Sustainable containment of COVID-19 using smartphones in China: Scientific and ethical underpinnings for implementation of similar approaches in other settings

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COVID-19 is a rapidly spreading infectious disease with pandemic potential, caused by the novel virus, SARS-COV-2. With intensive care support, the case fatality rate is approximately 2%, and around half of infections become cases [1]. More concerning is that the fraction of cases requiring intensive care support is 5%, and patient management is complicated by requirements to use personal protective equipment (PPE) and engage in complex decontamination procedures [2]. Fatality rates are likely to be higher in populations older than in Hubei province (such as in Europe), and in low-income settings where critical care facilities are lacking [3]. Even modest outbreaks will see fatality rates climb as hospital capacity is overwhelmed, and the indirect effects caused by compromised health care services have yet to be enumerated. Effective containment must be achieved.

Epidemic control in China. Chinese cities and provinces have achieved effective containment despite receiving significantly more introductions from Wuhan than anywhere else, following mass movements of people around Chinese New Year and the start of the Wuhan lockdown [4]. Despite this, today 4 March 2020, China has achieved a situation where only 120 cases were recorded in the last 24 hours, 5 of which occurred outside of Hubei province. This situation compares starkly with growing epidemics in Italy and South Korea, and emerging epidemics in many countries including the UK. China have enforced a variety of measures aimed at social distancing including lockdowns, restrictions on movement and cordon-sanitaires, as well as the Alipay Health Code smartphone application (an add on to the WeChat app system) now adopted in over 200 cities and by 90% of individuals in one Chinese province. A separate system has been implemented in South Korea, and both have come under public scrutiny over issues of data protection and privacy.

We sought to design a broadly acceptable version of this platform, leveraging commonly used smartphone functionality. This system is currently in development, and based on a very simple algorithm, that we show mathematically will enable public health agencies to prevent a COVID-19 epidemic while minimizing social and economic disruption.

We first set out why such an approach is necessary, explaining why the current policies, such as those in the UK, are unlikely to work. We then describe a version of the system configured to our own detailed estimates of COVID-19 transmission, and discuss issues surrounding the ethics, social acceptability and optimal implementation of the platform.

Isolation and contact tracing as currently practiced is unlikely to prevent an epidemic. Currently, most cases have been identified through testing of symptomatic individuals. The case is then interviewed and asked to list travel and contacts, who are themselves tested, and quarantined. Relying on patient memory leads to incomplete contact tracing, and long delays between case presentation and diagnosis leading to poor patient outcomes and further transmissions. These problems are further compounded by high rates of infectiousness and short generation times [5]. We estimate 46% of all transmissions are sourced from pre-symptomatic individuals (95% CI: 33% - 64%), based on estimates of the generation time distribution (the time between becoming infected and transmitting the disease onwards) [Ferretti & Wymant et al in this issue]. Our data analysis and modelling of COVID-19 shows that this approach will fail to control the epidemic. Modelling the effect of manual isolation and contact tracing with these estimates show this approach is very unlikely to contain an epidemic because the delays are too long [6, 7, 8, 9].

This finding is supported by observations of the first 425 cases infected outside of the Wuhan seafood market, of whom 83% did not recall a contact with a symptomatic individual [10]. Conversely, in Singapore, where contact tracing was done retrospectively with the aid of the police and serological methods, ~90% of locally acquired cases were traced back to an individual who eventually became symptomatic (this number changes daily, decreasing with new cases as tracing takes days, see https://www.moh.gov.sg/covid-19). Together these two results imply a large contribution to transmission from individuals who have not yet developed symptoms.

Reactive approaches. One approach is 'wait and see', where reactive measures are brought in as cases accumulate in a city. A recent modelling analysis suggests that for each death observed in a city, more than a thousand are infected (https://cmmid.github.io/topics/covid19/current-patterns-transmission/cases-from-deaths.html). Regaining epidemic control from this situation is challenging, and due to lags between infections and deaths, may necessitate more costly measures such as lockdowns and school closures.

After the experience from Wuhan, China enforced pre-emptive managed lockdown in most major cities. A drop in contact rates between infectious and susceptible individuals is the likeliest explanation for the subsequent decline in case reports that followed. This approach is however unsustainable and damaging to the economy.

Negative impacts of these measures. The economic and social costs on individuals and communities caused by lengthy and widespread quarantine measures cannot be overstated. Individuals on low incomes may have limited capacity to remain at home. Psychological impacts are likely to be lasting. Support for people in quarantine requires resources. Businesses will lose confidence, causing negative feedback cycles in the economy.

Descriptions of the WeChat App used in China. As a method to relax the lockdown and allow economic activity to restart, China implemented a public health policy dependent on the adoption of an App, not compulsory, but required to move between quarters and into public spaces and public transport . The App allows a central database to collect two kinds

of information about the user - movement and coronavirus diagnosis - and gives a green-orange-red code to enable free movement, local movement only, or quarantine. The mechanism is a centralised collation of users' real-time contact networks by three means: proximity sensing between phones, co-location by GPS, and QR code scanning at the entrance and exit of areas inaccessible to phones (e.g. underground, large buildings). The database is reported to be analysed by an artificial intelligence algorithm that issues the colour codes
(https://www.nytimes.com/2020/03/01/business/china-coronavirus-surveillance.html).

A simpler and more transparent local adaptation. We hypothesise that an alternative could be implemented with an algorithm that is so simple it can be explained very intuitively (see Figure 1), and yet is shown mathematically to feasibly contain epidemics and configured using known transmission parameters (Ferretti & Wymant, in this issue). The core functionality is to replace a weeks' work of manual contact tracing with an instantaneous signal transmitted to and from a central server.

The App is in green mode during normal times. The App is 1. the central hub of access to all COVID-19 health services, information and instructions, 2. is the mechanism to request tests if a user is symptomatic, 3. it is a mechanism to request food deliveries during self-isolation (code red).

Why it works. A positive test result is instantly communicated to the server, and enacts risk-stratified quarantine and social distancing measures in those now known to be possible contacts. The mathematical demonstration of the feasibility of this algorithm (not linked to any App) was provided in Fraser in 2004 [6], elaborated Klinkenberg 2007 [7], Peak 2017 [8] and specifically for COVID-19 by Hellewell 2020 [9]. We returned to the original formulation of 2004 and have 1. confirmed and coded the mathematics, 2. estimated all the underlying parameters for the current COVID-19 epidemic, 3. established the thresholds that prevent epidemic spread under partial real-world effectiveness of the measures by potential users of the App, e.g. low uptake of the App or poor adherence with isolation.

Limitations. Specific issues surround specific groups that may not be amenable to such an approach, and could be rapidly refined in policy. The system would be impractical for school children - school closures could be triggered by the number of code oranges and code reds in the catchment area. Essential workers, such as health care workers, may need separate arrangements.

Ethics and social acceptability. The successful and appropriate use of the app as an intervention will only be achievable if it is capable of commanding well-founded public trust and confidence. This applies to the use of the app itself and of the data. There are strong, well-established ethical arguments recognising the importance of achieving health benefits and avoiding harm. These arguments are particularly strong in the context of an epidemic with the features described above. The situation is serious and there are significant levels of public concern. The app proposed above offers the potential for important benefit both to society and to individuals, offering the possibility of both reducing the number of cases and also enabling people to continue their lives in an informed, safe, and socially responsible way. It offers the potential to achieve important public benefits whilst maximising autonomy.

What are the requirements for the intervention to be ethical and capable of commanding the trust of the public? These are likely to comprise the following: 1. oversight by an inclusive and transparent advisory board, which includes members of the public. 2. The agreement and publication of ethical principles by which the intervention will be guided. 3. Guarantees of equity of access and treatment. 4. The use of a transparent and auditable algorithm. 5. The embedding of evaluation and research to ensure learning for the management of future outbreaks. 6. Careful oversight of and effective protections around the uses of data. 7. The sharing of knowledge with other countries, especially low and middle-income countries. Finally, it will be essential to ensure that the intervention involves the minimal imposition possible and that decisions in policy and practice are compatible with respect for three moral values: equal moral respect, fairness, and the importance of reducing suffering [11].

Recommendation. We recommend a strategy for attaining herd protection. This is a concept analogous to herd immunity: it is the population status that, no matter how many cases of infection are imported into the population, an epidemic cannot spread exponentially within it. It does not need to be perfect to work, just good enough to maintain $R_0<1$.

The system proposed here can in theory provide herd protection with much less disruption than lock down or even existing UK policy, since most users will be able to continue with regular activities most of the time. In practice we see no reason not to develop this system and combine it with other planned measures.

We are currently simulating scenarios to establish how many fewer people are isolated and quarantined with this approach compared to other reactive approaches, and have engaged major tech providers in it’s implementation.

The simple algorithm can easily be updated for specific areas, for example quarantining areas if infections become uncontrolled, or performing second- or third-degree contact tracing if case numbers are rising, resulting in a greater number of people being preemptively quarantined. It can also be manually overridden, if facts seen on the ground necessitate it. The algorithmic approach we propose avoids the need for coercive surveillance, since the system can have very large impacts and achieve complete herd protection, even with partial uptake [Ferretti & Wymant et al., in this issue]. People should be democratically entitled to decide whether to adopt this platform. The intention is not to impose the technology as a permanent change to society, but we believe it is currently necessary and justified.

A pandemic is not inevitable.

Figure 1

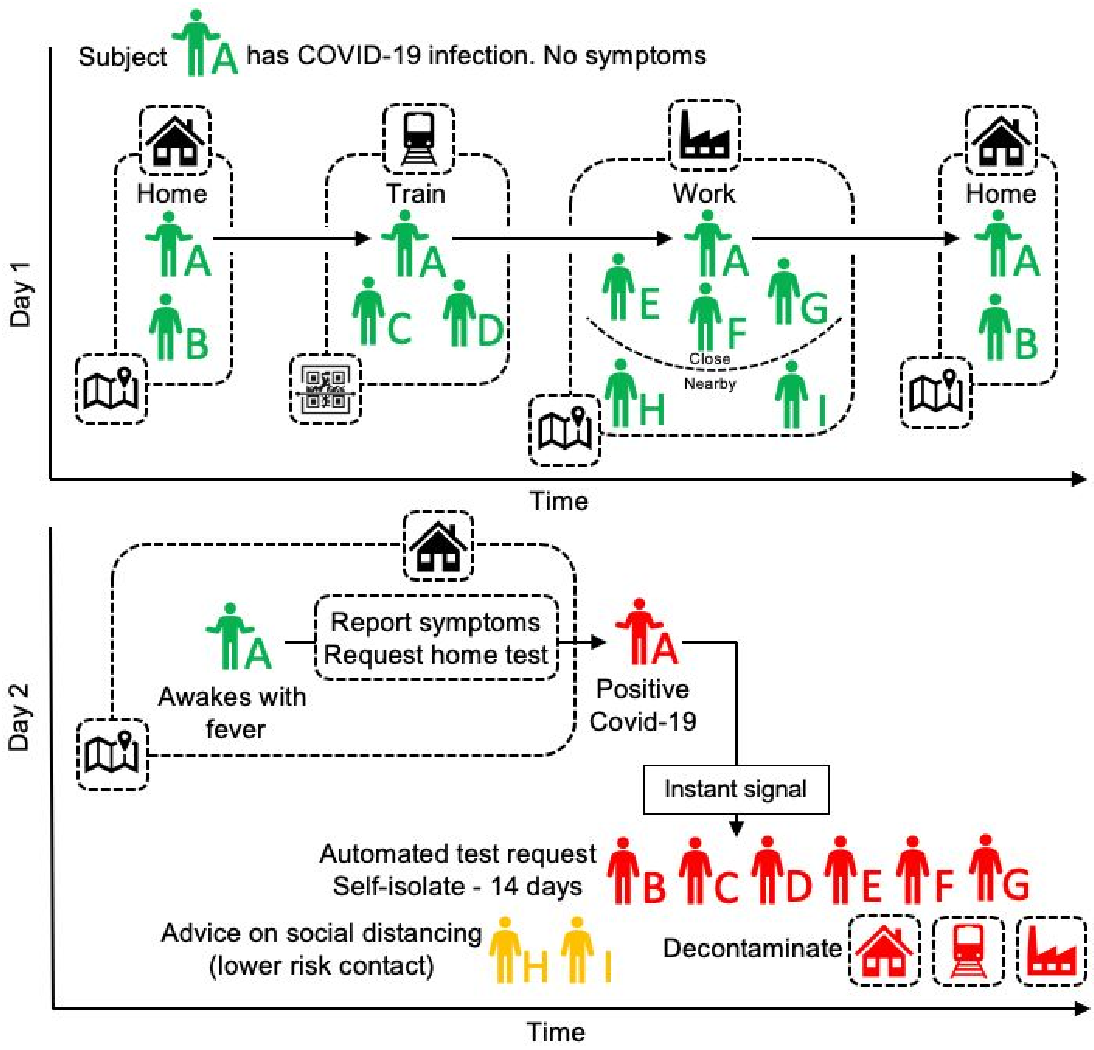

Figure 1 - Illustration of an algorithm that could underpin an App-assisted infection-control response to achieve herd protection from COVID-19. Contacts of person A (and all people with the App) are traced using GPS co-localisations with other App users, and by scanning QR-codes displayed on high-traffic public amenities. Patient A requests a SARS-COV-2 test (using the App) and their positive test triggers an instant notification to individuals who have been close contact. The App directs case and contact isolations, recommendations and decontamination procedures.

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