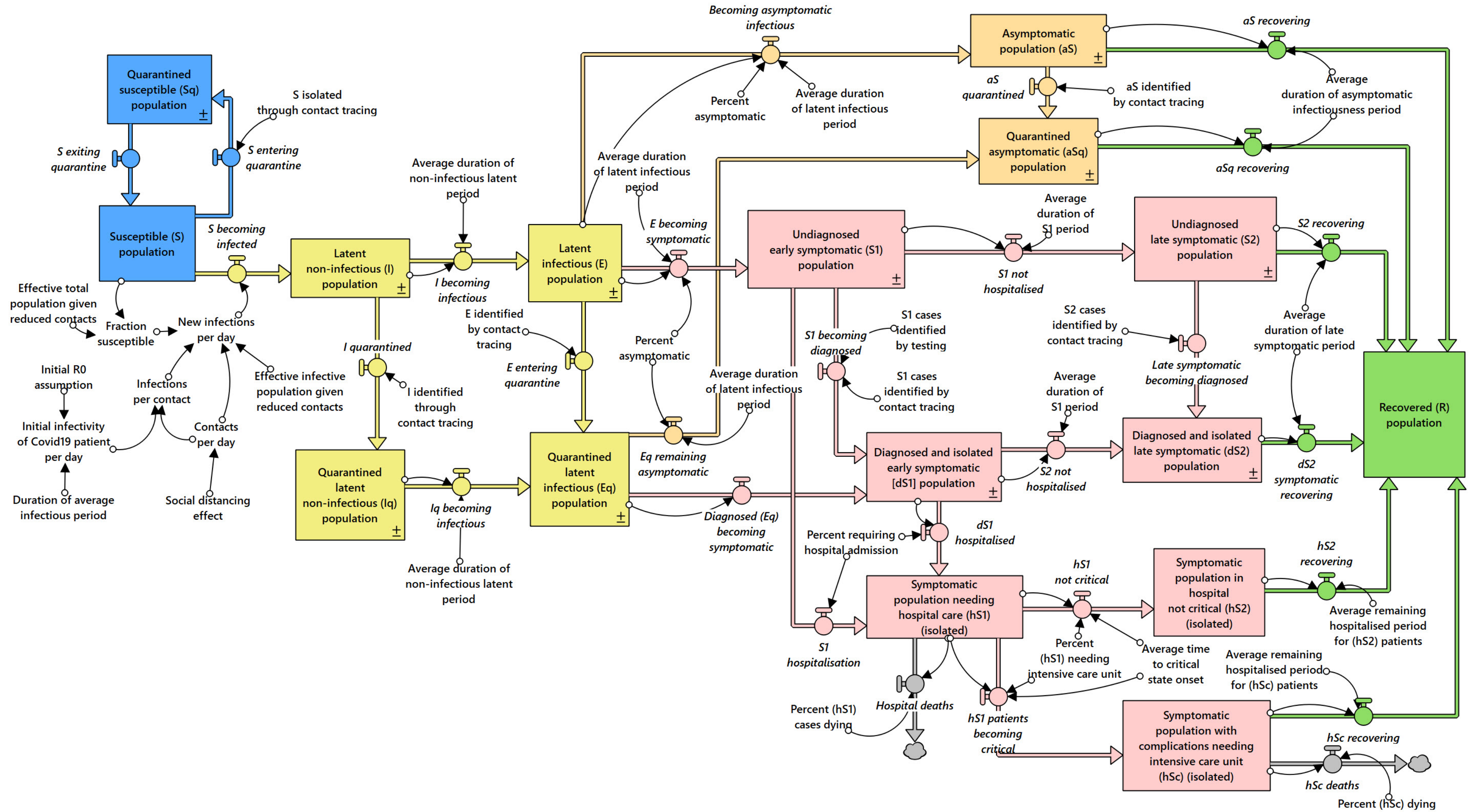
25 January 2020	First confirmed case in Australia notified
31 January	Restrictions on air travel from China introduced
29 February	Emergency Management Plan activated in Australia
1 March	First death from COVID-19 in Australia (imported case from cruise ship quarantined in Japan)
2 March	First confirmed cases of community transmission notified in Australia
19 March	Global Level 4 restrictions (‘Do not travel’) imposed on all international travel
19 March	Infected passengers from cruise ship Ruby Princess disembark in Sydney
20 March	Australia closes borders to all non-citizens and non-residents
23 March	Level 1[a] restrictions imposed (e.g. all clubs, restaurants, cinemas, places of worship, casinos and gyms closed)
25 March	Level 2[a] restrictions imposed (e.g. weddings restricted to five people, visiting others minimised)
29 March	All travellers returning from overseas quarantined for 14 days in a hotel or designated facility
30 March	Level 3[a] restrictions implemented (e.g. gatherings limited to two people; people may only leave their home for essential reasons)
24 April	Testing made available to anyone with respiratory symptoms
26 April	COVIDSafe smartphone app launched
8 May	Three-step national plan to relax restrictions announced

[a] Restrictions imposed by the Australian Government and implemented by states and territories with some differences

Trajectory of COVID-19 testing and community participation in social distancing

To use the model for projections of the pandemic in Australia with different levels of uptake of the smartphone app, we examined a range of hypothetical time trajectories relating to the intensity of COVID-19

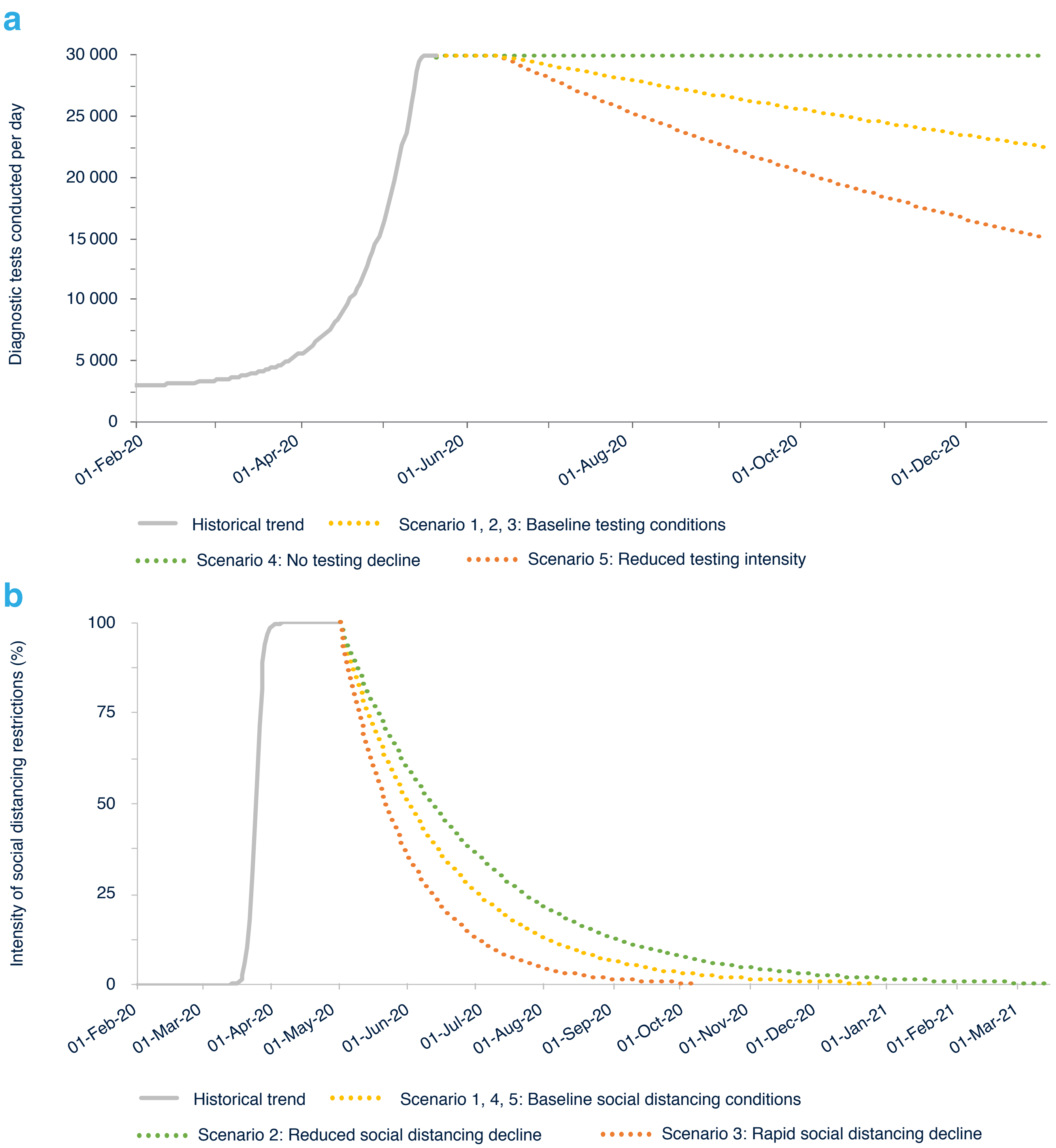
Figure 1. Simplified model structure of COVID-19 disease states



testing and social distancing. We expected that testing and participation in social distancing would decline as restrictions eased (Figure 2).

The default scenario for case finding of COVID-19 by reverse transcriptase polymerase chain reaction testing of pharyngeal secretions assumes that approximately 30 000 tests are conducted daily and that this level is maintained until mid-June 2020. We modelled three testing scenarios: 1) maintaining testing at May 2020 levels until December 2020 (no tapering), 2) testing levels tapering by 5% per month, and 3) testing levels tapering by 10% per month. The tapering rates simulate the possible decline in test-seeking due to a community perception of reduced risk because of a low incidence of COVID-19.

Figure 2. Projected hypothetical time trajectory scenarios for (a) COVID-19 diagnostic testing intensity and (b) intensity of population-wide social distancing measures



The extent of social distancing was specified from previous and current levels of participation in Australia, combined with the Australian Government's three-step plan for easing restrictions.[18] Social distancing began in mid-March 2020, and reached a peak by early April, remaining at this level until the end of April. The effect of social distancing was captured by scaling the reduction in the average number of contacts per day from 20[15] (representing pre-COVID-19 conditions) to 1.6 (representing one household member in the average Australian household[19]), based on the intensity of social distancing, assuming that 75% of the population are able to practise social distancing and 90% compliance is achieved in those who can. We allowed a 50% reduction in social distancing each month, following a negative exponential curve, and resulting in social distancing requirements being totally lifted by 31 December. Two further hypothetical social distancing scenarios were modelled: one with a more rapid reduction (a 50% reduction every 3 weeks), and another with a slower reduction maintained over time (a 50% reduction every 6 weeks). A 50% reduction in social distancing over 1 month, 3 weeks or 6 weeks means that the number of daily contacts made by individuals will, on average, double over that time period, starting from their most restricted contact rate at the height of government-ordered social distancing and rising to the pre-COVID-19 average contact rate of 20 contacts per person per day.

Application of the model

The model was used to simulate the potential effect of varying uptake levels of the COVIDSafe smartphone app on daily and cumulative COVID-19 case counts up to 31 December 2020 under different testing and social distancing scenarios. The effect of the app was estimated as the difference in the cumulative case count from the comparator scenario (no app use).

Projections for the cumulative number of COVID-19 cases from 27 April (the day after the app was launched) to 31 December 2020 were made for five levels of COVIDSafe app uptake:

- Zero uptake – the comparator for the other levels of uptake
- Low uptake – 27% of smartphone users aged 14 and over (6 million users)[20], the approximate uptake level as of 20 May 2020
- Medium uptake – 40%[21], an aspirational figure in early promotional material on the app that we assumed would be achieved 45 days from the release of the app
- High uptake – 61%, representing our best estimate of the proportion of the Australian population that has a smartphone, is in the age range likely to use the app (older than 14 years), and has sufficient technical literacy to download it
- Optimal uptake – 80%, an aspirational level that would require an increase in smartphone ownership.

We believe that the realistic range of uptake is 27–61%.

Projections were also made for five potential hypothetical intensity levels of government-ordered social distancing and diagnostic testing. These are shown in Figure 2:

- Scenario 1 is the baseline scenario. This is our best estimate of the ongoing situation, with a decline in social distancing of 50% and a decline in testing intensity of 5% every month
- In scenarios 2 and 3, the testing intensity decreases at the baseline rate of 5% every month, while social distancing declines more slowly (50% every 6 weeks) and more rapidly (50% every 3 weeks), respectively, than the baseline rate
- In scenarios 4 and 5, social distancing declines at the baseline monthly rate of 50%. In scenario 4, testing intensity does not decline at all; in scenario 5, testing intensity declines more rapidly (10% every month) than in scenarios 1 (baseline), 2 and 4.

Results

Under the baseline scenario (i.e. our estimate of the ongoing situation), modelled projection of historical daily and cumulative COVID-19 case notifications during 1 January to 5 June 2020 demonstrated strong model fit when plotted alongside publicly released figures[15] for the same period, as shown in Figure S1 of the Technical Supplement (available from: www.saxinstitute.org.au/how-much-can-the-smartphone-help-control-covid19-supplement/).

Projections to 31 December 2020 are displayed in Figure 3, and their implications are summarised in Table 2. In all five scenarios, the modelling projects a second wave of COVID-19 if the easing of restrictions continues. The size and timing of the second wave will depend on the rate of decrease of restrictions:

- In the baseline scenario, an app uptake of 61% has the potential to reduce the cumulative total number of new cases between the end of April and the end of December 2020 by more than half. Continuation of the 20 May app uptake level (27%) would reduce the total number of new cases by about one-quarter. These reductions would be achieved by means of earlier and/or more complete case detection and isolation
- With a slowed reduction in social distancing (50% every 6 weeks), coupled with testing intensity falling 5% each month, a 61% app uptake has the potential to reduce new cases by more than one-third, but a 27% app uptake would reduce new cases by just over one-eighth
- With a faster reduction in social distancing (50% every 3 weeks until September 2020), again coupled with testing intensity falling 5% each month, 61% uptake of the app would reduce the total number of new cases by almost three-fifths, while a 27% app uptake would reduce new cases by one-fifth

Figure 3. Projected cumulative COVID-19 case counts (left column) and daily new COVID-19 case counts (right column) in Australia for five levels of COVIDSafe app uptake under hypothetical (a) baseline, (b) slower easing of social distancing, (c) rapid easing of social distancing, (d) sustained diagnostic testing intensity, and (e) reduced diagnostic testing intensity scenarios

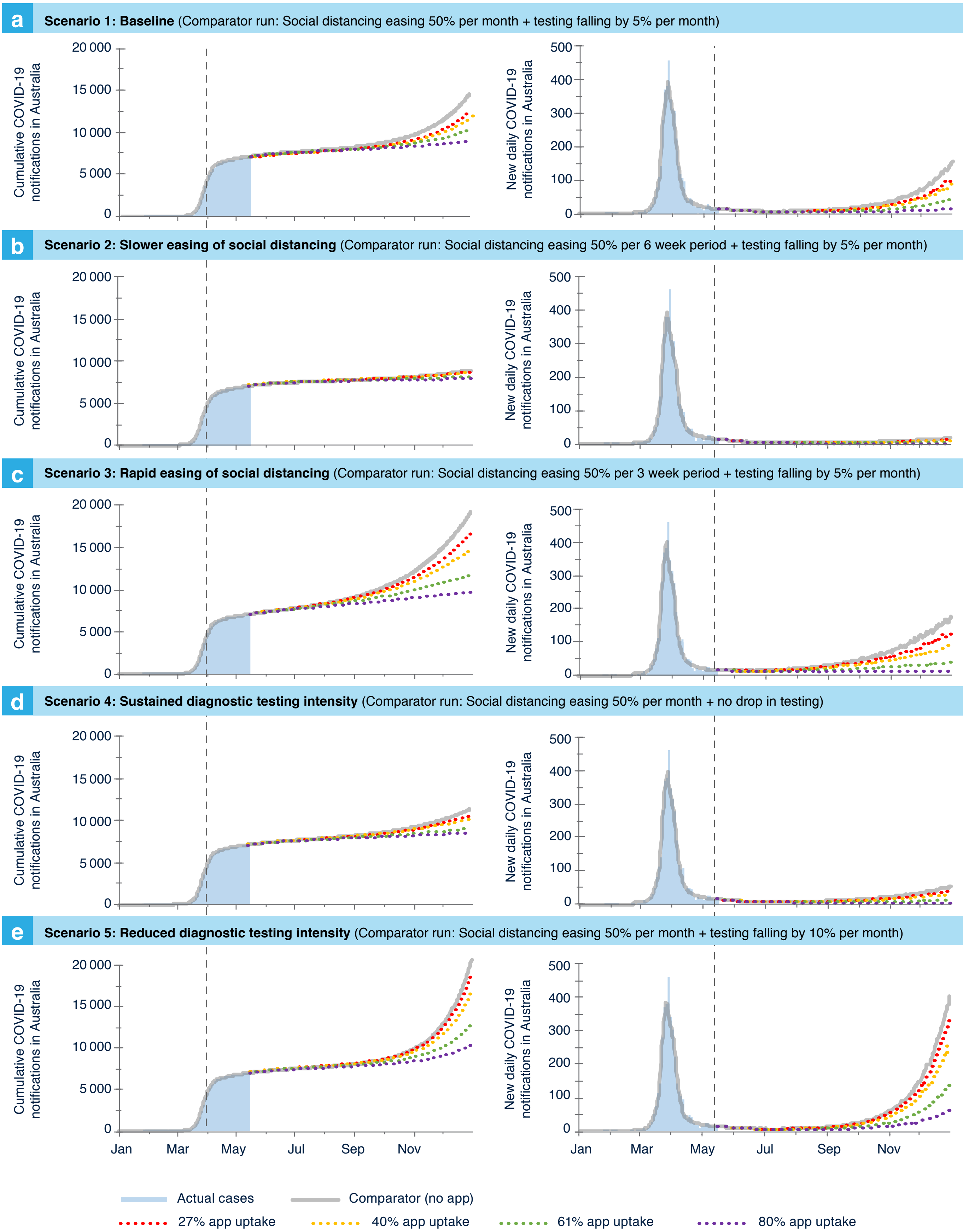


Table 2. Percentage change in cumulative COVID-19 case counts, Australia, 27 April – 31 December 2020, for different uptake levels of the tracing app

	Scenario 1: Baseline	Scenario 2: Slower easing of social distancing	Scenario 3: Rapid easing of social distancing	Scenario 4: Sustained intensity of diagnostic testing	Scenario 5: Reduced intensity of diagnostic testing
		Testing intensity declining at baseline rate		Social distancing declining at baseline rate	
App uptake	*n* (% change)	*n* (% change)	*n* (% change)	*n* (% change)	*n* (% change)
Comparator (no app)	7 800	2 200	12 500	4 500	14 000
27%	(–24%)	(–13%)	(–20%)	(–16%)	(–13%)
40%	(–32%)	(–17%)	(–35%)	(–24%)	(–28%)
61%	(–55%)	(–36%)	(–59%)	(–49%)	(–55%)
80%	(–71%)	(–47%)	(–76%)	(–62%)	(–73%)

- If testing intensity were sustained at the May 2020 level, coupled with a 50% monthly reduction in social distancing, 61% uptake of the app would reduce the total number of new cases by almost half, and 27% uptake by almost one-sixth
- If testing intensity fell more rapidly (10% per month), again coupled with a 50% monthly reduction in social distancing, 61% uptake of the app would reduce the total number of cases by more than half; 27% app uptake would reduce the total number of new cases by more than one-eighth
- In all scenarios, a high app uptake (61% or 80%) noticeably flattens the epidemic curve, giving time for the health system to respond and social distancing measures to be promoted.

These findings affirm that important factors associated with a second wave of COVID-19 in Australia are reduced testing intensity and reduced social distancing. The COVIDSafe app has the potential to moderate the size of the second wave. The effect of the app increases as its uptake increases, to a disproportionately greater extent than the increment in uptake.

Discussion and conclusions

The model suggests that the low Australian COVID-19 incidence and mortality during February–May 2020 are probably attributable to prompt restrictions on international travel, a high intensity of testing, efficient contact tracing and follow-up, rigorous enforcement of case isolation and quarantining of susceptible individuals, and widespread community engagement in social restrictions. Although apparently effective, some of these interventions are difficult to sustain. Restrictions on travel to, from and within Australia and the many different forms of social restrictions have had severe effects on employment and the economy, and cut deeply into societal norms. Capacity to increase the coverage of contact tracing is needed if a second wave of COVID-19 occurs. Our results show that the COVIDSafe smartphone app potentially has the capacity to contribute substantially to this.

Three important conclusions are projected on the occurrence of a second wave of COVID-19 in Australia. First, the maintenance of a large-scale testing regimen for SARS-CoV-2 infection in the Australian population is vital. Second, widespread community persistence with social distancing is very important. Third, the COVIDSafe app is a potentially valuable adjunct to testing and social distancing. If a high level of community uptake can be achieved, the app could have a mitigating effect on any new wave of COVID-19 by enhancing contact detection regardless of the presence or absence of individuals' symptoms.

The projections were developed for the present situation in which an effective vaccine against SARS-CoV-2 is unavailable. Even after a vaccine is available, the need for extensive testing and community-wide practice of social distancing may continue, and the app may continue to be an important adjunct to these measures. Whether induced by COVID-19 or a vaccine, the extent and duration of immunity to SARS-CoV-2 are uncertain. Coronaviruses have a history of mutation into harmful new antigenic forms.[22]

Our conclusions are drawn from aggregate-level dynamic modelling, and this has several limitations. Like all models, ours is based on a set of assumptions that were current when the model was developed. However, the pandemic pattern is constantly evolving, and the assumptions may or may not reflect conditions over the time period of the projections. Transmission pathways and symptoms of COVID-19 differ greatly among groups in the population.[23,24] The model is based on a population-wide 'average' disease profile and on behaviours generalised to the whole Australian population. The effect of the app may have been underestimated if the uptake is higher among younger people (aged under 65 years) and lower among older people, because younger people are likely to contribute more to disease transmission – they are more active and mobile. Also, the model does not account for events with low probability and large effect, such as simultaneous arrival of a large number of infected international travellers. An agent-based model that permits stratification on multiple variables and heterogeneous behaviours would enable a more detailed evaluation of public health strategies.

There are instances where the app may not work. For the app to be effective, a large proportion of the population must be motivated to download it on their smartphones, carry their smartphones and have the app switched on. The app's software and Bluetooth sensing system must operate reliably across different types of smartphones and settings, and health authorities' follow-up processes must be activated promptly and comprehensively. Communities must also have high levels of adherence to isolation requirements.

These conditions cannot necessarily be met population wide. The Australian community has concerns about personal privacy.[12] Although legislation for the COVIDSafe app addresses data security and privacy[14], it seems likely that these concerns may affect app uptake. Although the app would have benefits in a second wave of COVID-19, the current low incidence of COVID-19 in Australia may create a perception that a second wave will not occur, and this may militate against preparedness for a second wave.

Even if these concerns are set aside, we estimate that no more than 16 million Australians (approximately 61% of the population) will ever use the app, and not all users will be consistent and conscientious in their usage. The early technical limitations of the app may also have discouraged users, but improvements have been made, as noted above. However, the groups most likely to contract COVID-19 from community spread (people aged 15–65 years[16] who are mostly physically mobile and generally encounter larger numbers of other people) are also most likely to be 'smartphone aware', to be technically adept with smartphone apps, and to carry their smartphones at all times.[25] Promoting the app to these groups rather than the population as a whole is worth considering.

If an adequate uptake of COVIDSafe can be achieved, it has the potential to be an important component in the management of future waves of the COVID-19 pandemic. The app fits into and reinforces a cycle of complementary interventions. Its major contribution is likely to be in the extent and coverage of community case finding – helping to identify contacts not known to index cases and detecting infectious individuals who are asymptomatic or presymptomatic. In addition, it may help to speed up case finding. This could minimise the time between recognition of an infectious individual and the start of isolation, and increase contact tracing capacity, which may be necessary if large numbers of cases exceed health services' conventional contact tracing capacity. In the event of future waves of COVID-19, however, prevention will depend heavily on social distancing and a high intensity of testing. The app is a supplement to these measures, rather than a replacement for them. It is an insurance, not much utilised when the incidence of COVID-19 is low, but should be ready to contribute to contact tracing early during any resurgence of cases, when time is of the essence to control the pandemic.

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Peer review and provenance

Externally peer reviewed, not commissioned.

Competing interests

None declared.

Author contributions

DC conceived and developed the system dynamics model, led the writing of the methods section, constructed Table 2 and the three figures, and made major contributions to the writing of the results and discussion sections. CP contributed significantly to the conception and development of the system dynamics model, and the writing of the methods, results and discussion sections. DL made significant contributions to the overall direction of the project, contributed extensively to the analysis of the results of the modelling, and contributed to the writing of all sections of the paper. BJ conducted most of the literature review, constructed Table 1, wrote parts of the COVIDSafe app and discussion sections, and coordinated the work of the other authors. MF led the project overall, reviewed literature, and drafted the whole paper with contributions as above.

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