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Analytics and IT in the Response to COVID-19: A research Framework and Lessons for the Future

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ABSTRACT

This paper examines the usage and effectiveness of analytics and information technology solutions to the micro-level and macro-level health-related challenges that emerged with the SARS-CoV-2 virus. Case studies are discussed in order to paint a portrait of the development, evolution, and effectiveness of health-related analytics tools and information technologies in the context of the response to COVID-19. By considering and synthesizing examples of what worked very well, what worked moderately well, the paper develops a lucid framework for classifying the effectiveness of different analytics and IT artifacts as they pertain to the coronavirus pandemic. The framework is proposed to have a great deal of utility not only for helping scientists and decision-makers to document and understand the current state of analytics and IT as they relate to COVID-19, but also as a forward-looking guide that can support managerial, medical, scientific, and political decision-making in preparation for future pandemics.

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1. Introduction

Few would disagree that the COVID-19 pandemic has had an extraordinary and permanent impact on human society. Despite breathtaking scientific achievements in the development of treatments and vaccines for the SARS-CoV-2 virus, COVID-19 has already claimed millions of lives, with more than 100 million other people known to have contracted the disease (Johns Hopkins, 2021). While the toll of the COVID-19 pandemic in terms of lives lost and families shattered has been truly devastating, so too has been the impact of the disease on organisations and the global economy. The ultimate extent of the health and economic impacts of COVID-19 is not yet known, but analyses and forecasts suggest that the effects of the virus will haunt humanity for many years to come (McKibbin & Fernando, 2020).

As the world has grappled with the immediate and anticipated long-term impacts of the SARS-CoV-2 virus, scientists from a wide range of industries and academic disciplines have forged new alliances and new research pathways in an effort to combat the COVID-19 crisis. To a greater extent than ever before in human history, data, analytics, and

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information technology (IT) have emerged as pivotal figures in the battle to contain and ultimately nullify a catastrophic global pandemic (Pietz et al., 2020). From healthcare administrators to epidemiologists to political leaders, the availability of near real-time information about the status and spread of the virus at local, national and international levels has enabled health-related collaboration and data-driven decision-making on an unprecedented scale. Managerial, scientific, and political decision-making notwithstanding, analytics and IT have also profoundly transformed the way in which healthcare services have been delivered during the pandemic, with telemedicine and other methods of virtual patient care being widely adopted by physicians ranging from generalists to specialists, working in settings ranging from private practices to massive healthcare organisations (Hollander & Carr, 2020; Portnoy et al., 2020).

When considered collectively, many of the changes that have occurred in public health-related decision-making and the provision of healthcare services as a result of the coronavirus can be classified as impromptu or extemporary. For better or worse, and with few exceptions, both governments and healthcare providers alike generally found themselves in the unenviable position of being unprepared or ill-equipped for a fast-developing crisis on the scale of the COVID-19 pandemic (Horton, 2020; Sternfeld, 2020). As a result, new policies and procedures relating to tasks as critical as emergency surgery to those as benign as arranging the furniture in patient waiting rooms had to be created, adopted, and refined spontaneously by medical practitioners and administrators as the crisis unfolded, without the benefit of careful planning or deliberate forethought. Similarly, much of the technological infrastructure for gathering, analysing, and communicating information about the virus, its rates of infection and mortality, and potential treatments and therapies also had to be refined and enhanced, repurposed from existing technologies, or simply designed and built from scratch (Keesara et al., 2020; Ting et al., 2020). In light of these circumstances, we are left with two different applications of analytics and IT as they pertain to the health-related response to the coronavirus pandemic – one of which concerns the actual practice of medicine and the provision of healthcare services to individual patients, and the other of which concerns issues associated with the tracking and management of a large public health crisis. The former of these two applications of analytics and IT deals with the health and well-being of individual human patients, and is hence more personal and intimate in nature. By contrast, the latter of these two applications of analytics and IT emphasises the health and well-being of the group at the local, national, or international levels, and is hence more communal and collectivist in nature.

Many questions remain about the development, evolution, and effectiveness of the analytics initiatives and IT platforms and solutions that have been adopted or implemented in response to the COVID-19 pandemic. Clearly, a complete picture of the role of these tools and technologies must necessarily consider a spectrum ranging from the micro-level provision of healthcare services to patients to the macro-level handling and management of COVID-19 as a large-scale public health emergency. The assessment of effectiveness is about "how well the system contributes to mitigating the pandemic".

The goal of this paper then, is to shed light on these issues by considering the usage and effectiveness of analytics and IT-based solutions to the micro-level and macro-level health-related challenges that have emerged as a consequence of the SARS-CoV-2 virus. In so doing, the paper will consider both case studies and sources from the literature to paint a portrait of the development, evolution, and effectiveness of health-related analytics initiatives and information technologies as they pertain to COVID-19. By considering and synthesising examples of what worked very well, what worked moderately well, and what worked poorly at the micro and macro levels of analysis, a framework is developed for classifying the effectiveness of different analytics and IT artefacts as they pertain to the coronavirus pandemic. The framework is proposed to have a great deal of utility not only for helping scientists and decision-makers to document and understand the current state of analytics and IT as they relate to COVID-19, but also as a forward-looking guide that can support managerial, medical, scientific, and political decision-making in preparation for future pandemics.

The balance of this paper is organised as follows: in the next section, insights into the micro-level use of analytics and information technologies in response to COVID-19 are provided, with a particular focus on the rise and effectiveness of both inpatient and outpatient virtual care. Section 3 provides a review and insights into the more macro-level uses of analytics and information technologies in response to COVID-19, with a particular focus on the management and communication of information about the public health crisis at the local, national, and international levels. Finally, Section 4 provides a summary of the lessons learned about the effectiveness of different analytics and IT solutions as they pertain to individual and communal health and well-being during the COVID-19 crisis, and proposes a research framework and agenda to guide future work in this area. It is hoped that these contributions will facilitate the deployment and use of analytics and IT-based solutions as effectively as possible when the next global pandemic inevitably arrives and casts its gloomy, unwelcome pall over the future of humanity.

2. Analytics and IT for individual health in the COVID-19 pandemic

One of the most common uses of analytics and IT for individual patient care during the COVID-19 crisis has been to facilitate virtual care interactions between physicians and patients (Hollander & Carr, 2020). Such interactions typically involve either inpatient virtual care in which physicians provide IT-mediated care to patients who have been admitted to a healthcare facility, or outpatient virtual care in which physicians interact remotely with patients by leveraging information technology tools such as videoconferencing.

During the COVID pandemic, it became apparent that critical resources (physicians, nurses, space and PPE) were not going to be sufficient if used in traditional ways. Telehealth solutions (e.g. video consultations) were used to leverage these scarce resources to ensure the best care for ever-expanding numbers of patients in multiple hospitals. For example, the intensivist physicians at CHI Franciscan utilized their virtual ICU to continuously monitor and optimize ventilator settings at night, in keeping with the medical literature that pro-active virtual intensive care (in addition to in-person care and rounding) reduces the risk of death in the ICU. Virtual visits, where appropriate (not requiring an in-person exam to maintain the standard of care) allowed for subspecialty consultations (like infectious disease) to be provided where the service otherwise would not have been available in a timely manner. Video technology was also used to reduce exposure of nursing staff in the setting of high-risk medications (e.g. a second nurse would verify the dose, strength, and other details of a high risk medication virtually, rather than walking into the patient's room). Using these strategies, among others, ensured care of all patients at the highest possible level while protecting the healthcare workforce from infection and sidelining. All hospital systems were continually faced with the challenge of caring for the workforce of caregivers, without whom the COVID response would have collapsed.

The need for increased use of telehealth services became obvious at the outset of the coronavirus pandemic, and adoption of virtual care accelerated very rapidly thereafter (Koonin et al., 2020). Since most major health systems adopted virtual care across the enterprise out of necessity in response to the COVID-19 crisis, an understanding of the state of the medical evidence for the modality is urgently needed. In this regard, a cursory review of the literature can be misleading, since many studies examining the efficacy of virtual care are of low quality, are insufficiently powered, or cannot be used for decision-making purposes due to the risk of bias or the lack of a credible comparison to usual care.

These concerns notwithstanding, the existing body of evidence in favour of virtual care is sufficiently robust to support its safe use in many specialities and patient scenarios. In fact, in certain cases – such as the management of diabetes – virtual care has been found to deliver superior outcomes to traditional, in-person only care. In light of these considerations, this section aims to provide a brief summary of what is known to work well, moderately well, or poorly with respect to virtual care, along with a candid assessment of the strength of the evidence. As will soon become apparent, relying on information technology to provide virtual care is not a universal panacea, pandemic or no. Instead, the literature suggests that virtual care is appropriate in certain scenarios, but not in others.

For the purposes of this section, *virtual care* is defined as synchronous, real-time audio and video communication between a patient and a medical practitioner. Studies were considered only if they compared a virtual health service to usual, in-person care and if they were also conducted in the United States; these filtering criteria were adopted with a view towards ensuring some degree of inter-study comparability. Studies with poor methodological quality were also omitted, including those studies that were insufficiently powered, either individually or in meta-analyses. In accordance with evidence standards established by the Agency for Healthcare Research and Quality (AHRQ), the level of certainty for each conclusion is also provided (Owens et al., 2009). Strength of evidence (SOE) is used as a basis for assessing major outcomes and major comparisons. The AHRQ uses at least four scoring domains to create a single SOE score: risk of bias, consistency, directness, and precision. High bias lowers the SOE score, while high consistency and directness between the intervention and the outcome increase the SOE score.

Methodological limitations are notable when evaluating the efficacy of virtual care. Randomised controlled trials can, for example, minimise bias, but randomisation can be impractical in virtual care scenarios, with double-blind research designs being nearly impossible. Cohort studies carry the risk of bias from grouping, as patients with high-speed Internet connectivity tend to be demographically different from those without it. For these reasons, the strength of the evidence for all conclusions must be reported. In the most exhaustive review of virtual care to date, a total of 9,366 citations were considered by the AHRQ, with just 233 of those studies meeting inclusion criteria (Totten et al., 2019). These criteria required primary outcome reporting, including mortality and morbidity or other validated quality indicators, as well as information about resource utilisation and/or

Table 1. Primary outcomes for inpatient virtual care.

please use the table that is being submitted in the attached file

Inpatient Virtual Care Application	Primary Outcome and Strength of Evidence
Non-Emergency: Intensive Care Unit (77 studies)	◒ Reduced hospital mortality ◒ Reduced length of stay in ICU ◒ Reduced cost of care
Non-Emergency: Specialist Consultations (32 studies)	○ Reduced mortality and morbidity (cardiac arrest, low birthweight, falls, disability) ○ Reduced cost of care
Emergency: Telestroke (23 studies)	◒ No difference in 3-month and in-hospital mortality ○ Increased tPA administration ◒ No difference in hemorrhage
Emergency: Specialist Consultations (19 studies)	○ Improved clinical outcomes ◒ Increase in appropriate transfers ◒ Decreased time to decision
Emergency: Emergency Medical Services (20 studies)	◒ Reduced mortality for STEMI patients ○ Reduced costs due to avoided transfers

● = strong evidence ◒ = moderate evidence ○ = weak evidence

Table 2. Primary outcomes for outpatient virtual care.

Outpatient Virtual Care Application	Use Case	Primary Outcome and Strength of Evidence
Outpatient Virtual Visits (390 studies)	Remote Patient Monitoring	● Improved clinical care
	Dermatology	○ Equivalent clinical care
	Wound Care	◒ Better healing ◒ Fewer amputations
	Chronic Illness	◒ Equivalent or superior clinical care
	Diabetes Care	● Superior clinical care
	Psychiatry	● Better response to treatment
	Single Specialties (many studies)	◒ Improved response to treatment ◒ Well accepted by patients ◒ Clinically effective
	Orthopedics	○ Insufficient outcome reporting
	Cancer	○ Insufficient outcome reporting
	Ophthalmology	○ Insufficient outcome reporting
	Infectious Disease	◒ Comparable mortality, length of stay, readmission, cost

● = strong evidence ◒ = moderate evidence ○ = weak evidence

the cost of care. Discreet quantification of patient harm was found to be rare among the studies in the AHRQ analysis, and only 25% of those studies reported clinical outcomes. Many additional studies were excluded by AHRQ due to high risk of bias or other methodological problems.

The second most notable review in the virtual care literature is a Cochrane Database review conducted by Flodgren et al. (2015). This meta-analysis included 93 trials and 22,047 participants, and concluded that telemedicine improved quality of life for patients with congestive heart failure. IT-mediated virtual care was also found to be superior to in-person only care for diabetes in terms of lowering HbA1c levels, and was shown to be effective in decreasing LDL cholesterol and controlling hypertension. The AHRQ report and Cochrane review form the primary backbone for the tables below, which summarise what is currently known about the efficacy of virtual care. Specifically, Table 1 summarises the literature on using IT-mediated virtual care for inpatient scenarios, while Table 2 summarises the literature on using IT-mediated virtual care for outpatient scenarios. High, moderate, or low SOE rankings are also provided to indicate the level of confidence that the effects of virtual care for a particular scenario are correct and unlikely to change with additional research. The number of studies included in the analysis is also provided for each use case.

As shown in Tables 1 and 2 above, a robust body of clinical evidence exists to support the use of virtual care in certain scenarios, such as for remote patient monitoring, diabetes care, and psychiatry. For other scenarios such as ophthalmology, orthopaedics, and cancer care, however, the literature provides inadequate outcome reporting and insufficient evidence to support the use of virtual care as a safe and effective alternative to traditional, in-person care. From a practical perspective, perhaps equally useful as the literature in deciding whether to rely on virtual care in any scenario is the notion that the standard of care should be equal regardless of whether the patient is seen in a virtual care visit or in-person. Put differently, if the in-person standard of care can be upheld with a virtual visit, then virtual care may be appropriate. If not, then virtual care is inappropriate. This heuristic may be cautiously applied to simplify decision-making when the literature is silent or inconsistent on a particular virtual care scenario.

As additional high-quality studies become available, the content of Tables 1 and 2 will need to be updated to reflect new knowledge. The rapid, necessity-driven adoption of virtual care in response to the COVID-19 crisis portends a forthcoming swell in studies addressing the viability of telehealth initiatives for different scenarios during a pandemic, and the results of these studies will hopefully improve our collective understanding of IT-mediated virtual care. For now, the most important lesson for patients, physicians, and healthcare administrators alike is that virtual patient care is clearly not a panacea for all scenarios or medical specialities. In the absence of strong evidence from the literature, caution is warranted, and virtual care should be attempted only if the resulting standard of patient care is genuinely expected to be on par with that of traditional, in-person care.

3. Analytics and IT for communal health in the COVID-19 pandemic

This section presents examples of analytics initiatives and information technologies that have been developed and implemented to support communal health and decision-making processes in response to the COVID-19 pandemic. To begin, vaccine development and testing are proceeding rapidly in the U.S., and states are beginning to receive vaccines approved by the U.S. Food and Drug Administration for emergency use. Distribution of these vaccines to the population is underway using what has been called a 'phased approach', first in limited amounts to carefully selected high-risk groups and later to more and more people until everyone has access to the vaccine.

In its efforts to handle COVID-19 vaccine distribution, the government of Orange County, California partnered with CuraPatient to implement a mobile app called 'Othena' to manage vaccine schedules for individuals, providers, and organisations in Orange County.[1] After registering for the app, residents are able to schedule appointments and receive information continuously. In addition, Othena provides real-time data on vaccine availability, distribution, and shipment tracking, giving providers and public health authorities instant updates. In principle, this app was a great idea to distribute COVID-19 vaccines to residents in a secure and convenient way. In practice, however, the initial version of app was very expensive ($1.2 million), and received many complaints from citizens, including double-booking of appointments, not supporting multiple languages, broken links on its website, and not having live support for residents in need of assistance (Robinson, 2021). The revised version of the app made substantial improvements, but still did not include the multi-language support that had been agreed to in the original contract between the county and the app's manufacturer (Custodio, 2021). Once multi-language support was finally implemented, the app became both more effective and able to serve a larger proportion of the county's population. This local implementation of IT was marginally effective, and it illustrates how IT artefacts that are created in response to a pandemic can rapidly evolve in order to better meet the needs of their users.

A second example IT being applied in the midst of the COVID-19 crisis can be found in social media. As recently as 2011, when social media played a critical role in the Arab Spring in places like Tunisia, it was heralded as a technology for liberation and democratisation of information. It amplifies human intent – both good and bad. At its best, social media allows people to express themselves, receive information from official government sources (such as the U.S. Centers for Disease Control and Prevention), and take action. At its worst, it allows people to spread misinformation, to create conspiracy theories without any scientific evidence, and to create echo chambers where people only see viewpoints with which they already agree – fostering mistrust in scientists and government health officials, politicising a genuine global emergency, and further driving people apart at a time when unity and a shared sense of responsibility are most needed (Gharib, 2021). During COVID19, social media had a great opportunity to share correct information to inform people and support their decision making. Unfortunately, emerging capabilities or artificial intelligence and information harvesting could not govern misuse of social media and/or miss share of incorrect information.

A third example of a macro-level implementation of analytics and IT in response to COVID-19 can be found in the Johns Hopkins Coronavirus Resource Center (https://coronavirus.jhu.edu). This resource collects, aggregates, and disseminates coronavirus data from a large number of local and international government offices, and quickly became one of the world's most highly effective, widely used, and highly cited data analytics dashboards during the COVID-19 pandemic. Launched in March 2020 – the same month that COVID-19 was declared to be a pandemic – the Coronavirus Resource Center has become a trusted destination for data on the spread and reach of COVID-19. Its continuously updated data trackers and tools help the public, policymakers, and health-care professionals worldwide make better decisions about the pandemic. The site includes the latest numbers on cases, testing efforts, and the vaccine rollout, as well as expert analysis (Rosen, 2021). In brief, the Coronavirus Resource Center has been a resounding success, with TIME magazine adding the Center's dashboard to its list of 2020's Best Inventions, calling it '2020's Go-To Data Source' (Korn, 2020).

Finally, CommonSpirit Health took an approach similar to Johns Hopkins, utilising artificial intelligence and analytics to solve complex system-based and individual patient care problems in real time. Through its Mission Control centre (created in partnership with GE Healthcare), CommonSpirit's CHI Franciscan division was able to proactively identify at-risk patients during each COVID surge, maximising resources for patients before they needed them. These efforts encompassed all patient needs, from ICU beds to ventilators so that patients could get home sooner. The centralised command centre serves as an 'air traffic control system' for all patients, focusing on anticipatory capacity management, bed control, nurse staffing, patient transfers, and care coordination. The team is led by a group of expert physician, nursing and operational leaders in Mission Control who ensure that all decisions uphold the highest standard of care. Throughout the pandemic, the Mission Control team continues to predict near-term demand for critical resources. This approach provides healthcare teams with a birds-eye view of what is about to happen, giving a modicum of space to anticipate and then adapt to changing patient needs. Similar to the Johns Hopkins clinical command centre, CHI-Franciscan's centre staff have the benefit of being able to see every patient's data at once, enabling better real-time decision-making and improvements in the provision of healthcare services (Siwicki, 2021).

4. A research framework and lessons for the future

The preceding sections presented and discussed several examples of analytics tools and information technologies being applied to a variety of individual and communal health-related scenarios in the context of the COVID-19 crisis, with particular attention being given to the effectiveness of those tools and technologies. These examples, of course, represent only a tiny fraction of the vast array of analytics tools and information technologies that have been marshalled for service during the pandemic, but they nevertheless illustrate two important truths. The first of these truths is that analytics tools and information technologies are not universally effective when applied to pandemic-related problems, but instead fall on a spectrum ranging from highly effective to highly ineffective. The second truth is that the scope of the impact of each of these analytics tools or information technologies also resides on a spectrum, with that spectrum ranging from micro-level concerns such as the provision of healthcare services to individual patients, to macro-level concerns such as ensuring that accurate and up-to-date information about global infection and mortality rates is readily and freely available online. Together, then, these two truths form the foundation of a lucid and highly useful conceptual framework that can be used not only to document and understand the effectiveness of different analytics tools and information technologies during a pandemic, but also to guide future research in this area by laying bare the gaps in our scientific knowledge. This proposed

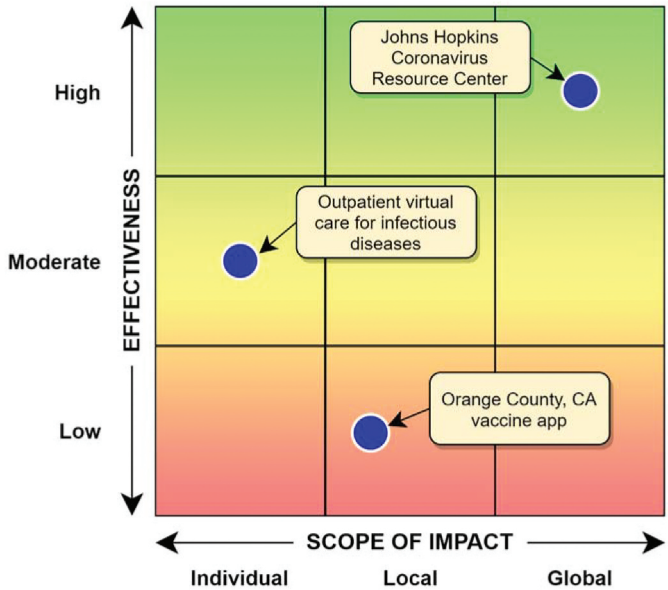

Figure 1. A research framework for understanding the effectiveness of analytics initiatives and information technologies during a pandemic.

framework is shown graphically in Figure 1 below, along with a few illustrative examples from the previous sections.

As shown in Figure 1, the proposed framework contrasts the scope of the impact of a given analytics tool or IT artefact (horizontal axis) with the effectiveness of that analytics tool or IT artefact at achieving the pandemic-related goal for which it was deployed (vertical axis). Lessons learned about individual analytics tools or IT artefacts can be easily documented or summarised in the research framework by appropriately positioning the artefact within the geometric space. Further, the nature of the framework allows geometric concepts such as location, distance, and direction to be leveraged when comparing and discussing artefacts, and also allows classification and prediction methods that are based on Euclidean geometry – such as clustering, support vector machines, and perceptron algorithms – to be applied to the artefacts that are documented in the framework, thus providing solid foundations for scientific inquiry and data-driven decision-making. Additionally, the proposed framework also lends itself very well to studying and comparing analytics tools and IT artefacts as they evolve and change during the course of a pandemic. For example, the first version of the Othena vaccine app discussed earlier received widespread complaints from Orange County, California's citizens. Despite being initially defended by local health officials, county supervisors eventually responded to their constituents' complaints by demanding major revisions from the app's manufacturer (Ludwig, 2021). The subsequently revised vaccine scheduling app was more effective than its predecessor, but still did not include the diverse language options that were required by the county's contract with the app's manufacturer (Custodio, 2021). When multi-language support was eventually added, the app became both more effective and

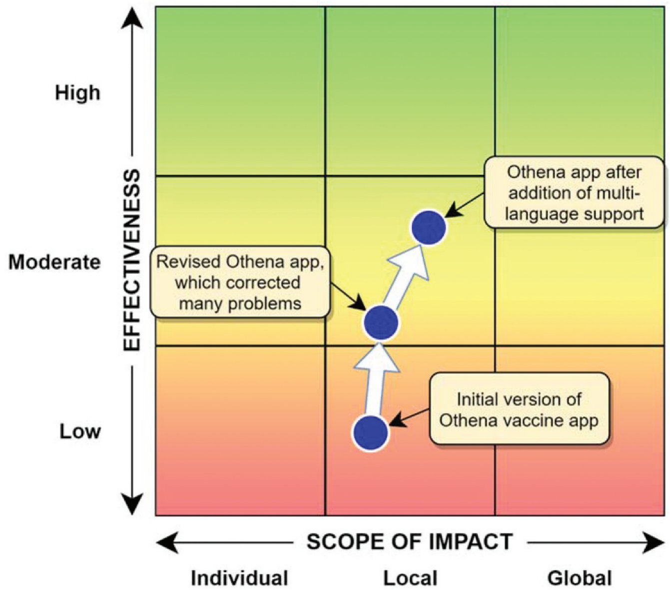

Figure 2. Evolutionary trajectory of Orange County, California's 'Othena' vaccine scheduling app during the COVID-19 pandemic.

more useful to the county's linguistically diverse population. The trajectory of this app across its various incarnations is shown in Figure 2, with this case serving as an illustrative example of the utility of the proposed framework for documenting the evolution of an IT artefact's scope and effectiveness during a pandemic.

Concluding remarks

Finally, we would like to conclude with a few philosophical thoughts about the role played by analytics and IT in the response to the COVID-19 pandemic and the lessons that can be learned in preparation for the inevitable pandemics of the future. To begin, the deadliest and perhaps most notable global pandemic of the 20th century emerged in 1918 as a result of the A/H1N1 influenza virus, with the associated disease quickly becoming colloquially known as the *Spanish Flu*. Humanity was much less connected at in 1918 than it is today, and intercontinental travel was an arduous, time-consuming, and expensive undertaking. As a result, more than a year passed before the Spanish Flu reached all of the world's inhabited continents (Keesara et al., 2020). By contrast, humanity is now much more interconnected, with more than 240 million people travelling internationally by airplane in the year immediately preceding the COVID-19 pandemic (Bureau of Transportation Statistics, 2020). Consequently, the SARS-CoV-2 virus spread to every inhabited continent on Earth within just weeks of its initial identification (Nachega et al., 2020). The march of progress is irreversible and unrelenting, and there is no going back to the detached and disconnected world of centuries past. Put simply, the world has changed, novel viruses and contagious diseases can spread much more rapidly, and the persistent risks of a global health emergency are therefore higher than they have been at any prior point in human history. What has also changed, however, are the tools and technologies that can be brought to bear to combat these threats.

The analytics platforms and information technologies that are so ubiquitous today simply did not exist during the Spanish Flu pandemic, and hence neither did the potential pandemic-fighting benefits that they afford. If used properly, analytics and IT can clearly serve as uniquely powerful allies during a pandemic. Unfortunately, these tools and technologies can also be used to interfere with our collective efforts to speedily resolve a global health emergency. For example, substantial evidence suggests that political leaders in many countries actively engaged in misinformation campaigns or censorship in order to delay, prevent or otherwise interfere with their citizens' ability to access timely or accurate information about the pandemic (Abazi, 2020, Dyer Dyer 2020). Such behaviour, unfortunately, is not new; indeed, it is now well-documented that a great deal of governmental censorship prevailed in the midst of the 1918 Spanish Flu pandemic as a consequence of World War I, which was still ongoing at that time. Whereas abundant, uncensored information about the disease was frequently published in many neutral nations, in the name of national security the governments of the warring nations regularly prevented accurate information about the Spanish Flu from being shared with their citizens, thus worsening the pandemic (Arnold, 2018; Byerly, 2005, Flecknoe, Wakefield, & Simmons, 2018). More than a century later, it would seem that many contemporary leaders have still not learned the lessons of history.

Modern analytics tools and information technologies clearly hold great promise in the context of global health crises such as the COVID-19 pandemic. There is ample scientific evidence, for example, demonstrating that they can help physicians provide remote care to patients, improve administrative and political decision-making, and help to quickly and effectively communicate critical information and guidance to the public. There is also ample evidence demonstrating that these tools and technologies are not useful for all virtual care scenarios, can be used to interfere with or prevent effective decision-making, and can serve as both sources of frustration and conduits of misinformation. The scientific community must therefore undertake to systematically learn more about which technologies can help or hinder beneficent efforts during a pandemic, and document the circumstances in which those technologies are the most or least useful (Demirkan, 2013). The research framework described in this paper may prove to be very useful in this regard.

It is evident that many analytics tools and information technologies can be powerful weapons in humanity's struggle with future pandemics, but only if we have the courage to use them properly. Doing so will require that we make the health and welfare of all of our fellow humans our preeminent concern, that we build and reinforce a culture of cooperation and nonpartisanship in our national and international health organizations, and that we choose leaders who, in the midst of a pandemic that threatens our entire species, will behave honorably and do what is right, rather than what may be politically expedient. Finally, and most importantly, we must learn the lessons of history by setting aside censorship and suppression, using our technologies to identify and combat misinformation, and embrace the open and transparent communication of critical pandemic-related information. Doing so may quite literally save millions of lives when the next global health crisis inevitably arrives.

Note

1. https://www.othena.com/

Disclosure statement

No potential conflict of interest was reported by the authors.

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