CHAPTER

12

Mobile health (mHealth)

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Introduction

One of the most exciting technological developments over the last few years has been mobile health, also known as mHealth. Various definitions of mHealth exist. According to the United States' National Institutes of Health "mHealth is the use of mobile and wireless devices to improve health outcomes, healthcare services, and health research."[433] The World Health Organization defines mHealth very broadly as "The use of mobile and wireless technologies to support the achievement of health objectives."[434] mHealth has been enabled by a vast amount of progress over the last 10 years in miniaturizing phones and physiological sensors and combining communication devices and computers into highly reliable and very portable devices.

Today, mHealth is enabled by three kinds of mobile phones, so-called basic phones, feature phones, and smartphones, and a host of miniaturized devices that collect health-related data including activity measurement. Basic phones support only text messaging besides making calls. Feature phones add multimedia display capabilities in a small form factor. For example, the Motorola RAZR, one of the most popular feature phones, had a small color display about 15.2 cm squared in area. These phones, often based on the SYMBIAN operating system, had some limited programming capabilities.

On the other hand, smartphones are very powerful computers with high-resolution color displays and excellent graphics that also function as communication devices for voice, access to the Internet, and two-way transfer of video and image communications. There are additional add-ons, like connectivity through Wi-Fi, infrared and bluetooth, and special sensors that can be and are being used for health apps. These include cameras with a very high degree of clarity—25+ megapixels (on high-end phones) for still image and video capture, touchscreen, gyroscope (orientation sensor), accelerometer (or motion sensor), and location awareness (GPS).

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In developed countries, basic phones and feature phones have largely been replaced by smartphones like the Apple iPhone, Samsung Galaxy, Google Nexus, and similar. Smartphones tend to be expensive, and so in developing countries, basic phones and feature phones still predominate. However, even here, smartphones mostly based on the Android operating system are rapidly increasing in ownership and usage. Although feature phones have limited computing capabilities, they can still be used to obtain and transmit health-related data. For example, text messages can be transmitted using short message service (SMS).

mHealth can be viewed as a form of telemedicine/telehealth since the phone can be used to transmit and receive health-related data over distances. The SMS feature of mobile phones enables patients and health workers located remotely to rapidly send text messages and images containing health data to remote medical facilities and specialists who can then respond with expert advice using the same means. Mobile phones enable this communication to occur from the location of the person needing medical advice, which could be anywhere, like their home or an injury scene, rather than having to transport the patient to a clinic. This "anywhere" capability is provided by basic mobile phones, feature phones, and, of course, smartphones. Advanced software on smartphones, such as WhatsApp, offer secure, fast, and easy two-way transmittal of images, text, and video. Secure communications provided by WhatsApp are particularly desirable in the medical context since it supports provider-patient confidentiality. It should be noted that in such an exchange, the medical knowledge/expertise is provided from a remote location.

However, since smartphones are essentially very powerful computers capable of storing large amounts (16–128 Gb or more) of data, a vast amount of medical knowledge can be stored in the phone itself in the form of apps and databases. This is a powerful capability enabling medical knowledge, advice, and expertise to be available not only anywhere but also anytime. This should be contrasted with some common kinds of telemedicine in which the person needing medical care is interacting directly with the medical expert by phone or by video conference. In such a scenario the telemedicine hardware and software enable geographical distances to shrink, while patient and medical specialist are in synchronous two-way communication, and the expertise is transmitted synchronously. Of course, this means that a busy medical specialist has to find the time to participate in the remote encounter with the patient or their local caregiver and could be delayed or unable to participate at the scheduled time due to unexpected events. In other words, scheduling time from a busy remote specialist or medical expert could be challenging. The local caregiver could be a physician, health worker, or a family member. On the other hand, making medical expertise available inside the smartphone itself enables *asynchronous* medical care scenarios. For example, if a frontline health worker needs to assess a patient's mental health state, instead of calling for help, describing the symptoms, and then getting advice, the health worker could bring up an app that executes the Suicidal Behaviors Questionnaire-Revised (SBQ-R)[435] consisting of four multiple choice questions. The health worker could obtain responses to the questionnaire from the patient on the spot and almost instantly get advice that helps in decision-making. Specifically, the app-score may indicate that the individual is at high risk and needs transportation to the nearest mental health clinic. Or the app could indicate low risk, and the patient's mental state could be alleviated by soothing his/her feelings with the assistance of family and friends. Certain benefits of mHealth can be identified in this scenario. One is that the care is immediate and possible anytime/anywhere. Second is that, since the SBQ-R is a validated scale, it has high probability of making correct assessments of suicidal tendency. This means that the decision-making of the health worker can be more appropriate than relying on unaided assessment. In turn, this means that the person, really in need to see a mental health specialist and requiring treatment as an in-patient, can be identified with high accuracy, while those who do not need to be so treated get to avoid unnecessary transportation and medical care costs. This also decreases the burden on the local healthcare system.

Of course, just as any other technology, mHealth on smartphones also needs to be used carefully and judiciously. A quick search on any medical topic in the app store will likely produce hundreds if not thousands of matching apps. Many of these may be from dubious sources that have not been validated scientifically. Only those apps that have been validated and approved for use by local medical authorities should be used.[436]

Apart from medical assessments such as the scenario described earlier, the powerful multimedia and programming capabilities of smartphones enable the creation of apps that describe how to do medical/surgical procedures. For example, in the military context, health workers called medics many a times need to handle trauma situations in remote and combat locations in the absence of physicians and surgeons, including performing invasive procedures like blood transfusions and crico-thyroidotomies. Apps containing step-by-step instructions that integrate voice, images, and video can assist the medic in performing these procedures. Although such medics typically receive two or more years of intensive training, they are expected to be knowledgeable in very many medical conditions and to perform more than a 100+ medical and surgical procedures. For example, the US Special Operations Forces Medical Handbook contains 150 medical topics, including behavioral and veterinary health. Clearly a medic cannot be expected to know the details of all of these topics and this knowledge, presented in easy to access, searchable, step-by-step media-rich formats on a smart phone, rather than on bulky paper materials, could be very useful.[437]

mHealth on smartphones, in general, supports task shifting from physician, specialists, and surgeons, to other kinds of providers like medics, as we have seen earlier, or community health workers.[438–440] Often the latter kind of providers are mobile professionals, going from village to village in rural areas or situated in rural clinics that have limited facilities and expertise. It typically takes 7–8 years of education and training to become a physician and several more years to become a specialist. On the other hand, in many parts of the world, primary healthcare is provided by health workers who do not receive such lengthy and expensive training. Using mHealth tools on smartphones, such health workers can function as "physician extenders" who handle routine cases anytime/anywhere, enabling physicians and specialists to handle the difficult medical cases.

Apart from phones the last 5 years have seen an explosion of highly miniaturized sensors, wearable and otherwise that continuously measure and monitor health and health-related data such as heart rate and pulse rate, activities such as the number of steps walked and hours and times slept. Note that such data can also be obtained by apps on smartphones and smartwatches. In addition, other physiological sensors such as glucometers and blood pressure gauges have become communications enabled using the Bluetooth[441] system. External devices—like a telescopic zoom or microscope attachment—can also be connected directly or wirelessly.

This means that the data can be transmitted instantly to a smartphone or a computer and automatically integrated into a database that provides a longitudinal record to enable health analytics. Rapid changes in physiological parameters can be tracked, and alerts issued to caregivers that the patient may need rapid medical intervention.

Benefits of mHealth

The key benefit of mHealth is within the name itself—mobility. An extreme example was initiated recently by www.tardigrade.in—a virtual doctor who only does house visits, not for emergencies but for routine care. A health assistant travels to the patient's house, notes the patients' complaint, takes pictures as required and sends to the doctor and further enables a video conference with him, and then provides, as well as explains, the medications back to the patient based on the prescription created by the doctor.

Many available accessories and sometimes tools within the mobile itself allow blood tests and a few investigations. There is convenience, easy reach, and with connectivity—through coming up of 3G and 4G—and seamless access to Wi-Fi wherever available, which means that one can get health support anywhere anytime. The cost of healthcare has come down, because phones are also inexpensive, easy to use, and available ubiquitously

Drawbacks and issues

The small screen makes typing difficult, and autocorrect sometime makes it worse. There is near total dependence on connectivity for any type of data access, leading to the lack of reliability. Cell phone towers, after all, incur a certain cost and hence will be provisioned for only where there would be adequate number of people. Signals cannot reach walled-off areas and basements. Mobiles do get lost and misplaced. More important than the monetary or personal data loss is the privacy breach that may ensue if somehow the data can be pried open. Whatever privileges the mobile owner had, can become the privilege of the finder! Remembering that a doctor, an insurance provider, or even a hospital medical record person has secure access to data of thousands of patients, this can and has been misused. Health data security breach has ramifications next to the seriousness of stolen credit card information!

Hot areas of research

There are as of now over 325,000 health apps[6] out of the overall 3 million worldwide, though only a few are being used.

Health bots and AI can replace or, at least to some extent, compensate for the lack of physicians. While some of these issues are discussed in Chapters 6 and 14, there is much scope on how a physician can make the mobile a complete single tool to diagnose and treat patients—it has access to the EMR and can work as a stethoscope; the flashlight provides light; the camera records and also provides a magnified view of hard-to-reach areas; a flexible endoscope can be further attached, for example, such a view of the vocal cords helps intubation so that even a lay person can do it. The possibilities are immense, including complete telehealth solutions like the example for teleradiology in Fig. 1.

mHealth in supporting health workers

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Health workers could be those serving in the community such as community health workers (CHW) to more specialized roles such as nursing staff in noncommunicable disease (NCD) clinics.

As mentioned earlier, CHWs work in field areas such as patient's residences in villages or in camps held in these villages. These could be rather remote or rural areas, where there may not be mobile or Internet connectivity. Lately, devices such as tablets and smartphones have been introduced to these workers rather effectively, with applications that facilitate their work in the field. It has been found that these CHW and

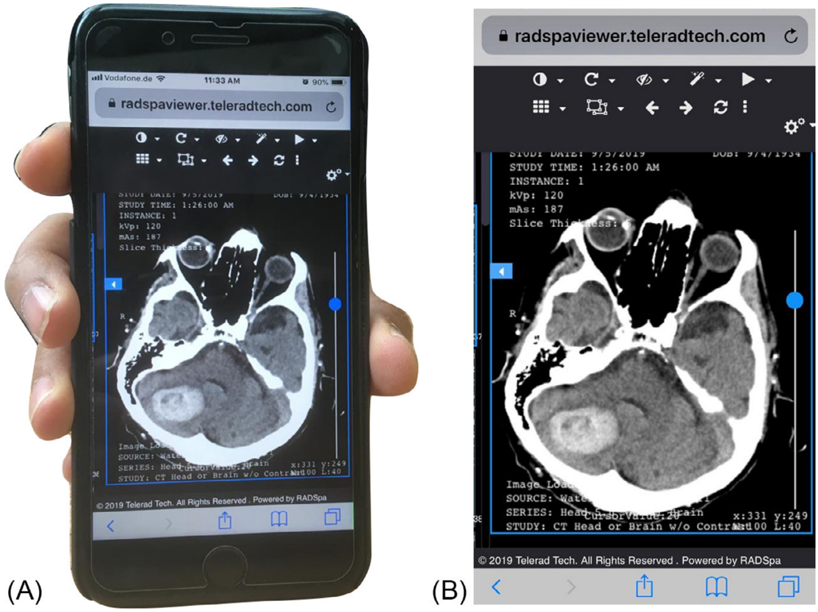

FIG. 1 (A) Axial noncontrast head CT image demonstrating an acute right cerebellar hematoma. Image is displayed on the RadSPA teleradiology workflow Zero-footprint viewer (TeleradTech, Bangalore) on a handheld mobile device (iPhone 7 Plus). (B) Mobile device screen capture of the same image (A). *Courtesy: Dr Arjun Kalyanpur, Teleradiology Solutions, Bangalore.*

other health workers are comfortable with android-based applications and thumb typing, as most of them have been introduced to technology via their own personal mobile or smartphones. So, they can be trained to work with applications that are tablet or smartphone based, as far as the application is intuitive, rather simple and user friendly. CHW can use such devices to carry out screening such as keep a track of BP, blood sugar, antenatal care, and vaccination records as well as other screenings for NCDs (Fig. 2).

Apps exist to enable the CHW to upload data to remote databases in real time if connectivity is available, or to store on the phone and upload later when connected. The uploaded data can easily be time and location-stamped. Use of the latter allows counterchecking, and validity of the information besides facilitating advanced processing of information like warning for alarming rises in incidence of particular problem in a certain area. Some aspects to cover are as follows:

1. No connectivity means that any application designed for these health workers will have to be housed completely in the device, including the decision support algorithms. Also, all the patient

FIG. 2 Health care worker saves patient information and related notes in a smart tablet app. *Curtsey PHFI, India.*

records of the CHW case load will have to be in the device, or if they are being loaded at regular intervals, then a process where the CHW loads the patient records of those patients she/he will be interacting on a given day or week will have to be preloaded before she goes out into the field, so that they can retrieve the record of a given patient to look at history, trend of health parameters, etc. They should then be able to enter new data into the respective patient's record into the device and store it. Also, they should be able to register new patients and start new records for them. When they reach connectivity, the new data is uploaded to the main server or cloud—in real time or batch mode once the CHW reaches her base—a process labelled as *synchronization*.

2. Application design should be in accordance with the workflow and related processes. Example tasks are creating of history, taking images, and measuring vitals including BP, blood sugar, and components of the antenatal chart, that is, simple work items, which are within the purview of the health worker. While CHWs may have simple straightforward applications, health workers such as NCD nurses may have more complex and sophisticated applications that include decision support and more depth in the information collected.

It is very important that the design of the applications and the screens move in congruence to the flow and relevance of their activities, without them having to toggle between screens to complete their tasks. Hence, before deployment of the app it is crucial to obtain user input during the design phase and also to test the app for usability, functionality, and compatibility with workflow.
Addition of AI through chatbots can help by asking related questions, for example, one can use the PQRST (Provocation/Palliation, Quality, Region/Radiation, Severity, and Time) chart for pain evaluation.[442] An image analyzer can be useful for skin lesions—an app that could assist diagnosis of venereal diseases, which however, when used by the author, it ran into problems related to patient privacy even though planned to be provided to female health workers only.

3. There may be local language capability required especially for patient reminders, alerts, and health education matter that are handed over to patients as printouts or sent via SMS or WhatsApp messages. This could be challenging in a country like India where there are numerous languages. Enabling the devices to input in local languages could be a requirement too (Fig. 3).
4. In many countries like India, there are regulatory bodies like Telecom Regulatory Authority of India (TRAI) that require the messages being sent to patients be vetted and authorized by them.

Developing apps for mobile devices

Sriram Iyengar

Today the landscape of mobile devices is vast, ranging from feature phones to smartwatches to small size phones to tablets that can range in size from a paperback book to a writing pad. Developing apps for feature phones is not typically possible for a third-party developer since most of these phones are closed environments: The apps on the phone are factory installed, and it is not at all easy for you and me to provide new apps. In fact the ability for people other than the hardware and software manufacturers to freely and easily add apps is what distinguishes a feature phone, such as the Motorola RAZR, from a smartphone such as the Samsung Galaxy. Similar to writing software for computers, anyone with the talent, skills, and knowledge can write a smartphone app and publish it in the major app stores. Anyone who likes the app can download it on to their smart mobile devices, sometimes after paying a small fee. Therefore, in this section, we will focus on developing apps for smart devices such as smartwatches, smartphones, and smart tablets.

App development is a complex topic involving many activities such as design, story boarding, user-experience design, programming, and

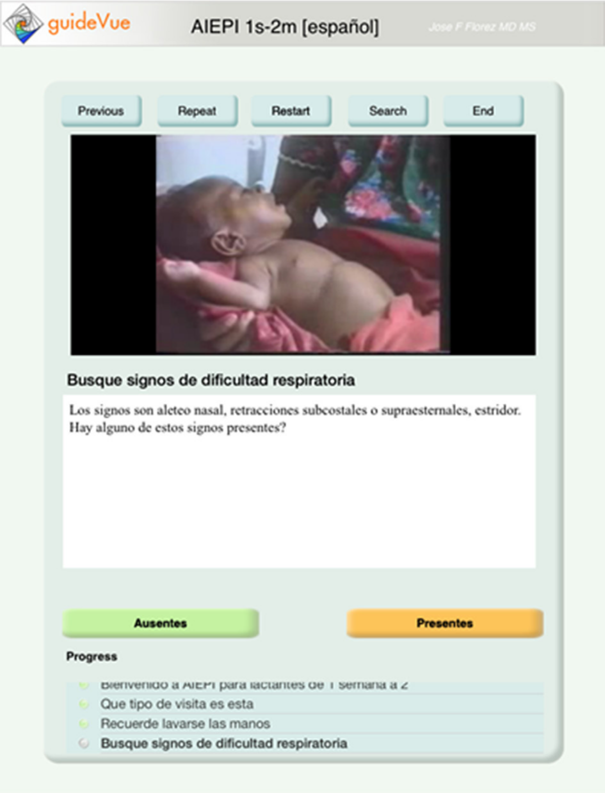

FIG. 3 Screen from a media-rich smartphone app to assist health workers in Spanish-speaking countries to use the World Health Organization's Integral Management of Childhood Illness guideline. Each screen also plays voiced instructions.

quality testing. A full description would take up several books of the same size as the current one and hence certainly beyond the scope of this chapter. Therefore we limit ourselves to providing only a high-level overview of this fascinating topic.

Smart mobile devices

Smart devices are essentially computers with additional capability of seamless two-way data and voice communication. Being computers, they need to have operating systems (OSs). Two operating systems, iOS, from Apple Inc., and Android, from Google, have the major market share among smart mobile devices with Windows Mobile at a distant third.[443] Android is most common in developing countries. iOS is used exclusively on hardware manufactured by Apple Inc. Google Inc. licenses Android OS to numerous manufacturers such as Samsung, LG, and Huawei. New versions of these OSs are released at regular intervals. It should be noted that since Apple owns both the hardware and the iOS software, you can expect your apps to perform exactly as designed on all hardware that runs the targeted iOS version(s). On the other hand, since Android can run on devices from multiple hardware manufacturers, there is a possibility that the app will function slightly differently, particularly with respect to the user interface, on different devices. Apps that function on multiple mobile operating systems are called cross platform apps. If an app is intended to execute on small to large format devices (phones to tablets), the developer must take care to acquire the screen size from the OS and then scale the user interface elements such as buttons, graphics, images, and text proportionately. This task cannot be considered trivial, especially since smartphones and tablets are designed to switch from landscape (long side horizontal) to portrait (long side vertical) mode and the app developer must make sure not only does the app continue to look good in all sizes and orientations, but there is seamless visibility of the buttons and easy help and use features.

Native apps versus HTML5 apps

Apps that are developed using the programming language of the mobile device, or to be more precise, its operating system, are called *native apps.* Such apps, once downloaded and installed on a mobile device, can be written so that they can execute stand-alone, that is, without needing continuous connectivity to cellular or Wi-Fi networks. If the app functionality calls for it, such apps can, of course, send and receive data to/from remote service native apps that are developed using a programming environment provided by Apple for iOS and Google for Android. A *cross platform* app is one that executes identically, or at least very similarly, on two (or more) operating systems. To make full-feature native cross platform apps, developers typically need to write code separately in the different development environments and different programming languages. On the other hand, if the app is intended to function in an environment relying upon continuous Internet connectivity, it can be developed using a method that essentially is equivalent to running the app under a web browser as a *web app*. Apps developed using this method typically use the HTML5 specification. A major advantage of such HTML5 apps is that they are inherently cross platform except for minor variations mostly due to hardware differences. The need for continuous Internet connectivity to function as intended becomes however its major drawback too and a likely problem in developing countries, which may be lacking widespread high-bandwidth Internet infrastructure. Hence, native apps tend to be preferred in these areas. Further the developer may need to target only Android apps in these countries. The website[443] provides current OS market-share information for specific countries and regions and can guide the developer in making OS choices.

Developing native apps

The procedure is similar for both Android and iOS.

(1) Register with and acquire a developer license from the OS owner. There are typically costs associated. In the case of Apple, at the time of writing, this license costs about U$100/year, and there may be additional license fees for specialized capabilities such as Apple watch or data storage.

(2) Download and install the app development environment, called a software development kit (SDK) on your computer. The SDK provides a visual interactive development environment (IDE) where you can design the user interface by dragging and dropping screen elements. The iOS IDE is known as "Xcode." The SDK uses a programming language to develop your app. In the case of iOS (Apple), the programming language Objective-C or another called SWIFT is used, while in the case of Android, the JAVA programming language is used. For Android development you can use the SDK provided by Google, called Android Studio. Other SDKs such as Eclipse are also available at varying costs. While the iOS SDK can execute on both Windows and Macintosh (MacOS) computers, it is preferable to create iOS apps using the MacOS SDK since a MacOS computer is required for final distribution of your iOS app. Android app development can be done exclusively on Windows computers. In either case, you need to become proficient in programming one of these languages. It is advisable to take formal courses and, of course, to learn the capabilities of the SDK(s) you choose to use. Excellent tutorials and courses are available on the web.

(3) After developing the app on your Windows or MacOS computer, you can transfer it from the computer via cable or Wi-Fi connection to the target mobile hardware for testing. On the mobile device you will observe how well the app works, its shortcomings, bugs, and capabilities. Having noted these aspects, you will go back to the SDK and fix your program and the user interface elements iteratively until results are to your satisfaction. Note that in commercial environments, app development is a complex multidimensional process that involves the active daily participation of programmers (coders), user interface and user-experience experts, graphic designers and artists, operating system and networking experts, quality assurance specialists, and others. This iterative process can take up considerable time and resources but is absolutely necessary to ensure the app works as intended and provides a pleasant experience to the target user.

(4) Whether in small one-person outfits or very large ones, a stage will come when the app can be released to the public by placing it in the app store. For iOS, this is the iTunes store, and for Android, it is uploaded to Google Play Store. In both cases the app has to be approved for distribution and placement in the store by Apple or Google. This approval process can take several days. Your app may be rejected because it does not meet acceptable criteria for performance, functionality, or content. Once approved the app will be available at the app store. You can choose to make it free, charge for it, make it available to everyone, or restrict to a private group.

(5) Typically, native apps designed to execute on iOS and on Android must be written in SWIFT or JAVA, respectively, and considerable effort must be expended in making sure that identical, or very similar, user experience and functionality are provided. If not, users may get confused, and there may be incompatibilities between the functionality experienced by users of the same app across the iOS and Android implementations. This means that two teams of programmers must be employed to develop and maintain the same native app on the two different operating systems. One way out of this dilemma is to use a *cross platform* environment. A system called XAMARIN, owned by Microsoft, enables this kind of development. Here the native programming language is called C# (C-Sharp). The IDE used is typically Microsoft's Visual Studio augmented with software tools that enable the development of highly compatible native iOS and Android versions of the same app. Of course, programmers using this system must become very proficient in C#, Visual Studio, and the nature and capabilities of iOS and Android. Note that some systems enable the development of native apps without programming. For example, Mobiloud Canvas[444] is able to convert certain kinds of websites to function as native apps. It is unclear whether the full range of mobile device features can be accessed with such tools.

Developing HTML5 apps

HTML5 stands for Hypertext markup language version 5.[445] Developing an HTML5 app is essentially the same as developing a website using the features and tools associated with HTML5. Teams that are proficient in developing websites can create mobile apps provided they use of HTML5 features and tools. These apps execute on the mobile phone within a web browser. Thus, as long as the web browser supports HTML5, the app will execute on iOS and Android with identical or very similar functionality and user experience. Proficiency in the JavaScript programming languages and HTML standards such as cascading style sheets (CSS) is needed for HTML5 app development. HTML5 apps are therefore cross platform apps, and, for the app developer, this route is an easy way to provide "write once, run on many platforms" capability. The app itself "lives" on a web server to which the browser on the mobile device connects. This means, of course, that the mobile device must have continuous web connectivity using either Wi-Fi or at least a 4G cellular data service. A major benefit of this approach is that any necessary app changes or updates can be made at the web server on which the app lives. All such changes will be reflected immediately to all users. However, there are certain deficiencies with this approach since HTML5 apps cannot access the full range of capabilities of the mobile devices such as access to the camera and microphone. This means that HTML5 apps may not be as powerful as native apps. If you do not need these capabilities and you can be assured that your target users will have continuous connectivity, there are many HTML5 app building tools available with powerful visual app building capabilities. A quick search on the web for "HTML5 development" will result in a plethora of tools. Choosing between these is often a function of personal taste, cost, and the anticipated learning curve associated with each product.

An aspect that used to be an issue in applications during the time of older mainframe computers but still of consideration specially in low resource areas is the classifying of the app features to front end (that is, what the user sees) and back end (that is, the actual storage and transfer of the information). In a completely web-based environment, both the screen and data reside on the remote system; in a native system, both may reside locally, but issues arise when the front end is local and the data server distant. Here the number of times the displayed data has to refresh or change for every entry while waiting for the back-end server to respond becomes a key issue. It also impacts upon the battery power expended by the mobile device. If the refresh is not complete, the cursor keeps spinning, and the screen remains unchanged while the user is literally twiddling his/her thumbs. Certain databases—the most famous being SQL Anywhere—allow data sharing on a synchronization basis, that is, the data currently in use are stored locally in a temporary albeit small memory slot within the mobile and then uploaded and synchronized with the bigger remote database as and when connectivity is considered good enough. Thus it behaves like a native app but allows functionality of a Web app even for less memory devices. Sometimes, this kind of an app is called a *hybrid* app.

Summary

Developers of apps for smart mobile devices typically need to make several decisions before embarking on app development. These include native apps versus HTML 5 apps, Android, iOS, Windows mobile, or cross platform, execute on smartphones and/or tablet, along with which database to use. Development of rich functionality apps typically requires the development of native apps and requires expertise in a variety of disciplines including interface design, programming, graphics, and user experience.

Persuasive technology and mHealth

Sriram Iyengar

Technology of various kinds plays an increasing role in modern life. This is especially true, even in developing countries, of information and communication technologies (ICTs) like mobile phones, including smartphones. Persuasive technology or PT is a vibrant emerging discipline that studies how technologies can be designed to encourage beneficial behaviors, of course, without coercion. The beneficial behaviors we are concerned with here relate to health, including encouraging health workers to use clinical practices that have been approved and shown to be effective, instructions from medical experts to patients to assist recovery from disease conditions, or advice and techniques for those who have no current health issues to improve and maintain wellness. In the case of smartphones and mobile/wearable sensors, the principles of PT can be used to design apps and technologies that help meet health goals.

Behavior change plays an important role in healthcare. Those who have chronic conditions like diabetes need to change their dietary habits, increase physical exercise, learn how to inject insulin, and monitor their glucose levels. People who are well may want to maintain or improve wellness by moderating intake of alcohol, quitting smoking, and losing weight. Health workers may need to modify the care they typically provide to their patients by adopting clinical care guidelines that have been recommended by authorities. For example, the World Health Organization has developed a set of clinical procedures called Integrated Management of Childhood Illnesses to guide community health workers in developing countries in diagnosing and treating health problems in children up to 5 years of age. Adherence to these can be aided by tools on smartphones.[438–440]

PT was originally developed by BJ Fogg,[446] who suggested that technology, especially computing technologies, can promote behavior change if they include one or more of the following attributes. These are sometimes known as primary task support principles.

1. Reduction: Complex tasks should be broken down into a series of smaller steps that the user can perform easily.
2. Tunneling: Users should be provided with guidance to navigate through the steps, especially if there is more than one step to be chosen from.

3. Tailoring: The information provided by the system should be designed to be compatible with their educational, cultural, and social background.
4. Personalization: The system should be very closely aligned with the needs and characteristics of the targeted individual
5. Self-monitoring: The users should be provided with feedback about their performance or status.
6. Simulation: Helps users understand the connection between the behavior change they are being asked to perform and the resulting benefits.
7. Rehearsal: Provides facilities for the user to rehearse the desired behavior change prior to putting it into practice.

These principles were extended and refined in the persuasive systems design (PSD) model,[447] which provides specific analytic and design principles for developing persuasive systems. In PSD, 21 such principles have been identified and divided into three categories:

1. Dialogue: Computer to human interactions directing humans toward target behaviors. Two important such principles are the self-explanatory rewards and reminders.
2. System credibility: Trustworthy systems can influence human behavior. Design principles here include verifiability of the process and a real-world feel.
3. Social support: Systems that leverage social factors such as cooperation and competition can produce the desired behavioral change.

The specific primary task support and persuasive systems design principles to be applied in a particular case depend on multiple factors including the culture, technology availability, economic status, educational attainments of the target users, and their environment. The following table provides an example in the mHealth context. Here the goal is to develop smartphone apps that assists community health workers in developing countries to follow the World Health Organization's Integrated Management of Childhood Illness (IMCI).[448] IMCI is complex and can be hard to learn since it covers a wide spectrum of childhood illnesses. mHealth solutions such as smartphone apps have the potential to replace bulky paper-based materials with a highly portable and interactive tool. However, these apps have to be designed carefully, taking into account multiple user and environmental challenges. The principles of PT described earlier provide a systematic conceptual basis and framework, rather than ad hoc methods with which to design such apps. One benefit of the PT approach is that design solutions based on PT are evidence based with a reasonably high expectation of success.

TABLE 1 Application of principles of persuasive technology in a mHealth app for a developing country.

User and environment challenge	Persuasive technology principle	Design solution for smartphone app
Literacy deficits among target users	Tailoring	• Provide images, video, audio in addition to text information • Media should be culture and language sensitive to target users
Poor Internet connectivity in user's environment	Tailoring	App should be able to function stand-alone
Training/educational deficits	Reduction	Break up the health information in the apps into small steps
Training/educational deficits	Tunneling	App should present clinical information as a series of steps and help user choose the next step
Performance feedback needed for improvement	Self-monitoring	App should document user activities and provide reports

Table 1 provides an example of the application of PT principles to the design of mHealth applications. The mHealth application is being designed to provide anytime-anywhere clinical decision support and procedure guidance for community health workers in a developing country. In Table 1 the first column describes the operating environment for the mHealth app. For instance the first row notes that the health workers have poor literacy in terms of reading complex medical terms and may, indeed, have only basic reading and writing skills. The app will then have to be "tailored" to enable them to overcome these literacy deficits. The design solution is to supplement the text content of the app using multimedia including voiced instructions, still images, and videos. Instructions using video are especially useful to enable understanding and skill development of medical procedures such as performing cardiopulmonary resuscitation (CPR) and dressing wounds. Providing video of medical conditions such as the various kinds of breathing distress (asthmatic wheezing, stridor, and so on) can improve diagnostic accuracy. Video of medical procedures enables health workers to perform these procedures accurately, following prescribed guidelines, and thereby include patient recovery.

The tailoring in row 1 in the succeeding text can benefit not only the health workers but also their patients. This is because in locations where health worker literacy is deficient, there patients themselves are also likely to be poor. The health worker could show the images and videos to patients to improve their knowledge about their condition and improve their ability for self-care, such as taking care of wounds. Iyengar et al provide examples.[438–440]

mHealth evaluation

Meghan Corin Bradway, Eirk Årsand

Evaluation of new and emerging ideas or devices in the medical realm—and mHealth is one such—offers challenges and opportunities. The approach you take to evaluation depends on what is being evaluated and why. It is incumbent upon the healthcare stakeholders involved to establish appropriate evaluation approaches that accounts for the priorities and input of all parties involved in the inception, idea, development, and usage of mHealth platforms.

The challenge of mHealth evaluation: Merging two independent environments

While mHealth technologies were originally intended for individual consumers, patients also often present these technologies and abundance of self-gathered data, to their healthcare providers. In response to mHealth, clinical practices need to adapt appropriately, and the medical world is calling for evidence that mHealth is safe and effective.

To look at the status and limitations of mHealth evaluation today, first we have to note that we are dealing with two environments that have evolved separately and are now trying to merge: clinical evidence-based medical care and commercially based mobile health (mHealth). While traditional healthcare and research depend on rigorously tested protocols and health standards developed over hundreds of years and generations of understanding, the commercial mHealth environment has evolved very rapidly—roughly between 2008 and 2018—in response to technological capabilities and the needs of individuals, providing near immediate self-management solutions.

The added needs of mHealth evaluation

To understand mHealth, we need to understand health behavior and motivation. Traditionally, evaluation of health interventions has been based upon noncontinuous or cumulative measures of health change, for example, HbA1c and lipid levels. The purpose of evaluation is to determine if a health intervention is safe and effective for end users. However, the concept of “effective” becomes a more complex issue than the traditional drug trial scenario in which the drug either works or does not work. Today, one must take into account the more frequently or even continuous accounts of a patient’s unique self-management routine that are gathered via mHealth technologies. The concepts of safety and effectiveness for mHealth are based upon several questions in addition to changes in clinical measures. These include the following: Is the device relevant to the patient? Does the patient want to use it? Is it commensurate with that particular patient's health needs? Does it pose any risks? Does it meet the expectations of patients and their care providers? Therefore evaluation of mHealth requires not only traditional measures, such as resource use and changes in a medical condition, but also additional insight into what motivates a patient to choose to use mHealth technology, how they choose to use it, and what impact such use has on their health.

Racing against the clock to evaluate mHealth

While patients are increasingly more engaged in not only testing, even do-it-yourself (DIY) movements[449] and formal development, one main challenge still remains—time. Due to the rapid evolution of mHealth, by the time trials conclude,[450] the technology may become outdated. Fortunately the technology also allows researchers to collect the same continuous and relevant data that individuals choose to record—everything from steps taken to blood glucose to medication. Yet few are able to incorporate these "usage logs" and self-gathered data into conclusive clinical trials[451,452] due to the lack of evaluation standards for mHealth. Instead, most trials rely on changes in clinical health measures at, for example, 3-month intervals and standardized questionnaires, often reliant upon memory, which is prone to human error.

In response, governmental, research projects, health, and independent organizations, such as the FDA,[453] WHO and mTERG's mERA checklist,[454] FI-STAR,[455] PatientView, and online app stores, are also stepping up to propose more comprehensive frameworks and certifications for evaluation. Each approach is unique, with variations of target audience, intended level of evaluation, and the related capabilities of the assessors themselves. Some incorporate end-user reviewers, such as PatientView's App Directory (See http://myhealthapps.net/), provide assessment themselves as a service, such as the AppSaludable Quality Seal[456] or the NHS App Library,[457] or provide toolkits and recommendations for others to follow to formally assess mHealth technologies for clinical integration, such as the WHO's MAPS toolkit.[448] While the level of evaluations range from testing individual mHealth technologies to assessing a particular region's or health system's readiness for mHealth integration, most focus on common criteria including data security, reliability, and privacy as well as technical usability and user experience. Despite these efforts and increased patient engagement, there is little consensus on which methods or even which questions should be considered most important and relevant to answer the relevant needs of both, patients and their care providers. However, we can agree that each stakeholder group, from patients to care providers, not just health authorities and commercial developers, should have a role in mHealth evaluation—after all, they are the end users of these technologies.