The digital response to COVID-19: Exploring the use of digital technology for information collection, dissemination and social control in a global pandemic

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Abstract

In response to the COVID-19 pandemic, there has been a global surge in the development and implementation of digital interventions to diagnose, track, prevent and mitigate the spread of the SARS-CoV-2 coronavirus. To date, however, there has been little research to characterise the vast scope and scale of these novel, ad hoc and widely varied digital tools. This paper helps fill this gap by providing a

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descriptive summary of the digital response to COVID-19. The research finds that the digital response can be broken into four main categories: 1) tracking the spread of the virus (contact tracing); 2) controlling social behaviour during the outbreak (social behaviour monitoring); 3) information gathering and dissemination about the virus (one-way and two-way public communications); and 4) diagnosis and treatment (remote diagnostics and treatment). This paper describes the four response categories and provides examples of the digital technologies being developed and implemented for these purposes. This descriptive understanding provides a contextual foundation for subsequent research to analyse the opportunities and challenges associated with the development, implementation and uptake of digital interventions, alongside the development of analytical frameworks and guidance.

Keywords: COVID-19, innovation, digital technology, infodemic, risk analysis, digital response, surveillance

INTRODUCTION

The COVID-19 pandemic is an international public health emergency with immediate and secondary health impacts, as well as cascading and compounding crisis effects that are global in nature. Millions of people have been infected, and COVID-19 continues to spread globally with differing patterns and waves of infection nationally and regionally.[1] Clinical, public health, scientific and political responses have aimed to contain, control and mitigate the pandemic while seeking diagnostic, treatment and vaccination solutions. These actions have in turn been radically influenced by the digital responses to the challenges the pandemic continues to pose.

Digital response to crisis (such as a natural disaster or complex public health emergency) involves the use of digital technologies to support the ability to prepare for, respond to and recover from a crisis. In the context of the present paper, the term 'digital technology' is used to refer to physical technologies, like mobile phones and drones, as well as soft technologies, like short message service (SMS) functionality and social media platforms.

Digital response involves three forms of innovation: 1) using existing digital technologies for their intended purpose but in a disaster context (like the use of SMS for 9/11 reporting[2]); 2) repurposing existing technologies for a different purpose in a disaster (like using mobile Global Positioning System (GPS) data to track population movement); and 3) creating new technologies for the disaster response context (like the development of crisis mapping platforms or defibrillator drones). These different uses and applications originate from the top down — for example, through government or response organisations implementing smart sensors to detect earthquakes or through the establishment of mass-notification systems to alert the public in emergencies — as well as from the bottom up — such as citizens using social media to coordinate large-scale collaboration (as seen in the Arab Spring[3] or the Occupy Movement[4]) or creating tools (like Hala Systems' Sentry app, used to alert civilians of incoming airstrikes in Syria).

Prior to COVID-19, the penetration of digital technologies was an emergent phenomenon: as technology infiltrates society in normal times, it finds its place in moments of disaster. With the COVID-19 pandemic, however, novel conditions have shaped the digital response to crisis. From a service delivery perspective, physical distancing measures have hindered health providers from providing face-to-face care, decision makers from physically convening to coordinate the response, and the general public from providing in-person support to one another.

The criticality of sharing new information has stimulated the demand for new information to such levels that the volume of information generated has become increasingly difficult to navigate. The result is an *infodemic*[5] — a situation where the excessive amount of information available makes it difficult to find a solution.[6] This is highly problematic given the importance of digital connectivity and digital tools for controlling the pandemic, keeping society functioning and recovering in the future.

Since the onset of the pandemic, societies have played both witness and guinea pig to the surge of digital innovation associated with managing the spread of the virus. With a specific focus on the interaction between public service providers (government, response agencies, humanitarians and first responders) and the broader public, digital innovations have been used to track the spread of the virus; monitor and control public behaviour; manage information demands; and provide diagnostics and treatment support. With urgent timelines, the ongoing real-time and evolving scientific discovery and understanding of the characteristics of COVID-19, the myriad and scale of clinical public health impacts worldwide, and the varied actors involved in the response to the virus, digital innovation has moved faster than it has been studied. Service providers have been forced to react instead of being proactive. Human survival has at times been prioritised at the expense of human rights protections, and interventions have been implemented in ways that bypass the standardised testing, risk mitigation and ethical oversight mechanisms that exist in normal times. There is little understanding of the true nature of this digital response and, subsequently, little understanding of the downstream short and longer-term opportunities and challenges affecting the efficacy and ethical viability of these interventions. To enhance the ability to manage not only the COVID-19 pandemic but also future pandemics, the present study aims to contribute to an understanding of the nature of the digital response to the COVID-19 pandemic by examining how digital technologies are being used around the world to respond to the COVID-19 pandemic.

The study will address this issue with a focus on the interactions between service providers and the general public. A descriptive summary will explain the digital response context through four main response tasks: digital contact tracing, social behaviour monitoring, public communications and remote diagnostics and treatment. This paper aims to establish a foundation for subsequent research papers focused on the analysis of the digital response. Future study strives to explore the opportunities and challenges associated with the development, implementation and uptake of digital technologies in crises like the COVID-19 pandemic, as well as generate an analytical framework and provide guidance support.

METHODOLOGY

Research was conducted through meta-analysis of grey literature (public and private media reports, blog posts and social media data) and peer-reviewed literature where available (given the novel nature of the study, little peer-reviewed literature was available at the time of the research). Areas of study were divided along four response purposes (described above) for digital tools including mobile apps, mobile data, SMS, online platforms, drones, artificial intelligence (AI)/machine learning and telemedicine.

THE DIGITAL RESPONSE CONTEXT

Contact tracing

Contact tracing is a public health measure that is a standard practice in the management of outbreaks of infectious disease, such as the spread of Ebola in Africa.[7,8] Contact tracing tracks the epidemiological spread of a pathogen by mapping the movements and interactions of people that have tested positive.[9,10] Prior to COVID-19, contact tracing had been conducted almost exclusively through manual methods. Manual contact tracing is performed through in-person interviews with infected persons and the individuals with whom they have come in contact in order to identify potential carriers and spreaders.[11] During COVID-19, digital contact tracing has emerged as a potentially viable approach to complement manual contact tracing. Digital contact tracing is typically performed through the use of mobile apps, but also through other digital interventions like QR codes or tokens. Mobile apps function through location-based tracking (which uses GPS to trace individual movements by location) and Bluetooth-proximity tracking (where, upon detection of proximity for a specified duration between two mobile devices, normally smartphones, encrypted keys are exchanged between phones to enable later identification). quick response (QR) codes, registered through scanning a specific type of barcode on a mobile phone, track individual contact and enable access with specific locations (like stores, restaurants, public transportation services) when individuals scan a QR code upon entry/use of a public service. Tokens are wearable devices that can supplement smartphone applications. Applied in Singapore with the elderly population, for example, tokens use Bluetooth signalling to other tokens or smartphones with the contact-tracing app to log interactions.[12]

Digital contact tracing has been driven and implemented by both the public and private sectors in response to situational needs and opportunities. While a great deal of innovation in digital contact tracing is taking place in the private sector, this is beyond the scope of the present paper, which focuses on the public sector only. The global rollout of these interventions has followed two main approaches in terms of data storage: centralised and decentralised. Data collected through location-based tracking, QR codes and e-bracelets are typically stored centrally (ie on government or public health servers). Bluetooth-proximity tracing, by contrast, is generally decentralised — the data are stored on a user's mobile device and will remain there unless the user opts to upload their data to the public health servers (if they are COVID-19 positive, for example).

Some countries and states have adopted streamlined approaches to the development of collaborative digital contact tracing interventions to ensure interoperability across borders. The EU and Canada, for example, have taken a collaborative approach to the development of digital contact tracing tools. In the USA, by contrast, intervention design is more distributed, with digital contact tracing solutions made at the state level.

Public participation in contact tracing measures ranges from voluntary to involuntary, with a number of countries monitoring people without their explicit consent. In China, for example, measures have been particularly invasive, and have included tracking people's movements and digital wallet activity, conducting facial scans, and partnering with tech companies to harvest personal health data.[13] Israel initially used location-based tracking, framed by some as counter-terrorism technology.[14] Banned shortly after its implementation, due to the lack of public consent,[15] a bill was later passed to reinstate the tool.[16]

Singapore, meanwhile, introduced the Safe Entry App as a means to impose mandatory QR code tracking for access to public spaces such as supermarkets and workplaces. This effectively requires individuals to share their name, mobile number and National Registration Identity Card to access public spaces.[17]

South Korea has also adopted an invasive nationwide strategy, combining digital data collection (CCTV cameras, satellite-based phone tracking, credit card transactions) with a network of contact tracers;[18] polls, however, show that South Koreans have high trust in their authorities and do do not object to these measures.[19] Within India, employees in specific sectors and residents in certain regions of Delhi have been required to download a location-based digital contact-tracing app.[20,21] In Bahrain, meanwhile, the government has published sensitive information (collected via its contact-tracing app) about suspected COVID-19 cases.[22]

Countries and regions that have implemented centralised but voluntary digital contact-tracing apps include Europe, the UK and certain US states (notably Utah and North and South Dakota). Europe initially approached digital contact tracing through the Pan-European Privacy Preserving Proximity Tracing (PEPP-PT) model — a collaboration between eight countries that promoted centralised data collection. The UK was one of the first to implement a Bluetooth-proximity tracing app that used centralised data storage.[23] France has similarly adopted centralised data storage for its digital contact-tracing app, TousAntiCovid.[24] Like Singapore, New Zealand has adopted a centralised QR code approach but scanning has been voluntary.[25] The Singapore government has also developed an app, TraceTogether, that uses Bluetooth-proximity tracing and assigns a randomised userID to the user's phone, uploading data only with consent. This app has been mimicked around the world at different stages of the pandemic, including in Australia, Canada, Germany and Poland.

Decentralised tracing measures have been implemented strictly through voluntary participation. Google and Apple have developed an application programming interface (API) that opens up their operating systems to enable privacy-preserving proximity tracing via Bluetooth. This Google Apple Exposure Notification (GAEN) API dominates decentralised digital contact tracing innovation in Europe and North America. Switzerland, initially leading the development of the Decentralized Privacy-Preserving Proximity Tracing protocol (DP-3T), has since partnered with both Google and Apple, implementing the first application of the GAEN API in Europe.[26] Northern Ireland was the first region within the UK to adopt the API,[27] while the UK as a whole has now shifted from a centralised approach to the GAEN API.[28] In Canada and the USA, the Canadian government and individual states (eg Virginia and Alabama) have released digital contact-tracing apps that also use the GAEN API. Beyond Google and Apple, Iceland has developed its own decentralised app, Rakning C-19, and has achieved one of the greatest digital contact-tracing app adoption rates of 40 per cent.[29] Academic institutions, like the University of Waterloo, Stanford, MIT and Oxford also have been developing their own privacy-centric apps.

Social behaviour monitoring

Social behaviour monitoring (SBM) entails the observation of people's actions in order to: 1) analyse and understand associated patterns; and 2) control/manage those actions.[30] SBM can take many forms, including car dash cameras, stop-light cameras, food delivery location tracking, traffic congestion on web and mobile map applications based on smartphone data, and targeted advertisements based on search engine history.

While SBM is typically outside the scope of the healthcare field, in the case of the COVID-19 pandemic, social behaviours are integrally tied to individual and public health (ie the risk of contracting and/or spreading COVID-19). For this reason, the monitoring of social behaviours has been deemed necessary to control the pandemic, and digital solutions around the world have been developed or repurposed to monitor people's behaviour in public and private spaces. There are three main approaches to SBM during the pandemic: 1) quarantine-monitoring and surveillance; 2) physical distancing enforcement; and 3) next-step planning.

The first approach to SBM — quarantine monitoring and surveillance — has been used to ensure quarantine measures are observed. There are numerous digital solutions to support this kind of monitoring. In both Poland[31,32] and Moscow, Russia,[33] for example, people in quarantine are required to verify their compliance by taking selfies using a mobile application that tags their photos with geo-location data. Indeed, mobile applications have become widely embraced as a medium for verifying quarantine compliance. For example, Turkey,[34] Thailand,[35] Ecuador,[36] Taiwan[37] and Argentina[38] are just some of the countries that have leveraged mobile applications and/or mobile device location data to ensure quarantine. Some countries — such as South Korea,[39] Bahrain[40] and Hong Kong[41] — have resorted to monitoring quarantined persons through the use of electronic wristbands (e-bracelets) that connect to a mobile application on the individual's phone. Other digital solutions include security cameras (in use in Moscow[42] and China[43]); QR health codes that dictate who may leave home and who must stay home (also in use in China[44]); and web-based health management information systems with the ability to register and track persons (in use in Sri Lanka[45]). In many of these contexts, if an individual breaks quarantine rules, steps are taken to address their behaviour; such actions can range from sending text alert warnings to fines and imprisonment.

The second approach to SBM — physical distancing enforcement — is similar to the first approach, but rather than enforce quarantine, these digital solutions are designed to enforce physical distancing and other measures designed to help stop the spread of COVID-19 (such as wearing masks). Hungary[46] and Italy,[47] for example, have used drones to monitor and enforce physical distancing measures, while companies in India[48] and the USA[49,50] have respectively developed AI-driven video surveillance tools to detect crowd-gathering and compliance with physical distancing. Dubai, meanwhile, has been using AI-driven speed radars that can track vehicles and determine whether a person is travelling for essential purposes.[51] The region also has been leveraging AI-powered surveillance cameras to detect the temperature of those passing by, as well as determine whether people are maintaining proper physical distance.[52] One city in Russia has required service providers to install surveillance cameras to check "whether social-distancing norms and other precautions are being followed";[53] this same city also has been monitoring residents through a QR code system that allows citizens to leave their homes for various purposes while tracking these individuals.[54,55]

The final approach to monitoring behaviour — next-step planning — involves the collection and analysis of social behaviour data to help entities determine the next steps to contain, control or mitigate the spread of the COVID-19 virus. For example, Germany,[56] Belgium,[57,58] Austria,[59] France[60] and Italy[61] have partnered with various mobile-technology companies to access data in order to analyse population movements, assess whether various measures are working and decide on next steps that are evidence-based. In Switzerland, SIM card geolocation technology has been used to inform authorities about gatherings of more than 20 people, although authorities are not notified in real time.[62] Rather, the purpose of gathering such data is to identify locations where gatherings are consistently taking place and to take measures to limit or stop these congregations from happening.[63] Artificial intelligence is proving to be a popular tool for next-step planning. For example, some academic institutions in the USA[64–66] have developed models that examine the effect of different interventions, or varying degrees of the same intervention, on the spread of COVID-19. France, meanwhile, has adopted a mask detection software program that has been used to determine mask adoption rates in the Paris subway system,[67] and Argentina has been trialling a predictive analytics AI platform to determine how citizens can return to work.[68,69] Finally, big tech companies such as Facebook[70] and Google[71] have been using data to provide maps of population movements to help researchers and public health officials understand the pandemic and make decisions about the next steps to combat COVID-19.

Public communications (one-way and two-way)

For the purposes of this paper, public communications refers to information sharing between service providers and the general public. Sharing is conducted through two means: one-way and two-way communications. One-way refers to the *dissemination* of information to an audience with no means of response. Traditional examples include radio, newspapers and television, although mobile devices, web platforms and drones are increasingly being used for the mass broadcasting of information. Two-way communications refers to the *exchange* of information between two parties. For example, SMS, video conferencing and AI-driven chatbots on mobile and web platforms (among other digital tools) may be leveraged to facilitate manual or automated two-way communication. Manual two-way communication implies human-to-human interaction (eg disaster victims and humanitarian responders). It often involves a smaller audience, where the discussion or information provided is more tailored towards the needs of the recipient. This form of communication is covered in more depth in the following section on remote diagnostics and treatment. Automated two-way communications involves human-to-robot interaction (eg disaster victims and an AI algorithm).

During the COVID-19 pandemic, governments and organisations have used a wide variety of one-way public communications methods to communicate with their respective audiences. Emergency alert systems have been used by countries — such as Canada, New Zealand, the UK, Denmark, the Netherlands, France, Germany[72] and Romania — to keep citizens up to date regarding critical information such as social distancing, quarantine or lockdown measures.[73] Vodafone has committed to facilitating targeted text messaging (for example, to residents in communities severely impacted by COVID-19) as well as text alerts to the general public.[74] BRCK in Kenya, along with Viamo (in use in countries such as Haiti, Nepal, Mozambique, Democratic Republic of Congo and Indonesia) use automated text or audio message services sent in different languages in order to connect communities with information about COVID-19. Drones also have been in use in India,[75] China[76] and New Jersey, USA[77] to deliver public messages to remind citizens about physical distancing protocols, personal protective equipment and areas with high COVID-19 rates.

In terms of automated two-way public communications, many countries are leveraging SMS, mobile applications, web platforms and AI-powered tools to exchange information and enable discussion between parties. The World Health Organization (WHO) has repurposed the WhatsApp messaging application and leveraged AI technology to respond to users' questions on topics surrounding COVID-19 on a global scale.[78] New Zealand has also used WhatsApp to ask citizens how they were feeling and to act as a reliable information source regarding COVID-19.[79] Similarly, the Lithuanian government has used an AI-powered robot called ViLTė to answer the public's questions about COVID-19 as well as to provide a reliable source of information throughout the pandemic on a wide variety of topics. Kenya and India have been using askNIVI — a repurposed chatbot service provided through Facebook's messaging feature — to provide COVID-19 related news, statistics and best practices. Meanwhile, some organisations have tried to tackle the issue of fake news and the spreading of misinformation in regards to the COVID-19 virus. Google, for its part, has been promoting the consumption of accurate information by ensuring that the top-ranked search results pertaining to COVID-19 come from trusted local, national and international sources.[80] Eurocom and Cornell University have partnered to establish a machine-learning fact checker to mitigate the spread of fake news.[81] Lastly, Facebook has implemented an algorithm to locate and block posts that are providing inaccurate information.[82]

Remote diagnostics and treatment

Traditionally in healthcare, diagnosis and treatment occur in-person at healthcare facilities such as medical clinics or hospitals. Given the infectious nature of COVID-19 alongside the need to 1) continue diagnosing and treating COVID-19 patients as well as persons with other healthcare issues; 2) protect healthcare workers, other patients and members of the community; 3) prevent the overburdening of healthcare systems; and 4) consider other highly relevant issues such as shortages in personnel and personal protective equipment, the possibility and need to diagnose and treat persons remotely becomes salient. As such, digital tools have been repurposed and developed to enable diagnosis and care to be facilitated from a distance. These tools fall under one of three approaches: 1) screening and assessment; 2) healthcare delivery; and 3) decision-making and research support.

Within the diagnostic process, screening and assessment entails identifying the likelihood an individual has been infected with COVID-19, engaging diagnostic testing, and where necessary, planning appropriate treatment. Tools that can contribute to or facilitate these components fall under two areas: self-screening and physiological monitoring.

Digital tools that are considered *self-screening tools* can enable individuals to do three things: 1) facilitate a self-assessment for COVID-19 symptoms; 2) share their data for analysis purposes; and 3) receive information about next steps. Various public health, technology and government organisations have implemented mobile and web applications that prompt users to enter their contact information, answer evaluation questions, and receive both risk assessment results and recommendations regarding the next steps to take (as determined by AI algorithms). Organisations identified as developing and/

or implementing such self-screening tools include Stallion.ai in Canada, [89] Diagnostic Robots in Israel,[88] the Ministry of Health in Nepal (CoVid19-Dashboard), Andrija.ai in Croatia,[85] communities in Spain[83,84] and various partnerships in the USA.[86,87]

Physiological monitoring tools observe a wide range of a person's vital bodily functions in order to screen, assess and diagnose an individual. Within the COVID-19 context, this includes detecting fevers, monitoring vital signs and analysing lung and other body sounds. In China, companies such as Amorph Systems,[90] INESA,[91] Sensetime[92] and Sunell[93] have used digital software and AI-driven programs to detect high temperatures in high-traffic or crowded areas. Drones and surveillance cameras also have been used to this end in Colombia[94] and the United Arab Emirates,[95] respectively. Rather than focus on the screening component of diagnosis, various companies have developed devices and sensors to monitor the vitals of both COVID-19 and non-COVID-19 patients in order to assist with the assessment and monitoring components of healthcare. The Indian Institute of Technology of Bombay, for instance, has designed a 'digital stethoscope' to identify heart and lung abnormalities in the COVID-19 assessment stage.[96] Vocal and lung changes have been a particular focus for many researchers looking to identify potential diagnostic markers for COVID-19. For example, Vocalis Health has partnered with the Israeli government while Voca.ai has partnered with Carnegie Mellon researchers in the USA to determine whether voice recordings can be used to identify whether an individual is COVID-19 positive.[97] Cordio Medical in Israel,[98] Strados Labs in the USA[99] and the Cough for the Cure initiative in the USA have focused on recording lung sounds and coughs. The first two initiatives are attempting to detect and monitor lung changes that are specific to COVID-19 patients while the latter initiative is collecting coughs to train AI algorithms to diagnose COVID-19 patients based on the individual's cough.

Besides diagnosing COVID-19 patients, healthcare workers must also provide healthcare delivery. In order to connect with patients to provide care, telemedicine technologies have been used for virtual consultations to allow patients and health providers to remain physically distant while obtaining care. Pakistan,[100] India,[101] Nigeria,[102] Kenya[103] and Israel[104] have all used mobile applications and websites in order to connect with physicians through video chat. Meanwhile, Israel and parts of Europe and Asia have partnered with TytoCare, a telehealth company that has been acknowledged for its innovative all-in-one telehealth platform that enables AI-powered, on-demand, remote medical exams that respond specifically to the pandemic.[105] The Chinese provinces of Sichuan and Hubei have been equipped with a 5G network to better facilitate not only video consultations, but also support the digital technologies discussed in this report.[106] These include unmanned vehicles monitoring and communicating with individuals, temperature detection technologies, and medical robots designed to conduct consultations, clean and disinfect, and deliver essential supplies such as food and personal protective equipment.[107] In a rural town in Ontario, Canada, a virtual triage assessment centre was established so that individuals seeking medical attention could connect to physicians or nurse practitioners via phone or video.[108] Meanwhile, in an attempt to improve the triage process and provide more information to emergency responders, 911 dispatch centres in New Orleans, USA have started to use video-chat technologies with callers.[109] Digital tools have also been used to deliver medication. For instance, Drone Delivery Canada is using drones to deliver COVID-19 supplies to a First Nation Community in Ontario, Canada.[110] In Asia, a medical services queue management application (developed by the IVT Group with VANTIQ technology) dispenses medications without the need for manual intervention.[111] These interventions complement existing digital solutions for medication delivery, such as automated medication machines that provide patients with their appropriate medication based on their prescription.[112] As seen with the examples above, patients with COVID-19 can be managed and treated entirely through virtual means. Such is the case at Jefferson Health in Philadelphia, USA, where patients with COVID-19 have been evaluated and treated without referrals to in-person care.[113]

Digital innovations have also been used to assist with decision-making and research support at individual and systemic levels. In Malaysia[114] and Africa,[115] for example, various organisations have developed applications that support healthcare professionals by providing accurate information, screening tools and general support to diagnose and care for COVID-19. Collaborations have also been made between academic institutions and hospitals in Denmark,[116] Canada[117] China[118] and the USA[119] to develop and implement an AI system that can project future COVID-19 cases and demands on intensive care, so that they can plan resource allocation and maximise efficiency. In Singapore,[120] Latin America[121] and the USA,[122] some companies have established partnerships with governments or healthcare systems to optimise healthcare by reducing wait times, reducing exposure to the COVID-19 virus, as well as improving patient triage, patient tracking, health system capacity and patient flow. AI is also being used to assist with research to find a treatment for COVID-19. Benevolent AI and the Imperial College London;[123] Insilico Medicine and Arctoris;[124] Google's Deepmind;[125] Allchemy;[126] Deargen, based in South Korea;[127] My Intelligent Machines, based in Montreal, Canada;[128] Iktos and SRI International;[129] Gero;[130] Exscientia[131] and Sensetime[132] have all used AI in different ways for this purpose. Whether it be identifying drug targets, determining a set of inhibitors for COVID-19 treatment, predicting protein folding, identifying progeny drugs or potentially effective existing commercial drugs; or personalising COVID-19 treatment and vaccination, all the above partnerships and initiatives are thoroughly leveraging digital solutions to assist with researching and finding treatment for COVID-19.

NEXT STEPS

Given the nature of the digital response to COVID-19 described here, substantial analytical research is needed to better understand and account for the opportunities and risks associated with the phenomena of study. Many digital innovations discussed reflect the potential to transform the future of healthcare and broader disaster response. Use of existing telemedicine or e-health capacity, for example, has been amplified and integrated with new digital responses, and there is actual and potential opportunity for remote and virtual health care services expansion to improve the accessibility and inclusivity of at least some healthcare services.

To ensure a more efficient, more effective, more resilient crisis management approach, it is vital to understand the immediate, upstream and downstream risks in both the short and longer term. During a major crisis, society will likely face the complex challenge of balancing individual rights with collective ones, and in the event of a public health crisis, individual rights are frequently sacrificed in the name of the public good.[133] These decisions have drastic implications for privacy, individual security and the broader preservation of human rights. Considering the widespread uptake of the GAEN API, important questions have been raised about the ability of private companies to dictate public health decision-making. The way these decisions are made has a direct impact on the efficacy, equity, accessibility, inclusivity, and nature and means of information sharing, as well as the exchange and spread of misinformation.

The tangible outcomes of these decisions, like the laws and regulations passed to enable situational awareness raise deeper concerns regarding the potential for longer-term surveillance beyond the needs of the pandemic. From invasive measures used to track individual movements for quarantine enforcement to the centralised storage of personal information and behaviours for contact tracing, these actions infringe on privacy, risking human security with the potential for public stigmatisation if sensitive information is revealed,[134,135] and the risk of exclusion from public services in the event of a false diagnosis.[136]

Digital responses can also exacerbate the negative impacts of the so-called digital divide, where some individuals, communities or populations have access to digital technologies and platforms, while others do not —especially not to the latest cutting-edge digital innovations. Where access to and uptake of a technology is a precondition of its use, and the accuracy and degree of use across an infected community use is a major determinant of sensitivity and specificity, its effectiveness as a clinical public health tool becomes questionable. Through understanding these risks, among others, and leveraging the descriptive understanding of the digital response using the context provided in this study, one can start to identify prevention and mitigation measures to manage these risks in a way that prioritises ethics and efficacy, while also developing the mindfulness[137] to recognise and adapt to the risks that cannot be predicted.

For a more directed research agenda, the present research identifies five priority areas for closer study. First, a deeper understanding of how to measure, develop and prioritise efficacy with new technologies is needed. Better comprehension is needed regarding the capability for these interventions to be efficient and effective, as well as how to maximise this capability. This may include rigorous assessment of the impacts of proximity-based contact tracing on viral spread, evaluating the effectiveness of varied social behaviour monitoring mechanisms through a human rights lens, or measuring the ability of digital solutions to mitigate the spread of misinformation. Secondly, research is needed regarding the accessibility and inclusivity of digital interventions in crisis. Areas of study could explore inclusivity of digital contact tracing measures or quarantine monitoring applications, how to effectively integrate digital interventions into marginalised populations, and identifying the value and impact of remote diagnostics and treatment measures as a means not only to increase inclusion of rural populations but also to determine and improve the applicability of digital solutions for rural versus urban communities. Thirdly, more research could explore the risks and benefits of digital interventions. This may imply articulating the ethical challenges associated with individual human rights versus social good as it relates to digital interventions, understanding the role of context on risk and benefit with digital interventions, characterising risk associated with automated communications in contrast to the impact of these interventions (eg using a WhatsApp chatbot to respond automatically to frequently asked questions about COVID-19), or studying the margin of error associated with false negatives (as it relates to contact tracing or remote diagnostics) balanced with the margin of success and impact of successful data gathering and reporting. Fourthly, more study of risk mitigation measures is needed. Despite the emergent nature of risk accompanied with digital innovation, many of the risks are known. Mitigation measures are needed relating to: 1) privacy and human rights risk for all digital response measures described in this paper; 2) misinformation risk in cases (like a pandemic) where insufficient information is available and understanding is evolving; and 3) international standards pertaining to data use for training AI algorithms. Finally, more research is needed on the digital transformation of healthcare and emergency response. This may include studying how digital solutions may assist with managing sexually transmitted infections to social infodemics, articulating when digital interventions are more ethical and efficacious over manual health interventions, or creating guidance to optimise the balance of manual with digital contact tracing.

CONCLUSION

This study provided a descriptive summary of the digital response to COVID-19 as it relates to information collection, dissemination and social control between public service providers (governments, first responders, humanitarian responders) and the general public. The discussion focused on four main emergency response purposes (contact tracing, social behaviour monitoring, public communications and remote diagnostics and treatment) using digital tools and processes such as mobile devices and apps, online platforms, artificial intelligence, drones and online data. Next steps were also provided for subsequent study to analyse opportunities and challenges associated with the digital response in complex crises like the COVID-19 pandemic.

Since the WHO first designated the coronavirus a global pandemic, the digital response has evolved, grown and transformed on a daily basis. New discoveries have been made, new opportunities arisen, and new and unsolvable challenges and risks have presented themselves. This study aimed to provide a solid foundation for understanding the digital response to COVID-19 to build upon as global pandemics evolve. It is hoped this study has captured the attention of the implementers and recipients of these interventions to better understand innovation in terms of digital technology use, repurpose and development, and, more broadly, to help to leverage the generative nature of crisis to improve society – not worsen it.

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