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A Conceptual Framework to Evaluate Usability in Mobile Aged Care Applications: a health care initiative

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Abstract

Information technology has the potential to provide enormous benefits and enhanced quality of life among the elderly. Yet the use of information technology among the elderly, especially mobile applications is limited. This study seeks to develop a conceptual framework for the design and evaluation of usability of mobile applications for the elderly; and to understand the limitations that the elderly experience while using mobile devices. In order to achieve these goals, the study performs a comprehensive literature review in the area of technology for aged care. Based on the literature review, this paper presents a conceptual framework that synthesizes perceptive, cognitive, physical limitations and motivational factors, to determine how an application and a specific mobile device satisfy the needs of the senior population. This initial conceptual framework is a part of a larger project and will allow further research into design and evaluation of usability of mobile applications for the elderly.

Keywords

Usability, user experiences, aged care, mobile user interfaces, evaluation.

1. Introduction

Population ageing is considered a widespread problem across the world. For instance 20%-22% of the USA population will be older than 65 years old by 2030 and more than 25% of the population will be older than 65 years old in Australia by 2030. As developed countries' productive sector of the populations shrinks, the senior citizens ratio increases, creating a burden to the health care systems, and a challenge to different governments. It is foreseen that in the future the health care systems will have a difficult time coping with the expenses of supporting a larger elderly population.

Under this context, governments see Information and Communication Technologies (ICT) as a possible solution to the problem. ICT could help reducing the recurrent costs that affect the system, and could provide a better quality of service. The aged population would benefit from IT

services by promoting a healthy lifestyle, allow elders to age seamlessly at home, enable them to be close to family and friends and improve the general quality of life. However, researchers have found that there is a digital divide affecting senior citizens. Older adults that did not use ICT in their younger years are not familiar with the use of technologies, and will usually have several difficulties when facing a computer system, even more so for mobile devices.

Furthermore, mobile devices have become an essential part of today's life. These devices help users in everyday tasks, communicating, and providing all types of IT services. As mobile devices such as iphones and tablets have become the most common way to keep the society connected, the senior population has not adopted and used mobile technologies successfully in their everyday health related activities. This is the reason why the study at hand analyzes how this problem could be solved.

This paper is a research-in-progress study that aims to shed some light on the factors that discourage and enhance the appropriation of mobile technology in the elder population. In particular this study is aimed to answer the main research question: *What standardized methodology can be used to measure the usability of mobile applications from the perspective of a senior user?* To answer this research question, two sub-questions are addressed:

- *What are the limitations that the elderly experience while using IT?*
- *How can we measure the usability of a mobile application when used by the elderly?*

In an attempt to answer the questions, this initial study as a part of a larger project, does an extensive literature review of the present-day research in the area of technology in aged care. The findings of this research are then used to develop a conceptual framework that attempts to answer the main research question. This proposed conceptual framework may be used as supporting tool for designers to evaluate the usability of mobile applications developed for the elderly.

2. Research approach

The aim of this study was to gather three aspects: (1) information about technologies used by the aged; (2) the current challenges of aged care technologies and (3) usability issues faced by the elderly and solutions; and (3) to design a conceptual framework for usability of mobile applications by the elderly.

The researcher employed a systematic and rigorous approach to identify patterns and themes relevant to *information technologies* and *aged care solutions*. To be able to do this, both descriptive and exploratory methods were used. Sixty four prominent and recognised conference and journal papers were reviewed. The literature was collected through electronic resources such as IEEE, PubMed and Web of Science. The papers were from specific fields such as The National Aged Care in Information Technology (ITAC) Conference, or the International Conference on Universal Access in Human Computer Interaction. The sourced journals were also obtained from Science Direct, the Journal of Nursing Administration, Medical Informatics and the Internet in Medicine.

In the first round of information gathering (36 papers), the themes identified were based on the technologies used as a solution to medical conditions (eg., heart, diabetes, incontinence, obesity,

cognitive conditions etc.), assisted independent living, clinical facilities and quality of life improvements for the elderly. Five main types of technologies were identified in literature namely: mobile devices; wireless sensor networks; personal computer applications; robotics and artificial intelligence; and wearable computing applications.

In a second round, the study narrowed its focus on information about usability issues faced by the elderly specific while using technologies, especially mobile applications (23 papers), and 30 papers on usability issues were reviewed. Finally, some limitations were identified (Section 3.7) and a conceptual framework (Section 4.2) was developed by extending a hierarchical model (Ham et al. 2009).

3. Literature Review

To review and synthesize the literature, this study classifies different research studies into the following categories: (1) assisted independent living; (2) quality of life improvement; (3) clinical facilities, and (4) medical diseases and conditions. In addition, the research presents some findings of the impairments faced by the elderly when attempting to use IT, with a particular focus on mobile devices. Furthermore, the study also presents usability concepts that could be used for the estimation of usability of mobile applications by the elderly.

3.1 Independent living

Some prior studies have focused on assisting independent living of seniors to support long-term care outside of clinical facilities by providing services that include remote monitoring (Moulton, et al. 2009), mobile devices with medical alerts (Chan, et al. 2006), and different ways of interaction through IT services (Meriggi, et al. 2009). Remote monitoring is especially beneficial for patients and caregivers in remote locations. Patients avoid the need to travel long distances to get treatment. This approach prevents inconvenience and the aggravation of the patient's condition and allows quick responses to prevent emergencies.

3.2 Quality of life

Regarding technologies focusing on improving the quality of life, some studies are concerned with encouraging a healthier life style and improving social interaction. For example, one study focuses on video games to encourage physical exercises and social activities among the elderly population (Smith, et al. 2009). Other studies consider elders adapting a variety of technology solutions to enhance their quality of life. For instance Intel presents a surveying solution that evaluates the health of the elderly on a daily basis, a sensing solution that records information regarding the elders activities, and a social care solution that encourages seniors to participate in social communities (Dishongh, et al. 2009).

3.3 Solutions for clinical facilities

Some studies in the literature are concerned with improving the quality of care provided inside clinical facilities. For instance, there are systems for monitoring and management of aged care facilities, improving living standards and providing faster response under critical conditions (Celler, et al. 2006; Shih, et al. 2010).

3.4 Medical diseases and conditions

Other research areas focus on health conditions that commonly affect seniors. For instance one particular study focuses on a remote monitoring system for patients with heart disease that conveys streaming video, WSN, and pulse oximeters (Fischer, et al. 2008). In the same way there are some studies that present home based surveillance with ECG functionalities aimed at patients with heart conditions (D'Angelo, et al. 2010; Gund, et al 2008).

Further studies review the usability of mobile systems developed for people with diabetes. For instance, LeRouge, et al (2011) analyses the benefits of user profiles and personas in consumer health technologies for chronic diabetes patients. Other studies were concerned with cognitive disabilities, where information technology is applied to improve the quality of life of patients, reduce stress on caregivers, and assist physicians in monitoring patients. (D'Angelo, et al. 2010)

3.5 Mobile technologies: challenges and barriers faced by the elderly

To address the research question: *What are the limitations that the elderly experience while using IT?,* some challenges and barriers experienced by the elderly while using mobile devices are synthesized from the literature in the following sections:

Older adults are likely to have special issues when using IT systems. Some issues noted in the literature are: (1) restricted manual dexterity; (2) vision problems; (3) reaction speed issues; (4) lack of Internet experience (Jimison, et al 2002). The elderly usually need more coaching and need assistance to familiarize on how to use an application. The research developed by Holzinger, et al. (2007) identifies four main areas of difficulty for older users. Physical limitations, such as restricted movement in the hands, perceptual difficulties such as reduced acuity of hearing and sight, cognition problems such as poor attention and memory, and motivational problems such as fear, beliefs and anxiety.

3.5.1 Cognitive Limitations

According to Holzinger et al. (2007), cognitive complexity is considered to be a barrier to the adoption of mobile technology by older people. Slower rate of learning, easy adaptability and "cognitive congeniality" which is, adaptability within a real learning curve of older people, are a few attributes that hinder adoption and effective use of mobile technologies among the elderly (Holzinger, et al. 2007). Other studies conclude that cognitive abilities between older person and the younger have significant differences in terms of the methods and speeds of comprehension (Soares, et al. 2012).

3.5.2 Motivational challenges

Motivational issues are significant, as older adults may feel they cannot cope with technology. The elders often feel anxious when expected to use ICT resources. Also, if they are unable to complete tasks successfully, they tend to become frustrated, and loose interest in using the system (Holzinger, et al. 2007). These feelings are related to how insecure they feel using technology. The more familiar they are with the technology, the more comfortable they feel.
According to Xie, et al. (2010), applications that are aimed for the older population should provide additional motivation to encourage the process of adopting and using technology with effective training and support.

3.5.3 Physical Difficulties

The elderly usually have a slower ability to response to external stimuli. As a consequence they are not able to interact with applications at the same speed as younger users. They also have less flexibility and limited motor skills, a condition that reduces their ability to manipulate computers, phones, tablets, and other devices (Holzinger, et al. 2007). For instance, basic IT usage might result a challenge for most elders, since they might have a difficult time locating items on screen, and will require substantial effort to have the hand-eye coordination required to use mobile devices.

3.5.4 Perceptive Difficulties

Older people also may not have the patience required to learn new skills, especially if they are struggling with a screen they are not able see and a keyboard too small for them to manipulate comfortably. Since age usually comes with hearing and eyesight deterioration, applications for older users should focus on some special considerations in terms of the size of the text, icons, acoustic notifications and graphical interface (Holzinger, et al. 2007).

In order to address the research question: *How can we measure the usability of a mobile application when used by the elderly?,* the following section focuses on usability concepts identified in the literature:

3.6 Literature on usability concepts

The concept of usability has been largely discussed by academia leading to an ISO definition, as *"the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"* (ISO/IEC 1998). The most important aspect of this definition is that it defines usability as a property that is relative to each user, their goals, and the context in which they use applications. This means that a device that might have high usability for a young adult performing multiple tasks might have a low usability for another type of user, such as an older adult.

Special considerations are made regarding specific usability issues related to the use of technology by older adults. As an example Johnston, et al. 2009 analyses the design principles that guide the development of applications for the senior population. Furthermore, Fung et al. 2006 studies the usefulness templates made for specific medical conditions. Other studies explore the difficulties of seniors using tablets (Hess, et al. 2008), and age related differences in the design and usability of mobile applications interfaces (Leung, et al. 2011)

Previously, aspects of mobile phone usability have tended to be studied in the same way as computer software is studied (Blanson, et al. 2008). The researchers believed that a new usability concept should be created, reflecting the fact that mobile applications have many aspects that make them more complex than traditional software (Kaufman, et al. 2006).

Mobile phones usability is affected by many factors. For example, the layout of objects, screen size, battery life, key size, functionality of keys, design and aesthetics of the phone, user guidance, patterns of use, signal availability, user's experience level and a host of other factors (Sparkes, et a. 2011).

Some particular studies developed conceptual frameworks for organizing and identifying usability features on mobile phones (Ham, et al. 2009; Yon, et al. 2008). These frameworks foster the creation of better applications, and enable improvements in design and functionality in a structured and organized fashion.

3.6.1 Usability Framework

The hierarchical model proposed by Ham, et al. (2009) offers three views covering various aspects of the way users interact with mobile applications. They are: user view, product view, and interaction view.

User view: The user view helps to understand usability from the users' perspective. This view involves how the user perceives a mobile device, and how he or she perceives the applications in the device. For instance, a user might perceive a mobile phone to be small and difficult to use. In addition, this view also considers the emotions that are experienced by a user when interacting with the application such as anxiety, satisfaction and amusement.

Product view: The product view involves the specific characteristics exhibited by the mobile device, this is related to how reliable a device might be, how durable and what performance it exhibits.

Interaction view: The interaction view is focused on how the user is able to complete tasks, how often the user completes this tasks, what is the error rate completing specific tasks, and similar such aspects.

Ham et al (2009)'s hierarchical model is designed with a higher level that shows indicators that are used to measure the different views. At the second level, the model has usability properties common across all mobile devices. And finally, in the third level of the model, usability criteria are indicated that is specific to each mobile device. These criteria are measurable and can be quantified. Based on these measures the framework is able to assess the usability of mobile applications under specific mobile devices.

3.6.2 Usability indicators

Among the usability indicators used to determine different views, the model defines common concepts such as how effective is a task, the efficiency of performing a task, or how difficult it is to learn how to use a device. Ham et al (2009) and Yong et al (2008) classify them as: effectiveness, efficiency, learnability, satisfaction and customization.

3.6.3 Usability properties

Likewise, the usability properties are used to measure observable features of mobile devices that influence usability. The properties presented by Ham et al. (2009) are classified in five main groups:

- Logical User Interface (LUI): These properties are related to the task flow and interaction. For example: input methods, menus and navigation methods.
- Graphic User Interface (GUI): These are related to the presentation aspects of the mobile applications or the mobile operating system. For instance: size of the text, fonts and colors.

- Physical User Interface (PUI): These properties are related with the properties of the mobile devices that allow human-machine interaction such as size of the device, shape and sounds.
- Hardware (HW): The hardware in each device provides usability properties such as weight, balance and size.
- Accessory: Observable features of the accessories for mobile devices include: size, shape, and functionalities.

3.6.4 Usability Criteria

The usability criteria can be measured by interacting with the mobile application under specific scenarios. These criteria are used to evaluate how a usability property meets the usability requirements of specific tasks. The criteria proposed by Ham et al. (2009) are directly related to the indicators:

- Logical User Interface Criteria: Error prevention, information organization, task automation, etc.
- Graphical User Interface Criteria: Layout, adaptability, aesthetics, etc.
- Physical User Interface Criteria: Affordance, ergonomics, convenience, etc.
- Device Hardware Criteria: Performance, durability, reliability, etc.
- Accessory Criteria: Easy installation, supportability, etc.

Figure 1 illustrates the hierarchical model by Ham et al (2009). As levels, there is a Usability level at the top of the model, followed by the usability indicators, and then the properties and criteria.

The framework presented by Ham, et al. (2009), organizes usability impact factors on mobile devices, however it can be extended to address additional usability concerns. Ham et, al. (2009) extends this framework adding a Dynamic View. In this study at hand, this framework will be extended to address the specific set of requirements that affect the elders with the appropriation of technology.

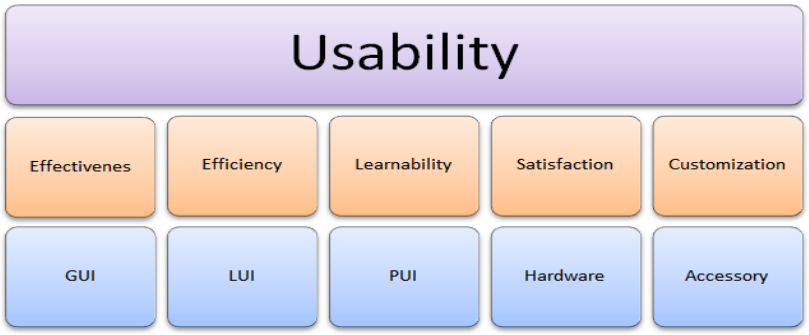

Figure 1: Hierarchical Model (Ham et al. 2009)

3.7 Limitations in the literature

Mobile applications are designed in a standard fashion with no specific focus on the usability of such devices among the elderly. In particular, a model presented by Ham et, al. (2009) evaluates usability of mobile devices in a general approach. However, this model does not specifically take

into account the motor skill limitations, motivational factors, cognitive difficulties, and perceptive limitations of senior users.

This study attempts to extend Ham et al (2009)'s evaluation model to help analyze how mobile applications fulfill the requirements related to different challenges and barriers in aged care. A conceptual model is described in the next section. It provides an answer to the main research question: *What standardized methodology can be used to measure the usability of mobile applications from the perspective of a senior user?*

4 Discussion

Based on the existing literature and limitations stated, this study attempts to develop a conceptual framework that measures how different properties of a mobile application affect usability factors for the elderly. To develop this conceptual framework, the study uses three aspects: (1) the software measurement process framework (ISO/IEC 2000); (2) the abstraction hierarchy commonly found in cognitive systems (Rasmussen 1986) and (3) establishes a relation between the challenges and barriers identified in Section 2.5 with the usability criteria and usability properties as suggested by Ham et, al (2009)'s hierarchical usability model.

4.1 Components extending the hierarchical model

Following the hierarchical model presented in Section 2.6 by Ham et al. 2009, usability is estimated by the defined indicators: effectiveness, efficiency, learnability, satisfaction, and customization. These indicators are determined by the usability criteria. However, these indicators are defined as an abstract concept common across all mobile devices and applications. To be able to determine the indicators for a specific mobile device, the hierarchical model uses the usability properties. These properties are instances of the usability criteria, specific to the mobile application and the mobile device under study.

For instance, as in the hierarchical model the effectiveness indicator could be determined by measuring the criteria of LUI, GUI, PUI and the hardware (see Figure 2). But in this study, the conceptual model designed uses the relation between the usability properties to measure Cognition Limitations, Motivation, Physical and Perceptive difficulties.

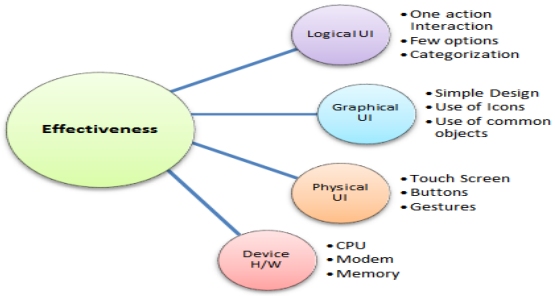

Figure 2: Mapping of effectiveness with usability properties

In this study, the effectiveness indicator is determined by a set of four usability criteria. To be able to determine these criteria for a specific context, the model requires defining the properties of the mobile device and the application under study. One of the criteria defining effectiveness is the Logical User Interface. These are characteristics such as Navigation and User Guidance.

Nevertheless, to be able to measure usability, these criteria must be defined in terms of the usability properties of the mobile application under study. These properties are specific to the context such as the Key Mapping of the application, the Navigation Method, or the Labels (see Figure 3).

In the following paragraphs this study details how the usability properties and criteria are assigned to define the usability challenges and barriers of the elder.

4.1.1 Cognitive Limitations

The cognitive limitations faced by the elders can be mitigated by taking special considerations in the GUI design, the flow of the LUI and by adding specific accessories that could reduce the

Figure 3: Hierarchy of effectiveness

learning curve. The GUI could enhance usability by using a simple design, and using simple icons. Likewise, the LUI will improve usability by allowing one action interaction, limiting the number of options, and using proper categorization. In addition, accessories such as styluses could improve usability. Figure 4 illustrates how cognitive limitations are related with GUI, LUI and accessories in the conceptual framework.

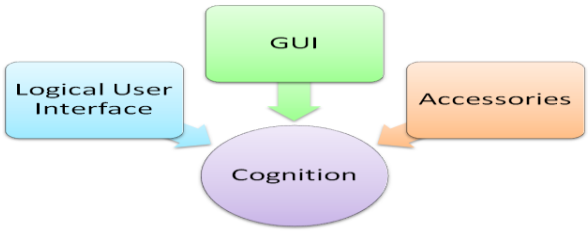

Figure 4: Link between cognitive limitations and usability aspects

The PUI and HW are not considered to have a high impact on the cognitive limitations. Some properties of the PUI are the touch screen, and the dedicated hardware buttons. It is important to mention that cognitive ergonomics is an emerging area of research that studies the cognitive implications of physical user interfaces and human-machine interaction.

However these types of interfaces are not considered in this study under the basic physical user interfaces properties, but as accessories that could enhance the usability. Some of these interfaces are haptic feedback devices, or tangible user interfaces (Wang, et al. 2011). In addition

characteristics such as the size of the screen, which have important impacts in the usability, are considered under the GUI properties rather than under the PUI. Likewise, the impact generated as consequence of better hardware resources, such as better quality of graphics, is also considered under GUI rather than as a property of the HW.

4.1.2 Physical Limitations

The physical limitations that affect the elders are directly related with the PUI, GUI, and the accessories. For instance the PUI could reduce the difficulties of interacting with the device by allowing gesture interaction. In the same way, the GUI could help by using graphical objects that reflect real world behaviors. And also hands-free kits accessories could help the elders using mobile devices.

This indicator does not consider the LUI and the HW properties to affect the Physical Limitations of the elderly. Since properties such as the task flow do not really enhance or discourage the elders' motor-skills, there is no direct relation between the LUI and the Physical Limitations. The HW properties are also not considered. Factors such as graphics would be measured under the GUI properties.

4.1.3 Motivation

The motivational factors that affect the elders could be addressed by the GUI, PUI, the hardware and accessories. The GUI directly affects the elders' motivation by providing them a simple design, which makes them feel more comfortable using IT. The PUI also affects the motivation of the users by providing easy interaction and familiarity. The hardware affects the motivation by supporting the operation of different resources. Other tangible factors of the HW will have an impact in the motivation such as weight, size, etc. In addition, eye-catching accessories could motivate the elders to use mobile applications.

The LUI is not considered as a high impact property in the motivation; elements of task flow and navigation are not directly related with motivating the user. Factors that could affect the motivation, such as an appealing design, cultural adaptations, and customization, are rather considered under the GUI properties rather than as LUI.

4.1.4 Perception

The perceptive difficulties experienced by the older population could be mitigated by PUI, GUI and accessories of mobile devices. A GUI with larger text and high contrast colors will help elders with reduced eyesight. In the same fashion, the PUI will affect the motivation. If physical characteristics of a mobile device, does not allow a simple human-computer interaction for a senior user to familiarize with the device, they will feel discouraged. In addition, accessories such as headphones will help elders with hearing problems.

The LUI and HW properties are not considered to measure the perceptive difficulties. The study suggests that a user with poor eyesight, or hearing difficulties will not impact on a simpler task flow in a positive nor negative manner. In addition, HW properties are not considered under this context with a similar reasoning to that of physical and cognitive limitations explained in sections 3.1.1 and sections 3.1.2.

Following these guidelines, this study creates an extended conceptual framework that enables the evaluation of usability in mobile applications for the elderly.

4.2 Proposed conceptual framework to evaluate usability

Based on the above-mentioned components as indicators and guidelines, Figure 5 shows the conceptual framework that presents the usability properties in a multiple relation scheme, that impacts on both the indicators and the challenges and barriers. For example, criteria such as key mapping, and navigation methods instantiated by the LUI properties as user guidance and simple navigation, will affect the effectiveness of the mobile application as well as the cognition limitations.

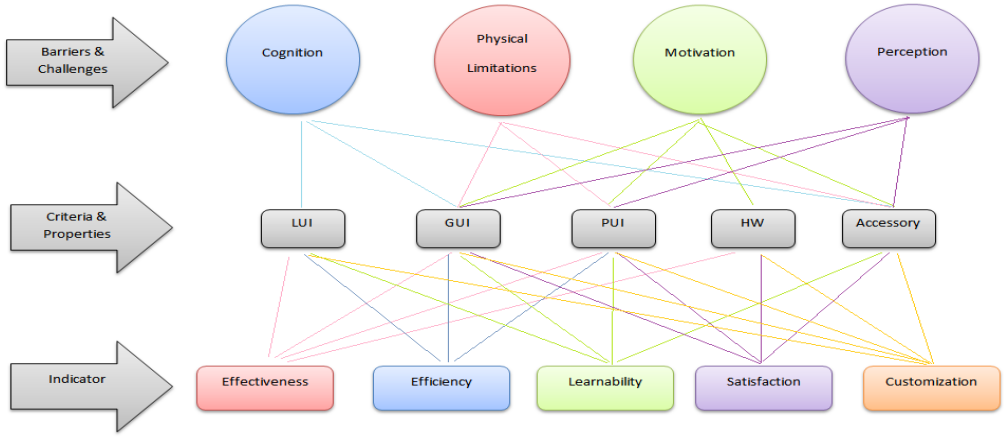

Figure 5: Conceptual framework for evaluation of usability of mobile applications for the elderly (extended from Ham et al. 2009)

This conceptual framework shown in Figure 5 can be used by designers to evaluate the usability of mobile applications for the elderly. While the study at hand is limited to the development of the conceptual framework, future work will include design for checklists and an elaborate evaluation scheme for designers. For example, in order to evaluate the usability, one suggestion is in using a checklist for each criterion (LUI, GUI, PUI, HW, and Accessory) as shown in the model (Figure 5). A score on a scale of 1-5 may be used to quantify specific properties against the criteria as the elderly use the application. For LUI, the properties evaluated could be: the ability to execute a task assigned to the user; the number of errors committed when trying to complete the task; navigation issues and multitasking abilities. This score (out of a 5) will then be assigned to all links of LUI to soecific indicators shown in Figure 5 (effctiveness, efficiency and customization).

5 Conclusions

The conceptual framework developed in this study is able to determine in a quantified manner how an application and a specific mobile device satisfy the necessities of the elderly. It has brought together three aspects within one framework that include: (1) the software measurement process framework (ISO/IEC 2000); (2) the usability hierarchical model and (3) establishes a relation between the challenges and barriers identified with the usability criteria and usability properties.

This framework is flexible and can be extended further to analyze additional characteristics, such as changes in usability over time. The proposed conceptual framework may be used by designers and developers as a support tool to evaluate the usability of prototypes in mobile applications for the elderly. The framework may also be a tool for comparative evaluations of existing mobile devices and mobile applications, to help in the decision-making process of acquiring technology for an organization, or deployment considerations.

Furthermore, the evaluation of usability has to be considered taking a holistic approach. Different views have to be considered, that include: the users point of view, the context under which the usability is being evaluated, the properties of the devices being analyzed and the accessories that these systems can use to enhance usability. Future work includes testing and evaluation of this framework in the real world with a larger sample of senior participants.

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