Rialtas na hÉireann
Government of Ireland

Literature Review

Digital Contact Tracing: Benefits and Enablers

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MAY 2020

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Irish Government Economic and Evaluation Service

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Executive Summary

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- This brief was conducted in the context of the Covid-19 pandemic and the public health-led response in Ireland and there were three central research questions which guided this research brief:
    - What are the benefits of digital contact tracing?
    - What are the factors that enable effective digital contact tracing?

Key Findings

Benefits of digital contact tracing

- Overcoming recall bias
  The detection of the source of infection (or index case) and clusters of cases and transmission routes in a rapid manner is crucial to the prevention of the further spread of an infectious disease, and contact tracing aids this detection (Leong et al., 2009). However, manual forms of contact tracing may be limited by their reliance on recall (Leong et al., 2009) and it is argued that, for a highly infectious disease with a long incubation period, capacity to recall decreases and the likelihood of the disease being spread beyond known and usual contacts increases (Hart et al., April 2020). Furthermore, manual contact tracing also requires substantial human resources in the form of contact tracers (Hart et al., April 2020). Emerging literature suggests that manual contact tracing procedures is too slow, lacks efficiency, and occurs at too small a scale to contain SARS-CoV-2 (Ferretti et al., March 2020, Hinch et al., April 2020).

- Limiting disease transmission while minimising the number in quarantine
  Contact tracing using smartphone technology has emerged as a potentially powerful tool that may be employed to limit disease transmission during an epidemic or pandemic (Yasaka et al., April 2020, Hart et al., April 2020, Ferretti et al., March 2020, Hinch et al., April 2020). Further, research has been carried out on the role a contact tracing app can play in the removal of mass quarantine ('lock down') measures through the targeting of those identified as being 'at risk' (Ferretti et al., March 2020, Hart et al., April 2020) and enabling what some term 'smart testing'[1], that is, the deployment of available testing resources optimally.

  Minimising time in individual and/or mass quarantine ('lock-down') involves releasing uninfected individuals from quarantine while attempting to contain transmission. It is argued that a measure of success for digital contact tracing is the extent to which it reduces onward transmission of the virus while simultaneously minimising the number of people in quarantine (Hinch et al., April 2020). This has public health, social and economic benefits.

- Evidence for policy responses
  There is substantial public health and epidemiological value in mobile app generated data, especially for targeting and monitoring the impact of public health measures to contain the virus (Oliver et al., March 2020). With location information, near real-time data on mobility and hotspots can play an important role in understanding the impact that lifting and re-establishing various measures may have on observable population behaviours such as transport patterns. This evidence can be used to inform the optimal combination and timing

of policy measures (e.g. general mobility restrictions, school closures, banning of large gatherings), and to balance these restrictions with aspects of economic vitality (Oliver et al., March 2020).

Enabling factors

- ### Operational factors

It is argued that a contact-tracing app which builds a memory of proximity contacts and immediately notifies contacts of positive cases (Hart et al., April 2020) can achieve epidemic control if used by enough people (Ferretti et al., March 2020). **Immediate notification, which is possible with app-based methods, can assist in tracing pre-symptomatic contacts** (Hinch et al., April 2020) before transmission. It is also argued that instant identification of cases by self-reporting of symptoms is likely to be highly effective (Hinch et al., April 2020) and **integrating the app with community testing of index cases is argued to have the greatest impact on numbers of people in quarantine as tests which prove negative for the index case can release their quarantined contacts**. However, high numbers of tests are needed to achieve this, estimated at approximately 100,000 tests per day for the UK (Hinch et al., April 2020). Proportional to the Irish population, this figure is approximately 7,500 per day which is lower than the capacity for testing as of 18th May 2020 (15,000).

- ### Adoption

Several studies focus on estimating the adoption rate for an app in a population in order for an impact on disease control to be observed and these studies show that, overall, the greater the adoption, the greater the impact (Yasaka et al., April 2020). Estimates range from 25-60%, however the policy scenarios and assumptions relating to the epidemiology of the disease and population behaviour that underpin these estimates differ widely in the studies reviewed. Further factors such as user engagement, integration with other policy measures, and the context for deployment are also relevant.

The most substantial and influential contribution in this regard comes from Hinch et al. (April 2020) who find that the epidemic can be ***suppressed*** (no need for further mass quarantine) with 80% of all smartphone users using the app, or 56% of the population overall (UK). Lower rates of app adoption can ***delay*** the time between first and second mass quarantine, where this time is a function of the adoption rate.[2] However, it is important to note, as the authors state in their work, that a limitation of their model is that they consider app-based contact tracing in the context of social mixing that is identical to the pre-'lock down' period. They therefore state that it is plausible to assume that in a post-'lock-down' context, some social distancing will continue, in which case the scenarios explored in their paper could be overestimate epidemic resurgence.

Turning to successful voluntary adoption of a contact tracing app, Hart et al., (April 2020) highlight the important role of **public engagement and communication**, arguing that it needs to be clear to the public that a technical solution will help to solve the problems that they are experiencing and witnessing around them.

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[1] Hart et al., April 2020 state that the methodology required for 'smart testing' is a continual loop of testing and identification of those infected, finding those who have been in contact with COVID-positive individuals and quarantining and testing them, and finally identifying those who have recovered so they can safely work in the economy. If this process is in place, the rate of infections can be kept low enough for the medical system to cope and for the economy to continue without the lockdown

[2] 'Lockdowns' are assumed to start at 1% prevalence of the total population.

- Population characteristics and behaviours

Identifying and understanding individuals' **capability, opportunity, and motivation** in relation to health behaviour-change apps and contact tracing apps can help to inform approaches to increase adoption, use, and engagement with contact tracing apps, but comparisons should be treated with caution due to the global pandemic context and the novel features of contact tracing apps. Based on a review of relevant literature, Thornloe et al. (2020) note that in terms of capability, lower confidence in one's own ability to use technology among women and older people, and digital literacy was associated with lower adoption and use of health-behaviour change apps. In terms of opportunity, older people were often less likely to have a mobile phone, or a smartphone and therefore less likely to use these apps. In terms of motivation, issues related to privacy and confidentiality, perceived usefulness, perceived benefits were also noted. These barriers and enablers differ from those that are often identified at an operational and policy level and should be understood and analysed prior to and post deployment.

- Comprehensive approach to disease prevention and control

Several papers note that **an App that supports contact tracing should be just one of several tools for public health approaches for disease prevention** and should complement physical distancing, enhanced hand and respiratory hygiene, and regular decontamination (Ferretti et al., March 2020). Kretzschmare et al., (April 2020) argue that a combination of social distancing with isolation and contact tracing leads to synergistic public health effects that increase disease control and containment.

- Public trust

Several papers outline the importance of public trust and confidence in apps, in contract tracing operations, and in the use of data from apps (Ferretti et al., March 2020). Hart et al., (April 2020) argue that **it is crucial that the technology is compliant with privacy requirements, so that people are protected from excessive data collection and potential loss of agency**, particularly in the long term. Yasaka et al., (April 2020) highlights that location tracking may deter many from using an app, especially when this data is being collected by or shared with government entities. **All papers reviewed recommended a voluntary 'opt in' approach to data sharing.**

With regard to the successful implementation of e-government projects more generally, Anthopoulos et al (2016) identified reasons and factors that can contribute to e-government failure. These include design–reality gaps, execution issues, regulatory issues, user dissatisfaction, ambiguous business needs and unclear vision, under-estimation of the operation of 'deliverables', underestimation of maintenance costs, failure to secure maintenance costs, problems with infrastructure, data, compatibility, and information management. However, they argue that managers of e-government projects can analyse and manage, and mitigate the risk of failure through performance monitoring, public engagement, and an appropriate communications management plan.

1. Introduction

Purpose

During epidemics, and pandemics, testing and tracing operations have an important role to play in determining how effectively the health system can identify individual disease incidents and clusters and respond. The purpose of this literature review is to provide a summary of empirical evidence regarding digital contact tracing using app-based technology for disease control during pandemics and epidemics. This brief was conducted in the context of the Covid-19 pandemic and the public health-led response in Ireland.

There were two central research questions which guided this review:

1) What are the benefits of digital contact tracing?
2) What are the factors that enable effective digital contact tracing

   … from a development and operations perspective?

   … from a user and population perspective?

This research brief is presented in three sections. **Section 1** presents the key findings of the literature and data review, with reference to the Irish context. **Section 2** provides a detailed review of the published research literature with regard to the first two central research questions: what are the benefits of digital methods for contact tracing, and what are the factors that enable effective digital contact tracing? A significant enabling factor for the effectiveness of mobile contact tracing is the rate of smartphone ownership and smartphone user behaviour and preferences, in any given population.

Scope

A standardised approach to screening empirical studies and published literature is employed to ensure that the evidence describes the population, context and concept (PCC) of the research area. The PCC framework applied for this review is outlined as follows; Population: global, i.e. not limited to any nation, Context: digital contact tracing, Concept: benefits/value, enablers for effectiveness.

It is important to note that at the time of review, empirical research into the efficacy of digital contact tracing using app-based technology as a public health response to the Covid-19 pandemic is emergent. Considering this, grey literature is included in the review, but limitations are made towards media articles. The evolving nature of intelligence in this area presents a challenge for translating evidence for decision-making. As more research becomes available, it is therefore the intention that this research brief will be updated accordingly to incorporate emerging evidence.

2. Digital contact tracing benefits and enablers

What follows is a summary of the emerging literature on the use, impact, and effectiveness of digitally supported contact tracing for public health responses to epidemics and pandemics. Research papers are summarised and discussed in turn and a summary of the key messages from each paper is presented.

Research papers and studies

Quantifying SARS-CoV-2 Transmission Suggests Epidemic Control with Digital Contact Tracing (March 2020)[3]

In this study, the authors estimated key parameters of the SARS-CoV-2 epidemic, using an analytically solvable model of the exponential phase of spread and of the impact of interventions. Their approach suggests that between a third and a half of transmissions occur from pre-symptomatic individuals.[4] Their infectiousness model suggests that the total contribution to R0[5] from pre - symptomatic is 0.9 (0.2 - 1.1), almost enough to sustain an epidemic on its own.

Transmission occurring rapidly and before the presentation of symptoms implies that the epidemic is highly unlikely to be contained by the practice of isolating symptomatic individuals alone. The authors modelled the combined impact of two interventions; (i) isolation of symptomatic individuals, and (ii) tracing the contacts of symptomatic cases and quarantining them. Delays in these interventions make them ineffective at controlling the epidemic and it is argued that traditional manual contact tracing procedures are not fast enough for SARS-CoV-2.

Considering their quantification of SARS-CoV-2 transmission, the authors suggest that, with a mobile phone app, implementing instantaneous contact tracing could reduce transmission enough to achieve R < 1 and sustained epidemic suppression, stopping the virus from spreading further. A mobile phone app can make contact tracing and notification instantaneous upon case confirmation. By keeping a temporary record of proximity events between individuals, it can immediately alert recent close contacts of diagnosed cases and prompt them to self-isolate.

The authors state that the delay between symptom development and case confirmation will decrease with faster testing protocols, and, indeed, could become instant if presumptive diagnosis of COVID-19 based on symptoms were accepted in high prevalence areas. By targeting recommendations to only those at risk, epidemics could be contained without need for mass quarantines ('lock-downs') that are harmful to society. It is argued that the app should be one tool among many general preventative population measures such as physical distancing, enhanced hand and respiratory hygiene, and regular decontamination.

The authors argue that people should be democratically entitled to decide whether to adopt this platform. With regard to ethical considerations, the authors argue that successful and appropriate use of the app relies on it commanding well founded public trust and confidence. This applies to the

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[3] Ferretti et al. (March 2020) *Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing.* Science 10.1126/science.abb6936 (2020). https://science.sciencemag.org/content/early/2020/04/09/science.abb6936

[4] This is in line with estimates of 48% of transmission being pre-symptomatic in Singapore and 62% in Tianjin, China, and 44% in transmission pairs from various countries.

[5] The basic reproduction number R0 is the typical number of infections caused by an individual in the absence of wide-spread immunity. Once immunity becomes widespread, the effective reproduction number R will become lower than R0 and once R is less than 1, the population has herd immunity and the epidemic declines. The authors argue that immunity can only safely be obtained by vaccination.

use of the app itself and of the data gathered. It is argued that requirements for the intervention to be ethical and capable of commanding the trust of the public are likely to comprise the following:

- Oversight by an inclusive and transparent advisory board, which includes members of the public;
- The agreement and publication of ethical principles by which the intervention will be guided;
- Guarantees of equity of access and treatment;
- The use of a transparent and auditable algorithm;
- Integrating evaluation and research in the intervention to inform the effective management of future major outbreaks;
- Careful oversight and effective protection around data use; and,
- The sharing of knowledge with other countries, especially low- and middle-income countries.

Summary

Digital contact tracing could play a critical role in avoiding or leaving mass quarantines ('lock-downs').

Viral spread is too fast to be contained by manual contact tracing, but could be controlled if this process was faster, more efficient and happened at scale.

A contact-tracing app which builds a memory of proximity contacts and immediately notifies contacts of positive cases can achieve epidemic control if used by enough people.

By targeting recommendations to only those at risk, epidemics could be contained without need for mass quarantines ('lock-downs') which are harmful to societies and economies.

Successful and appropriate use of the app relies on it commanding well founded public trust and confidence. This applies to the use of the app itself and of the data gathered.

Effective Configurations of a Digital Contact Tracing App: A report to NHSX (April 2020)[6]

In this report, the authors present strategies that could minimize numbers of quarantined individuals while maintaining sustainable epidemic control after 'lockdown'[7] restrictions are lifted. It is argued that digital contact tracing can limit quarantine requests to those most at risk of transmitting the virus and therefore minimise the number of people in quarantine. **It is argued that a measure of success for digital contact tracing is the extent to which it reduces onwards transmission of the virus while simultaneously minimising the number of people in quarantine.** Instant identification of cases by self-reporting of symptoms is likely to be highly effective at tracing their contacts, including pre-symptomatic contacts, before they transmit. Substantial reductions in the proportion of uninfected people in quarantine can be achieved by rapid follow-up testing of index cases, which could release whole clusters or networks of contacts.

[6] Hinch et al., (16 April 2020) *Effective Configurations of a Digital Contact Tracing App: A report to NHSX*. University of Oxford; Welcome Trust Centre for Ethics and the Humanities. https://www.research.ox.ac.uk/Article/2020-04-16-diontactg-can-slow-or-even-stop-coronavimissioease-us-out-of-lockdow

[7] In this report a 'lockdown; is regarded as a quarantine applied broadly to most of the population, excluding only key workers for example.

The authors argue that a functional contact tracing app is one that can successfully suppress the epidemic and requires a transparent algorithm that is (1) epidemiologically sound, (2) has been assessed by simulation with extensive sensitivity analysis, and (3) can be audited and optimised as data from the app becomes available and the epidemic evolves.

The authors simulated an urban population of 1 million individuals. COVID-19 infections were seeded into the modelled population and permitted to spread via the interaction network[8]. Without intervention, COVID-19 transmission was assumed to have a generation time with a mean of 6 days and an epidemic doubling time of 3 to 3.5 days resulting in an R 0 of 3.4 and 3, respectively.

The baseline assumption is that a 35-day lockdown is initiated when 1% of the population are infected. Individuals over 70 are asked to self-isolate throughout, in accordance with UK policy on 'shielding'. This provides additional protection to this vulnerable group who are less likely to use smartphones. The proposed app begins collecting data 7 days before the end of lockdown and begins contact tracing when lockdown ends. When a user self-diagnosis, contacts of the past 7 days are considered when calculating the probability that the contact resulted in a transmission. 100% of individuals were assumed to self-isolate after receiving a notification, with a drop-out rate of 2% per day.

With regard to the various scenarios modelled[9], compared to release from lockdown with only self-isolation of symptomatic individuals, all configurations of the app result in a substantial reduction of new cases, hospitalizations and ICU admissions and in a substantial number of lives saved. Direct contact tracing with the app maintains epidemic suppression only under optimistic assumptions of epidemic growth (doubling times of 3.5 days, generation time of 5 days). Allowing recursive contact tracing to household members of first-order contacts controls the epidemic under even the most pessimistic assumptions of epidemic growth. However, it also quarantines the largest number of uninfected people, with only a 50% reduction in numbers of people quarantined compared to lockdown.

When the results of the scenarios that were modelled were compared the authors concluded that integrating the app with community testing of index cases has the greatest impact on numbers of people in quarantine. In this scenario, index cases still trigger contact tracing by self-reporting symptoms, but are then followed up with virological testing which, if negative, releases them and their quarantined contacts. High numbers of tests are needed to achieve this, (estimated as approximately 100,000 tests per day for the UK, pro rata, this is approximately 7,500 for Ireland). The simulation highlights the potential for community testing to release significant numbers of people.

[8] On a daily basis all individuals in the model move between small world networks representing households and a second network representing either workplaces, schools, or regular social environments for older people. Individuals also enter random networks representing public transport, transient social gatherings etc. Inside each network, individuals can transmit the infection to each other on each day that a connection is made. To model digital contact tracing, the past network of an infected individual is recalled and used to quarantine their contacts. The proportion of the network visible to, and informing, the intervention is set by parameters controlling coverage of the app in the population, self-diagnosis by users, compliance with the advice, drop-out rates, and the sensitivity of the technology in detecting transmission events.

[9] The paper considers the following scenarios: Scenario 1 - No app. Scenario 2: App without recursion, Quarantine: index cases, their households, their contacts, Release: everybody after 14 days from notification. Scenario 3: App with recursion, Quarantine: as scenario 2 plus household members of contacts, Release: as scenario 2. Scenario 4: App with recursion and cluster release, Quarantine: as scenario 3, Release: as scenario 2&3 plus release of an index case cluster if nobody from the cluster develops symptoms within 5 days. Scenario 5: App with recursion and testing as follow-up, Quarantine: as scenario 3&4, Release: as scenario 2&3 plus release of an index case cluster if index case had a negative test. Scenario 6: App with recursion and notification upon testing, Quarantine: contacts are notified only after index case tests positive, Release: as scenario 2&3

In one scenario, the authors explore contact tracing upon positive test only, as currently planned by many countries in continental Europe. Quarantining contacts only after the index case has been confirmed positive avoids the peak of quarantine right after lockdown, but even assuming an extremely fast turn-around time for the test (24 hours from self-diagnosis to result), the delay results in more transmission from contacts in the presymptomatic phase, and an overall higher number of cases and deaths compared to the scenario in which testing the index case is used to release contacts from quarantine.

The authors studied the dependence upon variable uptake of the app. They find that the epidemic can be suppressed (no need for further lockdowns) with 80% of all smartphone users using the app, or 56% of the population overall. Lower rates of app coverage delayed the time to a second lock-down. Lockdowns are assumed to start at 1% prevalence of the total population.

In the context of a public-health led response and relying on the current definition of a close contact (ECDC), the authors also suggest the use of risk scoring to increase the safety of the app by controlling the mean number of quarantine notifications initiated from a single index case and argue that, once the app has been running for some weeks, the risk-scoring method can be improved by analysing data acquired by the app, such as follow-up clinical data and test results of traced individuals. For example, it would be possible to test the relative importance of very long contacts, such as may be experienced at home, compared with shorter contacts. It would be possible to test the distance-dependence of contacts or compare inside/outside contacts. It is proposed that machine learning approaches could also be used to improve predictions. The better the predictions of what constitutes a high-risk contact, the better the accuracy with which notifications to quarantine can be targeted.

It is important to note, as the authors state, a limitation of this report with the exception of the shielding of over 70s, is that **they consider app-based contact tracing in the context of social mixing that is identical to the pre-lockdown period.** They therefore state that it is plausible that relaxation of a lockdown may result in some continued social distancing, in which case the scenarios explored in this paper could be pessimistic about epidemic resurgence.

Summary

Manual contact tracing is too slow to reach people before they transmit, whereas the scalability and speed of a digital approach, using proximity sensors of smartphone devices, is theoretically fast enough to stop the epidemic.

A measure of success for digital contact tracing is the extent to which it reduces onwards transmission of the virus while simultaneously minimising the number of people in quarantine.

Substantial reductions in the proportion of uninfected people in quarantine can be achieved by rapid follow-up testing of index cases, which could release whole clusters of contacts.

The authors suggest that the virus can be suppressed with 80% of all smartphone users using the app, or 56% of the population overall (UK), which would prevent the need for further 'lockdown'. It was found that lower levels of app usage delay the time to second lockdown, dependent on rate of usage.

Outpacing the Virus: Digital Response to Containing the Spread of COVID-19 while Mitigating Privacy Risks (April 2020)[10]

This paper argues that proactive use of intentionally designed technology can support voluntary participation from the public toward the goals of 'smart testing', effective resource allocation, and relaxing some of the physical distancing measures, but only when it guarantees and assures an individual's complete control over disclosure, and use of data in the way that protects individual rights.

'Smart testing' utilises software to prioritise individuals who are likely to be at the highest risk of an infection based on their previous proximity to someone who has been diagnosed. Because the individuals involved are notified immediately as soon as someone in their proximity was diagnosed, this method shortens exposure risk and enables health-care providers to suppress the virus rapidly. Combined with other policies, such as priority testing of health-care workers, a smart testing policy focuses testing resources where they can create the most public good.

The methodology required for 'smart testing' is a continual loop of testing and identification of those infected, finding those who have been in contact with COVID-positive individuals and quarantining and testing them, and finally identifying those who have recovered so they can safely work in the economy. If this process is in place, the rate of infections can be kept low enough for the medical system to cope and for the economy to continue without the lockdown.

There are several attributes of digitized smart testing that present benefits vis a vis manual contact tracing. These are:

1. **Increased accuracy.** It no longer relies on memory to create a list of contacts;

2. **Speed.** A list of alerts can be created and dispatched near-instantaneously;

3. **Lower cost.** Trained interviewers are not needed, and follow-ups can be done automatically in cases where medical care is not needed;

4. **More effective**. As opposed to manual contact tracing which has been proven insufficient to contain COVID-19 on its own, both theoretically and in practice. In countries like Taiwan and South Korea, digital contact tracing has been an integral part of slowing the spread of COVID-19. At present, the outbreaks in those places are under control through a combination of contact tracing and other measures.

Further to these benefits, the ECDC notes that app-based digital contact tracing allows for contacts that are unknown to the case to be traced.

Widespread use of smartphones creates possibilities for smart testing that didn't exist in the past and that can shore up the limitations of traditional contact tracing that make it ill-suited to fight COVID- 19. The higher the saturation of devices enabling selective smart testing, the more effective the suppression algorithms will be. Optimally, more than 70% of the population use the app, although lower penetration could also be combined with other contact tracing interventions.

They argue that it is possible to deploy a system that is voluntary, respects privacy and agency, and is resistant to fraud and abuse, while achieving the 'smart' testing loop necessary to prevent another wave of infection or continuous lockdown. In order to drive voluntary adoption, it needs to be clear

[10] Hart et al,.(April 2020) *Outpacing the Virus: Digital Response to Containing the Spread of COVID-19 while Mitigating Privacy Risks.* COVID-19 Rapid Response Impact Initiative | White Paper 5. Edmond J. Safra Centre for Ethics. Harvard University.

to people that a technical solution will help solve the problems that they are experiencing and witnessing around them.

They argue that it is crucial that the technology is respectful of privacy, so that people are protected from excessive data collection and potential loss of agency, particularly in the long term. Privacy controls that include fully voluntary use, robust data security, de-identification, verifiable retention, and more are necessary to protect society and to enable trusted adoption. It is argued that much care will have to be taken to ensure data collection is proportionate, fully justified, and has a fixed end date and that all adoption is opt-in, with no consequences for not using the proposed technology. Care must be taken not only to create a system people are willing to participate in at first. It must also be truly secure and privacy-preserving over the long term, so that failures will not cause a mass rejection of the technology or health-related apps, causing negative health impacts.

Summary

Proactive use of intentionally designed technology can support voluntary participation from the public toward the goals of 'smart testing', effective resource allocation, and relaxing some of the physical distancing measures, but only when it guarantees and assures an individual's complete control over disclosure, and use of data in the way that protects individual rights.

If a continual loop of testing and identification of those infected is in place, the rate of infections can be kept low enough for the medical system to cope and for the economy to continue without lockdown.

Widespread use of smartphones creates possibilities for smart testing that didn't exist in the past and that can shore up the limitations of traditional contact tracing that make it ill-suited to fight COVID-19.

In order to drive voluntary adoption, it needs to be clear to people that a technical solution will help solve the problems they're experiencing and witnessing around them.

It is crucial that the technology is respectful of privacy, so that people are protected from excessive data collection and potential loss of agency, particularly in the long term.

Peer-to-Peer Contact Tracing: Development of a Privacy-Preserving Smartphone (April 2020)[11]

Contact tracing using smartphone technology is a powerful tool that may be employed to limit disease transmission during an epidemic or pandemic. However, contact tracing apps present significant privacy concerns regarding the collection of personal data such as location. The study aims to develop an effective contact tracing smartphone app that respects user privacy by not collecting location information or other personal data.

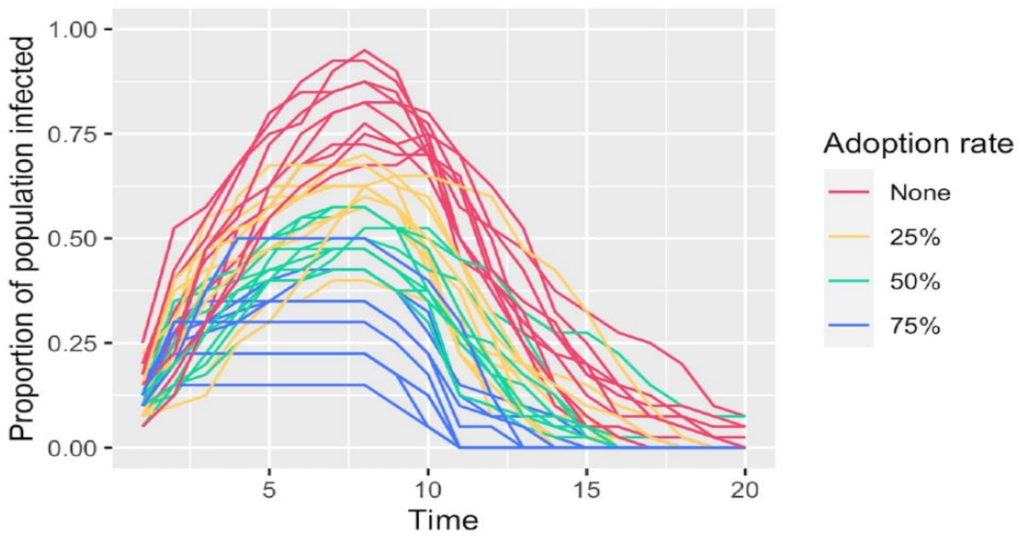
This study proposes the use of an anonymized graph of interpersonal interactions to conduct a novel form of contact tracing and the authors developed a proof-of-concept smartphone app that implements this approach. This proof-of-concept smartphone app allows users to create

[11] Yasaka et al., (April 2020) *Peer-to-Peer Contact Tracing: Development of a Privacy-Preserving Smartphone App.* JMIR Mhealth Uhealth 2020 | vol. 8 | iss. 4 | e18936. https://mhealth.jmir.org/2020/4/e18936/

"checkpoints" for contact tracing, check their risk level based on their past interactions, and anonymously self-report a positive status to their peer network.

Additionally, they developed a computer simulation model[12] that demonstrates the impact of their proposal on epidemic or pandemic outbreak trajectories across multiple rates of adoption. A comparison of simulations produced by their simulation model with varying levels of adoption is presented in figure one. Results demonstrate that adoption rate is key to the impact that such an app could have on the extent of an outbreak. Visually, even a 25% adoption would provide some suppression of the infection curve compared to no adoption. However, more substantial improvements on the trajectory of the outbreak are observed at higher levels of adoption.

Figure 1 Effect of adoption rate of app on proportion of population infected



Source: Yasaka et al. (2020)[13]

Simulation Model

The time between infection and awareness of infection (*diagnosis delay*) is a parameter of the model. Similarly, individuals are in the *infected* state for a time period according to the *infectious period* model parameter. Individuals may transmit disease to each other at the same contact location in a point in time according to the *transmission rate* parameter.

Individuals that have adopted the app will perform three additional actions, in addition to the standard model behavior: (1) Participating individuals will log their diagnosis of infection onto the transmission graph, at their earliest contact point within the *estimated diagnosis delay* (2) these individuals will log all their contact points and movements between contact points onto the graph; and (3) participating individuals will self-isolate if a path between a status positive contact point and

[12] The authors developed a low-fidelity computer simulation model that facilitates disease spread through interaction of individuals at contact points across time, allowing for the explicit modeling of the transmission graph structure proposed. With this model of disease spread, they compare outbreak trajectories both with and without peer-to-peer contact tracing. Such a model, while not intended to describe real-world trajectories, allows for the demonstration of the feasibility of our proposal and provides a rudimentary mechanism to compare various scenarios and app parameters, such as the adoption rate, the diagnosis delay estimated by the app, and the safety period used by the app. The model was written in the R (R Foundation for Statistical Computing) programming language, and the source code is publicly accessible on GitHub. Additionally, a public, web-based interface for the model is provided. The model is based on the susceptible, infected, and recovered epidemiological model, where each individual is considered to be in one of the *susceptible*, *infected*, or *recovered* states.

[13] The proportion of the population with active infection is plotted across time for multiple adoption rates. Time is an arbitrary unit that represents the sequence of events in the simulation. The results of 10 random simulations per adoption rate are given.

a recent contact point exists, where 'recent' is defined as those contact points within the time frame specified by the *safety period* parameter.

Potential complications and reasons for failure

Location tracking is a type of data collection that may deter many from using an app, especially when this data is being collected by or shared with government entities. The authors argue that by not requesting access to location data, their proposed app avoids this potential hurdle to adoption.

An additional barrier to entry that may often be overlooked is user registration. By user registration, they are referring to the process of creating an account to use a web-based service, often by providing an email address and password. Some individuals will refrain from such a process due to concerns with disclosing their email address or other personal information such as their name or home address. For others, the process will become a barrier simply due to the inconvenience associated with the process. Regardless of the motivating factor, user registration is likely to play a role in determining user adoption.

Development Time and Complexity

Two aspects of developing smartphone apps that are often underappreciated are development time and complexity. Complex software not only takes longer to develop, but also is more prone to failures. COVID-19 pandemic represents a time-sensitive public health crisis, and any technological solution applied to this crisis would need to be developed in a manner that is not only rapid, but also robust.

Summary

Contact tracing using smartphone technology is a powerful tool that may be employed to limit disease transmission during an epidemic or pandemic

However, contact tracing apps present significant privacy concerns regarding the collection of personal data such as location. Location tracking is a type of data collection that may deter many from using an app, especially when this data is being collected by or shared with government entities. The use of an anonymized graph of interpersonal interactions to conduct a novel form of contact tracing is proposed.

The simulation used in this study, demonstrates that adoption rate is key to the impact that such an app could have on the extent of an outbreak. Even a 25% adoption would provide some suppression of the infection curve compared to no adoption. However, more substantial improvements on the trajectory of the outbreak are observed at higher levels of adoption.

An additional barrier to entry that may often be overlooked is user registration, that is, the process of creating an account to use a web-based service, often by providing an email address and password.

Two aspects of developing smartphone apps that are often underappreciated are development time and complexity.

Mobile phone data and COVID-19: Missing an opportunity? (March 2020)[14]

This paper[15] describes how mobile phone data can guide government and public health authorities in determining the best course of action to control the COVID-19 pandemic and in assessing the effectiveness of control measures such as physical distancing. It identifies key gaps and reasons why this kind of data is only scarcely used. It presents ways to overcome these gaps and key recommendations for urgent action, most notably the establishment of mixed expert groups on national and regional level, and the inclusion and support of governments and public authorities early on.

Effective and rapid decision-making during all stages of the pandemic requires reliable and timely data not only about infections, but also about human behaviour, especially on mobility and physical co-presence of people.

It is argued that work on human mobility has shown that mobile phone data can assist the modelling of the geographical spread of epidemics.[16] The use of mobile phone data into analytical efforts to control the COVID-19 pandemic can offer a critical contribution to four broad areas of investigations:

- Situational awareness would benefit from increased access to previously unavailable population estimates and mobility information to enable stakeholders across sectors better understand COVID-19 trends and geographic distribution;
- Cause-and-effect use cases can help stakeholders identify the key drivers and consequences of implementing different measures to contain the spread of COVID-19. They aim to establish which variables make a difference for a problem and whether further issues might be caused;
- Prediction tasks would leverage real-time population counts and mobility data to enable new predictive capabilities and allow stakeholders to assess future risks, needs, and opportunities;
- Impact assessment aims to determine which, whether, and how various interventions affect the spread of COVID-19 and requires data to identify the obstacles hampering the achievement of certain objectives or the success of interventions.

The authors state that, in the **early recognition and initiation phase** of the pandemic, the focus is on situational analysis and the fast detection of infected cases and their contacts. Research has shown that quarantine measures of infected individuals and their family members, combined with surveillance and standard testing procedures, are effective as control measures in the early stages of the pandemic. Individual mobility and contact data offer information about infected individuals, their locations and social network. Contact data can be collected through mobile-app interviews, surveys, voluntary sharing of data, or by accessing individual mobile phone data, which presents serious ethical and legal concerns.

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[14] Oliver et al., (March 2020). *Mobile phone data and COVID-19: Missing an opportunity?* hps://arxiv.org/abs/2003.12347

[15] Authored by a group of experienced data scientists, epidemiologists, demographers and representatives of mobile network operators.

[16] This paper highlights that researchers and governments have started to collaborate with private companies, most notably mobile network operators, to estimate and visualize the effectiveness of control measures. In China, Baidu data has been used to evaluate how the lockdown of Wuhan affected the spread of the virus. In Italy, researchers and local governments are collaborating to estimate the effectiveness of travel restrictions. European authorities (including Austria, Belgium, Germany, Italy, France, and Spain) are working with researchers and mobile network operators to understand the compliance and impact of the social distancing measures put in effect to combat the COVID-19 pandemic and to identify and predict potential hotspots of the disease Using the city of Boston, United States, as a test case, researchers aggregated location data from over 180 apps to enable precise measurements of social distancing on a day-by-day basis, and project in great detail the effects of different policies on the spread of COVID-19.

During the acceleration phase, when community transmission reaches exponential levels, the focus is on interventions for containment, which typically involve social contact and mobility restrictions. Aggregated mobile phone data is here crucial to assess the efficacy of implemented policies through the monitoring of mobility between and within affected municipalities. Mobility information also contributes to the building of more accurate epidemiological models that can explain and anticipate the spread of the disease. These models, in turn, can inform the mobilization of resources (e.g. respirators, intensive care units).

Finally, **during the deceleration and preparation phases,** as the peak of infections is reached, restrictions will likely be lifted. Continued situational monitoring will be important as the COVID-19 pandemic is expected to come in waves. Near real-time data on mobility and hotspots will be important to understand how lifting and re-establishing various measures translate into behaviour, especially to find the optimal combination of measures at the right time (e.g. general mobility restrictions, school closures, banning of large gatherings), and to balance these restrictions with aspects of economic vitality.

The paper identifies some examples of aggregated metrics that can be computed from such data sources.[17]

Summary

Governments should be aware of the value of information and knowledge that can be derived from mobile phone data analysis, especially for sensible targeting and monitoring the necessary measures to contain the pandemic. They should enable and leverage the fair and responsible provision/use of aggregated and anonymized data for this purpose.

Effective and rapid decision-making during all stages of the pandemic requires reliable and timely data not only about infections, but also about human behaviour, especially on mobility and physical co-presence of people.

As the peak of infections is reached and restrictions lifted, continued situational monitoring will be important as the COVID-19 pandemic is expected to come in waves. Near real-time data on mobility and hotspots will be important to understand how lifting and re-establishing various measures translates into behaviour, especially to find the optimal combination of measures at the right time (e.g. general mobility restrictions, school closures, banning of large gatherings), and to balance these restrictions with aspects of economic vitality. After the pandemic has subsided, mobile data will be helpful for post-hoc analysis of the impact of different interventions on the progression of the disease, and cost-benefit analysis of mobility restrictions.

[17] These are: Origin-destination (OD) matrices. Researchers can compute the number of people that move from two different areas daily, which is assumed to be a proxy of human mobility. They are also useful to monitor the impact of different social and mobility contention measures and to identify regions where the measures might not be effective or followed by the population. Dwell estimations and hotspots are estimates of particularly high concentration of people in an area, which can be favourable to the transmission of the virus. Amount of time spent at home, at work, other are estimates of the individual percentage of time spent at home/work/other location, which can be useful to assess the local aversion to countermeasures adopted by governments. The home and work locations need to be computed in a period of time prior to the deployment of mobility restrictions measures. The percentage of time spent in each location needs to be computed from stationary points, thus excluding people that move. Variations of the time spent on different locations is generally computed on an individual basis, and then spatially aggregated. Contact matrices estimate the number and intensity of the face-to-face interactions people have in a day. They are typically computed by age-groups, and they showed to be extremely useful to assess and determine the decrease of the reproduction number of the virus. However, it is still challenging to estimate face-to-face interactions from co-location data.

Effectiveness and cost-effectiveness of public health measures to control COVID-19: a modelling study (March 2020)[18]

Economic modelling from China has shown that the isolation-and-quarantine (tracing) was the most cost-effective public health intervention to control the spread of Covid-19, and that personal protection and isolation-and-quarantine (tracing) was the optimal strategy in averting more infections. When the likelihood of tracing a close contact was reduced to 25%, the number of people infected increased significantly.

Summary
Investment in contact tracing is a cost-effective component of public health interventions, and digital methods can enhance the efficacy of these measures.

Use of a Mobile Application for Ebola Contact Tracing and Monitoring in Northern Sierra Leone: A Proof-of-Concept Study (2019)[19]

The study demonstrated that it was possible to implement mobile health (mHealth) in an emergency setting. This study showed that advantages of the app over the paper-based system for contact tracing included a more accurate, timely, and permanent record of information, and improved data completeness, quality and security. However, the challenges of using an app in this setting and epidemic context were substantial but may be of less relevance in high income countries that do no face comparable geographical or infrastructural challenges.

Operational requirements needed to introduce effective mobile-based contact tracing/monitoring during an epidemic include effective coordination with technical partners, understanding the structure of the evolving contact tracing and monitoring process in real-time, accessing study hardware and software, and the technical expertise to design, develop, pilot and deploy the app during the epidemic.

Summary
This study showed that advantages of a contact tracing app over the paper-based system for contact tracing included a more accurate, timely, and permanent record of information, and improved data completeness, quality and security.

Epidemic Contact Tracing via Communication Traces (2014)[20]

This study explored a data-driven avenue for contact tracing in epidemic prevention using social interaction data from mobile phones. There were two underlying assumptions: 1) an infection is spreading in a person's physical interpersonal network, but which can never be fully profiled due to privacy and recall constraints; and 2) contact traces occur in a person's communication network which acts as a proxy for the first.

[18] Wang et al., (March 2020) *Effectiveness and cost-effectiveness of public health measures to control COVID-19: a modelling study* https://doi.org/10.1101/2020.03.20.20039644

[19] Danquah et al., (2019) *Use of a mobile application for Ebola contact tracing and monitoring in northern Sierra Leone: a proof-of-concept study.* BMC Infect Dis 19, 810 (2019). https://doi.org/10.1186/s12879-019-4354-z

[20] Farrahi et al., (2014) *Epidemic Contact Tracing via Communication Traces*. PLoS ONE 9(5): e95133.

Data was used from 72 students over a 9-month period, for which both the physical interactions as well as the mobile communication traces were recorded, analysed, and compared. The simulated contact tracing results suggest that a wide range of contact tracing strategies may significantly reduce the final size of the epidemic, by mainly affecting its peak of incidence. Across multiple realistic scenarios for contact tracing, the authors find that contact tracing is an effective means for epidemic prevention, even when there exists a low overlap between the physical and communication networks. When considering tracing effort, and based on these results, the authors suggest that contact tracing is greatly beneficial when the epidemic is starting, however, this effort will increase greatly as the epidemic grows. Overall, contact tracing via mobile phone communication traces may be a viable option to arrest contagious outbreaks.

Summary

This study demonstrates mobile phone communication history to be a useful data source in disease prevention by obtaining contact information readily for epidemic contact tracing.

Feasibility of controlling COVID-19 Outbreaks by Isolation of Cases and Contacts (April 2020)[21]

This study developed and used a stochastic transmission model, parameterised to the COVID-19 outbreak. The authors used the model to quantify the potential effectiveness of contact tracing and isolation of cases at controlling a severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)-like pathogen. The authors measured the success of controlling outbreaks using isolation and contact tracing and quantified the weekly maximum number of cases traced to measure feasibility of public health effort.

Summary

Highly effective contact tracing and case isolation is enough to control a new outbreak of COVID-19 within 3 months. However, several factors decreased the probability of outbreak control; long delay from symptom onset to isolation, fewer cases ascertained by contact tracing, and increasing transmission before symptoms. These factors should be monitored closely, and models should be updated to provide revised estimated probability of outbreak control.

Evaluation of the Effectiveness of Surveillance and Containment Measures for the First 100 Patients with COVID-19 in Singapore[22].

Singapore implemented aggressive measures to contain local transmission of COVID-19 by implementing a multipronged surveillance and containment strategy that contributed to enhanced case ascertainment and slowing of the outbreak. This report analysed the first 100 COVID-19 patients in Singapore to determine the effectiveness of the surveillance and containment measures.

Singapore's multipronged surveillance strategy included applying the case definition at medical consults, tracing contacts of patients with laboratory-confirmed COVID-19, enhancing surveillance

[21] Hellewell et al., (February 2020) *Feasibility of controlling COVID-19 outbreaks by isolation of cases and contacts.* The Lancet Global Health (2020). https://doi.org/10.1016/S2214-109X(20)30074-7

[22] Ng Y, Li Z, Chua YX, et al.(March 2020) *Evaluation of the Effectiveness of Surveillance and Containment Measures for the First 100 Patients with COVID-19 in Singapore — January 2–February 29, 2020.* MMWR Morb Mortal Wkly Rep 2020;69:307-311. DOI: http://dx.doi.org/10.15585/mmwr.mm6911e1external icon.

among different patient groups and allowing clinician discretion (i.e., option to order a test based on clinical suspicion, even if the case definition was not met) to identify COVID-19 patients.

The MOH carried out contact tracing around confirmed cases to identify persons who might have been infected. Contacts with fever (temperature ≥100.4°F [≥38°C]) or respiratory symptoms were transferred directly to a hospital for further evaluation and testing. Close contacts were defined as having close (within 6.6 ft [2 m]) and prolonged (generally ≥30 minutes) contact with the COVID-19 patient. Contacts at lower risk were persons who had some interactions with the COVID-19 patient for shorter periods of time. Asymptomatic close contacts were placed under compulsory quarantine for 14 days, and contacts at lower risk.

Contact tracing contributed to the primary detection of approximately half (53%) of COVID-19 patients. Another 20 (20%) patients were identified at general practitioner clinics or hospitals because they met the case definition; 16 were identified through enhanced surveillance and another 11 through medical providers' clinical discretion.

After an initial increase in locally transmitted cases, the number of newly identified cases decreased after approximately one month, determined by symptom onset dates. This decrease is likely a result of the early implementation of surveillance and detection measures while the numbers of patients were still small and individual-level containment was possible. A larger number of cases would have driven community transmission. However, it must be noted that generalizability of results in this study is limited because of the small sample size and lack of cases in settings such as long-term nursing facilities and health care settings.

Summary

Rapid identification and isolation of cases, quarantine of close contacts, and active monitoring of other contacts have been effective in suppressing expansion of the outbreak in Singapore and has implications for other countries experiencing outbreaks.

However, Singapore is a small island city-state, and nations with other characteristics might need to adapt and augment Singapore's approaches to achieve the same level of effectiveness.

Isolation and Contact Tracing Can Tip the Scale to Containment of COVID-19 in Populations with Social Distancing (April 2020)[23]

This study evaluates whether, and under which conditions, containment or slowing down COVID-19 epidemics are possible by isolation and contact tracing in settings with various levels of social distancing. The authors use a stochastic transmission model in which every person generates novel infections according to a probability distribution that is affected by the incubation period distribution (time from infection to symptoms), distribution of the latent period (time from infection to onset of infectiousness), and overall transmissibility. The model distinguishes between close contacts (e.g., within a household) and other contacts in the population. Social distancing affects the number of contacts outside but not within the household.

The proportion of asymptomatic or unascertained cases has a strong impact on the controllability of the disease. If the proportion of asymptomatic infections is larger than 30%, contact tracing and isolation cannot achieve containment for an R0 of 2.5. Achieving containment by social distancing

[23] Kretzschmare et al (April 2020) *Isolation and contact tracing can tip the scale to containment of COVID-19 in populations with social distancing.* medRxiv 2020.03.10.20033738; doi: https://doi.org/10.1101/2020.03.10.20033738

requires a reduction of numbers of non-household contacts by around 90%. Depending on the realized level of contact reduction, tracing and isolation of only household contacts, or of household and non-household contacts are necessary to reduce the effective reproduction number to below. A combination of social distancing with isolation and contact tracing leads to synergistic effects that increase the prospect of containment.

Summary

Isolation and contact tracing can be an effective means to slow down epidemics, but only if the majority of cases are ascertained. In a situation with social distancing, contact tracing can act synergistically and tip the scale towards containment, and can therefore be a tool for controlling COVID-19 epidemics as part of an exit strategy from current lockdown measures.

Introduction of Mobile Health Tools to Support Ebola Surveillance and Contact Tracing in Guinea (2015)[24]

This paper describes the design, implementation, and challenges of implementing a smartphone-based contact tracing system that is linked to analytics and data visualization software as part of the Ebola response in Guinea. The system allows for real-time identification of contacts who have not been visited and strong accountability of contact tracers through timestamps and collection of GPS points with their surveillance data. It is important to note that that this use of mobile health tools in this circumstance relates to the use by tracers as opposed to the mechanism of the contact tracing app, which is delivered through population use. However, there are key lessons from the disadvantages of the paper-based approach as this involves data entry.

In this case contact tracers used paper forms, based on internationally recognized templates, to record relevant information on the contacts they track daily. They then submit these forms to supervisors/field epidemiologists who collate them and enter the data into an Excel database. These data are aggregated at the prefecture level for review and submitted to national-level epidemiology teams for dissemination and analysis.

However, limitations of the paper-based Contact Tracing System are observed as follows:

- Paper based contract tracing systems create delays between data collection and consumption which impedes rapid response and decision making around contact tracing strategy;
- Human error is common with data entry, as is misunderstanding of data and communication gaps. This can lead to data becoming unreliable, out of date and inconsistent.
- Efforts for data cleaning, data entry and data compilation are time intensive. This takes away from time and resources needed for data analysis and troubleshooting.

However, the report does state that careful consideration must be given to whether it is feasible and beneficial to implement new technology during an ongoing outbreak. When the decision is made to implement technology, it is critical to accompany the deployment with close managerial oversight to quickly correct data inconsistencies and to address challenges. While there are inherent challenges

[24] Sacks et al., (2015) *Introduction of mobile health tools to support Ebola surveillance and contact tracing in Guinea.* Glob Health Sci Pract. 2015;3(4):646-659. http://dx.doi.org/10.9745/GHSP-D-15-00207

in introducing technology in complex emergencies, it is argued that the benefits of innovation to disrupt the status quo may be integral to controlling long-standing epidemics.

Summary

Human error is common with data entry, as is misunderstanding of data and communication gaps. This can lead to data becoming unreliable, out of date and inconsistent.

Efforts for data cleaning, data entry and data compilation are time intensive. This takes away from time and resources needed for data analysis and troubleshooting. A contact tracing app that avoids and automates the above processes are likely to prove very efficient.

When the decision is made to implement technology, it is critical to accompany the deployment with close managerial oversight to quickly correct data inconsistencies and to address challenges.

Contact Tracing in Healthcare Digital Ecosystems for Infectious Disease Control and Quarantine (2009)[25]

When an outbreak occurs, the detection of source of infection (or index case), clusters of cases and transmission routes in a rapid manner is crucial in preventing the infectious disease from further spreading. Contact tracing has proven to be helpful for these detections. Traditionally, contact tracing is a field work of the medical personnel with little assistance of IT if any. During the worldwide outbreak of SARS in 2003, HCIS (Health Care Information Systems) were built to facilitate contact tracing. However, contact tracing, and thus the detection process, is not a fully automatic process in these systems. In this paper, with SARS as a case study, they realize detection as an automatic process by applying algorithms and data mining techniques in the patients' activities and social interaction together with characteristics of the infectious disease

Traditionally, contact tracing for an outbreak of an infectious disease is usually performed in following steps:

- Medical personnel interview the confirmed cases and ask them where they have been and whom they have met and/or lived with before and after their onset dates;
- Medical personnel visit or contact the persons pointed out by the confirmed cases to see whether they have symptoms related to the infectious disease. If they have, medical personnel immediately ask them to go to hospital for testing. If they are confirmed cases of the disease, they are treated immediately. In this respect, medical personnel can be sure that the transmission route is from the previous case to the new case;
- Medical personnel carry out Step 1 and Step 2 for the new cases;
- When Step 1 – Step 3 are carried out iteratively during the outbreak, infection trees (or cluster trees) and the merged infection tree of the outbreak are identified.

The authors argue that a weakness of the traditional contact tracing is that it greatly relies on whether the confirmed cases can remember who they met in the places where they have gone. If they can't remember, can't be sure or even are not willing to point out the persons they met in the places they went, then it is difficult for contact tracing to fulfil its purpose.

[25] Leong et al (2009) *Contact Tracing in Healthcare Digital Ecosystems for Infectious Disease Control and Quarantine*. University of Macau**.** Management Conference Paper · July 2009. 10.1109/DEST.2009.5276730

Summary

A weakness of the manual contact tracing approach is that it greatly relies on whether the confirmed cases can remember who they met in the places where they have gone. If they can't remember, can't be sure or even are not willing to point out the persons they met in the places they went, then it is difficult for contact tracing to fulfil its purpose.

Why e-Government Projects Fail? An Analysis of the Healthcare.gov Website (2016) [26]

This paper focuses on the factors that lead to e-government project failures. It explores the context of e-government project failure and investigates the launch of the U.S. Healthcare.gov ('Obamacare') website. This case is concerned with a highly public e-government project failure where gaps between political agendas and planning are identified through an examination of media sources and social media data analysis of Twitter discussions.

With regard to the initial research question addressed in the study of top reasons and factors in e-government project failures, the paper presents a very useful 'failure taxonomy' resulting from of an extensive literature review, as seen in table one and table two.

Furthermore, the Twitter analysis utilised in this paper showed that managers of e-government projects can identify, monitor and analyse the occurrence and impact of failures from online discussions, and this should inform responses and communication efforts. With regard to the capability of social media analysis to depict the impact of failure on the end-user audience perspective, findings showed that although views on failure were widely shared, but they are highly influenced by a small number of opinion makers. This finding implies that project communications management will benefit from the use of social media for monitoring purposes.

[26] Anthopoulos et al (2016) *Why e-government projects fail? An analysis of the Healthcare.gov website*. Government Information Quarterly 33 (2016) 161–173. https://doi.org/10.1016/j.giq.2015.07.003

Table 1 e-Government project failure: reasons

Reason	Comments
Design–reality gaps	Concern hard-soft gaps (between technology and social context); private-public gaps (differences between the public and the private sector); and country context gaps (variances between counties).
Missing focus	Missing or ambiguous business focus and/or unclear objectives or absence of need.
Content issues	Project scope definition, change management, shifting requirements and or/technical complexity.
Skill issues	Project unaligned team and/or lack of skills.
Execution issues	Unrealistic schedule and/or reactive planning; and misinformation with regard to massive and unaccounted cost overruns, benefit shortfalls, and waste.
Regulatory issues	Lack in or missing of corresponding legal framework, policy and standards. Unpredictability of changes in the regulatory framework, failure due to legal disputes, implications of legal certainty in the digital realm
External factors	Outside the project organization
Missing user satisfaction	Projects do not succeed in meeting users' expectations and project products are not of public interest and use.

Table 2 e-Government project failure: factors

Factor	Explanation
Organisational power	Organisation structure and relations
Politics	Government and top-level leaders' commitment, and appropriate political support
Education	Appropriate skills for project operation and acceptance, as well as execution of training activities.
Project management issues	Underestimate of timeline; weak definitions of requirements and scope; inefficient risk analysis and management; unsuccessful monitoring and measurement.
Ambiguous business needs and unclear vision	Project's objectives are not clear or justified for their necessity.
Security and privacy	Project products do not secure transactions and sensitive information.
Finance and operational costs	Deliverables' operation and maintenance costs were underestimated and not secured.
ICT and system development process	Problems with regard to infrastructure, data, compatibility, information management

Summary

There are many reasons and factors identified that can contribute to e-government failure. These include design–reality gaps, execution issues, regulatory issues, user dissatisfaction, ambiguous business needs and unclear vision, deliverables' operation and maintenance costs were underestimated and not secured, problems regarding infrastructure, data, compatibility, information management.

Managers of e-government projects can realise the occurrence and impact of failures from online discussions (analysis of social media), and they should account for audience's behaviour and respond properly with an appropriate communications management plan.

Review of mobile phone app uptake and engagement to inform digital contact tracing tools for Covid-19[27]

A scoping review of existing literature on the adoption and engagement with health-behaviour change mobile applications was completed to inform the development and deployment of the NHSX contact tracing app. Literature surrounding health-behaviour change apps was reviewed due to the dearth of literature on the adoption and engagement with contact tracing apps for Covid-19 at the time of writing, and that this evidence is largely comparable and relevant.

In terms of barriers and enablers, the authors note the following issues that are of concern in terms of adoption that have been raised from the perspective of policy makers, developers, and operations; privacy, misuse of data, cybersecurity, data accuracy, creating or exacerbating social inequalities, and ethical and legal implications. Furthermore, and citing a rapid evidence review[28] the authors note that factors that influence adoption from an operational and policy perspective are; whether the use of the application is mandatory or voluntary, the accuracy of the test in terms of detecting contact, how data is collected and accessed and by whom, and how data from the application will be used to inform appropriate actions.

From a user perspective, the authors note that there are additional concerns that impact on adoption, engagement, and uptake and these reflect the COM-B framework[29]. In order for behaviour (B), such as downloading and using an app, to occur, people need the capability, opportunity and motivation. Capability (C) involves psychological (e.g. knowledge, comprehension and skills) and physical factors (e.g. dexterity, disability). Opportunity (O) involves social (e.g. social norms) and physical factors (e.g. time and resources). Motivation (M) includes reflective (e.g. belief in the benefits of the app and its safety) and automatic processes (e.g. emotion and habit). This framework is applied to the four inter-related behaviours that must occur: Download the app; carry a function phone at all times; report Covid-19 symptoms on the app; and, respond to app messages to self-isolate. The authors reviewed the literature with this framework with the following findings. In terms of capability, lower confidence in one’s own ability to use technology among women and older people, and digital literacy was noted. In terms of opportunity, older people were often less likely to

[27] Thorneloe, R., Epton, T., Fynn, W., Daly, M., Stanulewicz, N., Kassianos, A., … Hart, J. (2020, April 30). *Scoping review of mobile phone app uptake and engagement to inform digital contact tracing tools for covid-19.* https://doi.org/10.31234/osf.io/qe9b6
[28] https://www.adalovelaceinstitute.org/wp-content/uploads/2020/04/Ada-Lovelace-Institute-Rapid-Evidence-Review-Exit-through-the-App-Store-April-2020-2.pdf
[29] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3096582/

have a mobile phone, or a smartphone. In terms of motivation, issues related to privacy and confidentiality, perceived usefulness, perceived benefits.

The authors also highlighted a small body of literature surrounding the update of government recommended apps. The studies showed that higher uptake was correlated with the 25-34-year-old age group, gender (women), higher education, location (urban), but not income. Facilitators included perceived social justice, perceived usefulness, privacy and convenience, and social norms. Barriers identified were a lack of access to vulnerable cohorts (low eHealth literacy, older, English not a first language), privacy concerns, and a perceived lack of confidentiality and security.

Summary

There is a need to identify individuals' capability, opportunity, and motivation relating to digital contact tracing usage and engagement. Comparisons with other health behaviours change apps can be made but should be treated with caution due to the global pandemic context and the novel features of contact tracing apps.

Understanding the characteristics of the population for which an app is being recommended, and the behaviours required to adopt and use a health-behaviour change app from a user perspective, has provided a set of issues to address that are additional those that are most often identified by policy makers and operations. These user perspectives can inform efforts to increase adoption and sustain engagement.

Concluding remarks

It is important to note that at the time of review, empirical research into the efficacy of digital contact tracing using app-based technology as a public health response to the Covid-19 pandemic is emergent, and there is little evidence surrounding Covid-19 contact tracing app-related behaviours or user engagement, beyond adoption rates at a country level. The evolving nature of intelligence in this area presents a challenge for translating evidence for decision-making. As more research becomes available, it is therefore the intention that this research brief will be updated accordingly to incorporate emerging evidence.

Appendix

Methodology

Literature search

An initial keyword search of published literature was performed and restricted to the date range for the current Covid-19 pandemic 2019-2020. As published literature on the current pandemic is limited but emerging, a second search was conducted with the date limitation removed. A wider date search provided, inter alia, relevant literature relating to previous epidemics such as Ebola, influenza, and SARS. Keywords included: effectiveness, digital contact tracing, efficiency, apps, quarantine, Covid, Covid-19, SARS-CoV-2. Over 160 papers were retrieved and screened for relevance, resulting in 16 papers for review.

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