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Mobile Usability Testing in Healthcare: Methodological Approaches

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Abstract

The use of mobile devices and healthcare applications is increasing exponentially worldwide. This has lead to the need for the healthcare industry to develop a better understanding of the impact of the usability of mobile software and hardware upon consumer and health professional adoption and use of these technologies. There are many methodological approaches that can be employed in conducting usability evaluation of mobile technologies. More obtrusive approaches to collecting study data may lead to changes in study participant behaviour, leading to study results that are less consistent with how the technologies will be used in the real-world. Alternatively, less obstrusive methods used in evaluating the usability of mobile software and hardware in-situ and laboratory settings can lead to less detailed information being collected about how an individual interacts with both the software and hardware. In this paper we review and discuss several innovative mobile usability evaluation methods on a contiuum from least to most obtrusive and their effects on the quality of the usability data collected. The strengths and limitations of methods are also discussed.

Keywords:
Usability; Mobile phone; Mobile health; In-situ; Healthcare; Consumer informatics; Clinical informatics; Human factors.

Introduction

The use of mobile devices and healthcare applications among consumers and health professionals is rapidly increasing [1, 2]. Athough there has been an exponential rise in the use of mobile devices in conjunction with m-health applications, few researchers have explored the methodological approaches and issues encountered when conducting in-situ usability testing (i.e. usability testing conducted in the setting of use) in environments where healthcare activities take place [1-3]. In this paper the authors will outline several innovative approaches to conducting mobile usability testing of mobile healthcare applications and their devices. This work will also include a discussion of the strengths and limitations of each of these approaches in the context of quality of data collection.

Review of the Literature

With the advent of mobile health or m-health, more and more health professionals and consumers are using mobile devices along with healthcare software applications (e.g. mobile devices that provide diet and excerise advice). Consumers are using these devices to self-manage their wellness activities (e.g. diet and exercise) as well as chronic illnesses (e.g. chronic obstructive pulmonary disease, hypertension). Health professionals are also using these devices to review, communicate and undertake health care activities (e.g. prescribing medications, reviewing clinical guidelines) [4]. Yet, even as the use of these devices has grown in the consumer and health professional space, there has been less attention given to evaluating the usability of mobile devices and their software applications in healthcare [5]. General issues in the usability testing of mobile devices and their software applications have been described by a number of authors, including Nielsen and Budiu [6], Weiss [7] and others such as Pearrow [8]. However, these works have focused on conducting laboratory-based studies with fixed recording of users using mobile applications in laboratory settings [6-8]. In addition, research is needed for exploring the usabilty of complex eHealth applications that involve understanding their use and usability under both laboratory and real-world conditions in healthcare contexts (e.g. hospitals, clinics) or in contexts where health is being managed (e.g. at home, at the gym or at work) [3-5]. We describe and compare a number of methods that we have employed in in-situ usability testing of mobile devices and healthcare applications in this paper.

Review of Existing Materials and Methods

We have employed several mobile usability testing approaches. The approaches also vary to the extent they are invisible or unobstrusive to the end user of the mobile device and the healthcare applications being tested. It has been our experience that some users may find being audio and video recorded to be obstrustive. Obtrusiveness may lead some users to modify their performance of tasks, improve their behavour in order to please the usability researcher, and/or limit their negative comments about the software features, functions and layout in order to “please” or to “not hurt the feelings” of the researcher. This is known as the Hawthorne effect. The Hawthorne effect can compromise the quality or representativeness of the study results. In our work, we have identifed that less obstrusive methods of audio and video recording user interactions with hardware and software devices leads to the collection of data that is more representative of real-world settings in terms of participant behaviour [9]. Yet, in the process of reducing the obstrusiveness of recording techniques, the quality of the data collected is diminished in some cases (such as losing data about finger and hand gestures) and may limit the researchers ability to identify all potential usability issues [10]. We have found that obtrusivness of recording methods exists on a continuum. There are a number of tradeoffs that exist when selecting an approach to usability testing where obtrusiveness is concerned. On one end of the continuum of obtrusivness of usability appraoches, the mobile device the user interacts with

is also used to audio record user's "think aloud" verbalizations and video record healthcare software application screens (directly to the mobile device) as the user is interacting with the software. On the other end of the continuum, the usability researcher uses external (i.e. visible to the user and researcher) audio and video recording devices to collect user interactions (including finger and hand gestures) with the mobile device and the eHealth application under study. In between these two points on the continuum, we have differing levels of obtrusiveness of audio and video recording software and devices where user interaction with the eHealth application and mobile device is concerned. As the obstrusiveness of the recording methods increase so does their influence on participant behaviour which may become less representative with the user describing fewer usability problems in an effort to please the researcher.

Figure 1 –Continuum of Obtrusiveness

In addition, the approaches vary in the extent to which they can be effectively used to collect data in laboratory-based and in-situ settings. All of the approaches can be used in a laboratory settting (i.e. a room set aside for usability testing). Many of the approaches can also be used in-situ, depending on the tasks that the users will be asked to perform and the level of user mobility that is required to perform the task; for example, a physician user may be asked to perform a task typically done while sitting at a desk such as ePrescribing versus the nurse user having to move, bend over and stand while performing a task such as taking and recording a patient's vital signs.

Usability Testing with the Device as Screen and Audio Recorder

Usability testing with a mobile device, where the device also audio records user verbalizations and records the screens the user is interacting with, is the least obstrusive of these approaches (see Figure 1, left side of the continuum). The mobile device provides the user with access to mobile eHealth applications and is also used to collect verbal and screen recording data (see the left side of Figure 2). In this way, the usability researcher can use the device to record the participant's "think aloud" verbalizations and video record the screens the user moves through while performing the task (see the right side of Figure 2 for the Data View i.e. the view the researcher sees when playing back the recording for analysis).

Figure 2 –Device as Screen and Audio Recorder

There are a number of advantages to using this approach. In terms of hardware, only the mobile device itself is used, so the cost of conducting such usability tests is low: limited to the cost of the mobile device and the audio and screen recording application. The usability researcher installs the eHealth application, and the audio and screen recording application (e.g. Screen Recorder by ToySoft® on the mobile phone). The audio and screen recording application is used to record the user's verbalizations and to record the eHealth software application screens as the user moves through the application (see Figure 2). The approach affords the usability researcher and user high levels of portability. The use of a single mobile device with a healthcare software application and audio/screen recorder allows the user to move freely in a laboratory or an in-situ setting, performing tasks that require walking or other types of movement (e.g. taking a picture of a surgical wound to document healing in the patient record). From an in-situ perspective, the usability researcher can easily bring the device into the users' environment, begin the recording, and the user can use the device as he or she would in their healthcare setting. The ecological validity of this approach is very high as the environment, software and hardware are representative of what is used in the real-world. In addition to this, for studies of use of mobile eHealth applications in collaborative settings, each user may have the recording software deployed on their own mobile device, allowing for multiple recordings (that can later be synchronized during the analysis).

The one significant disadvantage associated with using this approach is that the users' finger, stylus or hand gestures, are not recorded so it is unclear as to exactly what the user is touching on the eHealth application interface (e.g. a button several times before the software responds), as this is not recorded (see right side of Figure 2). In addition to this, the impact of the mobile device on user activities is not fully known. In our studies, features of the hardware device may have an impact upon users' perceived usability of the software and hardware and this information is not fully recorded as there is no external view of the participant handling the mobile device. It must also be noted that not all mobile devices have recording software that can be effectively used to capture the screens that the user is moving through and many mobile devices will not have sufficient room to store large files used in screen recording. Ideally, the device the consumer plans to use or the health care organization has mandated should be selected for the testing to ensure ecological validity and representativeness of the data [10,11]. Pilot testing [10] of the study data collection methods is recommended, including testing the mobile health application, mobile device and recording software to ensure no interactions between differing software and hardware lead to audio and video data being lost.

Usability Testing by Mirroring to a Computer

Along these lines, in cases where a mobile device has insufficient memory to store audio and screen recordings from the usability test or in cases where audio and screen recording applications are of insufficient quality to provide high quality recordings, devices can be mirrored to a computer (e.g. transmitting iPhone® or Samsung Phone® screens to a computer). Usability testing by mirroring a device screen to a computer or laptop computer remotely and then using audio and screen recording software installed on the computer can be done effectively to record audio and video data. In other studies, we have found that computer screens (including a mirror image of the mobile health or eHealth application

display) can be recorded using software installed on a computer. The approach is of higher cost as a laptop must be purchased; however, costs can be limited by using free software that can be downloaded off the web such as HyperCam® to record mobile device screens.

We recommend pilot testing this approach prior to collecting usability data [10]. Care must be taken by the usability researcher to ensure that the mirror image of the device is of sufficient quality to provide video data, and a portable external microphone is carried by the user that connects the user and their device to the laptop with its audio and video recording software so as to fully capture think aloud verbalizations in conjunction with video data of the user moving through the eHealth software application screens (see Figure 3).

Figure 3 –Mirroring to a Computer

The approach is more obtrusive than *usability testing with the device as screen and audio recorder* as the user is aware of the usability researcher reviewing the recording using a laptop and the user is physically wearing a portable microphone. However, the user is able to move freely when using the device (provided it is sufficiently close enough to the laptop for the computer screens and audio verbalizations to be recorded). *Mirroring to a laptop* does have a number of drawbacks – cost increases to conduct the test as the user now needs to use a laptop. In addition to this, less information is gathered as the researcher is unable to record user finger, stylus and hand gestures when touching eHealth application screens as they interact with the healthcare software. However, this approach takes care of the problem of not having enough space to record files on the mobile device, as the recordings are stored on the computer the mobile screens are mirrored to.

Usability Testing Using a Headcam

Head Cams can also be used to conduct mobile usability testing. Here, the individual wears a camera that is fixed to an adjustable strap that is worn on the forehead. As the user interacts with the mobile device, video and audio data are recorded by the headcam including finger and hand gestures. Usability researchers must take care when selecting a headcam when conducting this type of research. Headcams need to have audio equipment built in. Such headcams are currently available for purchase (e.g. the goPro® camera) with a high resolution and frame rate, thereby allowing for the usability researcher to capture user interactions with the mobile device and healthcare software application. The device is more obtrusive with it being worn by the user on their head. Alternatively, the device does afford the user participant greater mobility and it is possible to observe what the user is focusing on in terms of the mobile healthcare software. The user must be trained to position their head to ensure the headcam captures the mobile device screens and their finger/hand gestures for recording (see Figure 4).

Figure 4 –Using a Headcam

Here, the headcam improves the quality of the data collection by allowing the usability researcher to record how the user is interacting with the device (i.e. we can see the user touching differing user interface features and functions using a stylus). The approach is also reliant on only one device (the head mounted camera) so it requires limited equipment.

Usability Testing Using Glasses

We are currently adapting our approaches to using glasses that record audio and video for usability testing of healthcare applications. Our initial investigation suggests that such eyewear can be effectively used to collect information about what participants are viewing in addition to hand, finger or stylus movements (See Figure 5).

Figure 5 –Using Glasses

The advantage of the approach is that the researcher can view the world as the participant views it, and the participant is able to physically move while wearing the glasses. Our initial research has found that careful consideration must be taken when selecting the type of glasses that will be used in usability testing; for example, glasses should be selected with the ability to record audio and video data (as not all glasses record audio data). Attention must also be given to ensuring the glasses have sufficient storage space to collect the data that is being sought and there is a need to determine at what points downloading should take place. The glasses themselves must also be considered in terms of their usability and ergonomics. Some eyewears are difficult to position on the nose to fully record activities. Other glasses have been reported by users as difficult to wear. Some users find wearing glasses that can video and audio record to be irritating to the nose. As well, some glasses that record audio and video data do not respond well to participants head movements (i.e. the video may become choppy and may not

fully capture what the participant is looking at). Some that are able to record audio and video data may also have a headup display. The headup display provides information to the participant in the form of a transparent display. The user sees data in their visual field and does not have to look away in order to review the information, much as a pilot is able to continue looking forward at the data typically found on an instrument panel rather than needing to look down to view his or her instrument panel while flying an airplane [12]. The usability researcher must take into consideration if the headup display supports or distracts the user from focusing on the mobile device and healthcare application. Distractions may diminish the quality of the participants "think aloud" as they focus on the headup display instead of the mobile device. Lastly, some individuals use eye glasses for vision correction. Glasses used for audio and video recording usability data cannot correct a participant's vision. Therefore, some participants may be excluded from being part of this study. In summary, careful consideration must be taken by the usability researcher when procuring and pilot testing [10] glasses that record video and audio data for the purpose of collecting usability data about mobile device and software application use.

Usability Testing Using a Document Camera

Mobile usability testing can also be done using newer, more portable document cameras [14]. Products such as the Hue® document camera can be easily taken to a in-situ setting and used for usability testing. The quality of document cameras has improved significantly over the past few years. They are smaller in size (approximately 25 cm long and 10 cm wide), have built in microphones, 10x the zoom function, can be adjusted to focus on any device, and can be plugged into a computer where the images and audio it captures is easily recorded (see Figure 6).

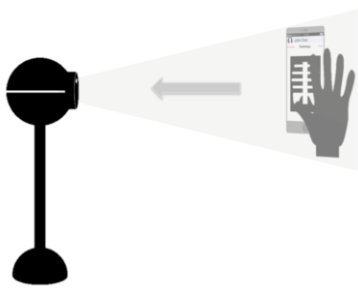

Figure 6 –Using a Document Camera

Document cameras offer a number of advantages. The smaller size of the camera allows for ease of portability and set-up in real-world settings, and the built in microphone no longer requires that the usability tester carry a microphone for capturing think aloud verbalizations [14]. A document camera has a number of advantages over the *use of the device alone for usability tests*, *mirroring to a computer* or *mirroring to a video projector*. Document cameras allow for recording of device screens, user hand and finger interactions with the software application as well as the mobile device. The document camera can be positioned to capture user interactions with the hardware and software. Some document cameras can be clipped to the device using plastic clips [14]. In capturing user interactions, the researcher is better able to link user activities involving the device to screen and audio recordings; for example, you can see what the user is touching with a stylus or their finger on the software application and this information is recorded. This approach does, however, require the mobile device to be located in a relatively fixed position, so its screen can be recorded by the camera (which makes it useful for laboratory style studies but less useful for studies where the user is moving around in a real or realistic environment). The methodology, although more intrusive, does provide additional insights as to what the user is doing with the software and the device.

Usability Testing Mirroring to a Projector

Early studies of mobile applications in healthcare focused on varying aspects of mobile device and software usability. For example, Kushniruk and colleagues found that the small screen size of a Personal Digital Assistant (PDA) could lead some users to make an error [11]. In this study, a statistical relationship between usability problems and medication errors was found by analyzing physician interactions with a mobile ePrescribing application installed on a PDA. The approach involved having end users of a prescription writing application (for use on a palm pilot) projected to a screen using an attachment called Presenter-to-go (which allows for connection of the mobile device to a data projector). Then, the usability researcher used a video camera to record both the computer screens and the audio of users while they interact with the ePrescribing application (see Figure 7).

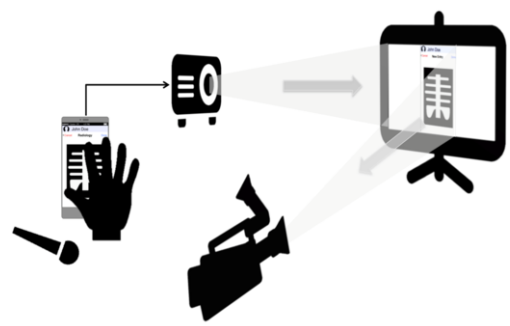

Figure 7 –Mirroring to a Projector

This approach allows for recording of mobile device screens and audio of the participants' "think aloud" verbalization, but requires a cable from the mobile device to the data projector. Usability testing mirroring to a projector is more obstrusive on the continuum of approaches, placing this method more to the right side of the continuum. Here, the user may become more aware of the presence of the video projector and the video camera. Also, the user is tethered to the projector and this limits what the user can do in terms of interacting with their environment (as they are limited by a cord), and less information is available about how the user is interacting with the mobile device (i.e. touching the screen). Using this approach requires more equipment, but as most of the equipment is normally available in most organizations it may be cost effective. Futhermore, the approach does not require installing software to record directly to the mobile device [11].

Discussion and Conclusion

When conducting usability tests involving devices, usability researchers must consider a number of differing issues, obstrusiveness is one of them. The level of obtrusiveness is

important to consider as participants may may modify their behaviours when performing study tasks as they are aware of the presence of equipment. In our work we have found that less obstrusive approaches to gathering usability data improve the ecological validity of the study, while at the same time reducing the likelihood of there being a Hawthorne effect.

Some less obtrusive approaches allow the user to move the mobile device and perform work activities more freely, but may not allow one to record stylus, finger or hand motions on the mobile device screen nor do they collect data about how the mobile device is held or used by the study participant (i.e. *usability testing with device as screen and audio recorder, mirroring to a laptop, mirroring to a projector*). Some more obstrusive recording approaches such as *using a document camera* may limit what the user can physicially do with a device, but will allow for recording of some more sedentary tasks such as entering medications into an ePrescribing system [11]. The headcam or glasses, although still obtrusive, may offer an advantage in that they allow for recording of user audio and video data involving hand gestures and finger touching where the healthcare software application and mobile device are concerned. Along these lines, some participants may find headcams and glasses to be a burden even though the recording method is less obtrusive than others used to collect data mentioned in this paper. There are advantages and disadvantages that need to be considered when planning for a study. Attention also needs to be paid to the types of tasks users will be asked to perform when identifying the best approach to data collection. For example, if the intent of the research is to study physicians using a Smartphone application that is used to for ePrescribing and there is interest in learning about how the device and the eHealth application work together, then using a document camera may be a solution.

Other factors may also influence the researchers' use of recording approaches. Availablity of screen and audio recording software for a Smartphone will determine if *usability testing with the mobile phone as recording device* can be employed as a methodology. Issues such as sufficient storage space for screen and audio recordings to be collected using a Smartphone is a concern. Some Smartphones do not have sufficient storage space to collect video and audio data from a usability session. As well, even if the Smartphone has sufficient storage space for usability recordings, the researcher needs to be able to determine at what point to download data to a computer or external hard drive from the device to free up space for continued recording. Use of laptops and video cameras to record data using mirroring overcomes some of these storage limitations. Cost is another aspect of mobile usability testing that needs to be considered. Using a Smartphone along with low cost screen and audio recording software is cost effective. The use of a headcam, glasses, laptop or a projector adds to the cost of conducting mobile healthcare research (if the equipment is not already in an organization).

In making these choices, researchers need to consider the strengths and limitations of each of these recording methods and their impacts on user behaviour to fully capture the data that answer the researcher's questions. From our work, we have also learned that pilot testing devices, study procedures and data collection approaches (audio and video) is key to avoiding any possible loss of data [10,13]. Also, a fullsome understanding of the tasks and activities that the user will be asked to perform will also influence selection of recording devices. For example, if the participant is asked to enter information into their mobile device while performing a physical activity (e.g. giving medication), the equipment that will be selected for use will differ from tasks where the user may be sitting (e.g. ePrescribing).

In summary, obtrusiveness influences ecological validity and the quality of the study results. Less obstrusive methods of capturing usability data may lead to poorer quality data. Consideration of study design is key when selecting from a range of approaches and taking into account whether the recording devices are obtrusive. This is particularly important in healthcare where there are many contexts and settings of use for mobile applications and devices (e.g. tablet and SmartPhone). In our studies, we have typically employed more than one of the methods described in this paper in combination. Such a multi-method approach may be useful when studies are used to assess both detailed and fine-grained user interactions as well as understanding how mobile applications fit into complex healthcare workflows.

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