Fighting Pandemics with Physical Distancing Management Technologies

Article *in* Journal of Database Management · September 2021

3 authors:

Veda C. Storey

Roman Lukyanenko
University of Virginia

Camille Grange
HEC Montréal - École des Hautes Études commerciales

Cite as:

Storey, V. C., Lukyanenko, R., and Grange, C. 2021. “Fighting Pandemics with Physical Distancing Management Technologies,” *Journal of Database Management* (Forthcoming), pp. 1–14.

Fighting Pandemics with Physical Distancing Management Technologies

Veda C. Storey
Computer Information Systems
J. Mack Robinson College of Business
Georgia State University
Atlanta, Georgia 30302
VStorey@gsu.edu

Roman Lukyanenko
Département de technologies de l'information
Department of Information Technologies
HEC Montréal
roman.lukyanenko@hec.ca

Camille Grange
Département de technologies de l'information
Department of Information Technologies
HEC Montréal
camille.grange@hec.ca

Abstract

As COVID-19 continues to wreak havoc in everyday lives, the need to limit the spread of the virus remains a challenge, even with advances in medical knowledge, patient care, and vaccine development. Furthermore, COVID-19 is one in a recent series of airborne diseases, and probably not the last, given the ongoing encroachment of humans into animal habitat. This paper addresses the challenge of managing physical distancing, a highly effective, yet unnatural and contentious, mitigation strategy against infectious diseases. It presents a *Pandemic Tech Stack* and proposes that physical distancing management technologies are underutilized to fight pandemics. The latter can help ensure that people remain apart when they need to, support the transfer of activities to an online format, and, ultimately, facilitate the gradual reopening of our economies. The challenges associated with the development and use of these technologies are identified and discussed from both a technical and socio-psychological perspective.

Keywords: COVID-19, coronavirus, virus mitigation, physical containment, physical distancing, social distancing, isolation, pandemics, infectious diseases, Pandemic Tech Stack, Physical Distancing Management Technologies (PDMT), COVID apps, COVID tracing.

1. Introduction

COVID-19, the infectious disease caused by SARS-CoV-2 virus, has shaken the world. The severe acute respiratory syndrome coronavirus (SARS-CoV-2) is a virus of a “perfect storm,” because it has shown to be capable of spreading from animals to humans (e.g., bats to humans) and vice versa

Cite as:

Storey, V. C., Lukyanenko, R., and Grange, C. 2021. “Fighting Pandemics with Physical Distancing Management Technologies,” *Journal of Database Management* (Forthcoming), pp. 1–14.

(e.g., humans to minks) (Munnick et al. 2020). Officially characterized as a pandemic by the World Health Organization in March 2020 (WHO 2020), the disease remains rampant, taking away more and more lives while deepening social and economic hardships. Coronaviruses, present in bats and other animals, are capable of making new versions of themselves while trying to infect new hosts, including humans (Haseltine, 2020; Munnink et al. 2020; O’Leary, 2020).

The rapid spread of COVID-19 cases, and associated deaths, have triggered global containment and mitigation measures (e.g., government mandated shut-downs), as well as the large-scale adoption of infection prevention practices in efforts to “flatten the curve” (Anderson et al. 2020; OECD 2020a). Governments committed billions of dollars to medical research in a frantic effort to develop, produce, and deliver vaccines. The potential benefits from these efforts are now being reported, as the wide-spread distribution of vaccinations becomes a reality. However, the virus has continued to mutate into genetic variants (Lauring and Hodcroft 2021), so considerable time might elapse before effective, durable herd immunity is realized (Edridge et al., 2020; Randolph and Barreiro 2020).

Even more troubling is the fact that COVID-19 is one in a recent series of airborne diseases. It is probably not the last one, given the ongoing encroachment of humans into animal habitat (Plowright et al. 2017). In fact, just two years prior to the onset of COVID-19, the scientific journal *Nature Reviews Microbiology* published an article with this ominous question: “Are we prepared against the next influenza pandemic?” (Medina 2018). The article observed the increase in the number of viruses that jumped from animals to humans, asserting that a major pandemic was a real possibility. Scientists estimate that approximately 1200 viruses have the potential to create other pandemics (Baumgartner and Rainey 2020; O’Leary, 2020).

It is, thus, very likely that the infection prevention practices that have become part of our daily habits during the COVID-19 crisis (e.g., mask-wearing, tele working, hand hygiene, physical distancing) are likely to remain relevant. This is especially so as health and socio-economic systems transition to a “new normal” and become better prepared for future pandemics (Kasai 2020). Among the above-mentioned practices, physical distancing is currently the best available mechanism to slow the pace of disease transmission within communities and is especially important for highly contagious and deadly viruses such as COVID-19 (Chu et al. 2020). Physical distancing measures have been defined and executed heterogeneously across countries, but, in essence, they all aim at reducing the frequency of physical contacts and the contact distances between people during an infectious disease outbreak (Kelso et al. 2009). Physical distancing could appear to have all desirable attributes of a pandemic management tool: theoretically effective, easy and inexpensive to deploy. However, in practice, it has proven fallible and contentious (Baum et al. 2020; Jonaitis 2020; Marlow and Hong 2020). Furthermore, arguably no digital technology has managed to successfully address this critical issue yet.

The goal of this paper is to highlight the opportunities and challenges associated with the development, acceptance, and effective use of physical distancing management technologies. We define physical distancing management technologies (PDMT) *as a constellation of platforms,* *apps, websites, data analysis algorithms and analytics tools used to encourage, facilitate, monitor, or enforce physical distancing among humans*. The main application of PDMT is to combat contagious disease outbreaks, such as that of COVID-19. This is a type of technology which holds especial promise in the fight against COVID-19, and other contagious diseases, but so far, remains underutilized.

The information systems community has an important role to play in investigating the various ways digital technologies can be designed and used to prevent, mitigate, and cope with a pandemic (Ågerfalk et al. 2020; French et al. 2021; O'Leary, 2020; Shiau et al. 2021). We focus specifically on the use of information technology for physical distancing for two main reasons. First, physical distancing has a high potential to help address the *immediate* needs associated with reopening the economies shut down by the COVID-19 crisis and can support our *preparedness* in coping with future pandemics. Second, it is yet unclear how digital technology, as powerful as they are, can help communities manage a seemingly paradoxical situation: how to adhere to physical distancing practices while maintaining social closeness and solidarity (ECDC, 2020). Thus, PDMT requires a nuanced analysis accounting for the fact that, in the end, its true effectiveness may rely on its ability to keep people apart, while facilitating safe and responsible social interactions.

In the remainder of this paper, we present what we call the *Pandemic Tech Stack* to emphasize the far-reaching potential of digital technologies to assist in coping with pandemics. We then depict the nature and challenges of physical distancing and specify the key characteristics of PDMT and their specific applications. Doing so provides a foundation for identifying the challenges of PDMT and future research directions.

2. Background: The Pandemic Tech Stack

Information technology can be incredibly helpful in times of crisis, with the COVID-19 pandemic no exception. Our review of existing and emerging digital innovation deployed to help cope with the COVID-19 crisis (Whitelaw et al. 2020; Budd et al. 2020), reveals the extensive use of what we call the *Pandemic Technology Stack*. The types of hardware and software capabilities being leveraged are highly diverse (e.g., from mobile apps to machine learning algorithms, drones, and robotics), with the scope of their application large (e.g., from epidemiological forecasting to automated thermal monitoring, digital contact tracing and digital immunity certificates).

<u>Analytics</u>. Data management and analytics technology in support of epidemiologists and other public health professionals were rolled-out early in the pandemic. A number of systems were set up to track and report the spread of the virus across locations, and to monitor and plan hospital capacity, medical supplies, and staffing. For example, the *Johns Hopkins University Dashboard* and the web-based platform *HealthMap* provide up-to-date visuals of COVID-19 cases and deaths around the globe. Another example is WorldoMeter.[1] Key indicators of disease prevalence have also been incorporated into mobile apps for use by the public. These apps that have been mostly

[1] www.worldometers.info/coronavirus

designed for informational purpose (e.g., education about COVID-19, updates of confirmed cases, and contact information of testing and treatment centres) (Sharma and Bashir 2020). These are critical given the spread of misinformation and the growth of cyberchondria (i.e., online health searches with a worsening of anxiety or distress) observed during the COVID-19 pandemic (Laato et al. 2020). Interestingly, citizens have also engaged in a complementary "crowdsourced" method for tracking symptomatic cases.[2] This phenomenon, referred to as web-based participatory surveillance of infectious diseases (Paolotti et al., 2014; Koppeschaar et al. 2017), relies on the digitally enabled self-reporting of data, in the spirit of contemporary citizen science (Bonney et al. 2014; Lukyanenko et al. 2019).

Contact tracing. One of the most highly debated technology during the pandemic is identifying people who might have come into contact with an infected person (e.g., contact tracing mobile applications). Contact tracing technology is part of a containment strategy, which relies on massive scale testing and prompts contact tracing and quarantining (Walensky and del Rio 2020). Contact tracing technology generally relies on Bluetooth-enabled digital proximity tracing using smartphones (Riemer et al. 2020). The app builds a memory of proximity contacts and notifies contacts of positive cases (Ferreti et al. 2020). In France, the *StopCovid* app was launched without much success in June 2020 and replaced in October 2020 by the *TousAntiCovid* app. The latter offers an additional informational layer to provide users with the most recent epidemiological data (including the infamous R metric, i.e., the average number of people an infected person infects), as well as data relevant to the strain caused by COVID-19 on the healthcare system. Canada launched a similar Bluetooth-based exposure notification app, *COVID-Alert*, in October 2020.

It is important to recognize that contact tracing can de designed and operated in many different ways (Goggin 2020). Both the Canadian and the French apps are decentralized: they use anonymous identifiers whom, when confirmed by a user, are broadcast to the network of other identifiers (users). In contrast, centralized apps share information about contacts and communicate events with a central server (e.g., owned by a central authority). Singapore was one of the first nations to develop a mobile-based contact tracing application (*TraceTogether*). The app, which was launched in March 2020, relies on a centralized architecture[3]. It was designed to alert the government when people have come into contact with the virus so they could be placed in quarantine (Stevens and Haines 2020). The Singaporean technology was developed to be based on a mobile app, but later supplemented (in June 2020) by a physical token so that individuals, who are less likely or able to use smartphones (e.g., children and the elderly), could participate in the contact tracing effort. Although mass acceptance by a population is the most critical factor determining the effectiveness of digital contact tracing technology (Trang et al. 2020), adoption remains very heterogeneous across countries. For example, at the end of December 2020, approximately 17% of the Canadian population had installed the *COVID-Alert* app[4]. In contrast,

---

[2] For example, https://outbreaksnearme.org/ca/en-CA/

[3] Indian's *Aarogya Setu* (Sanskrit for "a way to liberation from disease") is also a centralized app (Gupta et al. 2020a)

[4] https://www.canada.ca/en/public-health/services/diseases/coronavirus-disease-covid-19/covid-alert.html#a5

the percentage of Singapore residents participating in the *TraceTogether* Programme (the App of the Token) had surpassed the 70% mark[5].

Surveillance. Another set of digital technologies help governments monitor and enforce quarantine and self-isolation. In response to COVID-19, the Government of Hong Kong mandated the use of a wristband for all people entering the territory to track compliance with the 14-day self-isolation policy (Walline 2020). The Singapore travel and health control agency mandated the use of similar electronic monitoring device.[6] In Israel, the government passed legislature to permit tracking the mobile data of people suspected with a COVID-19 infection (Dar et al. 2020).

Screening. From classical, low-tech digital thermometers to more high-tech solutions, screening technologies help assess signs of disease in an apparently asymptomatic population (e.g., digital thermometers). Infrared thermal detection systems are already in widespread use in Asia and have started to be rolled-out in the United States (e.g., Hawaii, and LAX and JFK airports). Albeit promising, they still face challenges, including accuracy and infection predictive capabilities (Martinez-Jimenez et al. 2020, Mohammed et al. 2020).

Healthcare and medical research. Digital innovations have contributed to healthcare clinics by providing support for conducting remote healthcare via video conferencing and digital monitoring for COVID patients (Greenhalgh et al. 2020) and others who cannot meet with healthcare practitioners face-to-face (Gerke et al. 2020; Perrin et al. 2020). Advances in artificial intelligence (AI) have facilitated COVID-19 diagnoses using deep-learning models applied to CT scans (Li et al. 2020). In some hospitals, autonomous disinfecting robot with UV light are deployed to enhance sanitization (Ackerman 2020).

AI is particularly instrumental in two other areas of pandemic management. First, it facilitates data-based analysis, as well as modelling and forecasting COVID-19 outbreaks (Anastassopoulou et al. 2020; McCall 2020). Second, AI provides tools that empower molecular biologists in their search for treatment and vaccine discovery research. These tools help scientists better understand the virus, its structure, mutations, and functioning. Recently, the deep learning-based algorithm *Alphafold*, from Google’s DeepMind, made significant progress in the essential task of predicting protein structures from their amino-acid sequences (Callaway 2000).

Test/vaccine certification. Digital technology also promises to be immensely useful in facilitating the safe resumption of international travel. Pilot projects of digitally verifiable test and vaccination certificates aimed at preventing fraud and ensuring compliance to public health requirements are on their way (McMahon 2020). For example, since December 2020, travelers arriving at Singapore’s Changi airport can use the OCC *AOKpass* app[7], which relies on blockchain based QR code technology, to show evidence of a negative polymerase chain reaction (PCR) test (Koh 2021).

[5] https://www.smartnation.gov.sg/whats-new/press-releases/tracetogether-adoption-surpasses-70-ccs-to-re-open-for-token-collection-progressively
[6] https://safetravel.ica.gov.sg/health/shn-monitoring
[7] https://www.aokpass.com/

Cite as:
Storey, V. C., Lukyanenko, R., and Grange, C. 2021. "Fighting Pandemics with Physical Distancing Management Technologies," *Journal of Database Management* (Forthcoming), pp. 1–14.

Integrating and relying on reliable data between public agencies, testing labs, and airlines is an immense challenge and but also a necessity that digital technology can address (Atkison et al. 2020; Wilson et al. 2016).

3. Physical and Social Distancing

Physical distancing and social distancing are terms often used interchangeably[8] to refer to a nonpharmacological intervention against infectious diseases for which effective treatment or vaccination are not available. Physical or social distancing policies are put in place to ensure that people of different households keep a safe physical distance between them (OECD 2020a), thereby reducing the spread of the virus. To be consistent and aligned with existing research, we adopt the term physical distancing. Physical distancing measures cover a large spectrum and can vary in intensity. Examples include restrictions on mass gatherings (e.g., cultural or sport events, conferences) and lockdown-type measures (Koh et al. 2020). It also comprises closures of schools, workplaces, and public transportation (Islam et al. 2020) as well as non-essential stores and services such as restaurants and cafes (OECD 2020a).

The goal of physical distancing as a mitigation strategy is to decrease the effective reproduction number (R) to below 1. When this epidemiological threshold is reached, the disease is referred to as shrinking. The practice of physical distancing as a way to cope with virus dissemination has existed for a long time. Within in the past 15 years, distancing was used in the fights against Ebola, SARS and H1N1, as researchers scrambled to develop vaccines. The Spanish Flu took approximately two years to burn itself out. Even then, people understood the need to "keep a (safe) distance" from each other as can even be seen in children behaving, what we would now refer to as, a "socially distanced" manner.[9] Because COVID-19 spreads mainly amongst people who are in close contact (within approximately 6 feet) for a significant amount of time (e.g., 15 minutes), physical distancing is an essential means to reduce the spread of the disease.

Scientific studies have demonstrated that physical distancing interventions are associated with significant reductions in respiratory diseases transmission (Ahmed et al. 2018; Caley et al. 2008; Islam et al. 2020; Matrajt and Leung. 2020). However, physical distancing policies are contentious and sometimes not well-executed or complied with (Baum et al. 2020). Humans are fundamentally social animals, making physical distancing unnatural and disruptive (Crosier et al. 2012). Physical distancing is an incredibly difficult behavior for people to adopt, especially in communities with a large proportion of extended households or with people most impacted by poverty, poor sanitation, and political or social unrest (Mbunge et al. 2020). Some social groups (e.g., the younger and less

[8] Some experts contend that physical and social distancing are not exactly the same. According to Lisa Maragakis, senior director of infection prevention at Johns Hopkins, physical distancing for COVID-19 involves staying 6 feet from others, whereas social distancing involves a more radical approach of staying home and away from others as much as possible (John Hopkins Medicine, 2020). Some public health authorities favor discussing social distancing (e.g., the Center for Disease Control in the United States, the European Centre for Disease Prevention and Control); others prefer physical distancing (e.g., the Public Health Agency of Canada).

[9] After the Spanish Flu, school buildings were reported as being large, clean, and "airy" (https://theconversation.com/3-lessons-from-how-schools-responded-to-the-1918-pandemic-worth-heeding-today-138403).

educated) appear to be less likely to comply with physical distancing guidelines than others (Wirz et al. 2020). Furthermore, humans are quite poor at estimating distances in general (Jansen-Osmann et al. 2006). Other factors (e.g., distraction, reaction time) might also prevent appropriate physical distancing. As a result, adherence to physical distancing policies remains unequal and poses challenges even to the most well-intended and responsible citizens. Thus, it is not surprising to observe numerous instances of distancing violations, some of which are irresponsible and deliberate; others accidental and unintentional (Steinmetz 2021).

Physical distancing also has undesirable consequences, such as isolation, sedentarism, anxiety and other psychological damages (Meyer et al. 2021; OECD 2020b; Yang and Koenigstorfer 2020). It disproportionately affects people in low-paid and precarious unemployment (Williams et al. 2020) as well on those living alone, as found in approximately one third of the households in OECD countries (OECD, 2016). Physical distancing becomes especially important, but challenging, at the end of lockdown periods when the capacity of public health systems falls below high-risk levels, vaccination efforts increase, and economies gradually reopen. Some individuals will quickly seek to return to high levels of social interactions, whereas others voluntarily or habitually continue to physical distance (Williams et al. 2020). In addition, because immunity to COVID-19 remains uncertain (Kirkcaldy et al. 2020), one factor that public health authorities must monitor carefully during these transition periods is the distancing behavior of recovered and vaccinated individuals (Fenichel 2013). These signals suggest that the reopening of social hubs such as schools, workplaces, museums, places of worship, or restaurants will require the respect of some degree of physical distancing, even as COVID-19 shows widespread, consistent signs of shrinkage. As United Nation's Deputy Secretary-General Amina Mohammed stated, "No one will ever be truly safe until everyone is safe[10]." In summary, better management of physical distancing could help flatten the curve and ensure that important socioeconomic activities, which were mandated to stop during the peak of a pandemic crisis, could resume faster, more safely, and more equitably.

4. Physical Distancing Management Technology (PDMT)

Physical distancing management technology (PDMT) can help address three families of challenges associated with keeping people physically apart during pandemics. First, PDMT could help ensure the respect of the toughest measures associated with physical distancing, namely, curfews, quarantines, and lockdowns. Technologies such as drone surveillance, mobile data tracking, and wristbands have been used by governments for such purposes (e.g., Walline 2020).

A second category of PDMT have been particularly instrumental during periods of full or partial lockdowns to help transfer activities online, especially those involving a social component. The success of physical distancing measures that are implemented over an extended period may depend on ensuring that people maintain social contact – from a distance – with friends, family and colleagues. For example, the COVID-19 crisis has induced the explosive growth of telework technology and online learning tools (e.g., *Zoom*, *Microsoft Teams*). It has also triggered the emergence of technology to support both online gatherings between friends and family

[10] https://www.un.org/development/desa/en/news/sustainable/no-one-is-safe-until-everyone-is.html

(*HouseParty*) and larger events catered to people with a common interest (e.g., “cloud rave” musical events or fitness classes on *Zoom* or *TikTok*, live prayers on *Church Online Platform*). Technologies that have enabled the digitalization of activities that used to require human contact can also be included in this category of PDMT. For instance, autonomous delivery robots, contactless payment, smart lockers, and live streams have all helped keep people distance across different stages of the shopping process (Nicolai and Grange 2021).

Third, PDMT can accomplish more than just keeping people apart. They can bring confidence to communities when the strictest physical measures of pandemics are lifted – when people are allowed and willing to be in contact with one another again in shared physical spaces organized for full or reduced capacity (e.g., at work, school, airports, retail stores, restaurants, or concerts). Technology solutions built using IoT sensors, cameras, and artificial intelligence can help social life resume safely (e.g., *Openpath, Irisys, Xovis)*. They offer features such as: tracking and controlling occupancy; generating alerts when limits are approached or exceeded, detecting hot spots and problem area such as the spontaneous concentration of people in queues; and creating alternative working schedules. As another example, service robots have even been used to facilitate physical distancing in tourism (Seyitoğlu and Ivanov 2020).

The above discussion shows that the application of PDMT can be quite varied. Next, we propose that their success will be determined by how three core design characteristics are applied and assembled. The first characteristic is *context-sensitivity*. Depending upon requirements, PDMT can be designed to be more or less context (e.g., location or time) sensitive. Evidently, the ubiquitous, portable, and versatile smart phone technology, which enables high context-sensitivity, is likely to be attractive and useful to several types of PDMT. A mobile-embedded PDMT could leverage smart phones and assess and report distances between them in real time. The second core design characteristic pertains to the technology’s *architecture*, which can oscillate between autonomous and networked. Contrary to an autonomous architecture, one that is network-based requires that multiple agents (e.g., users) operate the technology in order for it to function and deliver its value. For example, a mobile app designed to encourage the keeping of adequate distances between people could make one’s phone gently vibrate after a certain number of minutes (e.g., ten) of identified proximity with another person. Because this technology would entail that the app also be installed on other people’s phones, it would require a networked architecture. The third design characteristic relates to *agency*. PDMT can oscillate between being self or third-party managed. “Self” refers to the agents who are required to physically distance (e.g., residents) whereas “third party” refers to agents in charge of executing or monitoring residents’ self-distancing. A PDMT could make different stakeholders responsible for the data and identify ways in which to act upon it, depending upon factors such as needs, regulation, sensitivity of the population to data privacy, and surveillance. Design decisions related to agency will have an important influence on the technology’s capabilities and the degree to which it is perceived as being invasive or socially acceptable.

5. Challenges of designing and using PDMT: research directions for future studies

Despite the obvious promises of a physical distancing management technology, numerous challenges, both technical and socio-psychological, must be overcome, creating and expanding research opportunities. Some work has already been started (Ågerfalk et al. 2020; O’Leary and Storey 2020; O’Leary 2020; Pan and Zhang 2020; Siau et al. 2020). Below we highlight several promising research directions related to PDMT.

Research direction 1: The development of mobile technology capable of effectively sensing other devices.

A major challenge is technical. Despite the ongoing improvements in smart technology sensors, there is no obvious solution for how one smart phone could sense another without having to download a common application and establish a common protocol for information exchange. To circumvent the problem, it is possible to install the same application on different devices, as in the prototype for the *CoReady!* App.[11] However, this creates an immediate participation barrier because, for the app to become effective, a sufficiently large number of users need to download it.

Another challenge is the accuracy of current positioning systems. Even in places with high GPS coverage, position accuracy can be +/-2 meters (Zandbergen 2009). This measurement is not granular enough to ensure that a distancing app would detect a person if distancing of less than 2 meters is desirable for preventing the virus. The technological aspect needs research on Bluetooth and radio signal detection, because one can reasonably assume that various kinds of devices have radio signals. However, this type of research invariably faces a privacy challenge, as discussed below. Research efforts might also contribute to existing work in machine learning on accuracy detection, triangulation and signal sensing (Rogers et al. 1999; Li et al. 2018). Thus, the technological challenge is to find a way for one device to sense another, in the absence of pre-agreed protocols for doing so.

Research direction 2: App analytics

A distancing app will generate unique kinds of data in real time. A challenge is to use these data effectively for both the user of the app and public agencies, as well as other parties privy to these data. This is under the assumption that appropriate privacy and legal considerations are met.

Research on analytics can consider how to effectively present information to the user. This can support a potential user who must decide whether to assist in the cold start problem rectification. Advanced analysis of data on the usage of an app by a user, as well as groups of users (again, with appropriate privacy and legal considerations), could support informed decisions for how to better

[11] https://spectrum.ieee.org/news-from-around-ieee/the-institute/ieee-products-services/social-distancing-heres-an-app-for-that

avoid the virus. Examples include suggesting areas of congestion or predicting likely problematic areas based on the movement trajectory of a user.

Analytics-related research can also consider the value of the aggregate data for informed public policy and enforcement decisions. Especially research on machine learning, as well as prescriptive and descriptive data analytics (Chen et al. 2012; Davenport and Harris 2017; Wand and Siau 2019; Mate et al. 2015) can be helpful in generating appropriate insights for decision-makers and policy enforcers. Other technical issues, such as identity encryption of users, are also of important and, hence, can motivate additional research (Mont et al. 2003).

Research direction 3: The diffusion of Physical Distancing Management Technologies

The diffusion of Physical Distancing Management Technologies and their likelihood of success will require collective forces. As a result, a second fertile avenue of research is studying the factors influencing the adoption of PDMT by both organizations considering deploying the technology into their spaces (e.g., workplaces, retail stores, universities, airports, parks) and the people visiting these spaces (e.g., employees, customers, students, travelers, residents).

The social acceptance lens is particularly suitable to examine the latter, especially when the design of a PDMT is based on a third-party agency model. Social acceptance redirects the research focus from the direct users of a system as the individual agents of adoption to the larger set of relevant stakeholders. Social acceptance remains understudied in information systems. However, other fields (e.g., human-computer interaction, healthcare, environmental studies) have demonstrated its applicability and relevance in contexts wherein an innovation's potential impacts transcend those of the sole people interacting with it or directly benefiting from it (Tabourdeau and Grange 2020). Because PDMT can be quite intrusive, especially when installed in public places (e.g., Gupta 2020b), it will be critical to account for the fact that people have intrinsically different propensities for welcoming context-sensitive technology that uses their data, and that of others, to "track" social encounters and send notifications (Dinev et al. 2015). The "critics" might be sensitive to factors that are quite different from those influencing "advocates," suggesting the study of how different technological configurations might generate differential responses among a heterogeneous community. PDMT with a network architecture are particularly likely to require mass acceptance. Mass acceptance is needed in situations where the efficacy of the technology depends on its adoption by a substantial proportion of the population, such as contact tracing apps (Trang et al. 2020). However, an important lesson from the moderate success of contact tracing apps to successfully combat the spread of the virus, is the apprehensiveness of users and the subsequent difficulty of reaching mass acceptance. To address this issue, researchers could explore the efficacy of specific design interventions (e.g., privacy and convenience design features as well as benefits appeal, in Trang et al. 2020) and the effects of digital nudging (Weinmann et al. 2016).

The many challenges of social (and mass) acceptance implies that organizations will, in turn, need to adopt a cautionary stance and engage in a responsible adoption process (Grange and Pinsonneault 2021). Responsible adoption proposes a critical perspective on organizational IT adoption, which recognizes the need to consider the socio-ethical implications of adopting a technology, especially one that might be contentious or socially sensitive (Doorn and van de Poel 2012; Van den Hoven 2013). Thus, this paradigm suggests that organizations pondering about the use of PDMT (especially those based on a third-party agency model) will benefit from assessing its value potential beyond narrowly defined economic indicators and a self-centered point of reference. Insights from this emerging paradigm identify factors such as transparency, civic-mindedness, and foresightedness as likely to be critical characteristics of responsible PDMT adoption decisions (Grange and Pinsonneault 2021).

Research direction 4: User-generated content

An intriguing design opportunity is to infuse direct user input (user-generated content) into a PDMT. For example, a user could share opinions and ideas on best avoidance behaviors. Effectively, this could turn a distancing app into an *observational crowdsourcing* platform (Lukyanenko and Parsons 2018) and a social media channel, with the potential to draw even more societal benefits from PDMT. However, such possibilities invite new challenges.

First, introducing direct user input immediately results in challenges related to ensuring there is no abusive, bullying or other malevolent activities. Research has begun to consider design interventions to prevent such malevolent activities and promote safe and enjoyable space for everyone (Ashktorab and Vitak, 2016; Bowler et al., 2015; Lowry et al., 2017). PDMT can motivate more work within this context.

Second, the quality of user generated content is always a concern. It is difficult to ascertain whether the information provided from people of various backgrounds, levels of domain expertise, perspectives, and points of view can be trusted in decision making or even shown to other users. There is an explosive growth in research on various aspects of user generated content, including how to evaluate and improve its quality (Chen et al. 2011; Lukyanenko et al. 2019; Bonney et al. 2014). PDMT provide a new impetus for further research on how to better design crowdsourcing systems and could become a nexus point for collaboration among various behavioral and design communities that are dealing with these issues in mobile, social and citizen science contexts.

Research direction 5: Legal, ethical and privacy issues

Broad challenges for a distancing technology centre around whether, when, and how mandatory use would be desirable and culturally or legally acceptable. While the responsible and effective use of PDMT has the potential to save lives and help both communities and public health officials make better decisions, ensuring such project success will be challenging. Cooperative efforts will be required on the part of policy makers, the private sector, and researchers in multiple disciplines to create this important and timely solution to the on-going crisis and likely future ones.

A distancing app involves usage by people in real time in personally sensitive contexts. An important research direction is understanding the varied privacy and ethical concerns of users, as well as their goals, intentions, and values. These issues are reflected in emerging work on legal, ethical and privacy issues of using mobile devices during COVID-19 (Oliver et al. 2020). However, much of this work focuses on tracking devices and cellular data. PDMT are much broader, requiring more work on understanding the legal, ethical and privacy issues of context sensitivity, architecture, and agency. For example, along the agency dimension, this work can benefit from research on values, goals, and intentions modeling, a subarea of conceptual modeling (Recker et al. 2021) which studies how to elicit, analyze and incorporate users’ values into a technology design (Horkoff et al. 2015; Poels et al. 2013).

6. Conclusion

This research has presented a *Pandemic Tech Stack* to bring attention to the far-reaching potential of digital technologies in helping to cope with pandemics. It has identified the continuing need for, and use of, physical distance management technologies and outlined the challenges in their widespread responsible adoption. The ongoing, important role of physical containment requires a mix of social responsibility and changes in psychological attitudes and measures, supported by the development of innovative information technologies. There is much hope for returning to a pre-COVID-19 era, given the current efforts to vaccinate large populations. However, COVID-19 remains undefeated, which means we should continue to innovate and seek new strategies for combating the virus. Physical distance management technologies can be instrumental in such endeavours.

Acknowledgement

The authors with to thank the review team for their valuable comments on our paper. This research was supported by Georgia State University.

REFERENCES

Ackerman, E. (2020). Autonomous robots are helping kill coronavirus in hospitals. *IEEE Spectrum*, 11.

Ågerfalk, P. J., Conboy, K., & Myers, M. D. (2020). Information systems in the age of pandemics: COVID-19 and beyond. European Journal of Information Systems. 29(3), 203-207.

Ahmed, F., Zviedrite, N., & Uzicanin, A. (2018). Effectiveness of workplace social distancing measures in reducing influenza transmission: A systematic review. *BMC Public Health*, *18*(1), 518. https://doi.org/10.1186/s12889-018-5446-1

Anastassopoulou, C., Russo, L., Tsakris, A., & Siettos, C. (2020). Data-based analysis, modelling and forecasting of the COVID-19 outbreak. *PloS One*, *15*(3), e0230405.

Cite as:

Storey, V. C., Lukyanenko, R., and Grange, C. 2021. "Fighting Pandemics with Physical Distancing Management Technologies," *Journal of Database Management* (Forthcoming), pp. 1–14.

Anderson, R. M., Heesterbeek, H., Klinkenberg, D., & Hollingsworth, T. D. (2020). How will country-based mitigation measures influence the course of the COVID-19 epidemic? *The Lancet*, *395*(10228), 931–934. https://doi.org/10.1016/S0140-6736(20)30567-5

Ashktorab, Z., Vitak, J., 2016. Designing cyberbullying mitigation and prevention solutions through participatory design with teenagers, in: *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. pp. 3895–3905.

Atkinson, K. M., Mithani, S. S., Bell, C., Rubens-Augustson, T., & Wilson, K. (2020). The digital immunization system of the future: Imagining a patient-centric, interoperable immunization information system. *Therapeutic Advances in Vaccines and Immunotherapy*, *8*, 2515135520967203. https://doi.org/10.1177/2515135520967203

Baum, N. M., Jacobson, P. D., & Goold, S. D. (2009). "Listen to the People": Public Deliberation About Social Distancing Measures in a Pandemic. *The American Journal of Bioethics*, *9*(11), 4–14. https://doi.org/10.1080/15265160903197531

Baumgartner, E., and J.Rainey , 2020. Trump administration ended pandemic early-warning program to detect coronaviruses. *Los Angeles Times*, April 2.

Bonney, Rick, Jennifer L. Shirk, Tina B. Phillips, Andrea Wiggins, Heidi L. Ballard, Abraham J. Miller-Rushing, and Julia K. Parrish. "Next steps for citizen science." *Science* 343, no. 6178 (2014): 1436-1437.

Bowler, L., Knobel, C., Mattern, E., 2015. From cyberbullying to well-being: A narrative-based participatory approach to values-oriented design for social media. *Journal of the Association for Information Science and Technology* 66, 1274–1293.

Budd, J., Miller, B. S., Manning, E. M., Lampos, V., Zhuang, M., Edelstein, M., Rees, G., Emery, V. C., Stevens, M. M., Keegan, N., Short, M. J., Pillay, D., Manley, E., Cox, I. J., Heymann, D., Johnson, A. M., & McKendry, R. A. (2020). Digital technologies in the public-health response to COVID-19. *Nature Medicine*, *26*(8), 1183–1192. https://doi.org/10.1038/s41591-020-1011-4

Caley, P., Philp, D. J., & McCracken, K. (2008). Quantifying social distancing arising from pandemic influenza. *Journal of the Royal Society Interface*, *5*(23), 631–639.

Callaway, E. (2020). 'It will change everything': DeepMind's AI makes gigantic leap in solving protein structures. *Nature*, *588*(7837), 203–204. https://doi.org/10.1038/d41586-020-03348-4

Chen, H., Chiang, R. H., & Storey, V. C. (2012). Business intelligence and analytics: From big data to big impact. *MIS Quarterly*, 1165-1188.

Chen, J., Xu, H., & Whinston, A. B. (2011). Moderated online communities and quality of user-generated content. *Journal of Management Information Systems*, *28*(2), 237-268.

Chu, D. K., Akl, E. A., Duda, S., Solo, K., Yaacoub, S., Schünemann, H. J., Chu, D. K., Akl, E. A., El-harakeh, A., Bognanni, A., Lotfi, T., Loeb, M., Hajizadeh, A., Bak, A., Izcovich, A., Cuello-Garcia, C. A., Chen, C., Harris, D. J., Borowiack, E., … Schünemann, H. J. (2020). Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: A systematic review and meta-analysis. *The Lancet*, *395*(10242), 1973–1987. https://doi.org/10.1016/S0140-6736(20)31142-9

Crosier, B. S., Webster, G. D. & Dillon, H. M. Wired to connect: Evolutionary psychology and social networks. *Review of general Psychology* 16, 230–239 (2012).

Dar, A. B., Lone, A. H., Zahoor, S., Khan, A. A., and Naaz, R. 2020. “Applicability of Mobile Contact Tracing in Fighting Pandemic (COVID-19): Issues, Challenges and Solutions,” *Computer Science Review*, Elsevier, p. 100307.

Davenport, T., & Harris, J. (2017). *Competing on analytics: Updated, with a new introduction: The new science of winning*. Harvard Business Press.

Dinev, T., McConnell, A. R., & Smith, H. J. (2015). Research Commentary—Informing Privacy Research Through Information Systems, Psychology, and Behavioral Economics: Thinking Outside the “APCO” Box. *Information Systems Research*. https://doi.org/10.1287/isre.2015.0600

Doorn, N., & van de Poel, I. (2012). Editors’ overview: Moral responsibility in technology and engineering. *Science and Engineering Ethics*, *18*(1), 1–11.

Dulaney M. 2020. The next pandemic is coming – and sooner than we think, thanks to changes to the environment. *ABC Science*. https://www.abc.net.au/news/science/2020-06-07/a-matter-of-when-not-if-the-next-pandemic-is-around-the-corner/12313372

Edridge, A. W. D., Kaczorowska, J., Hoste, A. C. R., Bakker, M., Klein, M., Loens, K., Jebbink, M. F., Matser, A., Kinsella, C. M., Rueda, P., Ieven, M., Goossens, H., Prins, M., Sastre, P., Deijs, M., & van der Hoek, L. (2020). Seasonal coronavirus protective immunity is short-lasting. *Nature Medicine*, *26*(11), 1691–1693. https://doi.org/10.1038/s41591-020-1083-1

ECDC (2020). *Considerations relating to social distancing measures in response to COVID-19 – second update.* Technical Report from the European Centre for Disease Prevention and Control, March 23, 2020. https://www.ecdc.europa.eu/en/publications-data/considerations-relating-social-distancing-measures-response-covid-19-second

Fenichel, E. P. (2013). Economic considerations for social distancing and behavioral based policies during an epidemic. *Journal of Health Economics*, *32*(2), 440–451. https://doi.org/10.1016/j.jhealeco.2013.01.002

Ferretti, L., Wymant, C., Kendall, M., Zhao, L., Nurtay, A., Abeler-Dörner, L., Parker, M., Bonsall, D., & Fraser, C. (2020). Quantifying SARS-CoV-2 transmission suggests epidemic control with digital contact tracing. *Science*, *368*(6491). https://doi.org/10.1126/science.abb6936

French, A.M., Storey, V.C., and Wallace, L. (2021) Les Misérables: The tale of COVID-19 and Role of Information Systems. Journal of Organizational Computing and Electronic Commerce. *32*(2). https://doi.org/10.1080/10919392.2021.1904093

Gerke, S., Shachar, C., Chai, P. R., & Cohen, I. G. (2020). Regulatory, safety, and privacy concerns of home monitoring technologies during COVID-19. *Nature Medicine*, *26*(8), 1176–1182. https://doi.org/10.1038/s41591-020-0994-1

Cite as:

Storey, V. C., Lukyanenko, R., and Grange, C. 2021. "Fighting Pandemics with Physical Distancing Management Technologies," *Journal of Database Management* (Forthcoming), pp. 1–14.

Goggin, G. (2020). COVID-19 apps in Singapore and Australia: Reimagining healthy nations with digital technology. *Media International Australia*. https://doi.org/10.1177/1329878X20949770

Grange, C., & Pinsonneault, A. (2021). The Responsible Adoption of (Highly) Automated Decision-Making Systems. *Proceedings of the 54th Hawaii International Conference on System Sciences*, January 2021, Maui, Hawaii. https://scholarspace.manoa.hawaii.edu/handle/10125/71213

Greenhalgh, T., Koh, G. C. H., & Car, J. (2020). Covid-19: A remote assessment in primary care. *BMJ*, *368*, m1182. https://doi.org/10.1136/bmj.m1182

Gupta, R., Bedi, M., Goyal, P., Wadhera, S., and Verma, V. (2020a). "Analysis of COVID-19 Tracking Tool in India: Case Study of Aarogya Setu Mobile Application," *Digital Government: Research and Practice* (1:4), ACM New York, NY, USA, pp. 1–8.

Gupta, M., Abdelsalam, M., & Mittal, S. (2020b). Enabling and Enforcing Social Distancing Measures using Smart City and ITS Infrastructures: A COVID-19 Use Case. *ArXiv:2004.09246 [Cs]*. http://arxiv.org/abs/2004.09246

Haseltine, W. , 2020. Want to prevent another coronavirus epidemic? *Scientific American*, January 29. https://blogs.scientificamerican.com/observations/want-to-prevent-another-coronavirus-epidemic/

Horkoff, J., Maiden, N., & Lockerbie, J. (2015). Creativity and goal modeling for software requirements engineering. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition* (pp. 165-168).

Islam, N., Sharp, S. J., Chowell, G., Shabnam, S., Kawachi, I., Lacey, B., Massaro, J. M., D'Agostino, R. B., & White, M. (2020). Physical distancing interventions and incidence of coronavirus disease 2019: Natural experiment in 149 countries. *The BMJ*, *370*. https://doi.org/10.1136/bmj.m2743

Jansen-Osmann, P. & Wiedenbauer, G. 2006. Distance cognition in virtual environmental space: Further investigations to clarify the route-angularity effect. Psychological Research 70, 43–51.

John Hopkins Medicine (2020), Coronavirus, Social Distancing and Self Quarantine, https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/coronavirus-social-distancing-and-self-quarantine (accessed on Jan 28, 2021)

Jonaitis, J. (2020). How to stand your ground on social distancing, without alienating family and friends. *Washington Post*. https://www.washingtonpost.com/lifestyle/wellness/family-friends-disagree-social-distancing-coronavirus/2020/06/06/ec4b034a-a769-11ea-b473-04905b1af82b_story.html

Kasai, T. (2020). From the "new normal" to a "new future": A sustainable response to COVID-19. *The Lancet Regional Health – Western Pacific*, *4*. https://doi.org/10.1016/j.lanwpc.2020.100043

Cite as:
Storey, V. C., Lukyanenko, R., and Grange, C. 2021. “Fighting Pandemics with Physical Distancing Management Technologies,” *Journal of Database Management* (Forthcoming), pp. 1–14.

Kelso, J. K., Milne, G. J., & Kelly, H. (2009). Simulation suggests that rapid activation of social distancing can arrest epidemic development due to a novel strain of influenza. *BMC Public Health*, *9*(1), 117. https://doi.org/10.1186/1471-2458-9-117

Kirkcaldy, R. D., King, B. A., & Brooks, J. T. (2020). COVID-19 and Postinfection Immunity: Limited Evidence, Many Remaining Questions. *JAMA*, *323*(22), 2245. https://doi.org/10.1001/jama.2020.7869

Koh, D. (2021). International SOS successfully pilots digital health certificates app at Singapore’s Changi Airport. *MobiHealthNews*. January 3, 2021. https://www.mobihealthnews.com/news/asia-pacific/international-sos-successfully-pilots-digital-health-certificates-app-singapore-s

Koh, W. C., Naing, L., & Wong, J. (2020). Estimating the impact of physical distancing measures in containing COVID-19: An empirical analysis. *International Journal of Infectious Diseases*, *100*, 42–49. https://doi.org/10.1016/j.ijid.2020.08.026

Koppeschaar, C. E., Colizza, V., Guerrisi, C., Turbelin, C., Duggan, J., Edmunds, W. J., Kjelsø, C., Mexia, R., Moreno, Y., Meloni, S., Paolotti, D., Perrotta, D., Straten, E. van, & Franco, A. O. (2017). Influenzanet: Citizens Among 10 Countries Collaborating to Monitor Influenza in Europe. *JMIR Public Health and Surveillance*, *3*(3), e7429. https://doi.org/10.2196/publichealth.7429

Laato, S., Islam, A. K. M. N., Islam, M. N., & Whelan, E. (2020). What drives unverified information sharing and cyberchondria during the COVID-19 pandemic? *European Journal of Information Systems*, *29*(3), 288–305. https://doi.org/10.1080/0960085X.2020.1770632

Lauring, A. S., & Hodcroft, E. B. (2021). Genetic Variants of SARS-CoV-2—What Do They Mean? *JAMA*. https://doi.org/10.1001/jama.2020.27124

Li, L., Qin, L., Xu, Z., Yin, Y., Wang, X., Kong, B., Bai, J., Lu, Y., Fang, Z., Song, Q., Cao, K., Liu, D., Wang, G., Xu, Q., Fang, X., Zhang, S., Xia, J., & Xia, J. (2020). Using Artificial Intelligence to Detect COVID-19 and Community-acquired Pneumonia Based on Pulmonary CT: Evaluation of the Diagnostic Accuracy. *Radiology*, *296*(2), E65–E71. https://doi.org/10.1148/radiol.2020200905

Li, Z., Wang, R., Gao, J., & Wang, J. (2018). An approach to improve the positioning performance of GPS/INS/UWB integrated system with two-step filter. *Remote Sensing*, *10*(1), 19.

Lowry, P.B., Moody, G.D., Chatterjee, S., 2017. Using IT design to prevent cyberbullying. *Journal of Management Information Systems* 34, 863–901.

Lukyanenko, R., & Parsons, J. (2020). Easier Crowdsourcing Is Better: Designing Crowdsourcing Systems to Increase Information Quality and User Participation. In *Design Science Research. Cases* (pp. 43-72). Springer, Cham.

Lukyanenko, R., & Parsons, J. (2018). Beyond micro-tasks: Research opportunities in observational crowdsourcing. *Journal of Database Management (JDM)*, *29*(1), 1-22.

Lukyanenko, R., Parsons, J., Wiersma, Y. F., & Maddah, M. (2019). Expecting the unexpected: Effects of data collection design choices on the quality of crowdsourced user-generated content. *MIS Quarterly*, *43*(2), 623-648

Marlow, I., & Hong, J. (2020, May). Hong Kong Police Arrest Protesters for Violating Social Distancing Guidelines. *Time*. https://time.com/5835103/hong-kong-protesters-coronavirus-restrictions/

Martinez-Jimenez, M. A., Loza-Gonzalez, V. M., Kolosovas-Machuca, E. S., Yanes-Lane, M. E., Ramirez-GarciaLuna, A. S., & Ramirez-GarciaLuna, J. L. (n.d.). Diagnostic accuracy of infrared thermal imaging for detecting COVID-19 infection in minimally symptomatic patients. *European Journal of Clinical Investigation*, *n/a*(n/a), e13474. https://doi.org/10.1111/eci.13474

Maté, A., Llorens, H., de Gregorio, E., Tardío, R., Gil, D., Munoz-Terol, R., & Trujillo, J. (2015). A novel multidimensional approach to integrate big data in business intelligence. *Journal of Database Management (JDM)*, 26(2), 14-31.

Matrajt, L., & Leung, T. (2020). Evaluating the Effectiveness of Social Distancing Interventions to Delay or Flatten the Epidemic Curve of Coronavirus Disease. *Emerging Infectious Diseases*, *26*(8), 1740–1748. https://doi.org/10.3201/eid2608.201093

Mbunge, E., Fashoto, S., Akinnuwesi, B., Gurajena, C., & Metfula, A. (2020). *Challenges of Social Distancing and Self-Isolation during COVID-19 Pandemic in Africa: A Critical Review* (SSRN Scholarly Paper ID 3740202). Social Science Research Network. https://doi.org/10.2139/ssrn.3740202

McCall, B. (2020). COVID-19 and artificial intelligence: Protecting health-care workers and curbing the spread. *The Lancet Digital Health*, *2*(4), e166–e167. https://doi.org/10.1016/S2589-7500(20)30054-6

McMahon, S. (2020). Tourists are buying fake covid-19 test results on the black market to travel. *Washington Post*. November 10, 2020. https://www.washingtonpost.com/travel/2020/11/10/fake-tests-covid-flights/

Medina, R. A. 2018. “1918 Influenza Virus: 100 Years on, Are We Prepared against the next Influenza Pandemic?,” *Nature Reviews Microbiology* (16:2), Nature Publishing Group, pp. 61–62.

Meyer, S. M., Landry, M. J., Gustat, J., Lemon, S. C., & Webster, C. A. (2021). Physical distancing ≠ physical inactivity. *Translational Behavioral Medicine*, *ibaa134*. https://doi.org/10.1093/tbm/ibaa134

Mohammed, M. N., Syamsudin, H., Al-Zubaidi, S., AKS, R. R., & Yusuf, E. (2020). Novel COVID-19 detection and diagnosis system using IOT based smart helmet. *International Journal of Psychosocial Rehabilitation*, *24*(7), 2296–2303.

Mont, M. C., Pearson, S., & Bramhall, P. (2003). Towards accountable management of identity and privacy: Sticky policies and enforceable tracing services. In *14th International Workshop on Database and Expert Systems Applications, 2003. Proceedings.* (pp. 377-382). IEEE.

Munnink, B. B. O., Sikkema, R. S., Nieuwenhuijse, D. F., Molenaar, R. J., Munger, E., Molenkamp, R., ... & Bouwmeester-Vincken, N. (2020). Transmission of SARS-CoV-2 on mink farms between humans and mink and back to humans. *Science*, *371*(6525), 172-177.

Nicolaï, M. & Grange, C. (2021). The Digital Transformation of Retail during the COVID-19 Pandemic: A Comparative Study in Canada, China, and France. In E. Mazaheri (Ed.), *The Impact of COVID19 On E-Commerce* (pp.1-18). Proud Pen. https://doi.org/10.51432/978-1-8381524-8-2_1

OECD (2016). *SF1.1 Family Size and Composition*, OECD Family Database, http://www.oecd.org/els/family/SF_1_1_Family_size_and_composition.pdf (accessed on January, 27th 2021).

OECD (2020a). *Flattening the COVID-19 peak: Containment and mitigation policies*. https://doi.org/10.1787/e96a4226-en

OECD (2020b). *COVID-19: Protecting people and societies*. https://doi.org/10.1787/e5c9de1a-en

O’Leary, D. E. (2020). Evolving Information Systems and Technology Research Issues for COVID-19 and Other Pandemics. *Journal of Organizational Computing and Electronic Commerce*, 1-8.

O'Leary, D. E., & Storey, V. C. “A Google–Wikipedia–Twitter Model as a Leading Indicator of the Numbers of Coronavirus Deaths.” *Intelligent Systems in Accounting, Finance and Management*, *27*(3), 2020, pp.151-158. http://dx.doi.org/10.1002/isaf.1482. Also appears on the NIH PubMed website under Wiley Health Emergency Collection: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7646638/. PMCID: PMC7646638.

Oliver, N., Lepri, B., Sterly, H., Lambiotte, R., Deletaille, S., De Nadai, M., ... & Vinck, P. (2020). Mobile phone data for informing public health actions across the COVID-19 pandemic life cycle. Science Advances 6 (23).

Pan, S. L., & Zhang, S. (2020). From fighting COVID-19 pandemic to tackling sustainable development goals: An opportunity for responsible information systems research. *International Journal of Information Management*, *55*, 102196.

Paolotti, D., Carnahan, A., Colizza, V., Eames, K., Edmunds, J., Gomes, G., Koppeschaar, C., Rehn, M., Smallenburg, R., Turbelin, C., Van Noort, S., & Vespignani, A. (2014). Web-based participatory surveillance of infectious diseases: The Influenzanet participatory surveillance experience. *Clinical Microbiology and Infection*, *20*(1), 17–21. https://doi.org/10.1111/1469-0691.12477

Perrin, P. B., Pierce, B. S., & Elliott, T. R. (2020). COVID-19 and telemedicine: A revolution in healthcare delivery is at hand. *Health Science Reports*, *3*(2), e166. https://doi.org/10.1002/hsr2.166

Plowright, R. K., Parrish, C. R., McCallum, H., Hudson, P. J., Ko, A. I., Graham, A. L., and Lloyd-Smith, J. O. 2017. “Pathways to Zoonotic Spillover,” *Nature Reviews Microbiology* (15:8), Nature Publishing Group, pp. 502–510.

Cite as:

Storey, V. C., Lukyanenko, R., and Grange, C. 2021. “Fighting Pandemics with Physical Distancing Management Technologies,” *Journal of Database Management* (Forthcoming), pp. 1–14.

Poels, G., Decreus, K., Roelens, B., & Snoeck, M. (2013). Investigating goal-oriented requirements engineering for business processes. *Journal of Database Management (JDM)*, *24*(2), 35-71.

Randolph, H. E., & Barreiro, L. B. (2020). Herd Immunity: Understanding COVID-19. *Immunity*, *52*(5), 737–741. https://doi.org/10.1016/j.immuni.2020.04.012

Recker, J., Lukyanenko, R., Sabegh, M. A., Samuel, B. M., and Castellanos, A. 2021. “From Representation to Mediation: A New Agenda for Conceptual Modeling Research in A Digital World,” *MIS Quarterly* (45:1), pp. 1–40.

Riemer, K., Ciriello, R., Peter, S., & Schlagwein, D. (2020). Digital contact-tracing adoption in the COVID-19 pandemic: IT governance for collective action at the societal level. *European Journal of Information Systems*, 1-15.

Rogers, S., Langley, P., & Wilson, C. (1999). Mining GPS data to augment road models. In *Proceedings of the fifth ACM SIGKDD international conference on Knowledge discovery and data mining* (pp. 104-113).

Seyitoğlu, F., & Ivanov, S. (2020). Service robots as a tool for physical distancing in tourism. *Current Issues in Tourism*, 1–4.

Shiau, W.-L., Siau, K., Yu, Y., & Guo, J. (2021). Research Commentary on IS/IT Role in Emergency and Pandemic Management: Current and Future Research. *Journal of Database Management (JDM)*, *32*(2), 67–75. https://doi.org/10.4018/JDM.2021040105

Siau, K., Woo, C., Storey, V.C., Chua, C., Chiang, R., and Beard, J. (2020) Information Systems Analysis and Design Methodologies: Past Revolutions, Present Challenges, and Future Developments.

Sharma, T., & Bashir, M. (2020). Use of apps in the COVID-19 response and the loss of privacy protection. *Nature Medicine*, *26*(8), 1165–1167. https://doi.org/10.1038/s41591-020-0928-y

Steinmetz, K. (2021). How Do You Tell Others to Observe Social Distancing Rules? *Time*. Retrieved January 28, 2021, from https://time.com/5819816/coronavirus-social-distancing/

Stevens, H., and Haines, M. B. 2020. “TraceTogether: Pandemic Response, Democracy, and Technology,” *East Asian Science, Technology and Society: An International Journal* (14:3), Duke University Press, pp. 523–532.

Tabourdeau, G., & Grange, C. (2020). From User Acceptance to Social Acceptance. *SIGHCI 2020 Proceedings*. International Conference on Information Systems (ICIS), December 2020, Hyderabad, India.

Trang, S., Trenz, M., Weiger, W. H., Tarafdar, M., & Cheung, C. M. K. (2020). One app to trace them all? Examining app specifications for mass acceptance of contact-tracing apps. *European Journal of Information Systems*, *29*(4), 415–428. https://doi.org/10.1080/0960085X.2020.1784046

Cite as:
Storey, V. C., Lukyanenko, R., and Grange, C. 2021. "Fighting Pandemics with Physical Distancing Management Technologies," *Journal of Database Management* (Forthcoming), pp. 1–14.

Van den Hoven, J. (2013). Value Sensitive Design and Responsible Innovation. In *Responsible Innovation* (pp. 75–83). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118551424.ch4

Walensky, R. P., & del Rio, C. (2020). From Mitigation to Containment of the COVID-19 Pandemic: Putting the SARS-CoV-2 Genie Back in the Bottle. *JAMA*, *323*(19), 1889. https://doi.org/10.1001/jama.2020.6572

Walline, J. H. 2020. "Quarantine Wristbands, Face Masks, and Personal Freedom in Hong Kong," *Journal of Emergency Medicine* (59:4), Elsevier, pp. 604–605.

Wang, W., & Siau, K. (2019). Artificial intelligence, machine learning, automation, robotics, future of work and future of humanity: a review and research agenda. Journal of Database Management (JDM), 30(1), 61-79.

Weinmann, M., Schneider, C., & Vom Brocke, J. (2016). Digital nudging. *Business & Information Systems Engineering*, *58*(6), 433-436.

Whitelaw, S., Mamas, M. A., Topol, E., & Spall, H. G. C. V. (2020). Applications of digital technology in COVID-19 pandemic planning and response. *The Lancet Digital Health*, *2*(8), e435–e440. https://doi.org/10.1016/S2589-7500(20)30142-4

Wilson, K., Atkinson, K. M., & Bell, C. P. (2016). Travel Vaccines Enter the Digital Age: Creating a Virtual Immunization Record. *The American Journal of Tropical Medicine and Hygiene*, *94*(3), 485–488. https://doi.org/10.4269/ajtmh.15-0510

Williams, S. N., Armitage, C. J., Tampe, T., & Dienes, K. (2020). Public perceptions and experiences of social distancing and social isolation during the COVID-19 pandemic: A UK-based focus group study. *BMJ Open*, *10*(7), e039334. https://doi.org/10.1136/bmjopen-2020-039334

Wirz, C. D., Schwakopf, J. M., Brossard, D., Brown, L. D., & Brauer, M. (n.d.). *Self-reported compliance and attitudes about social distancing during the COVID-19 outbreak Preprint*.

WHO (2020). WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. Retrieved March 11, 2020, from World Health Organization: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020

Yang, Y., & Koenigstorfer, J. (2020). Determinants of physical activity maintenance during the Covid-19 pandemic: A focus on fitness apps. *Translational Behavioral Medicine*, *10*(4), 835–842. https://doi.org/10.1093/tbm/ibaa086

Zandbergen, P. A. (2009). Accuracy of iPhone locations: A comparison of assisted GPS, WiFi and cellular positioning. *Transactions in GIS*, *13*, 5-25.