COVID-19 Evidence Update

COVID-19 Update from SAHMRI, Health Translation SA
and the Commission on Excellence and Innovation in Health

21 October 2020

Contact Tracing and COVID-19 SUPPLEMENT

To be read in conjunction with

Contact Tracing and COVID-19 (20 Aug 2020)

Executive Summary (2nd edition)

s1

This SUPPLEMENT reports on additional literature from an updated search of the literature on the topics of COVID-19 and contact tracing effectiveness, contact tracing strategies (forward; backward; multi-generational; digital), workforce skills, responses with priority and vulnerable populations and international examples of successes and failures in contact tracing.

Body of evidence:
The original search (August 2020) yielded 127 papers. 52 papers were classified as in scope for this evidence update, of which 25 (48%) were peer reviewed publications. There were 5 systematic reviews, 16 modelling studies, 31 observational studies, commentaries and reports. The World Health Organization [1], the US Centres for Disease Control and Prevention [2] and the European Centre for Disease Prevention and Control [3] have released contact tracing instructions and guidelines.

The supplementary search (October 2020) yielded 113 new references (plus two references which have gone from pre-print to peer-reviewed [refs 10 & 12 from original Evidence Update], all of which were reviewed and 89 of which are in-scope for this topic. Overall, 28 new articles address the effectiveness or impact of contact tracing; and 61 articles cover digital contact tracing.

Key findings (both searches):

- Nearly all studies that have assessed effectiveness (observational and modelling) indicate that **contact tracing**, in combination with other strategies (e.g. testing, isolation, social distancing), **is associated with better control of COVID-19.**
- Contact tracing has the most benefit when secondary cases are identified and isolated before they become infectious.
- A systematic review concluded that contact tracing effectiveness is maximised when the time from symptom development to isolation occurs **within 2-3 days** and **80% of close contacts are quarantined** [4].
- Contact tracing is less effective when there are delays to testing and obtaining results, when the case numbers surge beyond the capacity of the tracing system, and when most contacts cannot be traced.

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- **Delays of 4+ days** or **less than 60% of contacts successfully quarantined** may not meaningfully control transmission [4].
- In the wider literature, there is growing evidence of **super-spreading events** driving SARS-CoV-2 transmission (e.g. [s90]). In light of this, the importance of **backwards contact tracing** is increasingly being emphasised as it identifies a larger fraction of the transmission chain originating from a primary case. Only 2 pre-print modelling studies have assessed backwards contact tracing but both indicate that it is an efficient and effective strategy in identifying clusters of cases and preventing further transmission. [22, s23].

Policy strategies that complement contact tracing:
- The effectiveness of contact tracing also depends on achieving high quarantine compliance [5].
- Limits on social gatherings can reduce the burden on contact tracing [6].
- Contact tracing multiple generations of contacts can reduce the size of an outbreak but comes at the cost of quarantining a large proportion of a local population (in essence, becoming a local lockdown).
- Physical distancing in conjunction with contact tracing may achieve similar results without needing to quarantine as many people [7].

Technological complements
- Evidence on the effectiveness of automated or digital contact tracing is **scarce**.
- The available evidence suggests that high population uptake of apps is necessary, as both the case and the contact need to have the technology enabled, and it should be supplemented with manual tracing.
- Contact tracing apps are most useful when they allow instantaneous notification of contact with a positive case, with a rapid follow-up call by a public health official [8].
- Telecommunication provider-based measures are more efficient than voluntary-based digital tools (such as apps) [9].
- Trust in government and privacy concerns are barriers to digital tracing techniques, notably in Western countries.

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International Experience:
- Contact tracing strategies have been used to control COVID-19 successfully in a number of countries, some of which are more technologically driven (e.g. South Korea, Taiwan) whereas others have invested heavily in manual contact tracing systems through the deployment of a range of people (e.g. university students) to help (e.g. New Zealand, Germany).
- Contact tracing has <u>not worked effectively</u> in the UK and the US for a range of reasons, including **under-resourcing**, **delays in testing and obtaining results**, **relaxing social distancing measures while extensive community transmission was still occurring.**

Aboriginal and Torres Strait Islander communities:
- A modelling study of remote Australian Aboriginal and Torres Strait Islander communities showed that a contact tracing strategy that resulted in quarantining extended household members (i.e. residents of all dwellings used by the case) was more effective than immediate household or history-based contact tracing strategies [s21].

Prioritising groups:
- There is very little evidence discussing prioritising of different contacts. The US CDC recommend prioritising contacts when resources are scarce and provide a 4-tier hierarchy.
- Some difficulties have been reported when people have been reluctant to participate in contact tracing (e.g. outbreak in South Korea linked to nightclubs). There is an absence of evidence about novel strategies for contacts tracing during COVID-19, to minimise the impact of deliberate non-disclosure of contacts.

Summary of Key Evidence (Supplementary Search Only)

Effectiveness/impact of contact tracing - observational studies

s1. Malheiro R, Figueiredo AL, Magalhães JP, Teixeira P, Moita I, Moutinho MC, et al. Effectiveness of contact tracing and quarantine on reducing COVID-19 transmission: a retrospective cohort study. Public Health. 2020.

- Compared cases subjected to contact tracing and quarantine to those not subjected to these conditions on number of secondary cases per index case (primary outcome) and time from symptom onset to specimen collection and the number of secondary cases (secondary outcome). There was no difference between groups on primary outcome. Those subjected to contact tracing and quarantine had a shorter time between symptom onset and specimen collection and fewer close contacts. Study was conducted in Portugal and results may have been influenced by household size and timing of the declaration of the State of Emergency.

s2. Smith, L.E., et al., Adherence to the test, trace and isolate system: results from a time series of 21 nationally representative surveys in the UK (the COVID-19 Rapid Survey of Adherence to Interventions and Responses [CORSAIR] study). medRxiv, 2020: p.020.09.15.20191957.

- Time series of cross-sectional online surveys conducted between 2 March and 5 August 2020 in the UK (n=42,127). Only 48.9% of participants identified key symptoms of COVID-19. Self-reported adherence to test, trace and isolate behaviours was low (self-isolation 18.2%; requesting an antigen test 11.9%; quarantining 10.9%). Non-adherence was associated with: men, younger age groups, having a dependent child in the household, lower socio-economic grade, greater hardship during the pandemic, and working in a key sector. Intentions were higher; intention to self-isolate if they were to develop symptoms was around 70%, requesting an antigen test increased from around 35% to 50%, intention to share details of close contacts was 76.1%, intention to quarantine was around 65%.

Effectiveness/impact of contact tracing - modelling studies

Peer reviewed modelling studies supportive of finding reported in previous briefing

s3. Aleta A, Martín-Corral D, Pastore YPA, Ajelli M, Litvinova M, Chinazzi M, et al. Modelling the impact of testing, contact tracing and household quarantine on second waves of COVID-19. Nat Hum Behav. 2020;4(9):964-71.

s4. Arshed N, Meo MS, Farooq F. Empirical assessment of government policies and flattening of the COVID19 curve. J Public Aff. 2020:e2333.

s5. Bi, Q., et al., Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study. Lancet Infect Dis, 2020. 20(8): p. 911-919.

s6. Bilinski A, Mostashari F, Salomon JA. Modeling Contact Tracing Strategies for COVID-19 in the Context of Relaxed Physical Distancing Measures. JAMA network open. 2020;3(8):e2019217-e.

s7. Chiu, W.A., R. Fischer, and M.L. Ndeffo-Mbah, State-level needs for social distancing and contact tracing to contain COVID-19 in the United States. Nature Human Behaviour, 2020: p. 1-11.

s8. Kinoshita, R., et al., Containment, Contact Tracing and Asymptomatic Transmission of Novel Coronavirus Disease (COVID-19): A Modelling Study. J Clin Med, 2020. 9(10).

s9. Min, K.D., et al., Estimating the Effectiveness of Non-Pharmaceutical Interventions on COVID-19 Control in Korea. Journal of Korean medical science, 2020. 35(35): p. E321.

Pre-print modelling studies <u>supportive</u> of finding reported in previous briefing

s10. Davis EL, Lucas TCD, Borlase A, Pollington TM, Abbott S, Ayabina D, et al. An imperfect tool: COVID-19 'test & trace' success relies on minimising the impact of false negatives and continuation of physical distancing. medRxiv. 2020:2020.06.09.20124008.

s11. Eilersen, A. and K. Sneppen, Cost-benefit of limited isolation and testing in COVID-19 mitigation. medRxiv, 2020: p. 2020.04.09.20059790.

s12. Gardner BJ, Kilpatrick AM. Contact tracing efficiency, transmission heterogeneity, and accelerating COVID-19 epidemics. medRxiv. 2020:2020.09.04.20188631.

s13. Geffen, N. and M.O. Low, Isolation of infected people and their contacts is likely to be effective against many short-term epidemics. medRxiv, 2020: p. 2020.10.07.20207845.

s14. Grantz KH, Lee EC, Agostino McGowan L, Lee KH, Metcalf CJE, Gurley ES, et al. Maximizing and evaluating the impact of test-trace-isolate programs. medRxiv. 2020:2020.09.02.20186916.

s15. Johnson, K.E., et al., This time is different: model-based evaluation of the implications of SARS-CoV-2 infection kinetics for disease control. medRxiv, 2020: p. 2020.08.19.20177550.

s16. Kerr, C.C., et al., Controlling COVID-19 via test-trace-quarantine. medRxiv, 2020: p. 2020.07.15.20154765.

s17. Knudsen R. Testing for tracing or testing just for treating? A comparative analysis of strategies to face COVID-19 pandemic. medRxiv. 2020:2020.06.01.20119123.

s18. Low, M.O. and N. Geffen, Contact tracing and isolation reduces Covid-19 incidence in a structured agent-based model. medRxiv, 2020: p. 2020.10.06.20207761.

s19. Quilty, B.J., et al., Quarantine and testing strategies in contact tracing for SARS-CoV-2. medRxiv, 2020: p. 2020.08.21.20177808.

s20. Stuart, R.M., et al., Robust test and trace strategies can prevent COVID-19 resurgences: a case study from New South Wales, Australia. medRxiv, 2020: p. 2020.10.09.20209429.

Additional noteworthy findings

s21. Hui, B.B., et al., Modelling testing and response strategies for COVID-19 outbreaks in remote Australian Aboriginal communities. medRxiv, 2020: p. 2020.10.07.20208819.

- Modelled public health strategies in **remote Australian Aboriginal and Torres Strait Islander communities**. Results: Of the contact tracing strategies, quarantining extended household members (residents of all dwellings used by the case) is the most effective strategy for constraining the initial outbreak, reducing peak prevalence from 60-70% to ~10% (compared to immediate household and history-based contact tracing). However, large numbers of people must be quarantined for extended periods and infections may resurge when community mixing resumes, with overall community attack rates exceeding 80%. Clearance testing modestly reduces this attack rate to 65%. Lockdown of all non-quarantined households for 14 days, concurrent with this quarantine strategy, results in the greatest likelihood of definitive outbreak control.

s22. Kim J, Chen X, Bidokhti SS, Sarkar S. Tracing and testing the COVID-19 contact chain: cost-benefit tradeoffs. medRxiv. 2020:2020.10.01.20205047.

- Assessed the cost-benefit to contact **tracing multiple generations of contacts**. Results indicate that testing the contact chain can reduce the cumulative infection count and testing load. There are diminishing returns beyond contacting tertiary contacts.

s23. Kojaku S, Hébert-Dufresne L, Ahn Y-Y. The effectiveness of backward contact tracing in networks. arXiv preprint arXiv:02362. 2020.

- Using simulations on synthetic and high-resolution empirical contact datasets, results indicated that even at a small probability of detecting infected individuals, strategically executed **backward contact tracing** can prevent a significant fraction of further transmissions. The effectiveness and efficiency hinge upon the fact that backward tracing can detect super-spreading events exceptionally well.

Pre-print modelling studies that were inconsistent with findings reported in previous briefing

s24. Haug N, Geyrhofer L, Londei A, Dervic E, Desvars-Larrive A, Loreto V, et al. Ranking the effectiveness of worldwide COVID-19 government interventions. medRxiv. 2020:2020.07.06.20147199. (Pre-print)

- Compared the effect on the effective reproductive number of a large range of non-pharmaceutical interventions using data from 79 territories. Results indicate that a combination of strategies are needed, with local context and phase of epidemic important factors to consider. **Contact tracing ranked low in effectiveness**. However, it was noted in the discussion that it was **effective at the country level** when implemented early but was **not effective during March and April 2020 when testing and tracing capacity was exceeded in many countries**.

s25. Liu, Y., et al., The impact of non-pharmaceutical interventions on SARS-CoV-2 transmission across 130 countries and territories. medRxiv, 2020: p. 2020.08.11.20172643. (Pre-print)

- Based on OxCGRT multi-country data, not able to uncover evidence that supports the effectiveness of contact tracing and testing policies. This may be due to the way the policy was constructed for analysis.

Effectiveness/impact of contact tracing – Commentaries

s26. Bright, D., et al., COVID-19 contact tracing: The Welsh experience. Public Health in Practice, 2020. 1: p. 100035.

- Presents a summary of lessons learned from contact tracing experience in **Wales**, UK. Focusses on **staff training and mobilisation**.

s27. Rubin, G.J., et al., Improving adherence to 'test, trace and isolate'. Journal of the Royal Society of Medicine, 2020. 113(9): p. 335-338.

- Adherence to the test, trace and isolate system will be improved if we ensure that people understand exactly when and how to act, are motivated by perceived personal and sociocultural benefits, and are helped to overcome the many practical and social barriers to adherence.

s28. Schneider, J.A. and H.A. Pollack, Flipping the Script for Coronavirus Disease 2019 Contact Tracing. JAMA Health Forum, 2020. 1(9): p. E201129-e201129.

- In the **US**, on-the-ground experience suggests that a more pragmatic vision rooted in social determinants is needed. This requires changing the way that contact tracing engages communities and providing tools to support them to self-isolate. Tools include information, resources relating to food, housing, money, employment, health insurance and access to medical care.

Digital contact tracing – Observational studies

s29. Salathé, M., et al., Early Evidence of Effectiveness of Digital Contact Tracing for SARS-CoV-2 in Switzerland. medRxiv, 2020: p. 2020.09.07.20189274.

- Reports on the early findings of a digital contact tracing app deployment in **Switzerland** (July 23 to Sept 10). The study demonstrates a **proof-of-principle** that digital contact tracing reaches exposed contacts, who then test positive for SARS-CoV-2. This indicates that digital contact tracing is an effective complementary tool for controlling the spread of SARS CoV-2. Continued technical improvement and international compatibility can further increase the efficacy.
    - The Exposure Notification (EN) framework, jointly developed by Google and Apple, addresses concerns about confidentiality and privacy, as data remains on the user's device.
    - By September 10, 2020, the SwissCovid app has been downloaded 142 2.36 million times, and the number of active apps per day has been estimated at 1.62 million, corresponding to 18.9% of the Swiss population.

s30. Huang, Z., et al. (2020). "Performance of digital contact tracing tools for COVID-19 response in Singapore." JMIR Mhealth Uhealth.

- **Singapore** clinical setting contact tracing study. This study compared the performance of the contact tracing app-"TraceTogether" with a **wearable tag-based Real-Time Locating System** and validate them against the Electronic Medical Records at the National Centre for Infectious Disease (NCID), the national referral center for COVID-19 screening. The "TraceTogether" had a much lower sensitivity than tag-based RTLS in identifying patient contacts in a clinical setting. Although tag-based RTLS performed well for contact tracing in the clinical setting, its implementation in the community would be more challenging than "TraceTogether".

Digital contact tracing – Modelling studies

s31. Nuzzo, A., et al., Universal Shelter-in-Place Versus Advanced Automated Contact Tracing and Targeted Isolation: A Case for 21st-Century Technologies for SARS-CoV-2 and Future Pandemics. Mayo Clinic proceedings, 2020. 95(9): p. 1898-1905.

- Modelled and compared effect of digital contact tracing versus shelter-in-place on SARS-CoV-2 transmission. Digital contact tracing system: **assumed an automatic system alerted exposed individuals to self-isolate**. Digital contact tracing with **targeted self-isolation achieves reduction in infected and exposed individuals similar to shelter-in-place** without impacting a large number of individuals. For example, a **50% adoption rate mimics a shelter-in-place order for 40% of the population** and results in a greater than 90% decrease in peak number of infections.

s32. Ferrari, A., et al., Simulating SARS-CoV-2 epidemics by region-specific variables and modeling contact tracing App containment. medRxiv, 2020: p. 2020.05.14.20101675. (Pre-print)

- Proof-of-concept study that modelled the impact of a contact-tracing app in a number of scenarios using demographic and mobility data from Italy and Spain. Results indicate that app-mediated contact-tracing can successfully mitigate the epidemic even with a relatively small fraction of users, and even suppress altogether with a larger fraction of users. However, population density and transportation was also important. In all scenarios suppression was easily attained in the less densely populated regions, whereas it failed in the others.

s33. Braun, P., S. Haffner, and B.G. Woodcock, COVID-19 pandemic predictions using the modified Bateman SIZ model and observational data for Heidelberg, Germany: Effect of vaccination with a SARS-CoV-2 vaccine, coronavirus testing and application of the Corona-Warn-App. International journal of clinical pharmacology and therapeutics, 2020. 58(8): p. 417-425.

- Modelled the effects of interventional measures to control the COVID-19 pandemic in the future in Germany. Results indicated that lockdown measures alone are insufficient to control the pandemic during 2021. Vaccination, diagnostic tests, and use of the Corona-Warn-App with quarantine could successfully control the spread of the coronavirus infection in the community. The Corona-Warn-App applied correctly may be the most effective.

s34. Kim, H. and A. Paul, Automated Contact Tracing: a game of big numbers in the time of COVID-19. medRxiv, 2020: p. 2020.04.22.20071043. (Pre-print)

- Modelled automatic contact tracing. Authors concluded that relying largely on automated contact tracing without population-wide participation to contain the spread of the SARS-CoV-2 pandemic can be counterproductive and allow the pandemic to spread unchecked. The simultaneous implementation of various mitigation methods along with automated contact tracing is necessary for reaching an optimal solution to contain the pandemic.

s35. Bianconi, A., et al. (2020). "Efficiency of Covid-19 mobile contact tracing containment by measuring time dependent doubling time." Phys Biol.

- Analysis of data from epidemics / modelling study using data from 7 countries' actual outbreaks. Authors demonstrate that countries that selected and adopted advanced technologies i.e., the containment policy Lockdown, case Finding, mobile Tracing (LFT) **with mandatory "mobile contact tracing"** have been able to **reduce both the peak and the width of the epidemic** dome of the daily positive case curve of the Covid-19.
- The reduction of the time duration of the lockdown obtained by mandatory "contact tracing" was found to have minimized the impact on the economy keeping the manufacture close for a shorter time. The number of **fatalities per million people over 100 days**, covering the full width of the first wave, has been **more than a factor 100 smaller than in the countries, which have not used mandatory mobile contact tracing**.

s36. Ivers, L. C. and D. J. Weitzner (2020). "Can digital contact tracing make up for lost time?" The Lancet. Public health 5(8): e417-e418.

- Editorial - on modelling study in original Evidence Update (Kretzschmar et al [10])

s37. Plank, M. J., et al. (2020). "Potential reduction in transmission of COVID-19 by digital contact tracing systems." medRxiv: 2020.2008.2027.20068346. (Pre-print)

- Modelling study quantifying the impact on R of manual and digital contact tracing. The authors use an age-structured branching process model of the transmission of COVID-19 in different settings to estimate the potential of manual contact tracing and digital tracing systems to help control the epidemic. The authors investigate the effect of the uptake rate and proportion of contacts recorded by the digital system on key model outputs: the effective reproduction number, the mean outbreak size after 30 days, and the probability of elimination. The authors show that **effective manual contact tracing** can reduce the

effective reproduction number from 2.4 to around 1.5. The **addition of a digital tracing system** with a high **uptake rate over 75%** could further reduce the **effective reproduction number to around 1.1**.

s38. Pollmann, T. R., et al. (2020). "The impact of digital contact tracing on the SARS-CoV-2 pandemic - a comprehensive modelling study." medRxiv: 2020.2009.2013.20192682. (Pre-print)

s39. Urbaczewski, A. and Y. J. Lee (2020). "Information Technology and the pandemic: a preliminary multinational analysis of the impact of mobile tracking technology on the COVID-19 contagion control." European Journal of Information Systems: 1-10.

- Examines the effectiveness of voluntary and mandatory mobile contact-tracing apps by COVID-19-positive or suspected positive individuals in China, Germany, Italy, Singapore, South Korea, and the United States. Through a Difference-In-Differences test, the apps were found to be highly significantly correlated with a reduction in the spread of COVID-19 in countries which mandated apps (Singapore and Sputh Korea). The difference in average log (number of cases per day) by COVID-19-app before and after the time of launching the app are statistically significant (Before: −1.984 and After: −3.168, $p < 0.001$). The impact of mobile tracking technology (COVID-19-App) is highly significant. In other words, having **mandatory mobile tracking and monitoring of people who are or may be COVID-19-positive** may **reduce new cases per day by 3.3 on average**, *ceteris paribus*.

Digital contact tracing – Future technology solutions to overcome privacy concerns

s40. Whaiduzzaman, M., et al., A Privacy-preserving Mobile and Fog Computing Framework to Trace and Prevent COVID-19 Community Transmission. IEEE J Biomed Health Inform, 2020

s41. Alam, T., Coronavirus Disease (Covid-19): Reviews, Applications, and Current Status. Applications, and Current Status (July 25, 2020), 2020.

Digital contact tracing - Ethics of digital tracing technologies

s42. Klenk, M. and H. Duijf, Ethics of digital contact tracing and COVID-19: who is (not) free to go? Ethics Inf Technol, 2020: p. 1-9.

s43. Ryan, M., In defence of digital contact-tracing: human rights, South Korea and Covid-19. International Journal of Pervasive Computing and Communications, 2020. 16(4): p. 383-407.

s44. Nijsingh, N., A. van Bergen, and V. Wild, Applying a Precautionary Approach to Mobile Contact Tracing for COVID-19: The Value of Reversibility. J Bioeth Inq, 2020: p. 1-5.

s45. Ansari, R., Secure Digital Contact Tracing Methods Are Necessary for Slowing Down COVID-19. Pop Culture Intersections, 2020(46).

s46. Altshuler, T. and R. Hershkovitz, Digital Contact Tracing and the Coronavirus: Israeli and Comparative Perspectives. GOVERNANCE, 2020.

s47. Bodie, M.T. and M. McMahon, Employee Testing, Tracing, and Disclosure as a Response to the Coronavirus Pandemic. Washington University Journal of Law and Policy, 2020. 64.

Digital contact tracing - Narrative reviews and Commentaries of apps and other technologies

These papers overview the different apps that have been developed and deployed around the world and the digital architecture that underpins the different apps. They outline the opportunities for advancing contact tracing

offered by these digital solutions, and also cover the technical, legal, ethical and socio-cultural impediments to uptake (in Western and Asian countries).

s48. Azad, M. A., et al. (2020). "A First Look at Privacy Analysis of COVID-19 Contact Tracing Mobile Applications." IEEE Internet of Things Journal: 1-1.

s49. Basu, S. "Effective contact tracing for COVID-19 using mobile phones: An ethical analysis of the mandatory use of the Aarogya Setu application in India." Cambridge Quarterly of Healthcare Ethics: 1-15.

s50. Berglund, J. (2020). "Tracking COVID-19: There's an App for That." IEEE Pulse 11(4): 14-17.

s51. Buchanan, W. J., et al. (2020). "Review and Critical Analysis of Privacy-preserving Infection Tracking and Contact Tracing." arXiv preprint arXiv:2009.05126. Preprint

s52. Budd, J., et al. (2020). "Digital technologies in the public-health response to COVID-19." Nat Med 26(8): 1183-1192.

s53. Cheng, W. and C. Hao (2020). "Case-Initiated COVID-19 Contact Tracing Using Anonymous Notifications." JMIR mHealth and uHealth 8(6): e20369.

s54. Collado-Borrell, R., et al. (2020). "Features and Functionalities of Smartphone Apps Related to COVID-19: Systematic Search in App Stores and Content Analysis." J Med Internet Res 22(8): e20334.

s55. Dar, A. B., et al. (2020). "Applicability of mobile contact tracing in fighting pandemic (COVID-19): Issues, challenges and solutions." Computer Science Review 38: 100307..

s56. DeWitt, M. E. (2020). "Automatic Contact Tracing for Outbreak Detection Using Hospital Electronic Medical Record Data." medRxiv: 2020.2009.2008.20190876. Pre-print

s57. Grantz, K. H., et al. (2020). "The use of mobile phone data to inform analysis of COVID-19 pandemic epidemiology." Nat Commun 11(1): 4961.

s58. Hegde, A. and R. Masthi (2020). "Digital Contact tracing in the COVID-19 Pandemic: A tool far from reality." Digit Health 6: 2055207620946193.

s59. Jaca, A., et al. (2020). "Cochrane corner: digital contact tracing technologies in epidemics." The Pan African Medical Journal 37(8).

s60. Jahnel, T., et al. (2020). "[Contact-Tracing Apps in Contact Tracing of COVID-19]." Gesundheitswesen 82(8-09): 664-669.

s61. Jalabneh, R., et al. (2020). "Use of mobile phone apps for contact tracing to control the COVID-19 pandemic: A literature review." Anwarul, Use of Mobile Phone Apps for Contact Tracing to Control the COVID-19 Pandemic: A Literature Review (July 1, 2020). Doi. org/10.1016/j. arcmed 15.

s62. Jian, S. W., et al. (2020). "Contact tracing with digital assistance in Taiwan's COVID-19 outbreak response." Int J Infect Dis.

- Documents **Taiwan's** process and **high success**.

s63. John Leon Singh, H., et al. (2020). "Mobile Health Apps That Help With COVID-19 Management: Scoping Review." JMIR Nurs 3(1): e20596.

s64. Leslie, M. (2020). "COVID-19 Fight enlists digital technology: Contact tracing apps." Engineering (Beijing).

- Discussion piece about different countries' apps, includes the work of **Apple and Google**.

s65. Lucivero, F., et al. (2020). "COVID-19 and Contact Tracing Apps: Ethical Challenges for a Social Experiment on a Global Scale." J Bioeth Inq: 1-5.

s66. Martin, T., et al. (2020). "Demystifying COVID-19 digital contact tracing: A survey on frameworks and mobile apps." arXiv preprint arXiv:2007.11687. (Pre-print) s67. Mbunge, E. (2020). "Integrating emerging technologies into COVID-19 contact tracing: Opportunities, challenges and pitfalls." Diabetes Metab Syndr 14(6): 1631-1636.

s68. Nakamoto, I., et al. (2020). "A QR Code-Based Contact Tracing Framework for Sustainable Containment of COVID-19: Evaluation of an Approach to Assist the Return to Normal Activity." JMIR mHealth and uHealth 8(9): e22321.

- Describes **QR codes** ascribed to individuals in China as **COVID-status ID** - green for not infected, **Orange for infected or high risk**. (high risk includes contact with known case, from high-risk area, and/or purchasing “anti-fever medication”).

s69. Owusu, P. N. (2020). "Digital technology applications for contact tracing: the new promise for COVID-19 and beyond?" Glob Health Res Policy 5: 36

s70. Prabu, S., et al. (2020). "Mobile technologies for contact tracing and prevention of COVID-19 positive cases: a cross-sectional study." International Journal of Pervasive Computing and Communications.

s71. Ramakrishnan, A. M., et al. (2020). "From Symptom Tracking to Contact Tracing: A Framework to Explore and Assess COVID-19 Apps." Future Internet 12(9): 153.

s72. Riemer, K., et al. (2020). "Digital contact-tracing adoption in the COVID-19 pandemic: IT governance for collective action at the societal level." European Journal of Information Systems: 1-15.

s73. Roche, S. (2020). "Smile, you’re being traced! Some thoughts about the ethical issues of digital contact tracing applications." Journal of Location Based Services 14(2): 71-91.

s74. Schneble, C. O., et al. (2020). "Data protection during the coronavirus crisis." EMBO reports 21(9): e51362.

s75. Skoll, D., et al. (2020). "COVID-19 Testing and Infection Surveillance: Is a Combined Digital Contact Tracing and Mass Testing Solution Feasible in the United States?" Cardiovascular Digital Health Journal.

s76. Tibbetts, J. H. (2020). "Researchers Continue Quest to Contain Spread of COVID-19: Digital technologies aim to accelerate contact tracing." BioScience 70(8): 633-639.

s77. Uohara, M. Y., et al. (2020). "The Essential Role of Technology in the Public Health Battle Against COVID-19." Popul Health Manag 23(5): 361-367.

- Written by Microsoft authors. Includes a small amount on contact tracing. “The authors share the Microsoft perspective and illustrate how technology has helped transform the public health landscape with new and refined capabilities”

s78. Whitelaw, S., et al. (2020). "Applications of digital technology in COVID-19 pandemic planning and response." **The Lancet. Digital Health** 2(8): e435-e440.

- “**South Korea** has implemented tools for aggressive contact tracing, using security camera footage, facial recognition technology, bank card records, and global positioning system (GPS) data from vehicles and mobile phones to provide real-time data and detailed timelines of people's travel. South Koreans receive emergency text alerts about new COVID-19 cases in their region, and people who could have been in contact with infected individuals are instructed to report to testing centres and self-isolate. By identifying and isolating infections early, South Korea has maintained among **the lowest per-capita mortality rates in the world**.”
- “**Singapore** has launched a mobile phone application that exchanges short-distance Bluetooth signals when individuals are in proximity to each other. The application records these encounters and stores them in their respective mobile phones for 21 days. If an individual is diagnosed with COVID-19, Singapore's Ministry of Health accesses the data to identify contacts of the infected person. Like South Korea, Singapore has maintained one of the **lowest per-capita COVID-19 mortality rates in the world**.”
- “**Germany** has launched a smartwatch application that collects pulse, temperature, and sleep pattern data to screen for signs of viral illness. Data from the application are presented on an online, interactive map in which authorities can assess the likelihood of COVID-19 incidence across the nation. With

widespread testing and digital health interventions, Germany has maintained a **low per-capita mortality rate**, relative to other countries, **despite a high prevalence of cases**."

Digital contact tracing - predictors of download of and receptiveness to apps

s79. Abuhammad, S., et al. (2020). "COVID-19 Contact-Tracing Technology: Acceptability and Ethical Issues of Use." Patient Prefer Adherence 14: 1639-1647.

- Original research (opinion and use survey)
  Methods: A cross-sectional questionnaire-based study was used. The target population was Jordanian adults (>18 years). The survey was distributed to a convenience sample of 2000 general public in Jordan.
- Results: The results found that the number of people who accept to use COVID-19 contact tracing technology was 71.6%. However, the percentage of people who were using this technology was 37.8. The main ethical concerns for many of participants were privacy, voluntariness, and beneficence of the data.

s80. Akinbi, A., et al. (2020). "Contact tracing apps for COVID-19 pandemic: Challenges and potential." (Pre-print).

- Narrative review by UK based authors. This review encompasses the current challenges facing this technology in the fight against the COVID-19 pandemic in neo-liberal societies.
  Scope of review: challenges, recommendations and recommendations to address these challenges and considerations in the use of less invasive digital contact tracing technologies for future pandemics are presented.
  Asserts contact tracing apps acceptable in Asian countries less acceptable in neo-liberal societies, due to well evidenced privacy concerns
- Discusses "**conditional cooperators**" - includes reference to study reviewing social dilemma experiments concludes that *~60% of people will cooperate if they believe others are doing so*, but not if not.

s81. Ayres, I., et al. (2020). "How to Make COVID-19 Contact Tracing Apps work: Insights From Behavioral Economics." medRxiv: 2020.2009.2009.20191320. Preprint.

- An **online experiment** showing that **contact tracing apps (CTAs**) can still play a key role in containing the spread of COVID-19, provided that they are re-conceptualized to account for **insights from behavioral science**. The authors show that carefully devised in-app notifications are effective in inducing covid-protective behaviours. The authors suggest that to increase uptake and acceptability, CTAs should be **re-framed as Behavioral Feedback Apps (BFAs).** The main function of BFAs would **be providing users with information on how to minimize the risk of contracting COVID-19**, like how crowded a store is likely to be. This would make **contact tracing an ancillary, opt-in function** might facilitate a wider acceptance of BFA.

s82. Horvath, L., et al. (2020). "Citizens' Attitudes to Contact Tracing Apps." Journal of Experimental Political Science: 1-27.

- **Online experiment** assessing attitudes to apps. **UK-based** sample (n=1,504) of people who were given information about two apps. A total of 41 per cent of those questioned wanted a mixture of an app and human contact during the tracing process, 22 per cent wanted it purely human contact tracing, and 37 per cent who wanted the process to only be digital. A randomly selected group of people were also informed about the risk of data breach issues, but this didn't impact on people's preferences. People who took part in this research **preferred a balanced -- human plus digital -- approach to contract tracing**. **Privacy**

concerns were not as influential as expected by the authors. **Trust in the provider of the app** is currently more important

s83. Jonker, M., et al. (2020). "COVID-19 Contact Tracing Apps: Predicted Uptake in the Netherlands Based on a Discrete Choice Experiment." JMIR Mhealth Uhealth 8(10): e20741.

- Study to determine the potential uptake of a contact tracing app in the **Dutch** population, depending on the characteristics of the app. The most realistic contact tracing app had a predicted adoption of 64.1%. The predicted adoption rates strongly varied by age group. For example, the adoption rates of the most realistic app ranged from 45.6% to 79.4% for people in the oldest and youngest age groups (ie, ≥75 years vs 15-34 years), respectively. Educational attainment, the presence of serious underlying health conditions, and the respondents' stance on COVID-19 infection risks were also correlated with the predicted adoption rates but to a lesser extent.

s84. Kaspar, K. (2020). "Motivations for Social Distancing and App Use as Complementary Measures to Combat the COVID-19 Pandemic: Quantitative Survey Study." J Med Internet Res 22(8): e21613.

- **Germany** based experimental study applying protection motivation theory to receptiveness for apps (n=406). **Trust in other people's social distancing behavior** and general **trust in official app providers** were predictive of receptiveness to the app; however, the participants' age and gender were not.

s85. Saw, Y. E., et al. (2020). "Predicting public take-up of digital contact tracing during the COVID-19 crisis: Results of a national survey." medRxiv: 2020.2008.2026.20182386. (Pre-print)

- **Singapore** based study of predictors of downloading the TraceTogether app (n=505), Found that those who are more **compliant with recommended COVID behaviours was predictive of downloading the app**. Network analyses revealed that contact tracing downloads was associated with using hand sanitizers, avoiding public transport, and preferring outdoor over indoor venues during the pandemic. However, demographic and situational characteristics were not significant predictors of application downloads.

s86. von Wyl, V., et al. (2020). "Are COVID-19 proximity tracing apps working under real-world conditions? Indicator development and assessment of drivers for app (non-)use." medRxiv: 2020.2008.2029.20184382. Pre-print

- Six indicators were developed to monitor the **SwissCovid app** functioning and effectiveness in the Swiss population. Using official statistics and survey data, the authors calculated indicator values and examined socio-demographic factors associated with the SwissCovid app utilization. Indicators show that 1 in 3 adults in Switzerland have downloaded the app. However, only 15% of new cases also triggered DPT-app notifications, and indicators also reveal ignored app notifications. In the full survey sample (n=2,098), higher monthly household income or being a non-smoker were associated with higher SwissCovid app uptake; older age or having a non-Swiss nationality with a lower uptake. In a subsample including more detailed information (n=701), **high trust in health authorities** was associated with higher SwissCovid app uptake.

s87. Walrave, M., et al. (2020). "Ready or Not for Contact Tracing? Investigating the Adoption Intention of COVID-19 Contact-Tracing Technology Using an Extended Unified Theory of Acceptance and Use of Technology Model." Cyberpsychol Behav Soc Netw.

- Study in **Belgian** citizens of predictors of intentions to use app (n=1500).
  Results indicated that 48.70 percent of the respondents wanted to use the app. The most important

predictor was **performance expectancy**, followed by **facilitating conditions** and **social influence**. Effort expectancy was not related to intention. Moreover, individuals' innovativeness was positively related with app use intention, whereas app-related privacy concerns negatively influenced intention.

s88. Walrave, M., et al. (2020). "Adoption of a Contact Tracing App for Containing COVID-19: A Health Belief Model Approach." JMIR public health and surveillance 6(3): e20572.

s89. Wnuk, A., et al. (2020). "The acceptance of Covid-19 tracking technologies: The role of perceived threat, lack of control, and ideological beliefs." PLoS ONE [Electronic Resource] 15(9): e0238973.

- Two **Poland**-based studies - predictors of acceptance of surveillance technologies.
  Authors found that **perceived personal threat** and **lack of personal control** were significantly positively related to the acceptance of surveillance technologies, but their predictive value was smaller than that of individual differences in authoritarianism and endorsement of liberty. Moreover, we found that the relationship between the acceptance of surveillance technologies and both perceived threat and lack of control was particularly strong among people high in **authoritarianism**.

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Expert input: Prof Steve Wesselingh

Additional References:

s90. Adam, D.C., et al. (2020). Clustering and superspreading potential of SARS-CoV-2 infections in Hong Kong. Nature Medicine. doi:10.1038/s41591-020-1092-0