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Pandemic information support lifecycle: Evidence from the evolution of mobile apps during COVID-19

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ABSTRACT

Information sharing and consumption play an important role during a pandemic in managing constrained resources and devising effective plans to minimize a pandemic’s impact. The type of support extended by information also changes as a pandemic evolves. In this paper, we present a novel framework to understand the different types of information support needed during a pandemic crisis. Adapting phases from the pandemic crisis management lifecycle, we propose five different overlapping phases of our proposed Pandemic Information Support Lifecycle (PISL): awareness information support, preventive care information support, active information support, confidence-building information support and evaluation information support. To validate the proposed PISL, we examine the evolution of new mobile apps during the current COVID-19 pandemic by developing a taxonomy for mobile app-based information support. The proposed lifecycle presents future phases of information support for the ongoing COVID-19 pandemic, while identifying specific areas that need additional research and mobile-based information support development.

1. Introduction

The COVID-19 pandemic is ravaging the health of communities and economies around the world. There is an increased need for innovation convergence and value creation to meet the challenges posed by COVID-19 (Lee & Trimi, 2021). To manage a crisis and make effective decisions throughout the lifecycle of a disaster, information sharing and consumption play a critical role in information monitoring (also termed as infoveillance), building e-Health literacy and devising effective plans (Comfort, Ko, & Zagorecki, 2004; Hristidis, Chen, Li, Lu, & Deng, 2010; Jin, Pang, & Cameron, 2006; Kvalsvig, Barnard, Gray, Wilson, & Baker, 2020). In the current COVID-19 pandemic, information has been extensively utilized for critical tasks such as issuing public alerts, sharing case data, contact tracing, and planning for facilities and supplies needed to manage medical and other public health resources. As suggested by Ågerfalk, Conboy, and Myers (2020), information sharing and consumption can help first responders and policy makers in making informed choices and effective policies and operational decisions during the pandemic.

As a pandemic evolves, the information support for decision-making also evolves. The role of and need for information to effectively manage a pandemic change with time. Thus, understanding the nature of information available during different phases of a pandemic is important. In this paper, we study the role of information in different phases of a pandemic, so we can identify the type of information support required in the upcoming phases of the current COVID-19 pandemic and in future pandemics.

The role information plays during disaster management has been studied in the past. Celik and Corbacoglu (2010) reported that a lack of timely information inhibited response coordination during Marmara earthquakes (1999), whereas the use of timely information improved the response to the Duzce earthquakes the same year. Similarly, Comfort et al. (2004), using a simulation approach, demonstrated how access to core information improves decision making and response initiatives during disaster management. However, COVID-19 presents unprecedented threats and challenges on an enormous scale for all sectors of business and society, including stakeholders such as the scientific community, care provider institutions, etc. In particular, Information Systems (IS) researchers and developers can play a pivotal role in helping the community develop an improved understanding of these challenges, such as the infodemic (dissemination of wrong information), information surveillance, contact tracing, digital inequality, etc., that
are being exacerbated by COVID-19 (Rai, 2020). Systematic scientific inquiry and design science efforts will likely offer sustainable solutions to these pressing problems. In this study, we address the demand for sustainable solutions by developing a better understanding of various information support needs during each phase of the COVID-19 pandemic. To the best of our knowledge, there is a lack of taxonomy for representing varied information needs and requirements as they evolve with a pandemic. Therefore, the first objective of this paper is to formally conceptualize the type of support provided by information during different phases of a pandemic. We address this need by introducing a unique five-stage information support model, Pandemic Information Support Lifecycle (PISL). In the PISL, we also include the specific data shared and consumed within each phase. Subsequently, we discuss the role of information at these various stages in supporting the efforts to contain the pandemic, which is further translated into multiple applications and use cases.

We recognize there are multiple stakeholders during a pandemic, such as the general population, healthcare agencies (e.g., CDC and WHO), healthcare providers and policy makers. These various stakeholders exchange information for making pandemic-related decisions and managing diseases. In this paper, our focus is specifically on information flowing towards the general population. The public participates in all phases of pandemic management by sharing their own information, as well as consuming the information provided by other stakeholders. Focusing on the public will help us understand their inclusive interactions with other stakeholders during different pandemic phases. Through our public-focused PISL, we provide actionable guidance on the role of information systems as they relate to the public in the current COVID-19 pandemic and future pandemics.

To validate our proposed PISL model, we analyzed mobile app-based information support during the COVID-19 pandemic. During this pandemic, information is being collected and disseminated within various communities across the globe through mobile apps, in addition to various government channels and news portals. Currently, apps have largely been used to alert users about the number of incidences across the globe and provide various medical services, such as remote consultations to the users. Several nations have introduced their own contact tracing apps for tracking users, providing exposure alerts and informing users about the safe and unsafe places to visit (Oliver, Lepri, & Sterly, 2020). Indeed, the current pandemic is the largest in history since the emergence of mobile app markets in 2008. Due to the large use of mobile apps during this pandemic, researchers have explored the different types of apps available. For instance, Davalbhakta, Advani, and Kumar (2020) performed a systematic review of 63 apps to rate their overall quality, engagement, functionality, aesthetics and information provided. Sharma and Bashir (2020) analyzed 50 apps to discuss the privacy concerns. Recently, Urbaczewski and Lee (2020) showed that mobile apps have been used successfully in controlling the spread of COVID-19. However, none of these studies provide a comprehensive understanding of the nature of various COVID-19 apps and the role they play in various stages of a pandemic. Mobile apps are evolving at a fast pace during COVID-19 and providing different types of information support during different phases of the current pandemic. While validating the PISL, we aim to create a taxonomy of information support provided by mobile apps during COVID-19. Therefore, the second objective of this paper is to categorize the types of information support provided by mobile apps during the COVID-19 pandemic as mapped with different PISL phases. Subsequently, we discuss the direction of flow of information in each category of apps. The mapping of mobile apps to information support needs will help fill the void that presently exists in our understanding of the COVID-19-focused mobile apps and the type of information support they provide. This serves to identify areas that require further innovation as we look towards managing phases during future pandemics. Therefore, the description of the PISL and the support provided by mobile apps for each of the PISL phases in this study offer a justification for mobile app firms to lead innovation in the identified areas. This study provides guidance on these areas by showing areas in which app innovation is lacking and which areas require rapid app development.

This study makes important contributions in two specific areas. The first is the conceptualization of our PISL, which is adaptable to other pandemics. The second is the development of a mobile-app-based taxonomy for COVID-19 and identification of areas in mobile app development that need innovation to keep up with the needs of future pandemics. Our taxonomy reveals gaps in the current state-of-the-art app markets and identifies information support areas requiring a rapid response from app developers to support information needs in the current COVID-19 pandemic and any future pandemics. Our contributions provide guidance to policy makers, healthcare professionals and app developers in the present COVID-19 pandemic and in future pandemics by outlining the types of informational support required at different stages of a pandemic.

The next section, Section 2, outlines our proposed PISL. Section 3 applies our PISL phases as a framework to review the current state of COVID-19-related apps. Section 4 details the types of information support needed in the future phases of the ongoing COVID-19 pandemic and identifies areas for future investigation. Finally, we conclude by discussing the limitations of this study.

2. Pandemic information support lifecycle (PISL)

We draw on the literature about disaster and crisis management lifecycles to develop our PISL. In the past, researchers have debated on the definitions of crisis and disaster, but there is no universal definition for both (Shaluf & Said, 2003). In this paper, we broadly define a pandemic disaster as a crisis with a bad outcome, adapting our definition from Stephenson Disaster Management Institute1. A pandemic is a biological disaster that causes damage to human lives and negatively impacts the world economy, as evident in with COVID-19. As postulated by Khan, Vasiliscu, and Khan (2008), there is an uncertainty in the degree of resources needed to mitigate a pandemic and the losses suffered in a pandemic. Therefore, a strategic crisis management process is necessary to contain a pandemic’s impact. Pandemic crisis management is a continuous process comprising of different phases in which various stakeholders, such as government agencies, communities, etc., consume information to support various phase-specific tasks, devise policies and guidelines to mitigate the effect of a disaster and make plans for recovery. A pandemic goes through multiple phases throughout its life. Broadly, there are four phases of a disaster management lifecycle: mitigation, preparedness, response and recovery (Khan et al., 2008; Wisner & Adams, 2002). Likewise, Pauchant and Mitroff (1992) explained a crisis management lifecycle in five similar phases: warning, prevention and preparation, containment and response, recovery, and learning. They added learning as the last stage. In this paper, we adapt the latter to discuss the information support lifecycle in a pandemic.

To understand the rationale for developing our PISL, we must explain the five overlapping phases of a Pandemic Crisis Management Lifecycle (PCML) adapted from the five phases described by Pauchant and Mitroff (1992). The first phase of a PCML is the warning phase during which a pandemic is detected, and warnings are issued by experts to government agencies and the public. There could be a potential lag between the actual inception and recognition of the pandemic during this phase. In this phase, the purpose is to be able to generate alerts to the public and government, so they can start the planning and preparation needed to manage the pandemic. For example, as COVID-19 information became available around the world, some countries began to share information about the number of people who tested positive. As the number of COVID-19 cases grew, public health agencies began to share more descriptive analytics through mobile apps, as well as other channels. These analytics included stats such as the number of patients in hospitals.

1 https://www.sdmii.lsu.edu/about-us/faqs/.
and intensive care units, deaths, test positivity rates, various moving averages to understand a trend, etc. This information primed the public to take the pandemic seriously and implement proper precautions. The second phase of a PCLM is the prevention and preparation phase during which plans are made to effectively respond to a pandemic by creating new policies and guidelines. This phase also includes public education and training, a key part of which is reaching out to the public with an appeal for taking preventive measures. For instance, different government and healthcare agencies worldwide have requested for the public to self-monitor their health and record any symptoms for preventive care during COVID-19. The prevention and preparation stage is a continuous process and overlaps with other stages in a pandemic because a pandemic evolves over time, requiring continuous preparation and mitigation plans.

The third phase is the response phase during which major efforts are made to contain a pandemic’s impact while the pandemic is still underway. Efforts to stop the spread of a disease like COVID-19 involve the surveillance of public health, mobility restrictions and the deployment of persuasion mechanisms to convince the public to adopt preventative measures. Examples of persuasion mechanisms include literacy about the effectiveness of mask wearing and social distancing in preventing the spread of COVID-19. At the same time, it is important to create and enact policies for actively containing the spread of pandemic. Like the prevention and preparation stage, the response stage overlaps with other phases of a pandemic as the impact of a pandemic does not vanish immediately. A pandemic’s impact weakens over time, so the response phase will continue, overlapping other phases until the pandemic ends.

The next phase is the recovery phase, which occurs when the impact of a pandemic weakens, and plans and policies are made to reinstate order and restore communities and the economies. Based on the severity of a pandemic, the recovery phase can take a longer to get economies and communities back to the state they were in before the pandemic or to a new state of equilibrium. Supporting the recovery phase involves launching campaigns to ensure public health safety and instill confidence in the public, develop post-pandemic assistance programs and construct post-pandemic clinics (Chandrasekhar & Finn, 2013). The final stage of a PCLM is the learning stage. During this stage, an assessment of the previous stages is conducted to identify areas of strengths and weaknesses that will inform the development of better mitigation plans for future pandemics. This is an inter-pandemic phase i.e. a phase between two pandemics. The five stages of the PCML are presented as pandemic phases on the horizontal axis in Fig. 1.

Our paper proposes certain information support types are needed by the public during each of these pandemic phases. We note that every pandemic can be different in terms of the time interval between different phases. However, our proposed lifecycle for the type of information support required during different phases is applicable to future pandemics, regardless of the length of their phases. The proposed phases of our PISL are presented in Fig. 1. Fig. 1 also presents the type of information in each phase and the level of specific information support during the lifecycle of a pandemic. Notably, in Fig. 1, we map only one type of information support for each pandemic phase. Since pandemic phases overlap, the types of information support also overlap, with levels of demand differing over the course of a pandemic. We recognize
that the proposed levels of information support are subjective and provide an estimate of the relative importance of the support, rather than a precise quantification. The level of demand of information support will warrant validation once the pandemic is over and data become available for showing varying information demands across the pandemic phases. We also note that such information demands and the shape of each phase could have different slopes for different pandemics. However, the type of information support presented applies to all pandemics.

We propose that a PISL is comprised of five types of information support: awareness information support, preventive care information support, active information support, confidence-building information support and evaluation information support. The awareness information support during the first phase of pandemic is preceded by the pandemic detection, which includes sharing of relevant information with the public and government agencies to make them aware of the potential spread and risks of the pandemic. The awareness information support is mapped with the warning phase of the PCML. Visible in Fig. 1, the awareness information support continues until the last stage of the pandemic as the pandemic crisis lifecycle does not always follow a bell-shaped curve; the lifecycle can be cyclical, meaning the effects of a pandemic can oscillate over time and become worse again after initially showing some improvement (Liu, Moss, & Zhang, 2011). In addition, as understanding of a pandemic is likely to improve over time, continuous communication with the public is required to make them aware of new developments. For example, since the announcement of COVID-19 as a pandemic by the World Health Organization (WHO) on 11 March 2020, agencies such as the WHO and the Centers for Disease Control and Prevention (CDC) have continued to issue warnings to communities and governments so timely mitigating actions could be suggested to the public. Information during the warning stage has been predominantly disseminated through press releases and websites. Awareness-type information support is pertinent in all phases and provides tremendous value for communities by improving their understanding of the current state of the pandemic at the local level. This helps individuals, as well as stakeholders, make informed decisions about activities such as travel, dining, shopping, etc.

The second type of information support in the PISL, preventive care information support is mapped with the prevention and preparation phase of PCML. This type of information support includes e-Health literacy and training of the public and first responders to take preventive measures to minimize the spread of a disease. This includes information pertaining to self-care. Throughout a pandemic, this type of information support is the most prevalent. The primary information flow in this PISL phase is from authorities to the public, so the public understands the severity of the situation and supports the efforts of first responders. This preventive care information support phase is continuous and overlaps with the upcoming PISL phases. This type of information support has value to the public by helping them stay alert and avoid the disease. In the current COVID-19 pandemic, social distancing and mask mandates are the two primary preventive measures which require continuous broadcasting to the public to keep them alert.

The third phase of PISL is active information support, which aligns the most with the response phase of a pandemic. The data is actively shared by the public and other stakeholders to make decisions for coordination, better utilize available resources, implement sound policy and devise effective plans. Such datasets include symptoms, daily health related experiences and location data of the individuals and inventory records of the hospitals. Since the current COVID-19 pandemic is primarily amplified by public movement, the data of personal movement is expected to be used for pandemic management. A pandemic is at its peak during the response stage, so the information on the public can reveal some complex patterns. In this phase, the flow of information takes place both ways: from the public to responding authorities such as public health agencies and vice-versa. The information generated in this phase has primary value for authorities and researchers to allow them to understand the complexities of the pandemic. With this information, they can formulate an effective response. The active information support also enables researchers to understand the effectiveness of the policies for controlling the pandemic (Marchiori, 2020). Clearly, the active information support continues until the end of pandemic, but the extent of this support changes over time.

The fourth stage of a pandemic is recovery, which requires confidence-building information support in which measures are devised for bringing communities back into equilibrium. Confidence-building information support offers effective communication and transparent information sharing to build trust in public about the recovering situation and help them resume normal activities (Vaughan & Tinker, 2009). For example, communication about the safe places, activities and events can help encourage public to begin exploring such options. A pandemic, such as COVID-19, affects travel, brick and mortar shopping, education, dining and several other service-oriented operations (Krishnamurthy, 2020; Sigala, 2020). Confidence-building information support functions could be conducted by launching new communication campaigns with customers by informing them about various safety initiatives that will enhance public’s confidence in reinstituting the pre-pandemic activities. For instance, some people are beginning to book future trips in the hope of becoming vaccinated and immune to Covid-19. Confidence building in communities also involves disseminating information about various post-pandemic assistance programs. The primary flow of information is from authorities or businesses to the general public and from individual to individual to build trust among the community. Various information channels, such as social media, recommender apps, web portals and broadcasting channels could be actively deployed for this purpose. The primary stakeholders of this type of information support are individuals in a community, the public, who need to be confident to return to work and resume their normal level of economic activities.

The final phase in the PISL is evaluation information support in which research activities are conducted to understand the impact of the pandemic and the effectiveness of containment initiatives. This PISL phase is mapped with the learning phase of PCML. Although the evaluation of a pandemic begins in the first stage of PCML with the goal of understanding the current situation, the evaluation information support phase is prevalent post-pandemic as more data becomes available. To study the pandemic’s impact, data in the form of surveys, electronic health records, social media conversations, public location, etc. can be used. The use of big data analytics and deep learning methodology can help discover more complex patterns in the community spread of the disease (Akter & Wamba, 2019; Chaudhuri & Bose, 2020; Eryasoy, Delen, Davazdahemami, & Topuz, 2021). During the evaluation phase, the information delivered in different phases during the COVID-19 pandemic can be used to provide guidance for managing any future pandemics. Subsequently, researchers need to be vigilant about the current pandemic situation to ensure significant control of the pandemic. The primary stakeholders in this phase are the researchers who continue to find unknown complex lessons from the data to better predict, manage, and contain future pandemics.

We recognize the vast scope of the information exchanged and the type of information support needed by the public and other stakeholders during each of these five phases of PISL. A large swath of the economy is engaged in prevention, management, response, mitigation, and lessons learned from a pandemic. Identifying an ontology of the information needs, exchanges and types of support that occur during a pandemic is a significant undertaking in its own right. However, that is not the main purpose of this paper. Our focus is primarily on investigating public-based information support and the evolution of mobile apps during the COVID-19 pandemic.

3. Mobile-based information support during COVID-19: validation of the PISL

To validate the proposed PISL, we examine the evolution of mobile apps during COVID-19 and map the information support they provide to the different phases of pandemic and PISL. Specifically, we have
developed a taxonomy of mobile apps describing the type of information support provided by these apps during different PISL phases. To do so, we adapt a taxonomy development approach described by Nickerson, Varshney, and Muntermann (2013). The process begins with selecting a meta-characteristic of the objects to be classified and defining an ‘ending condition’. In our study, the objects to be classified are the apps, and the meta-characteristics are the types or categories of information support. The ‘ending condition’ occurs when all apps are classified in at least one category of information support. Notably, an app can provide other types of support, such as emotional (e.g., support involving feelings of trust, empathy, sympathy, and love), appraisal (e.g., providing evaluative feedback to others), or instrumental (e.g., providing resources such as time, material or money) in addition to information support (Malecki & Demaray, 2003). In this study, however, we restrict our focus to informational support only.

Nickerson et al. (2013) describe an iterative technique for taxonomy development using both inductive and deductive processes. The inductive procedure begins after selecting meta-characteristics, which involves an empirical-to-conceptual analysis of apps. We analyze the descriptions provided by the app developers in the iOS App Store to determine the primary objective of an app. Before they are published in the App Store, mobile apps go through a rigorous screening and review process for reliability, safety and performance. Specifically, all app-related information and metadata is assessed for accuracy (Guidelines, 2020). Hence, the use of data vetted by the App Store ensures credibility of app-related information and helps avoid the issue of misinformation that can be found in online reviews, social networks, etc., which present alternative, less reliable data sources than App Store descriptions for conceptualizing the PISL (Kouzy, Abi Jaoude, & Kraitem, 2020; Laato, Islam, Islam, & Whelan, 2020).

The steps performed to collect, prepare and analyze the data are outlined in a flowchart in Fig. 2. First, the descriptions of the COVID-19 related apps, in addition to their release dates, were obtained through a web scraping script developed specifically for scraping the US version of the iOS App Store using node.js. These apps are from 62 countries, in addition to two apps by the WHO and one by the United Nations (UN), and several app descriptions are in a language other than English. Fig. 4 presents the location-based distribution of the apps from these different countries. We translated all app descriptions into English using Google Translate. These transcriptions were validated by native speakers of each non-English language, who are students from a university in US.

After the data was prepared, the descriptions of the apps were analyzed qualitatively to discover informational themes in the text. First, the description of each app was independently read by two researchers for finding keywords in the text using the qualitative approach of open coding, and then, the common keywords were further categorized into 63 broad categories. These 63 broad categories were mapped to create a new COVID-19 mobile app taxonomy comprising of eight emerging themes. These keywords and categories are presented in Fig. 5. Appendix A provides a list of all the apps and the detailed categories developed. The eight categories or themes of the apps were used to identify the following types of information support: statistics/descriptive analytics, e-Health literacy, telehealth, self-evaluation, symptoms monitoring, resource management, geo-referencing and contact tracing.

The deductive procedure for taxonomy development was then initiated as the second iteration. We utilized the conceptual-to-empirical approach to identify additional characteristics of the apps and map the pandemic. However, 49 of the 239 apps were either developed before the current pandemic or did not fit under the definition of informational support. For example, apps focusing on stress management or raising funds to aid those impacted by COVID-19 were excluded from our dataset. The oldest app in our dataset was released on Feb 26, 2020. The remaining 190 apps (average age 67.7 ± 30.5 days) were included in our dataset and analyzed to understand the evolution of the types of informational support during the phases of the current pandemic. Our data collection includes both general and profile-specific apps. These apps are from 62 countries, in addition to two apps by the WHO and one by the United Nations (UN), and several app descriptions are in a language other than English. Fig. 4 presents the location-based distribution of the apps from these different countries. We translated all app descriptions into English using Google Translate. These transcriptions were validated by native speakers of each non-English language, who are students from a university in US.

3 The iOS app market assigns a genre to an app. Our dataset included the following number of apps in these specific genres: 75 in medical, 80 in health & fitness, 10 in utilities, 6 in news, 2 in productivity, 2 in social networking, 5 in reference, 3 in business, 3 in education and 4 in lifestyle.
themes identified in the inductive process i.e., the first iteration, with the five PISL phases. During this step, two other app attributes were included: data used and direction of information flow through the apps in the taxonomy. In this step, two independent researchers classified each app into one or more secondary categories, in addition to categorizing the app by its primary objective. Based on the apps’ primary objectives, the researchers identically categorized 95% of the apps, and based on their secondary objectives, the researchers identically categorized 85% of apps. For apps on which they disagreed, the researchers further discussed each app until they reached a consensus on how to categorize each. In the next section, we will explain the categories the researchers used in detail and map them with the proposed phases of the PISL. Analyzing this data helps us identify the types of apps currently included: data used and direction of information flow through the apps.

3.1. Taxonomy of information support provided by COVID-19 mobile apps

Using a thematic analysis, we developed a taxonomy of mobile apps related to COVID-19 pandemic. Fig. 5 shows the types of information support that emerged from the broader category of keywords and maps the different types of apps with the phases of the PISL and COVID-19 pandemic. Under each category, the broader keywords are included. The taxonomy in Fig. 5 also presents the mobile apps currently missing in the market.

The first category of apps identified is statistics or descriptive analytics. Statistics include dynamic information such as live tracking of the number of cases, daily developments about the pandemic and up-to-date information from around the world. Apps delivering statistics provide awareness information support from the initial stages of a pandemic outbreak. The type of information exchange in this category of apps is descriptive analytics. Such apps include dynamic information such as live tracking of the number of cases, daily developments about the pandemic and up-to-date information from around the world.

The second category is telehealth in which healthcare providers use apps to directly answer questions from users. Apps providing telehealth aim to deliver preventive care information support. Although these apps do not provide information directly to the general public, they serve as a medium for connecting providers with individuals, so users can get information. Telehealth has an important role to play in transforming healthcare delivery by allowing healthcare providers to remotely monitor patients (Wosik, Fudim, & Cameron, 2020). The primary data exchanged in this category of apps are instructions to encourage users to connect with their providers. Over 11% of apps in our dataset fall into this category, with either telehealth as their primary or secondary objective, and 6% of apps from our dataset have telehealth as their primary objective.

The third category is e-Health Literacy in which apps provide educational content, training, and the latest safety and health guidelines to keep the public informed. These apps provide preventive care information support. The data exchanged in this category is based on educational material and guidelines provided by healthcare agencies. Examples of such apps are COVID-KAYA by WHO, Apple COVID-19 and GVA Coronavirus. Over 33% of the apps from our dataset belong to this category, with e-Health Literacy either as their primary or secondary objective, and 16% of apps from our dataset have e-Health Literacy as their primary objective.

The fourth category of apps are those used for self-evaluation. Such apps are typically used for self-recording of symptoms, self-assessment, receiving automated recommendations and self-monitoring of a user’s health. These apps provide predefined recommendations for preventive care. Therefore, the apps with self-evaluation features provide preventive care.
care information support. The type of the data recorded by these apps is health data, meaning users record their health data, mainly their symptoms, and self-track them. Self-tracking features of an app are primarily used for self-evaluation without the involvement of a medical professional. About 28% of the apps in our dataset have self-assessment of a user’s symptoms as either their primary or secondary objective, and 13% of the apps in our dataset have this feature as their primary objective. Apps such as MyCovid Passport, Asistencia COVID-19 and NHS24: Covid-19 provide self-screening capabilities.

The fifth category of apps in our dataset is symptoms monitoring, and such apps are used for surveillance and research. These apps typically require users to share their personal information such as health data, including symptoms, disease-related experiences and voice samples of a cough and breathing sounds with healthcare providers, public health agencies and researchers. Users share their health data to receive personal recommendations, and the authorities use the data for monitoring. Various users actively engage with these apps to share their personal health data with health agencies and thus provide active information support.
support during the response phase of a pandemic. The flow of information is from app users to public health agencies and researchers, with users collecting and voluntarily sharing their personal data. Examples of such apps are Monitora COVID-19 from Brazil, COVID Control from John Hopkins University and KovidPower from US. A subset of apps in the symptoms monitoring category is used to collect data for scientific research projects. In most of these projects, university researchers and practitioners collaborate to understand the current health status of the public and understand the current state of an emerging pandemic. The app COVID19 Sounds from the University of Cambridge falls in this category. This app collects voice samples of breathing and coughing from users, in addition to their medical and demographics data, to develop machine learning algorithms for diagnosis. Similarly, apps such as COVApp asks for users to create a daily diary of symptoms that is shared with researchers. Over 34% of apps in our dataset provide support for symptoms monitoring as their primary or secondary objective, and about 28% of apps from our apps have this feature as their primary objective.

The sixth category of support provided by the apps in our dataset is resource management. Sharing information about current resources (such as Personal Protective Equipment or PPE, bed allocation, etc.) for pandemic management helps the public make informed health-related decision and assists authorities in planning and optimizing the use of these resources. Supporting the public and decision-making authorities requires sharing real-time data with the public, and thus, resource management apps provide active information support. A recent editorial by Donthu and Gustafsson (2020) highlights the importance of real-time data sharing for effective COVID-19 management. Despite state-of-the-art technology, there are very few publicly available apps providing support for resource management to the public. We classified only four apps in our dataset into this category. Among these apps, NIOSH PPE Tracker tracks the use of PPE within a healthcare facility but does not provide information support to the public. Other apps in this category include Bersatu Lawan COVID-19 from Indonesia that provides rapid diagnostic tests and logistics features to the authorities, and México’s Simulador Intubación COVID-19 app that uses a virtual simulation approach to reduce the contamination of spaces, equipment and health personnel. The type of data mainly shared in these apps is inventory records shared among government authorities and private agencies. There are very few resource management apps that deliver information to the public like India’s Delhi Corona app that provides real-time information on availability of hospital beds and ventilators. The lack of apps such as this one that provide resource management support directly to the public presents developers with the opportunity to create such apps and fill a void in the app market.

The seventh category of apps includes apps focusing on geo-referencing. Apps using location data to monitor a user’s physical movement and to identify COVID-19 hotspots fall into this category. Smartphone GPSes are used to collect user location information, which is automatically transmitted to a server to create aggregated results. Users are required to provide a one-time consent before using the app that allows the app to gather their location information. Some apps also allow users to manually add data about locations they visited in the past few days. For instance, users can report the places they visited in last 14 days, in addition to consent to mobile location detection, in the Care19 Diary app. Similarly, Canada’s BC COVID-19 Support app requests devices’ location data in order to provide users with location-based alerts. Over 15% of the apps in our dataset are used for geo-referencing, with this feature as either their primary or secondary objective. However, only three apps in our entire dataset were classified with this category as their primary objective. This category of apps continuously generates data and provides active information support during a pandemic.

The final category of the apps currently available in response to COVID-19 is the contact tracing. We differentiate geo-referencing from contact tracing support in our study. The purpose of the former is to obtain aggregated information about the public, but the objective of contact tracing apps is to provide feedback and exposure alerts to individual users. Contact tracing apps require continuous social interaction and sharing of data with other users, and thus, they provide active information support for pandemic management. Such apps use Bluetooth technology to measure the distance between two mobile phones and issue alerts in suspected cases of possible exposure. When two mobile phones come in close proximity, an overlap is detected, and users are notified. The apps are used to determine the social interactions between users. For this purpose, the apps do not utilize the location information as mobile phones communicate with each other directly. Examples of this type of app include Healthy Together - COVID-19, COCOA - COVID-19 Contact App and SwissCovid. Over 19% of the apps in our dataset belong to the category of contact tracing, with contact tracing as either their primary or secondary objective, and about 18% of the apps in our dataset have this category as their primary objective. Fig. 6 presents the number of apps in each category (with primary or secondary objective) and Fig. 7 presents the number of active apps in each category (with primary or secondary objective) during different weeks of 2020 during COVID-19 pandemic.

4. Implications from the evolution of information support in the upcoming phases of the COVID-19 pandemic

The app analysis performed in this study provides insight into the kinds of information support necessary for effective pandemic management in the future. As COVID-19 progresses and more data is collected by healthcare providers and government agencies, such as the National Institutes of Health (NIH), more research and learning can occur to foster better response and recovery plans. Given the novelty of the COVID-19 pandemic, most apps are evolving and adapting as the pandemic progresses. However, our analysis of the COVID-19-related apps in our dataset and our focus on developing an app taxonomy suggests that the existing apps lack confidence-building information support for the recovery phase and post-pandemic evaluation information support for the learning phase of the pandemic. Increased development and IS research need to happen in these information support categories. In addition, as we complete this paper, a significant need for apps to plan and schedule vaccine distribution is emerging.

Confidence-building information support is likely to play a crucial role in the post-pandemic recovery. This type of information support will be important post-pandemic when a promising solution will be implemented, such as the planned vaccine distribution in the population, and will necessitate the communication of reliable recovery information to the public for improved confidence building. Along the same lines, the use of apps for persuading the public to change their behavior to adapt to the post-pandemic environment can be effective. As discussed by Fogg (2009), technology can change user behavior by motivating and prompting users, making apps an ideal medium to precipitate post-pandemic changes in communities. The COVID-19 pandemic has restricted public movement, and as a result, businesses have incurred heavy losses. Individual businesses will be required to share customer safety information with customers to restore a sense of normalcy. In our app analysis, we found an interesting app named Disinfection Checklist which can help bring customers back to brick-and-mortar businesses. The app provides business owners a disinfection checklist based on CDC recommendations for COVID-19 and allows them to take photos, signature and dates of the disinfected surfaces, which can be shared with customers in a convenient PDF report. More apps like this one that enable social interactions can promote community resilience by building confidence in the public that businesses are fighting the spread of COVID-19 and thus safe to visit. However, such apps are rarely present in the current app market. Apps such as these could also be enhanced with additional functionalities that support confidence building in communities, such as a word-of-mouth approach. Our proposal aligns with prior research suggesting the effectiveness of using other approaches such as word-of-mouth. As discussed by Chandrasekhar and Finn in their
case study on the recovery efforts after Hurricane Sandy (2013), information passed by word-of-mouth among neighbors, friends and family members can play an important role in spreading information about assistance programs after a disaster-type event like Hurricane Sandy or the current COVID-19 pandemic. The social capital generated in the form of collective narratives can aid post-pandemic recovery in a community as suggested by Chamlee-Wright and Storr (2011).

Finally, the evaluation phase of the PISL will use information gathered on the pandemic to understand how the pandemic was managed and its impact on a variety of societal, economic and health-related outcomes. The post-pandemic information will also help determine what long-lasting lifestyle changes are necessary and enable researchers to assess all previous stages of the pandemic and identify the weak points. Such findings will help manage the next pandemic more effectively. Currently, research to devise effective plans for responding to a pandemic is underway but more research will need to be conducted post-pandemic as comprehensive datasets become available for researchers. Digital repositories may be created to provide access to COVID-19-related data to researchers. Efforts to create such repositories are already ongoing. More analytics and artificial-intelligence-driven efforts will need to emerge during the post-pandemic phase to fuel the development of apps oriented towards the recovery and learning phases.

Fig. 6. Number of apps in each category.

Fig. 7. Evolution of apps in each category.
We anticipate that improved research due to increased data availability and establishment of practice-based medicine guidelines will lead to better learning and evaluation of the pandemic management. We noticed similar improvements in the disease and pandemic management of other past outbreaks such as SARS and Ebola.

In addition to healthcare research, the use of sensors and wearable technologies for early COVID-19 detection, coupled with mobile apps, are gaining momentum. For example, physiological and biometric data can be promising contributors to early detection of diseases as the use of a wearable devices, such as Whoop smart bands, has shown; research with Whoop smart bands indicates that asymptomatic individuals may have imperceptible changes in bodily activity, such as change in respiration rate and heart rate, that would otherwise be missed without wearable technology (Leonard, 2020). A study conducted using Fitbit wearable devices shows that heart rate and other physiological data can detect flu-type infections in real-time (Radin, Wineinger, Topol, & Steinhubl, 2020). Similar initiatives for COVID-19 detection have been proposed. For example, the Digital Engagement & Tracking (DETECT) health study by Scripps Research 4 has aimed to collect data on heart rate and other symptoms through wearable devices to create real-time detection systems for COVID-19. Sensors can help not only at the individual level but also at the community level. For example, wastewater from sewage can be used to detect COVID-19 at the neighborhood level (Mallapaty, 2020). Therefore, data from sensors and the Internet of Things is expected to be promising for pandemic management in the future. Similarly, Adams-Dester et al. (2020) recently reviewed the use of mobile technology to monitor and mitigate the impact of COVID-19. They report on the use of mHealth for COVID-19-related clinical issues, monitoring service providers and patients in a disaster scenario, solutions to screen and monitor COVID-19 cases, remote monitoring of patients with COVID-19 and frontline healthcare workers, technology-assisted contact tracing in hospital and community settings, and data integration.

Mobile devices have enabled the collection of data at the population level, and this data can be used to generate models for COVID-19 detection. Fig. 8 presents a framework for mobile-based early COVID-19 detection. Different types of data can be used for creating a disease detection model. For example, self-reported health history, lifestyle, and demographic data and activity and location data collected using built-in mobile sensors can be combined with more detailed physiological data from external sensors to provide comprehensive insights and diagnostics. Using cloud technology, data from multiple sources can be combined to create models that provide real-time alerts to users through mobile apps. In addition, data can be used by health institutions for monitoring.

While our primary focus in this study has been on public-oriented information support, we recognize that apps and systems need to be developed for information sharing among other stakeholders for various pandemic phases. Examples of such stakeholders include healthcare professionals, research institutions and government agencies. Currently, pandemic response systems are existing in silos (Sokol, 2020) and, therefore, lack a unified information exchange framework. Fig. 9 presents a framework that illustrates a unified information sharing system among multiple stakeholders. Besides the general public, many entities are constantly exchanging information during a pandemic. For example, testing labs (i.e., healthcare stakeholder) upload results of testing data on a daily basis to state and federal facilities, which is used for various purposes such as reporting daily case counts in each locality/state/country, etc. It is also used to determine positivity rate, create predictive models and metrics. Such information then gets compiled nationally and internationally to be shared with other concerned entities (e.g., WHO, CDC) to inform policy decisions. This information exchange is facilitated by technology providers who may provide localized computing infrastructure or cloud-based technologies to support acquisition of privacy preserving data, generation of reports, and sharing of the appropriate information with relevant government agencies.

A unified information exchange structure, such as the one presented in Fig. 9, is warranted for an accurate data sharing across various stakeholders for better pandemic response. For example, it has been reported that there was a mismatch in COVID-19 data reporting from the trusted sources such as CDC and WHO (Sokol, 2020). A comprehensive and accurate information exchange among different entities is necessary for a cohesive response to the pandemic through collective intelligence where information systems and analytics techniques would be required to mediate the communication (Secundo, Shams, & Nucci, 2021). If the information generated from one stakeholder is seamlessly transferred to all the other stakeholders through a unified system, this can result in a better response through collaboration and creation of novel pandemic solutions. For instance, the readily available information from public such as self-reported health data, location, etc. and healthcare providers such as hospital resources (beds, ventilators, PPE kits, etc.) can be used by government agencies to devise better policies, which can collectively also inform healthcare research.

With respect to mobile technology, apps that facilitate communication between healthcare providers and government agencies could provide aggregated data reporting and real-time visualization tools. Similarly, apps need to be created that provide a seamless information link between healthcare research institutions and overworked healthcare providers during a rapidly unfolding crisis, such as the one created by COVID-19. Such apps are critical to reducing the time lag between clinical research and evidence-based practice in time-sensitive situations.

4.1. Future research

Now, we propose multiple research propositions for future work using the frameworks presented in Figs. 8 and 9 and our analysis related to the need for information sharing and the platforms. The early detection system is one of the most promising steps to slow the spread of virus as pointed out by Brilliant, Lipkin, Danzig, and Pak (2021). In addition, systems are required to identify individuals with exposure to prioritize the vaccination. Brilliant et al. (2021) also discussed the need for exposure notification and tracing systems to identify the population at risk. Currently, multiple contact tracing apps are available around the world but there is a greater need for a unified contact tracing system for the world population. This will also help in optimizing the vaccine distribution by finding the vulnerability of the specific population. Although it is generally accepted that early detection and mitigation measures can help with minimizing the spread epidemiologically, a design science research question remains on the efficacy of such systems. Besides the overarching question of effectiveness and efficiency of such systems in minimizing the spread, various features of such systems that would enable widespread adoption and use of such systems also remain topics of future research. Therefore, we propose:

Proposition 1. An early detection and analytics tool can minimize the virus spread by identifying the vulnerable populations and implementing mitigation strategies.

As noted above, design and development of the features of such systems offer many research opportunities. There is a major need to design and evaluate information systems to assist pandemic management as discussed by He, Zhang, and Li (2021). Multiple digital contact tracing apps are being used across the nations; however, the adoption rate has been very low (Toussaert, 2021). Studies to examine the antecedents and consequences of the use of these technologies are required to curtail the spread of virus. For example, Sharma et al. (2020) found intention to adopt contact tracing apps is positively affected by attitude, subjective norms and privacy self-efficacy. Studies to theorize newer

4 https://detectstudy.org/
constructs such as trust and confidence in the government (identified by Shareef et al., 2021) in the technology acceptance models are required.

**Proposition 2.** Empirical research on the acceptance of technology assisting pandemic management will result in newer constructs.

Another research opportunity to contribute to active response and outbreak network is to develop systems that aggregate information from the scientists, public health experts, first responders such as hospitals and public (Brilliant et al., 2021). Lack of such a system across the countries has resulted in multiple waves of the virus infections as authorities have failed to identify and respond to the novel variants of the virus in a timely manner. Recently, Maxmen (2021) has discussed that lack of data sharing among researchers have slowed down the speed of identifying new variants and presented a need for a unified health system for data sharing across research labs. Such systems will clearly pose major data protection and masking challenges, leading to additional research opportunities. Therefore, we propose:

**Proposition 3.** A unified information sharing system incorporating information from multiple stakeholders (with appropriate data protection mechanisms) can result into a cohesive response.

Social media has played an important role during the pandemic not just for disseminating the guidelines, reassuring and alarming information by the government and health experts (Rao, Vemprala, Akello, & Valecha, 2020) but also for serving as a platform for socialization during isolation and lockdown. For instance, Chakraborty, Kumar, Upadhyay, and Dwivedi (2020) discussed the intense use of social media sites for socialization while asking for a need to identify users requiring greater social support amid loneliness during the pandemic. Furthermore, Nabity-Grover, Cheung, and Thatcher (2020) have discussed the change in self-disclosure on social media during the pandemic, which raises a need for reexamining the antecedents and consequents of the
information sharing on social media. Generally, information exchange about sensitive topics (e.g. politics) on social media takes place among users with similar ideology (Barberà, Jost, Nagler, Tucker, & Bonneau, 2015). Since the social media use has increased during the pandemic, it may have caused more polarization on specific issues as discussed by Parra, Gupta, and Mikalef (2021). More empirical research is needed to identify the unintended consequences of the social media use during the pandemic. This leads to the next proposition:

**Proposition 4:** Information sharing platforms (such as social media sites) generate unknown positive (e.g., social support) and negative consequences (e.g., polarization of viewpoints).

The above is just a sampling of the research opportunities that have manifested during the pandemic, which arise from the PISL and the framework that we have discussed. Various papers cited in this study identify more detailed opportunities in specific dimensions.

5. Conclusion

We introduced multiple phases of a public-focused PISL by adopting the pandemic management lifecycle and employing it to understand the evolution of mobile apps targeted at the public using a qualitative thematic approach. We note that all pandemics go through the five phases of the PCML we have outlined in our paper, though the length of each PCML phase can vary from pandemic to pandemic. Therefore, the type of information support from our PISL that is required during each of the five PCML phases is the same across all pandemics, regardless of how long a certain PCML phase lasts in a given pandemic. Therefore, our PISL is applicable to pandemics besides COVID-19. On the other hand, while validating our PISL using COVID-19-related apps, we were able to create generalized taxonomical categories which can be replicated to future pandemics. Our app taxonomy is comprehensive, whereas apps during previous pandemics, such as Ebola, mostly provided awareness and prevention-related information as observed by Dahiya and Kalkar (2016). Specifically, for the COVID-19 pandemic, our taxonomy is applicable to all types of apps providing informational support since our taxonomy includes apps that focus on managing the user-level information as well as the apps broadcasting only general information. The apps in the categories of statistics, e-Health, telehealth and resource management spread general information and are not user-profile dependent. However, the apps in the categories of self-evaluation, symptoms monitoring, georeferencing and contact tracing are user specific. While the COVID-19 pandemic is ongoing, our proposed PISL and taxonomy for COVID-19-related apps present areas that app developers can focus on for innovation and value creation to meet the challenges posed by the current pandemic, as well as any future pandemics. Although the proposed PISL needs further validation, we believe it is applicable to other pandemics with different influencing factors.

We must note, our analysis has a few limitations. First, we considered the descriptions written by developers for each app on the marketplace. We recognize that developers may not always state all objectives of an app within the description, but we believe an app’s primary objective and critical information about the app are present in the description. Therefore, this limitation is somewhat mitigated. Note, we did not include user-generated content, such as user reviews, for classifying the apps in our dataset as this content was beyond the scope of this project. Second, we only used new apps, but certainly, older apps from health-care providers, social networks and other sources can also provide informational support. In addition, new apps are added frequently to the App Store, which will add to our cumulative plot (Fig. 7), and new themes are likely to emerge during the post-pandemic recovery and evaluation phases. Moreover, we only extracted apps from one app market, i.e., the iOS App Store. Although we focused on one app market, we know the same COVID-19 apps are also available on other app market stores and thus may not change our understanding of the evolution of the apps and the taxonomy in any significant way. Other researchers could validate our taxonomy and the information support categories identified in our PISL by analyzing apps in other stores or specific regions. Also, our focus in this study has been on app-based information support that focuses on the public. Different apps can be developed for other stakeholders and provide them with appropriate information support. An example of such an app is provided by McRae, Dapkins, and Sharif (2020), and their work investigates an app that can be used as a clinical decision support system assisting in assessing the severity of COVID-19, pandemic managing, and patient care. Most of these apps developed for stakeholders other than the public are proprietary and may not be available publicly. Future studies could be conducted that involve compiling of such apps, reviewing their functionalities and mapping them with the PISL phases.

We recognize there are significant reports of COVID-19-related misinformation and disinformation permeating across various regions and resulting in actions by authorities and public that negatively impact recovery and response phases. Although this does not affect the phases of our PISL, fake information can dilute the importance of information in pandemic management. For example, the use of dubious remedies such as Chlorine solution, which was initially labeled as fake news, has now become an officially supported remedy in South American nations such as Bolivia (Trigo, Kurmanaev, & Cabrera, 2020). Reliable information is necessary to provide answers to some of the paradoxes related to social distancing and masks (Marchiori, 2020). In response, there is a need to aggressively develop and test apps that can prevent a COVID-19 infodemic. A specific and unique use case for COVID-19 mobile applications would be to develop a comprehensive mobile phone kit that provides a single gateway for delivering reliable information and alerts for various phases of a pandemic. A single mobile portal is likely to increase its adoption. Moreover, it is now evident that we are not only dealing with a pandemic but also with an infodemic due to the COVID-19 outbreak. Due to the rapid development of new research and spread of misinformation, individuals find it difficult to parse through large volumes of information on COVID-19 and identify what is still relevant. Therefore, providing an appropriate level of scientifically vetted information support during each pandemic phase, coupled with an AI-driven feature that parses out COVID-19 misinformation, will benefit the public (Bunker, 2020). Integrating these features in an app with its ability to provide data-driven actions, such as delivering alerts based on contact tracing capabilities, will provide additional functionalities for the end user. Such standalone, smartphone-based technologies exist and use Bluetooth technology (Ferretti, Wymant, & Kendall, 2020) but are not blended in a single, comprehensive mobile platform. Developers could begin creating real-time surveillance and detection tools that harness the power of distributed computing paradigm by deriving them from existing tools such as FEND (Zhang, Gupta, Kauten, Deokar, Qin, 2019). Since much of the research and evidence supporting our understanding of a pandemic evolves with time, mobile apps need to be able to provide corrections to the community to repudiate outdated and contradictory evidence through raising awareness and supporting e-Health. For example, as COVID-19 was initially spreading, research on the effectiveness of using N95 masks and other mask types was lacking. More recent research contradicts the findings that masks only protect the wearer (Peeples & Digard, 2020). Similarly, mobile apps could bring awareness about vaccine misinformation and other facts to the community (Ball & Maxmen, 2020). Such an information-sharing effort could persuade the community to accept the most recent scientific findings regarding masks, a vaccine, social distancing, etc. during different phases of the pandemic lifecycle.

Since the PISL involves an exchange of user data, there are valid concerns regarding user privacy and confidentiality. Specifically, during COVID-19, there are concerns of privacy invasion through mobile apps as data is being collected and used at the individual level (Fabey & Hino, 2020; Rowe, 2020). Consequently, there were a few cases in South Korea of profiling and identification of infected individuals (Park, Choi, & Ko, 2020). The businesses where these individuals visited lost their
businesses. In our dataset of mobile apps, we counted the number of apps that acknowledge user privacy concerns by including discussions of privacy policies, confidentiality, security or encryption of data in their descriptions. There are a few apps which clarify that the app and any data it collected will be deleted after the pandemic is over. Interestingly, only 41% of the apps (78 out of 190) include a statement about privacy concerns. Clearly, there is a need to adopt a more balanced approach in creating laws and policies across the world, so the data collected through mobile apps can be used to develop effective measures to contain the pandemic as discussed by Park et al. (2020).

This study presents a useful framework for information support that could be adapted for future pandemics and guide policy makers to plan effective information sharing with the public at key times during a pandemic. Finally, given that mobile apps have been successfully used in controlling the spread of COVID-19, as evident in the study by Urbaczewski and Lee (2020), our study provides concrete guidance for firms engaged in app development during the pandemic by identifying gaps in the types of apps available to the public. Our analysis can also provide guidance for the government, healthcare professionals, technology firms and developers on the use of apps in the upcoming COVID-19 pandemic phases, namely the recovery and learning phases.

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Data statement

Appendix A lists the apps used in our analysis. The process of data extraction using publicly available API has been described in Section 3 of the main paper.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. COVID-19 app details and categories

| Title                     | Country   | Release Date  | Categories | Statistics (Stat) | e-Health Literacy (E) | Telehealth (Tele) | Self-evaluation (SE) | Symptoms Monitoring (Sym) | Geo-referencing (Geo) | Resource Management (Res) | Contact Tracing (Trac) | Primary Objective |
|---------------------------|-----------|---------------|------------|-------------------|-----------------------|-------------------|----------------------|------------------------|------------------------|------------------------|------------------------|----------------------|
| #BeatCovid19Now           | Australia | 6/2/2020      |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                      | SE                   |
| 1-Check COVID             | USA       | 4/2/2020      |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                      | Sym                 |
| AarogyaSetu               | India     | 4/11/2020     |            | 1                  | 1                     | 0                 | 0                    | 1                      | 0                      | 1                      | 1                     | Stat                |
| ACCESS COVID-19 Research  | USA       | 4/16/2020     |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | Sym                 |
| alminutes.rescue          | Germany   | 5/20/2020     |            | 0                  | 1                     | 0                 | 0                    | 0                      | 0                      | 0                      | 0                     | E                   |
| AMAN - Aman.jo            | Jordan    | 5/30/2020     |            | 0                  | 0                     | 0                 | 0                    | 1                      | 0                      | 0                      | 1                     | Trac                |
| JORDAN COVID-19           |           |               |            |                    |                       |                   |                      |                        |                        |                        |                        |                     |
| Apollo COVID-19           | USA       | 4/16/2020     |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | Sym                 |
| Apple COVID-19            | USA       | 3/27/2020     |            | 1                  | 1                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | SE                  |
| Aupteri Covid Latvia - SPRC | Latvia  | 5/28/2020     |            | 0                  | 0                     | 0                 | 0                    | 0                      | 0                      | 0                      | 1                     | Trac                |
| Artemis COVID-19          | USA       | 5/30/2020     |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | Sym                 |
| Asistencia COVID-19       | Spain     | 4/5/2020      |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | SE                  |
| Asistente COVID-19        | Mexico    | 5/15/2020     |            | 1                  | 1                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | Sym                 |
| BC COVID-19 Support       | Canada    | 3/22/2020     |            | 1                  | 0                     | 0                 | 0                    | 1                      | 0                      | 0                      | 0                     | Stat                |
| BCG-CORONA                | Netherlands | 4/22/2020  |            | 0                  | 1                     | 0                 | 0                    | 1                      | 0                      | 0                      | 0                     | Sym                 |
| Be+ against COVID         | Spain     | 5/11/2020     |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | SE                  |
| Bersatu Lawan COVID-19    | Indonesia | 6/9/2020      |            | 0                  | 1                     | 1                 | 1                    | 0                      | 0                      | 1                      | 0                     | Res                 |
| BeWellXcel                | USA       | 4/3/2020      |            | 1                  | 1                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | E                   |
| BMC Combat Covid19        | India     | 3/25/2020     |            | 0                  | 0                     | 0                 | 0                    | 1                      | 0                      | 0                      | 0                     | Geo                 |
| Bolivia Segura            | Bolivia   | 3/13/2020     |            | 1                  | 1                     | 0                 | 1                    | 0                      | 1                      | 0                      | 0                     | SE                  |
| Cachoeirinha ContraCoronavirus | Brazil | 3/24/2020   |            | 1                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | SE                  |
| Canada COVID-19           | Canada    | 3/30/2020     |            | 0                  | 1                     | 0                 | 0                    | 1                      | 0                      | 0                      | 0                     | E                   |
| Care19 Diary              | USA       | 4/7/2020      |            | 0                  | 0                     | 0                 | 0                    | 1                      | 0                      | 1                      | 0                     | Trac                |
| Castor COVID-19           | Netherlands | 4/2020      |            | 0                  | 0                     | 0                 | 1                    | 0                      | 0                      | 0                      | 0                     | Sym                 |

(continued on next page)
| Title                     | Country            | Release Date | Categories        |
|--------------------------|--------------------|--------------|-------------------|
|                          |                    |              | Statistics (Stat) | e-Health Literacy (E) | Telehealth (Tele) | Self-evaluation (SE) | Symptoms Monitoring (Sym) | Geo-referencing (Geo) | Resource Management (Res) | Contact Tracing (Trac) | Primary Objective |
| Central Coast COVID-19 Info | USA                | 3/25/2020    | 1 0 0 0 0 0       | Stat               |
| CISP - Covid19 Angola     | Angola             | 5/4/2020     | 1 1 1 1 0 0       | Stat               |
| Citizen SafeTrace         | USA                | 6/26/2020    | 0 0 0 0 0 0       | Trac               |
| CMICH Healthscreen        | USA                | 6/27/2020    | 0 0 0 1 0 0       | SE                 |
| COCOA - COVID-19 Contact App | Japan          | 6/18/2020    | 0 1 0 0 0 0       | Trac               |
| ComVida                  | Cape Verde         | 4/16/2020    | 0 1 0 0 0 0       | Sym                |
| Corona Check Screening    | Germany            | 4/24/2020    | 1 1 0 1 0 0       | SE                 |
| Corona Checker           | USA                | 3/26/2020    | 0 0 0 0 1 0       | Sym                |
| Corona Map               | Saudi Arabia       | 3/18/2020    | 1 0 0 0 0 0       | Stat               |
| Corona-Care              | USA                | 4/1/2020     | 0 0 1 0 0 0       | Sym                |
| CoronaControl            | Chile              | 6/29/2020    | 0 0 0 0 1 0       | Trac               |
| CoronaFACTS              | USA                | 3/28/2020    | 1 1 0 0 0 0       | E                  |
| CoronaApp-Colombia       | Colombia           | 3/15/2020    | 1 1 0 0 1 1       | Sym                |
| CoronaReport             | United Kingdom     | 5/29/2020    | 0 0 0 0 1 0       | Sym                |
| CoronaSurveys            | Spain              | 7/1/2020     | 0 0 0 0 1 0       | Sym                |
| CORONAVIRUS - Diagnosis   | Ukraine            | 5/11/2020    | 1 0 0 1 1 0       | SE                 |
| Coronavirus Australia     | Australia          | 3/28/2020    | 0 1 0 1 0 0       | E                  |
| Coronavirus COVID Tracker | USA                | 4/11/2020    | 1 1 0 0 0 0       | Stat               |
| Coronavirus Covid19       | Russia             | 4/9/2020     | 1 1 0 0 0 0       | Stat               |
| Coronavirus Karantina     | Turkey             | 5/1/2020     | 1 0 0 0 0 0       | Stat               |
| Coronavirus Support App   | United Kingdom     | 5/30/2020    | 0 1 0 1 0 0       | SE                 |
| Coronavirus UV            | Uruguay            | 3/20/2020    | 1 1 1 0 0 0       | Trac               |
| cov_cl                    | Chile              | 4/18/2020    | 1 0 0 0 0 0       | Stat               |
| COVA Punjab               | India              | 3/7/2020     | 1 1 0 1 0 0       | Stat               |
| COVapp                    | Netherlands        | 4/17/2020    | 0 0 0 1 1 0       | Sym                |
| COVI Qatar                | Qatar              | 3/31/2020    | 0 1 0 1 0 0       | E                  |
| COVID AI                  | USA                | 4/26/2020    | 0 0 0 0 1 0       | Sym                |
| COVID Asist               | Romania            | 4/25/2020    | 0 0 0 1 0 0       | SE                 |
| COVID Care Graubünden     | Switzerland        | 6/16/2020    | 0 0 0 0 1 0       | Sym                |
| COVID Control             | USA                | 4/30/2020    | 0 0 0 0 1 1       | Sym                |
| COVID izle                | Azerbaijan         | 5/22/2020    | 0 0 0 0 0 0       | Trac               |
| COVID Navigator           | USA                | 5/15/2020    | 0 1 0 1 1 0       | SE                 |
| COVID Protocols           | USA                | 6/2/2020     | 0 1 0 0 0 0       | E                  |
| COVID Puebla              | Mexico             | 4/10/2020    | 0 0 0 1 0 0       | SE                 |
| COVID Radar               | Netherlands        | 4/2/2020     | 0 0 0 0 0 0       | Sym                |

(continued on next page)
| Title                        | Country       | Release Date | Categories                                    | Primary Objective |
|-----------------------------|---------------|--------------|-----------------------------------------------|-------------------|
| Covid SafePass              | USA           | 5/29/2020    | Statistics, e-Health Literacy (E)              | Tele              |
| COVID Symptom               | USA           | 5/31/2020    | Self-evaluation (SE)                           | SE                |
| COVID Symptom Study         | USA           | 3/26/2020    | Symptoms Monitoring (Sym)                      | Sym               |
| COVID VS                    | Australia     | 6/15/2020    | Statistics, e-Health Literacy (E)              | Sym               |
| COVID-19                    | Vietnam       | 3/9/2020     | Contact Tracing (Trac)                         |                   |
| COVID19 - DXB Smart App     | UAE           | 4/10/2020    | Contact Tracing (Trac)                         | E                 |
| COVID-19 - Medisch Dossier  | Netherlands   | 3/17/2020    | Contact Tracing (Trac)                         | Stat              |
| Covid-19 Advisor            | USA           | 5/11/2020    | Contact Tracing (Trac)                         | Stat              |
| Covid-19 Armenia            | Armenia       | 4/2/2020     | Contact Tracing (Trac)                         | Stat              |
| COVID-19 Chihuahua          | Mexico        | 3/20/2020    | Contact Tracing (Trac)                         | Stat              |
| Covid-19 Cuernavaca         | Mexico        | 4/15/2020    | Contact Tracing (Trac)                         | E                 |
| COVID-19 Estatal            | Mexico        | 6/1/2020     | Contact Tracing (Trac)                         | Tele              |
| COVID-19 Intubation Simulator | Mexico       | 6/2/2020    | Contact Tracing (Trac)                         | Res               |
| COVID-19 MS SOS             | Russia        | 6/16/2020    | Contact Tracing (Trac)                         | Sym               |
| COVID-19 online test        | Russia        | 6/6/2020     | Contact Tracing (Trac)                         | Sym               |
| COVID-19 Quarantine Monitor | India         | 5/8/2020     | Contact Tracing (Trac)                         | E                 |
| COVID-19 Resource for Midwives | Canada      | 4/28/2020    | Contact Tracing (Trac)                         | E                 |
| COVID19 Sounds              | United Kingdom| 5/27/2020    | Contact Tracing (Trac)                         | Sym               |
| COVID-19 Tam                | Mexico        | 3/30/2020    | Contact Tracing (Trac)                         | Stat              |
| COVID-19 UAE                | UAE           | 4/1/2020     | Contact Tracing (Trac)                         | Stat              |
| COVID-19 Virginia Resources | USA           | 4/27/2020    | Contact Tracing (Trac)                         | Stat              |
| COVID-19 Wisconsin Connect  | USA           | 5/14/2020    | Contact Tracing (Trac)                         | E                 |
| COVID-19f                   | Czech         | 3/27/2020    | Contact Tracing (Trac)                         | E                 |
| COVID-19: Response          | UN            | 6/7/2020     | Contact Tracing (Trac)                         | E                 |
| coVIDApp - Guest            | Argentina     | 5/15/2020    | Contact Tracing (Trac)                         | Sym               |
| COVID-KAYA                  | WHO           | 6/3/2020     | Contact Tracing (Trac)                         | E                 |
| Covidom Patient             | France        | 3/10/2020    | Contact Tracing (Trac)                         | Sym               |
| CovidRadar.mx               | Mexico        | 4/19/2020    | Contact Tracing (Trac)                         | Trac              |
| COVID-RD                    | Dominican Republic | 4/9/2020   | Contact Tracing (Trac)                         | Sym               |
| COVIDSafe                   | Australia     | 6/4/2020     | Contact Tracing (Trac)                         | Trac              |
| CovidWatcher                | USA           | 4/10/2020    | Contact Tracing (Trac)                         | Sym               |
| CRUSH COVID RI              | USA           | 5/18/2020    | Contact Tracing (Trac)                         | Trac              |
| CUIDAR COVID-19 ARGENTINA   | Argentina     | 3/27/2020    | Contact Tracing (Trac)                         | E                 |
| DDC-Care                    | Thailand      | 3/16/2020    | Contact Tracing (Trac)                         | Sym               |
| Defender 2 The Corona War Application | Israel | 3/22/2020 | Contact Tracing (Trac)                         | Trac              |
| Delhi Corona                | India         | 6/8/2020     | Contact Tracing (Trac)                         | Res               |

(continued on next page)
| Title                                | Country     | Release Date | Categories                  | Statistics (Stat) | e-Health Literacy (E) | Telehealth (Tele) | Self-evaluation (SE) | Symptoms Monitoring (Sym) | Geo-referencing (Geo) | Resource Management (Res) | Contact Tracing (Trac) | Primary Objective |
|-------------------------------------|-------------|--------------|-----------------------------|-------------------|-----------------------|-------------------|----------------------|--------------------------|----------------------|--------------------------|-----------------------|------------------|
| Disinfection Checklist†             | USA         | 4/3/2020     |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     |                  |
| Druk Trace                          | Bhutan      | 5/2/2020     |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 1                       | Trac                  |                  |
| EndCorona                           | Indonesia   | 4/30/2020    |                             | 1                  | 1                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | Stat             |
| eRouiska                            | Czech       | 5/3/2020     |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 1                       | Trac                  |                  |
| Estamos ON - Covid19                | Portugal    | 3/29/2020    |                             | 1                  | 1                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | E                |
| FAMILY - COVID 19                   | Vietnam     | 3/26/2020    |                             | 0                  | 0                     | 0                 | 0                    | 1                        | 0                    | 0                       | 0                     | Sym              |
| First Responder COVID-19 Guide      | USA         | 4/7/2020     |                             | 0                  | 0                     | 0                 | 1                    | 0                        | 0                    | 0                       | 0                     | SE               |
| geoHealthApp                        | Switzerland | 5/6/2020     |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | E                |
| GH COVID-19 Tracker                | Ghana       | 4/26/2020    |                             | 0                  | 0                     | 1                 | 1                    | 1                        | 0                    | 0                       | 0                     | Trac             |
| GTO Sano                            | Mexico      | 4/4/2020     |                             | 1                  | 1                     | 1                 | 0                    | 0                        | 0                    | 0                       | 0                     | Tele            |
| Guanajuato COVID-19                 | Mexico      | 5/26/2020    |                             | 1                  | 0                     | 1                 | 0                    | 0                        | 0                    | 0                       | 0                     | Tele            |
| GVA Coronavirus                     | Spain       | 4/8/2020     |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | Sym             |
| Hamro Swasthya                      | Nepal       | 5/12/2020    |                             | 1                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | Stat            |
| HEALTHLYINKED COVID-19 Tracker     | USA         | 2/26/2020    |                             | 1                  | 1                     | 0                 | 1                    | 0                        | 0                    | 0                       | 0                     | Sym             |
| HealthMode Cough                    | USA         | 4/9/2020     |                             | 0                  | 0                     | 0                 | 1                    | 0                        | 0                    | 0                       | 0                     | Sym             |
| Healthy Together - COVID-19         | USA         | 4/21/2020    |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | Trac            |
| HM COVID RS                         | USA         | 6/5/2020     |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | SE              |
| HMushrif                            | Oman        | 5/15/2020    |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 1                       | 0                     | Trac            |
| HowWeFeel                           | USA         | 4/2/2020     |                             | 0                  | 0                     | 0                 | 0                    | 1                        | 1                    | 0                       | 0                     | Sym             |
| Hunala                              | USA         | 5/18/2020    |                             | 1                  | 1                     | 0                 | 1                    | 1                        | 1                    | 0                       | 0                     | Sym             |
| Immuni                              | Italy       | 6/1/2020     |                             | 0                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 1                     | Trac            |
| InfoCOVID                           | Italy       | 4/8/2020     |                             | 0                  | 1                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | E                |
| InNote Assistant                    | USA         | 4/14/2020    |                             | 0                  | 0                     | 1                 | 0                    | 0                        | 0                    | 0                       | 0                     | Tele            |
| SUS                                 | Brazil      | 5/28/2020    |                             | 0                  | 1                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | E                |
| JamCOVID19                          | Jamaica     | 4/23/2020    |                             | 1                  | 0                     | 0                 | 0                    | 1                        | 0                    | 0                       | 0                     | Sym             |
| Karantinas                          | Lithuania   | 4/6/2020     |                             | 1                  | 1                     | 0                 | 1                    | 0                        | 0                    | 0                       | 0                     | Sym             |
| Kencor COVID-19                     | USA         | 4/13/2020    |                             | 0                  | 0                     | 0                 | 0                    | 1                        | 0                    | 0                       | 0                     | Sym             |
| KovidPower                          | USA         | 5/8/2020     |                             | 0                  | 0                     | 0                 | 0                    | 1                        | 0                    | 0                       | 0                     | Sym             |
| LaPazCovid19                        | Bolivia     | 6/24/2020    |                             | 1                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | Sym             |
| Laxante Seychelles                  | Seychelles  | 5/15/2020    |                             | 1                  | 0                     | 0                 | 0                    | 0                        | 0                    | 0                       | 0                     | Stat            |
| LazioDiCovid                        | Italy       | 3/19/2020    |                             | 0                  | 0                     | 0                 | 0                    | 1                        | 1                    | 0                       | 0                     | Tele            |
| MapVi                               | Colombia    | 5/9/2020     |                             | 1                  | 0                     | 0                 | 0                    | 0                        | 1                    | 0                       | 0                     | Stat            |
| Mobile Angel Cancer Telemed         | USA         | 3/24/2020    |                             | 1                  | 0                     | 1                 | 0                    | 1                        | 1                    | 0                       | 0                     | Sym             |
| Monitor by Tracelinks               | USA         | 6/16/2020    |                             | 0                  | 0                     | 0                 | 1                    | 1                        | 0                    | 0                       | 0                     | SE              |
| Monitora Covid-19                   | Brazil      | 5/8/2020     |                             | 0                  | 0                     | 1                 | 0                    | 1                        | 1                    | 0                       | 0                     | Sym             |
| MorChana - Doctor Won               | Thailand    | 5/17/2020    |                             | 0                  | 0                     | 0                 | 0                    | 1                        | 0                    | 0                       | 0                     | Sym             |
| Title                                    | Country      | Release Date   | Categories                                                                 |
|------------------------------------------|--------------|----------------|---------------------------------------------------------------------------|
| MUSC COVID-19 Vital Link                 | USA          | 4/8/2020       | Statistics (Stat) e-Health Literacy (E) Telehealth (Tel) Self-evaluation (SE) Self-evaluation (Sym) Symptom Monitoring (Sym) Geo-referencing (Geo) Resource Management (Res) Contact Tracing (Trac) Primary Objective |
| MyAus COVID-19                           | Australia    | 4/22/2020     | 1 1 0 1 0 0 0 0 E                                                       |
| MyCOVID Passport                         | USA          | 6/22/2020     | 0 0 0 1 0 0 0 0 SE                                                      |
| MySejabterra                             | Malaysia     | 4/2/2020      | 0 0 0 1 0 0 0 0 SE                                                      |
| MyTrace                                  | Malaysia     | 5/26/2020     | 0 0 0 0 0 0 0 1 Trac                                                   |
| NCOVI                                    | Vietnam      | 3/11/2020     | 1 1 0 0 1 0 0 0 Sym                                                    |
| NHI24-Covid-19                           | United Kingdom | 4/13/2020 | 0 1 0 1 0 0 0 0 E                                                      |
| NIOSH PPE Tracker                        | USA          | 4/29/2020     | 0 0 0 0 0 0 0 1 Res                                                    |
| NJ COVID 19                               | USA          | 3/31/2020     | 1 0 0 0 0 0 0 0 Stat                                                   |
| NU Know COVID-19                          | Thailand     | 6/1/2020      | 1 1 0 0 0 0 0 0 Stat                                                   |
| Nuhealth Video Consultations             | Ireland      | 3/16/2020     | 0 0 1 0 0 0 0 0 Tele                                                  |
| NZ COVID Tracer                           | New Zealand  | 5/19/2020     | 0 0 0 0 0 0 0 1 Trac                                                  |
| Obvio-19                                 | USA          | 4/22/2020     | 0 0 0 0 0 1 0 0 Sym                                                   |
| Odisha COVID Dashboard                   | India        | 4/27/2020     | 1 0 0 0 0 0 0 0 Stat                                                   |
| Operativo Escudo Hidalgo                 | Mexico       | 6/1/2020      | 1 0 1 0 1 0 0 0 Tele                                                 |
| OSAKIDETZA-PRO                           | Spain        | 5/14/2020     | 0 1 0 0 0 0 0 0 E                                                     |
| Osler COVID Learning Centre              | USA          | 3/24/2020     | 0 1 0 0 0 0 0 0 E                                                     |
| PathCheck SafePlaces                     | Puerto Rico  | 5/2/2020      | 0 0 0 0 0 0 0 1 Trac                                                  |
| patientMpower for Covid 19 USA           | Ireland      | 4/27/2020     | 0 0 0 0 1 1 0 0 Sym                                                   |
| patientMpower for COVID-19               | Ireland      | 3/14/2020     | 0 0 0 0 1 0 0 0 Sym                                                   |
| PatientSphere for COVID19                | USA          | 3/19/2020     | 0 0 0 1 0 0 0 0 SE                                                   |
| Peduli Lindungi                          | Indonesia    | 4/13/2020     | 0 0 0 0 0 0 0 1 Trac                                                |
| Plan Jalisco Covid-19                    | Mexico       | 3/25/2020     | 0 1 0 0 0 0 1 0 0 Geo                                               |
| Prefeitura de Castanhal                  | Brazil       | 4/23/2020     | 1 0 0 0 0 0 0 0 Stat                                               |
| Preworkscreen                            | USA          | 6/16/2020     | 0 1 0 1 0 0 0 0 Sym                                                |
| ProjectCovid - Verified Info             | USA          | 7/1/2020      | 1 1 0 0 0 0 0 0 Sym                                                |
| ProteGO Safe                             | Poland       | 4/30/2020     | 1 1 0 1 0 0 0 1 Trac                                                 |
| Public Access Control System             | UAE          | 3/30/2020     | 0 0 0 0 0 0 0 1 Trac                                               |
| Public services STOP Coronavirus         | Russia       | 4/1/2020      | 0 0 0 0 1 0 0 0 Sym                                                 |
| RajCovidInfo                             | India        | 4/24/2020     | 1 0 0 0 0 0 1 0 0 Stat                                             |
| Rakning C-19                             | Iceland      | 4/2/2020      | 0 0 0 0 0 1 0 0 1 Geo                                              |
| SafeDistance: COVID-19 Map               | USA          | 4/15/2020     | 0 1 0 0 1 1 0 0 Sym                                                |
| Self-quarantine officials                | South Korea  | 3/13/2020     | 0 0 0 1 0 0 0 0 SE                                                 |
| Self-quarantine safety protection        | South Korea  | 3/13/2020     | 0 1 0 0 1 0 0 0 Sym                                                |
| Sentinel Monitor                         | USA          | 3/8/2020      | 0 0 0 1 0 0 0 0 SE                                                 |
| Shuurkhai 119                            | Mongolia     | 4/28/2020     | 0 1 0 1 0 0 0 0 E                                                  |

(continued on next page)
We classify this as a confidence-building app.

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