The thorny problems of Covid-19 Contact Tracing Apps: The need for a holistic approach

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Abstract
Once we accept the potential advantages that may arise from investing in contact tracing apps (CTA) as a response to the current COVID-19 crisis, we need to consider the different challenges that arise, and how they can be solved. In so doing, and to make the job surmountable, we must understand the challenging class of problems that spans both technical and behavioral issues (thorny issues). In thinking about the value of contact tracing, and the potential resolutions to some of the core problems, this short piece outlines what policy makers may need to consider, especially if we are to successfully deal with the predicted *second wave*.

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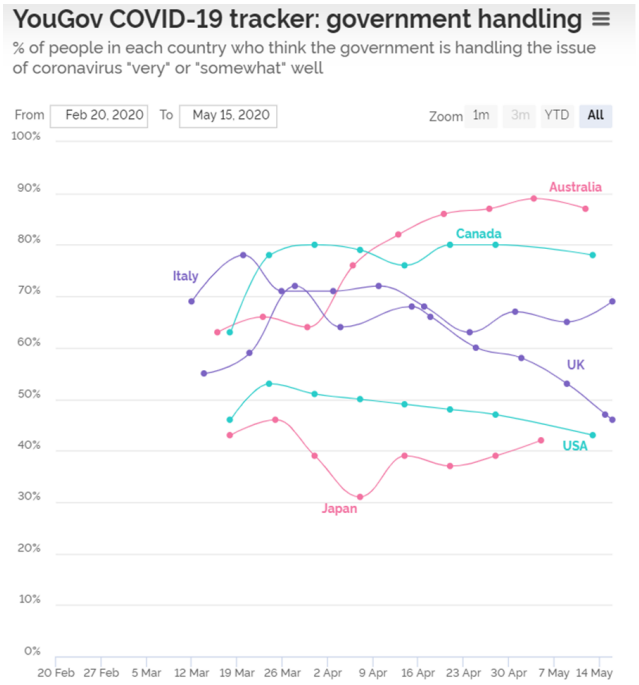
Introduction

From the time that the World Health Organisation (WHO) declared an international health emergency on the 30th of January 2020, and subsequently gave a name to the cause of it on 11th February 2020 by announcing a new coronavirus COVID-19, "our collective attention had been on its impact". Without the availability of pharmacological solutions, governments are still required to put in place policies that limit social contact in order to limit the spread of COVID-19.

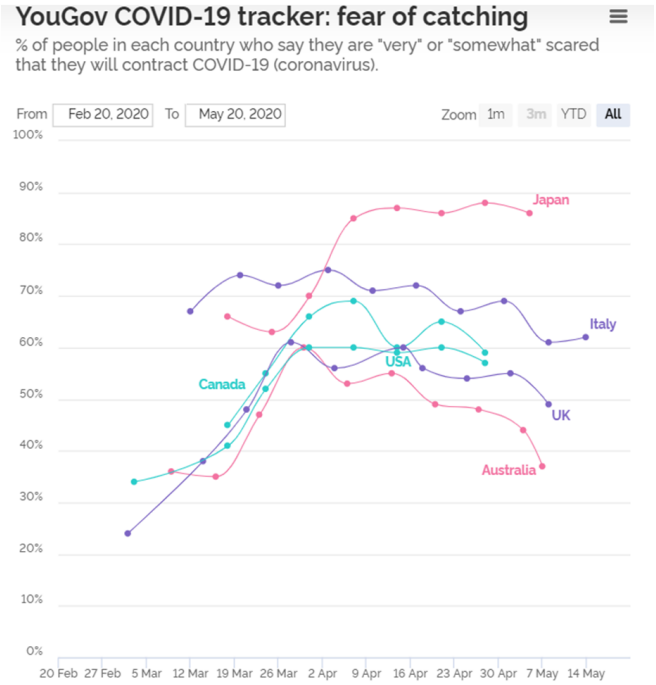
Governments have varied in their preparedness as judged by how early they put in place social distancing measures, and the types of social distancing measures (e.g. from no contact with others to moderate contact with groups ranging from 5 up to 30). Much of the public and political discussion to date is on the handling of the pandemic. This is where the importance of tracking public sentiment is critical because, ultimately, protection against infection is largely dependent on behavioral responses, which are graded with respect to the economic costs attached to them. Ongoing global opinion through opinion trackers (see Figure 1) suggest that there appears to be an inverse relationship between government handling of the pandemic, and public state of fear of contracting the virus. To illustrate the point about behavioral responses, Haushofer and Metcalf (2020) list several behavioral economic interventions based on prior tried and tested methods employed in previous health outbreaks. They discuss the need to routinize behaviors such as hand washing encouraged via text messaging reminders and widespread installation of soap dispensers in public spaces, with toys and games embedded in hand sanitizer bottles, to engage children and in turn encourage them to wash their hands frequently. These offer low cost solutions to address the need for maintaining personal hygiene.

Of course, behavioral economic interventions such as these are part of a wider armoury of instruments that policy makers have been using to combat the spread of COVID-19. The focus of the present article is on contact tracing (CT), and more specifically contact tracing apps (CTA). A key function of CT is to enable a relaxation of containment (e.g. lockdown) via a policy of outbreak management. This is of particular importance in response to the current Covid-19 pandemic, for which many countries have been, or will be, implementing CTA.

There are political, economic, social and cultural differences that help to account for why some countries moved to outbreak management, such as CT, earlier than others (Anderson et al, 2020; Bruns, Kraguljac, & Bruns, 2020; Hale et al, 2020). For some (e.g. South Korea, China, Taiwan, Hong Kong, Singapore), prior recent exposures to coronavirus epidemics, meant that there was experience and precedence in implementing CT methods early. This also helps to explain



Panel A



Panel B

Figure 1. The figures are reproduced from YouGov COVID-19 trackers that have sampled responses from 30 countries since February 2020, with approximately 21,000 in samples. Responses are from two countries each from Europe, Americas, and Asia/Pacific. Panel A includes responses to the question regarding government handling of the pandemic, and Panel B includes responses to the question of fear of contacting COVID-19 yougov.co.uk/covid-19.

why there is considerable variation between countries as to societal understanding of what track-and-trace means, and in turn is likely to explain some of the scepticism towards CTAs. Also, cultural attitudes, and social norms toward privacy present different challenges between countries. For some countries, considerable wide scale technological benefits offset what seem like, to others, an encroachment of personal boundaries (Acquisti, Brandimarte & Loewenstein, 2015); this no doubt will contribute to understanding variations in attitudes towards CTA. However, as Acquisti et al. (2015) point out, issues regarding the access to personal data people are willing to give, is highly contextualised with respect to the digital services that people want. This raises the question: *If CTA is seen as a necessary means to enabling society and the economy to function more freely, then is this a context for which people are willing to give considerable access to personal data?* As we will show, the answer to this, based on public polling, suggests not.

The remainder of this article discusses some of the most critical problems with respect to CTA, which combine technical issues with behavioral implications. Our overall thesis is that a holistic understanding of the overall factors that need addressing with respect to CTA (i.e. behavioral and technological) is necessary. Without such an approach, policy makers may end up with piecemeal solutions that undermine the successful outbreak management that is needed, as many countries may shortly face a second wave of Covid-19 infections. In the advent of a second wave, especially in periods of the year where seasonal flu is also likely to be an aggravating issue, absence of an effective *track, trace and isolate* system may unwittingly necessitate a return to lockdown.

Contact tracing

CT is a surveillance and containment strategy employed to fight the spread of infectious disease. It is a means of identifying the path an infection takes from an infected and diagnosed individual through to their contacts in the community. CT has generally only been employed for diseases of *low prevalence*: meaning diseases where only a small number of cases occur at any given time in the community. With mixed success it has been used to manage prior outbreaks of other diseases, including HIV, syphilis, and swine flu. There are different approaches that each change the scope for contact tracing (first-order, single-step, iterative and retrospective) each of which vary as to the extent of tracing and the approach to evaluating contacts (Eames, 2007). Prospective approaches consider those who were immediately in contact with the infected individual (first-order) and the individuals those contacts in-turn went on to infect (single-step). The retrospective

approach also considers recent past contacts of the infected in order to identify the prior source of their infection. The most productive, and consequently most resource intensive, method (iterative) continues to track and re-apply the relevant diagnostic test to contacts iteratively before their infection may even be detected through typical symptom screening. The advantage here, that the other methods cannot quite handle, are cases where individuals are infected and asymptomatic – especially problematic for tracing in general, and for CTA specifically (Ferretti et al., 2020).

Achieving CT has traditionally involved manual methods, employing individuals to interview infected patients and investigate the spread of infection through careful cataloguing of the patient's activities in the days prior to commencement of symptoms or their positive diagnosis. It has been proposed that a substantially less laborious method is to automate the process of CT, and that an obvious solution is through the use of smartphone apps. The idea is that individuals download one of the proposed CTAs that collects data recording where and when they came into close contact with others. For example, Taiwan, South Korea, Hong Kong and Israel implemented bespoke versions of CTA much earlier than most countries, including United Kingdom (UK), North America, and most of Europe, where CTA is still being developed or trialled as of May 2020.

Technical problems that have behavioral implications

To start with, public polling *inter alia* in China, France, Greece, Iran, UK, and US, favours social distancing measures, showing some reluctance for a return to normal life without other containment measures in place. This reflects a highly nervous and predominately fearful public and belies both a high subjective estimate of severity, and of individual susceptibility to the virus. Thus, a key behavioral barrier to surmount is to convince certain highly nervous sub-sections of populations to return to a resemblance of a normal functioning society. This is where *track, trace and isolate* policies that include a robustly functioning CTA ought to prove useful.

Downloading a CTA is on a voluntary opt-in[1] basis, which means that the public have to be willing to download the app on to their smart phones (Anderson et al., 2020; Dubov & Shoptaw, 2020). Thus, any technical problems are also impacted, and impact behavioral factors, because, ultimately, even if the technology works, and there are no privacy issues, if people don't download the CTA, then economically costly and time-inefficient methods of CT (without an app) need to be put in place to support a *track, trace and isolate* system. As Figure 1 implies, public attitudes towards assessing a governments' handling of COVID-19 is dynamic, and sensitive to any setbacks that are communicated in the media, and this can in turn impact the overall emotional state of the nation. Moreover, since the WHO announced that the world was facing a pandemic, risk perceptions (as outlined in Slovic, 2000) (i.e. perceived severity, perceived susceptibility) have significantly varied by population and over time. Therefore, a *track, trace and isolate* system that stumbles at the first hurdle because of an ineffective CTA will in turn impact public opinion on the policy measures overall, and the extent to which they comply with them.

1) Although not widely reported in discussions about CTA, a key problem is the uncertainty around the assumptions regarding infection rates and fatality rates that are necessarily incorporated into CT and CTA methods. For example, both CT and CTA depend on an accurate understanding of the transmission rate of the virus and the ability to do a diagnostic test for COVID-19 in a timely manner (preferably within 24 hours), assuming low false negative and false positive rates. In addition, those developing CTA also need to know the susceptibility, prevalence, and latency of the disease. Together, these details help contact tracers implementing traditional CT methods, and modellers and developers of CTA, estimate how contagious the disease is. This in turn, helps them to gauge how effective *track, trace and isolate* policies are likely to be overall. Put simply, if the inputs into the system are inaccurate, then that can undermine the effectiveness of the entire *track, trace and isolate* policy, and that in turn can have a significant impact on public sentiment.

2) It is important to know who actually own smartphones. As an example, in the UK, smartphone penetration for adults has only achieved 79%, reducing to 40% in the key COVID-19 demographic, the over-65s. This adds considerable pressure on lower economically costly behavioral solutions to ensure maximal uptake in the population for those that own smartphones – indeed, we have already demonstrated that the proposed National Health Service User Experience (NHSX) CTA in the UK would require a minimum 95% population take-up to be effective (McLachlan et al., 2020a).

3) As with the previous technological problem, another problem that might be solved more cheaply through behavioral economic solutions is, for those that have smartphones, compatibility issues arise. That is, some versions of CTAs are incompatible with more common smartphone operating systems. If there is an urgency to roll out a *track, trace and isolate* system, then there may not be enough time to develop CTAs that are compatible with a broader range of smartphones. If so, then a behavioral solution might be to focus on educational campaigns to promote the uptake of the CTA in populations that are likely to have compatible smartphones;

4) One of the most salient issues associated with CTA are potential violations of the privacy of potential users (Krishnan, Yang, & Schaumont, 2020) for the reason that those that handle personal data can make it available for third-party use. In addition, there is potential monopolisation by key tech companies, hampering the development of alternative software solutions that are privacy-preserving (Krishnan, Yang, & Schaumont, 2020).

[1] Though see Anderson et al. (2020) for an exploration of opt-out alternatives.

To the latter point, from the behavioral end, appetite for CTAs, at least in local country polling, appears to vary by country, with muted opinions in the UK comparable to predominately negative opinions in France, US, and Singapore. In the case of Singapore, while the National Development Minister had announced in March, at the launch of the TraceTogether CTA, that at least 75% of the population was required to have the app on their phone for it to be effective, only around 25% of the population downloaded and used it. Furthermore, legal and ethical challenges have been raised regarding how the CTAs are used. For instance, Israel's Supreme Court has banned its intelligence agency from tracing the phone location of those infected with Covid-19 until new laws are passed. Also, in France, several legal debates ensued after the government proposed the widescale use of their own CTA, with the EU Commission and European Data Protection Board (EDPB) each publishing guidance documents in an effort to ensure that privacy laws are not violated. Continued media reporting of issues such as these do not help to instil trust in CTA.

Also, public confidence in governments has also varied by country, along with public trust, and these also present behavioral barriers to uptake of CTAs (Anderson et al., 2020). However, there is evidence to suggest that perhaps these attitudinal barriers are not insurmountable. Anderson et al (2020) surveyed participants between March and April 2020 in France, Germany, Italy, the UK and the US to assess their likelihood of installing CTA (under an opt-in voluntary system) and their likelihood of keeping a CTA installed (under an opt-out system where there was automatic installation by mobile phone providers). There was broad cross-country agreement (responses in the range of "probably" or "definitely") for both opt-in (74.8%) and opt-out (67.7%) variants of CTA.

To summarise, the technical problems raised in this section may require behavioral solutions in the form of greater promotion of the need for CTA, and assurances that privacy issues, which dominate public consciousness, will be addressed. In addition, public attitudes towards trust in governments and their policies, along with dynamically forming emotional sentiment (e.g. expressed as fear), drives risk perceptions of the perceived severity and susceptibility of COVID-19, also impacting behavioral responses to social distancing measures generally, and likely uptake of CTA more specifically.

Conclusion: Policy solutions require holistic understanding

Why invest efforts in solving thorny problems raised by CTA? There are obvious behavioral economic advantages to an effective CTA. For instance, if a government announces the removal of 14-day quarantines for foreign tourists entering the country, then having an effective CTA built into a *track, trace and isolate* system is of enormous benefit. First, there would be economic advantages for industries dependent on tourism. Second, psychologically, this would be a significant assurance boost, because it signals internationally, as well as nationally, that COVID-19 is under control in that country.

So, what is the best way forward? Many of the problems presented here have, in isolation, been raised in the media and open letters by academics, and unfortunately none will be resolved by simple replacement of the underlying technology. The critical point we hope to have made in this article is to map out the need to target technological issues in relation to their behavioral economic consequences, since the two are interlinked. We can take the time in this concluding section to offer a potential solution that addresses both.

Our solution: Crucially, all existing and proposed CTAs for outbreak management are of the retrospective type. Recall that this method of CT records when an individual has already gone out, possibly multiple times, and is later is diagnosed with COVID-19. It is generally used to alert any contacts the person previously came in contact with that they too may also be infected.

McLachlan et al (2020a, 2020b) propose a technological solution to the above problems that complements – and can work with – the existing UKs NHSX and COVID Symptom Study apps. At its heart is a causal probabilistic model (a 'Bayesian network') that provides diagnostic-oriented feedback to users, while making it possible to monitor the population for new outbreaks and the locations at which these occur as early as possible. Unlike other CTAs, this solution requires minimal data transmitted to the server. Even if coupled with collecting a similar anonymous symptom-set as used for the COVID Symptom Study app, it would be far more palatable to people concerned about privacy. Only two pieces of data need to be transmitted: the probability the user has Covid-19 and their GPS-location. The solution is intended to also be a current and prospective CT method, by providing a probability for whether you might already be infected, and advising you as to whether or not you should be going out.

The privacy issue spans both behavioral and technical matters. However, academic, political and media circles have created somewhat of a false problem in suggesting that policymakers must trade-off effectiveness of the CTA against privacy of the citizens. We strongly believe that the trade-off does not need to be made. The technological solution we propose incorporates the best of current CTA and symptom screening approaches with the addition of a Bayesian network to assist the citizen in decision-making around questions such as *'whether or not I have the disease?'*, *'whether or not I should go out?'*, and *'Whether or not it is safe to be in contact with others?'*. This doesn't require the same level of personal data as other CTAs being trialled, or CTAs that have been implemented in other countries and that have posed significant legal concerns.

One final important matter that has a bearing, not only on the technical solution we present, but to any CTA that is trialled or implemented is the following: To what extent do people self-isolate if they are recommended to do so via a CTA, or a contact tracer, given that they are symptomatic, or

asymptomatic. YouGov polled the British public on 12-13th May 2020 and found that, if symptomatic, then over 70% of respondents ($n = 2471$) were very likely to self-isolate irrespective of whether they were contacted via CTA or a tracer. If on the other hand they were asymptomatic, more were very likely to self-isolate if contacted by a tracer (39%) than CTA (30%). This suggests that heavy reliance on CTAs for economically efficient reasons (i.e. because employing vast numbers of contact tracers is significantly costlier) carries one other significant behavioral consequence. The economic savings are unlikely to out-weigh the long-term costs of asymptomatic individuals ignoring CTA recommendations and continuing to spread a highly infectious virus, possibly because they may believe a human communicating the recommendation more than a text message. Therefore, one obvious solution is to employ a CTA along the lines proposed here, and coordinate it with contact tracers. That way, when the CTA advising you as to whether or not you should be going out, the advice need not be communicated via text, but rather via human interaction, which though moderately costlier, is likely to generate significant benefits economically and behaviorally, in the long run.

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