

A review of mobile applications developed by academics for COVID-19

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Abstract

Mobile applications have the characteristics of being available, acceptable, and easy to use. They offer a unique opportunity for remote communication in which to promote a social distancing strategy that has been taken to mitigate the rapid spread of COVID-19. Therefore, health organizations, governments, and academics have built mobile applications to potentially combat the pandemic. However, academics have made special efforts in the fight against the novel disease. The aim of this review is to explore the mobile applications being developed by academics to help manage the COVID-19 pandemic. To achieve this aim, firstly, the related applications were selected through conducting a search in the top indexed journals. Secondly, the goal of each app was identified. Thirdly, the technology used to achieve the app's goal was extracted. The review results revealed four goals for applications related to COVID-19, and eight technologies were utilised to achieve these goals. The significant finding of this review is that academics mostly depend on manual rather than automated data collection methods due to the users' concerns about protecting their privacy. However, they still face the challenge of unskilled users of smart phones especially older adults.

Keywords

COVID-19, Coronavirus, Mobile applications, Mobile apps, Mhealth, Academics.

1.Introduction

COVID-19 is a novel disease that first appeared in Wuhan, China in December 2019. Since then, it has rapidly spread around the world leading the WHO to declare a "pandemic" on 11 March 2020 [1]. To control its spread, several appropriate and urgent strategies have been suggested and adopted such as quarantine for a person who is suspected of being infected and adherence to hygienic practices (frequent hand washing, wearing a face mask) [2]. Moreover, countries have taken actions like imposing travel restrictions, banning public gatherings to limit the number of individuals in the same place [2], and even a complete lockdown [3]. Beside these plans, information and communication technology-based strategies have been adopted to raise awareness of ways to deal with the COVID-19 pandemic. These include mobile phone-based applications, web-based applications, online dashboards, and the development of electronic gadgets [4].

Mobile applications are available, acceptable, and easy to use, and they offer a unique opportunity for remote communication, which promotes social distancing efforts [5]. These characteristics have encouraged health organizations and governments to develop various mobile applications in response to the need to tackle the novel virus. The first national application for COVID-19 was launched on Friday 20 March 2020 [6]. The app, named "TraceTogether", was developed by the Singapore government [7]. It is a Bluetooth-based contact tracing app used to quickly identify the users who have been in close contact with an infected person [7]. Since then, various other types of apps have been developed, with each utilising a different technology and different methods of data collection.

This review paper aims to provide a thorough overview of mobile applications being developed for COVID-19. While previous studies reviewed mobile applications related to COVID-19 [4, 8] all the reviewed applications were developed by either health organizations or governments and uploaded onto the main mobile application stores (Google Play, App Store). To date, no study has assessed the apps related

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to the COVID-19 pandemic, which were developed by academics and published in scientific journals.

In order to fill the above mentioned lack of research, this study conducts a review of the mobile apps that have been developed by academics for COVID-19 and published in the top indexed scientific journals. It covers five top indexed journals and a period of 12 months (1/1/2020-30/12/2020). The review objectives were to (i) identify the top indexed journals in the field of engineering and computer science and the sub-field of medical informatics, (ii) search in the selected journals to find mobile applications being developed for COVID-19, (iii) investigate the apps in terms of the goals for which they were being developed, and (iv) explore the technology that was used to achieve each application goal.

2. Methodology

The study was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [9] and covers one year of the pandemic. It reviews, mobile applications related to the COVID-19 pandemic, specifically, the apps developed by academics and published in scientific journals from January to December. The review was carried out via the following steps, which are discussed in the sections below.

2.1 Review search strategy and selection

The source of this review was Google Scholar's top publication journals. We selected the top five listed journals in the category of "engineering & computer science" then the sub-category "medical informatics". The highest h-index and the chosen journals were as follows: the top listed journal is "Journal of Medical Internet Research" with an h-index of 96, the second listed journal is "Journal of the American Medical Informatics Association" with an h-index of 67, the third listed journal is "Journal of Biomedical Informatics" with an h-index of 60, the fourth listed journal is "Journal of Medical Internet Research - Mobile Health and Ubiquitous Health" with an h-index of 60, and the fifth listed journal is "Journal of Medical Systems" with an h-index of 58. Then, each journal was searched to identify the relevant articles using the following keywords: "COVID-19", "coronavirus", "pandemic", "mobile application", "mobile app", "mhealth", "smartphone", and "mobile phone". The number of identified articles was N=209. However, after adding exclusion criteria, such as "review articles", "article that uses an existing app not developing new one", and "article has an app that was not relevant such as entertainment app, doing activities app", the number of identified articles dropped to N=17. Additionally, one journal, namely, "Journal of Biomedical Informatics", was discarded since the articles published over the period for the review did not fulfil the review inclusion criteria. Thus, the review covers four journals, which are shown in *Table 1*.

Table 1 Selected journals with a number of identified articles regarding review criteria

No	Journal	Publisher	h-index in Google Scholar	Number of published articles related to "COVID-19" 1/1/2020- 30/12/2020	Number of relevant identified articles after applying exclusion criteria
1	Journal of Medical Internet Research	Journal of medical Internet Research	96	105	6
2	Journal of the American Medical Informatics Association	Oxford University Press	67	26	1
3	Journal of Biomedical Informatics	Elsevier	60	8	0
4	Journal of Medical Internet Research - Mobile Health and Ubiquitous Health	Journal of medical Internet Research	60	44	8
5	Journal of Medical Systems	Springer New York	58	26	2
Total				209	17

2.2 Data analysis

The identified articles N=17 were analysed to achieve the review aims. Firstly, the authors determined the goal of the app that was developed in each study. To extract the app purpose, we went through the article abstract, specifically the part on objectives, and kept notes of the stated goals. In some cases, when the objective was not mentioned in the abstract, we went

through the methodology section. To determine the technology used in each article, the authors usually read through the method section. Related technologies were grouped and clustered into categories of phone sensors, phone internal services, and phone camera. *Figure 1* shows the methodology steps.

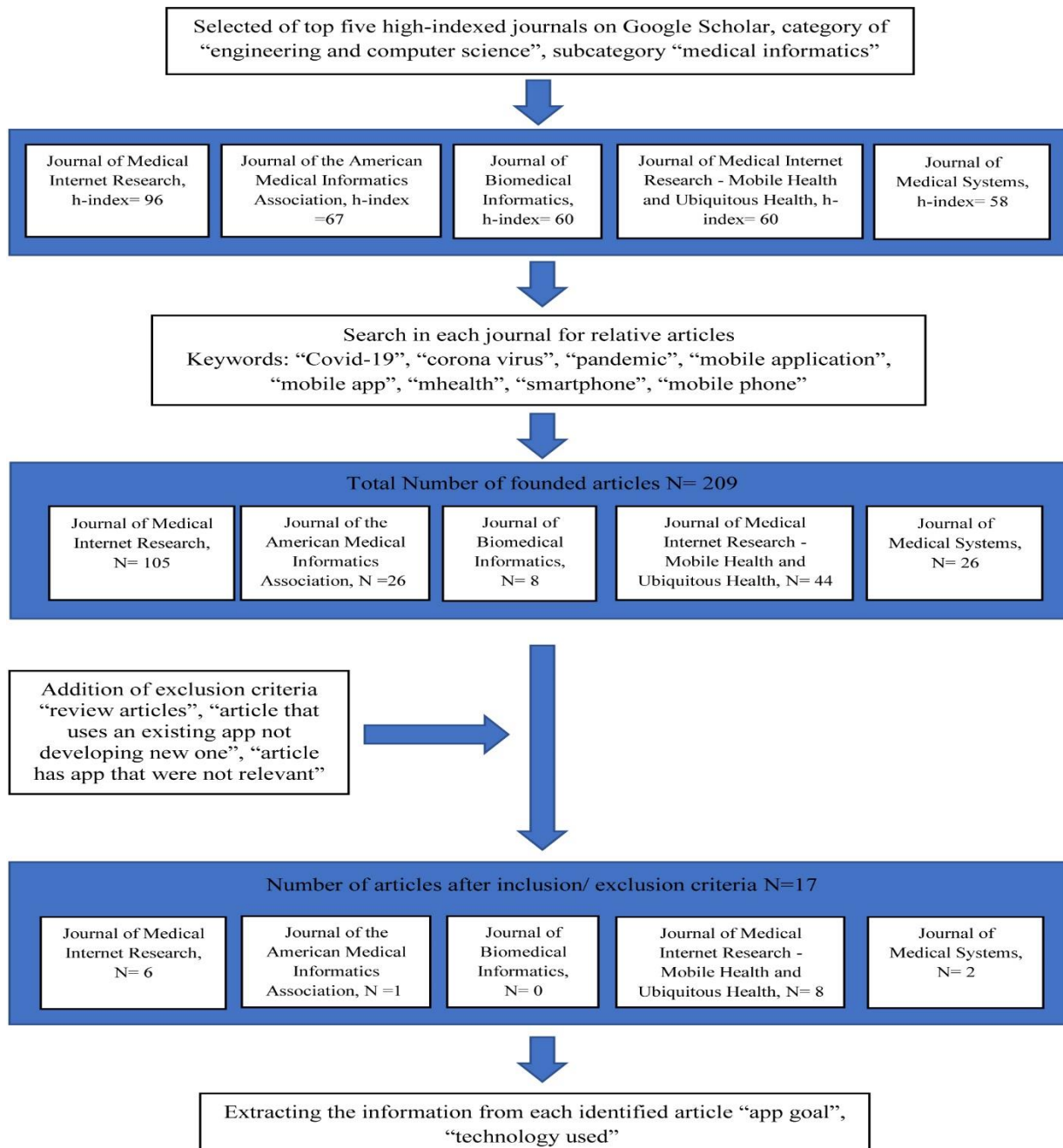


Figure 1 Flow chart of the methodology steps

2.3 Mapping of reviewed articles

The mapping step involved constructing two tables. *Table 2* illustrates the four indicated goals of the applications that were built by academics regarding the COVID-19 pandemic. This table meets the first research objective of identifying the goal of each

developed application in the reviewed paper. To achieve the second review objective, *Table 3* was constructed. It demonstrates the technologies used in each article according to each application goal.

Table 2 Reviewed articles according to each app's goal

No	App goal	Articles
1	Symptom monitoring and management	[10–17]
2	Symptom assessment	[11, 13, 14, 18–20]
3	Contact tracing	[21–25]
4	Information provider	[26]

Table 3 Technology used to achieve the goal of each app

No	Technology used to achieve the app goal	Symptom monitoring and management	Symptom assessment	Contact tracing	Information provider
1	phone sensors	GPS		[21, 25]	
		Bluetooth		[23]	
		Pulse oximetry		[18]	
2	Phone internal services	SMS	[13]	[13]	[22]
		E-mail	[10]		[26]
		Questionnaire analysis	[11, 12, 14, 17]	[11, 14, 19, 20]	
3	Phone camera	QR code		[24]	
		Face screening	[15]		

3. Results

This section describes the results of reviewing the selected mobile applications.

3.1 Application goal

Regarding the application goal in each of the reviewed articles, the majority of the reviewed applications (8 out of 17) were built to monitor and manage the symptoms of patients with COVID-19. This number represents 40% of the total number of the reviewed applications. The number of applications that were developed to assess the disease symptoms and detect the infected cases was six applications, that is, 30% of the identified applications. Five applications were built for tracing people who had been in close proximity to an infected person. The review succeeded in determining only one application (1 out of 17) that was developed to provide its users with the necessary information about the novel disease, which accounted for 5% of the total number of identified applications. From *Table 2*, it can be seen that some articles appear in more than one app's goal, as some applications were built to serve more than one purpose [11, 13, 14]; these three applications were built to monitor and manage COVID-19 symptoms and to assess its symptoms. In this review, the applications that do more than one task

are repeatedly counted in all the goals that the apps have achieved. *Figure 2* shows the number of applications regarding each goal.

3.2 The technologies used

Various technologies were used by the developers of COVID-19 applications to meet the requirements of these applications. A total of eight different technologies was identified in the reviewed articles. The indicated technologies were clustered into three main ones and assigned according to each application goal. The three main technologies used are as follows:

Phone sensors

To achieve the application's purpose, some developers used phone sensors like GPS, Bluetooth, or pulse oximetry. GPS sensor has been the most frequently used sensor, as it was employed by two articles to meet the requirements of contact tracing applications [21, 25]. However, to achieve the same goal, other articles utilized different sensors. For example, [23] implemented a contact tracing application based on Bluetooth to control the spread of COVID-19, while [18] depended on a pulse oximetry sensor for the early

detection and diagnosis of COVID-19 through assessing its symptoms.

Phone internal services

These include SMS, e-mail, and questionnaire analysis. While questionnaire analysis has been the most frequently used services, SMS was the service utilized to achieve each of the four identified goals. The review explored six applications that used questionnaire analysis for two purposes: symptom assessment [11, 14, 19, 20] and symptom monitoring and management [11, 12, 14, 17]. However, we identified three applications that used SMS services to achieve symptom monitoring and management [13], symptom assessment [13], and contact tracing [22]. Providing users with necessary information about COVID-19 was done by sending SMS as well [26]. E-mail service was used in only one application to manage and monitor the disease symptoms [10].

It is worth mentioning that some applications used the same service to achieve more than one goal [11, 13, 14]. All of these applications achieved both symptom assessments, and symptom monitoring and management. Initially, the apps help educate citizens about COVID-19, allow them to do self-assessment of

their own health, and assist GPs to follow up with patients during the COVID-19 outbreak [11, 13].

Phone camera

The QR code was one of the technologies utilized to develop applications for COVID-19. This technology was used in two articles, specifically, once for symptom assessment, where users have to scan the QR code to receive consultation services like remote diagnosis and treatment via an online outpatient clinic [16]. The QR code was used for a different purpose, namely, contact tracing in [24]. Here, users could host or join a checkpoint by scanning the QR code, check the risk level based on their past interactions, then report a positive status to their peer network.

Academics used the phone camera as a tool to do face screening and virtual video visits for patients with COVID-19 [15]. The app was a part of a telemedicine system that supports clinical needs to monitor and manage the symptoms of COVID-19 patients. *Figure 3* Show Distribution of reviewing applications regarding the technologies used to achieve each app's goal.

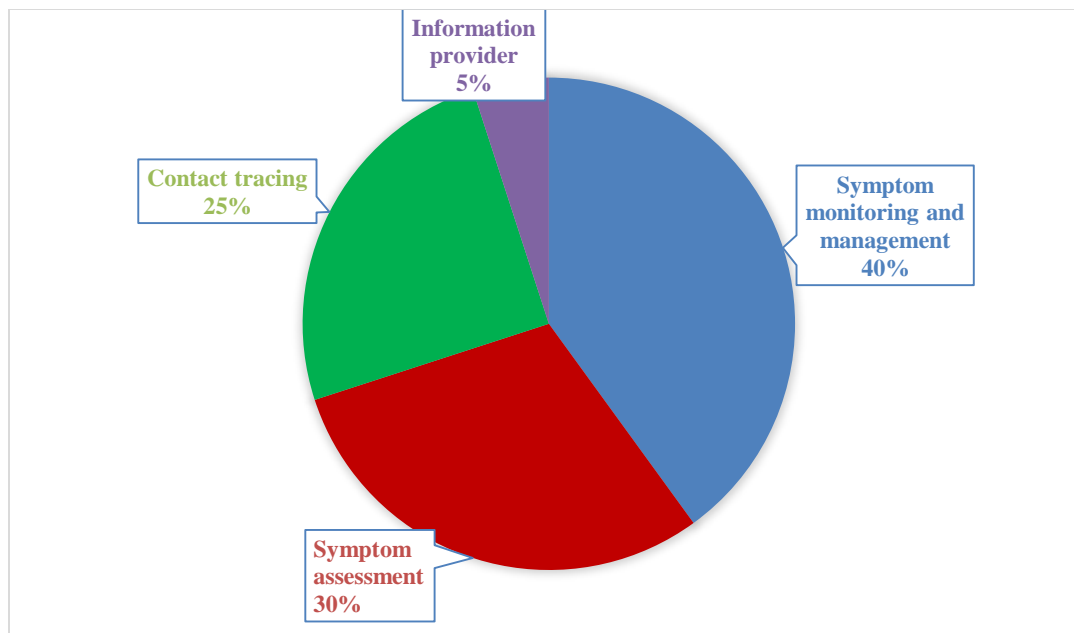


Figure 2 The number of the reviewed applications regarding each goal

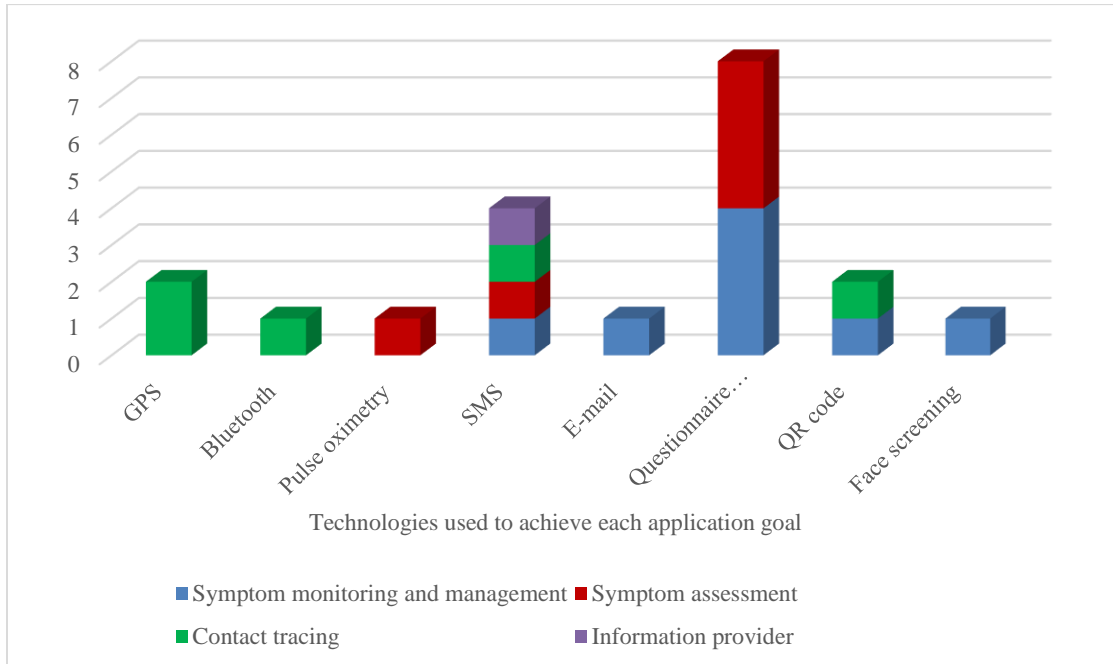


Figure 3 Distribution of reviewing applications regarding the technologies used to achieve each app's goal

4. Discussion

To the best of the authors' knowledge, this study is one of the first to perform a comprehensive review of mobile applications being developed by academics for use during the COVID-19 pandemic. Several previous studies attempted to assess the mobile applications being used during the pandemic [4, 8, 27] however, all of these studies reviewed mobile applications that were uploaded onto mobile app stores (Apple Store, and Google Play). Despite the majority of applications having been developed by health organizations and governments [28], academics have made extraordinary efforts to participate in the digital war against the new virus. Therefore, this research covers the digital responses to the COVID-19 pandemic by reviewing mobile applications that were developed by academics and published in top indexed journals.

From the reviewed articles, four types of applications were identified: symptom monitoring and management, symptom assessment, contact tracing, and information provider. Moreover, eight technologies were utilised to meet the requirements of each app: GPS, Bluetooth, pulse oximetry, SMS, e-mail, questionnaire analysis, QR code, and face screening.

Not surprisingly, academics utilized location-based GPS and Bluetooth signals to build contact tracing applications [21, 23, 25]. GPS characteristics make it

appropriate for identifying people who have been in the same location, and Bluetooth signaling between devices helps users to know whether they are in near proximity to a case without providing location information [29]. Furthermore, such technologies (GPS, Bluetooth) provide an opportunity to improve the ability of COVID-19 contact tracing applications in a similar way. For example, the performance of contact tracing software in the Democratic Republic of the Congo during the Ebola epidemic improved dramatically in 2019 with the implementation of the Go.Data contact tracing software [29].

However, using a location-based tracing method for health surveillance may present several issues. For example, the authors in [21] could not protect individuals' privacy, which might present a barrier to its acceptance and deter many from using the app [30], and Bluetooth can reach across only a few meters [23]. Therefore, two applications [22, 24] and used different technologies (SMS and QR code) to achieve the goal of contact tracing. These apps are based on manual inputs of data where the users have to send contact information or scan a QR code. Since no recording, analysis, or data processing occurs on the central server, this could potentially reduce personal privacy issues [22, 24].

The method of manual entry information was also adopted in symptom assessment applications and

symptom monitoring and management applications. The developed apps were based on the manual input of symptoms either by sending SMS [13], answering a questionnaire [11, 12, 14, 17, 19, 20], sending an e-mail [10], or scanning a QR code [16]. However, depending on user information entry has limitations: users might not be familiar with information and communications technology [10] and the use of a smartphone device requires intensive education and knowledge on the part of the users, especially older adults [19]. These concerns persuaded academics to adopt another method of data entry. Smartphone-based pulse oximetry was used for the early detection of infection by COVID-19 [18] and face screening was utilized to identify the disease progression in patients [15].

Additionally, our review identified one application that had been developed to educate the public about the virus [26]. The app was developed to promote healthy behaviors like washing hands, using elbow bumps, and avoiding crowds in order to prevent the spread of COVID-19. The goal was achieved by sending a text message that has a link. When the users click the link, they view eight frames that show how to stay safe and what they can do to avoid being infected with the disease.

5. Conclusion

At the time of the COVID-19 outbreak, health organizations and governments have developed numerous mobile applications for managing the pandemic. In addition, academics have participated in the digital war against this new disease.

The present review was conducted to identify the mobile apps developed by academics to be potentially useful for managing the COVID-19 pandemic. The review indicated four types of applications: symptom monitoring and management, symptom assessment, contact tracing, and information provider. The results showed that academics were mostly interested in developing apps for symptom monitoring and management purposes whereas information provider was the least developed type. Moreover, the review indicated that eight technologies had been utilized to achieve the goal of each app: GPS, Bluetooth, pulse oximetry, SMS, e-mail, questionnaire analysis, QR code, and face screening. Some of these technologies were used to collect the information automatically. This approach has raised some issues, especially those related to user privacy. To overcome this problem, some applications depend on the manual entry of information. However, this method revealed that

users, and especially older adults, would face a major challenge when using smart devices.

Acknowledgment

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Conflicts of interest

The authors have no conflicts of interest to declare.

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