Usability Evaluation Model Development for Chronic Disease Management Mobile Applications

Fatima Zahra, Azham Hussain, Haslina bt Mohd

Abstract: ***The ease of use while interacting with chronic disease management (CDM) applications leads the mobile application designers to integrate usability in their design process so that the usage of such applications become versatile, unique, user-friendly and successful. This paper aims to develop a usability evaluation model for CDM mobile applications through requirement gathering from real users and a systematic literature review (SLR). The analysis of current models and previous study results in a set of selected usability guidelines for mobile applications that are expended further into measurement model consisting of metric for evaluation.***

Index Terms: Chronic disease management apps, Dimensions, Mobile health, Usability.

I. INTRODUCTION

Mobile health (mHealth) is engaging many people living with long term disease to manage their health without depending on care takers. Currently, more than 325,000 mobile health applications (apps) are available to promote disease management, health awareness and well-being [1-3]. For instance a search regarding diabetes applications yield more than 1000 results in the Google Play Store [4]. Reason for a large number of chronic disease management (CDM) apps is steadily increasing diseases such as high blood pressure, diabetes, obesity, etc. especially among older adults. As these CDM apps proliferate, their usability is below perfection. Usable interface design and its effectiveness for patients is becoming a question. Because applications are produced without considering target user needs. At present CDM applications are designed based on existing usability models which are too general and may not be as effective as those that involve end-users needs. It highlights the need to consider ease of use and perceived usefulness during development process and importance of involving the end users as it will help to identify their requirements [5].

Composite design and low quality of CDM apps limit the positive user experience which lead towards failure of overall mHealth and produce unproductive results with worst outcomes. Previous literature mentioned that older adults do not accept the innovation and show less interest in adopting mobile technologies. One main possible reason could be ignorance of special usability requirements for older adults. Inadequate usability is also mentioned as the reason behind resisting technology by older adults [6] and [7]. In addition, declined physical and cognitive skills that require consideration according to the age and growth of chronic disease also create hindrance in the usage of health apps. Hence, developing CDM apps that consider usability requirements according to incapability of growing age of adults would benefit them. Moreover, usability play vital role in the acceptance of technology by older adults [8]. European Union (EU) commission's 2012-2020 eHealth Action Plan [9], highlighted that lack of usability and user-friendly applications and services within the available mHealth tools and limited usability is experience by older adults using mHealth [10, 11]. Therefore, ideal design and perfection of mHealth applications only could be achieved through usability evaluation. However, numbers of usability evaluation models and guidelines are available to evaluate the usability of any software. limited research is found on mobile applications, particularly for mHealth applications. Similarly, little research regarding usability testing of mHealth apps is found.

Moreover, researchers are performing usability testing by using basic usability models that are not able to explore the complex design of current mHealth apps. Usability features of CDM applications are different from general mobile application and current models are not suitable to evaluate their usability. Therefore, there is urgent need to develop systematic usability measurement for mobile applications as mentioned by [12]. Appropriate evaluation is required to reach the maximum usability and positive user experience. The available usability models for evaluation includes one or two usability dimensions and left remaining for future research and majority of these models are not tested and validated thorough commercially available mHealth applications and they are not flexible enough to extend to other domains, especially for medical applications.

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Unfortunately, measuring usability of mobile applications is still not clear and rigorous research is required to identify the relationship between usability dimensions, criteria and metrics because few guidelines are present with insufficient evidence of measuring usability of mobile applications. Developers employ few methods for usability evaluation however these methods are not suitable to use for the critical systems such as medical and banking etc. The traditional usability metrics deliberately based on desktop applications and may not be directly applicable to mobile applications [13].

Poor usability is major problem faced by mHealth apps which leads towards the low quality, bad user experience and misuse of these apps that result into serious consequences [14]. Therefore, it is necessary to perform usability evaluations to enhance acceptance for technology by older adults, cope with usability violation threat and increased effectiveness of CDM applications according to the need of end users. Additionally, a combination of usability evaluation techniques, including intended end users, is required to obtain the most effective and thorough usability evaluation results [2]. Therefore, to overcome these research gaps an extensive usability evaluation model is proposed comprised of dimensions, criteria, and metrics for chronic disease management applications. The next section of this paper presents the complete phases of model development.

II. RESEARCH METHOD

Model development comprises of three phases; (1) Requirements gathering from real users, (2) Conducting systematic literature review (SLR) and (3) Analyzing the data and model development.

Requirement Gathering From Real Users

Introducing requirements of the chronic diseases for intended users, into the disease management applications will increase the frequency of the application usage. Research point out that among mHealth and medical apps, only one-fifth of them facilitate the actual user behavior and improve physical health against the applications which only perform gimmicks or simple information provision [15]. One of the objectives of this study is to identify the basic requirements of CDM mobile applications according to users and litrature. Besides, the requirements, reasons for discontinues of these apps are also identified to enhance the usability of a mobile application for chronic diseases. Requirements for chronic disease patients have been identified through the interviews and systematic literature review. As the participants for interview were patients, a minimum of 10 people are considered enough, but they may not exceed 25 people [16].

Interviews were conducted with ten users who were currently using any chronic disease management mobile application, or they had prior experience of using any of them. Participants were gathered from the Pusat kesihatan University Utara Malaysia by using opportunity sampling technique. Chosen participants age ranged from 30 to 55 years old and were mobile application users for various purposes on a daily basis. Participants were interviewed with open-ended question encompassing the following domains: (1) experience of using disease management apps, (2) perceived effectiveness of health apps layout design, (3) navigation structure, (4) difficulty and challenges faced reasons for stopping use and (5) suggestion and reasons for health app use/non-use. Open-ended responses were examined qualitatively, and Audio outputs were turned into PDF files and analyzed using NVIVO software tool. During the interview, interviewees shared their experiences with medical applications to manage their disease and challenges they faced during usage, which lead towards the identification of the specific requirement for disease management mobile applications. Interview conducted were analyzed one by one, and specific keywords were identified such as “security features,” “difficult to input,” “navigation,” “tutorial help,” and “alerts” that lead towards the identification of similar requirements shared by the users. When the participants were asked generally on having used of any specific mobile applications to manage their disease, four participants were familiar about application specific for their disease management and had experience prior in using it, or they discontinued due to the difficulty in using the applications. Six other participants agree that they were currently using mobile applications to manage their disease.

Systematic Literature Review

The SLR technique recommended by Kitchenham [17] in reviewing the previous studies that were relevant to the usability issues in mobile application and especially in the chronic disease mobile applications are used in this study. This step consists of theoretical analysis that collaborates three sub-steps including planning, conducting the review and finally presenting the review report. Planning was done on the review protocol defined and needs for the reviews are identified. Execution or simply known as construction phase was done by studying primary sources, identifying and selecting dimension and metrics outlined. Once papers have been selected, the data were extracted and synthesized. Finally, the result reported as answering the objective of the study. Results obtained from this phase were used as part of model development. In this phase, after the depth review of the selected papers completed, usability dimensions for the mobile applications were generated respectively. It helps in discovering usability dimensions and criteria to be measured from the literature and provide ideas in identifying usability dimension to develop usability measurement for the model development. Thus, usability measurements that were identified are reported in the next subsection.

III. MODEL DEVELOPMENT

The proposed model is constructed based on the requirement gathered and SLR that was conducted in an earlier phase. The literature review provided a solid base for the proposed model. Usability dimension, criteria, and metrics were reported in SLR, and identified dimensions and criteria were then scrutinized to avoid repetition or duplication of similar measurements [18]. Later, usability metrics were generated from the literature reviewed such as from [19] and [20]. QUIM is chosen as guidance for proposing the usability evaluation model for this study because it unifies existing usability standards into a single consolidated, hierarchical model of usability measurement and declared its reliability and relationship. Studies also claimed that QUIM bring impact in usability measurement towards software testing by incorporating quality measurement in an arranged and proper way for the practitioner. The requirements gathered in phase one were used as part of the metrics developed in the proposed model. Generated metrics were then placed according to corresponding criteria and are furhter explained. According to [12] some criteria can be linked to many usability dimensions, depending on the features and functions of the application, similar to [21] that described how criteria linked directly to usability dimensions. Besides that, the categorization of the dimension to the related criteria and corresponding metrics for the proposed model are as agreed and used in many usability evaluation studies [12, 18, 22]

Selection of dimensions

Usability dimensions repeatedly used for the measurement of mobile applications were identified through SLR. The SLR is used in identifying. SLR comprise of eighty-five (85) selected papers and total of eighteen (18) dimensions were gathered according to their frequency of being used in selected papers for usability evaluation of mobile applications, usability in general as well for mobile health and chronic disease management in particular. Besides the empirical usability studies used, theories that provides support to HCI and the four contextual factors within the usability dimensions which comprises of users, environment, technology (device type) and task support (activities) [18, 23] were carefully considered in identifying the usability dimensions. Moreover, the Coursaris and Kim [24] method of summarization was employed to group the dimensions that are similar in meaning. In this study, dimensions are chosen based on the number of count of its appearance in literature. It is the same way of identification of dimension used by Baharuddin [18] in reviewing empirical mobile usability studies. Usability dimensions were chosen from the selected papers according to number of times mentioned and discussed their importance for usability studies. Therefore, count method was used such as the usability dimensions appeared at least three times (count = 3) were considered and the ones appeared only twice (count = 2) were considered as inadequate to defend their importance. This method deliveir consistency for the components selected in the proposed model.

Table. 1 Frequency of usability dimensions used in the 85 review studies

No.	Usability Dimensions	Count	No.	Usability Dimensions	Count
1	Efficiency	46	10	Attractiveness	31
2	Effectiveness	51	11	Simplicity	14
3	Satisfaction	42	12	Aesthetics	09
4	Learnability	30	13	Security	14
5	Ease of use	24	14	Safety	08
6	Usefulness	25	15	Reliability	07
7	Memorability	21	16	Trustfulness	06
8	Understandability	14	17	Accessibility	14
9	Accuracy	12	18	Functionality	04

The following technique was used by [18, 24] to maintain consistency and avoid redundancy of dimension; 1) define each usability dimension according to the literature, 2) identified the usability dimensions that are similar in meaning but different in words, 3) merged the usability dimensions that have the same meaning into one single usability measure, since error, and accuracy were overlapped with effectiveness dimension.

Table. 2 Summarization process of the usability dimensions

Dimensions Merged	Selected Dimensions	Source
Efficiency	Efficiency	[12, 18, 24]
Ease of use		
Effectiveness	Effectiveness	[12, 18, 21, 24]
Accuracy		
Usefulness		
Satisfaction	Satisfaction	[12, 18, 24]
Attractiveness		
Aesthetic		
Learnability	Learnability	[18, 24-28]
Simplicity		
Memorability		
Understandability		
Security	Security	, [29-31]
Trustfulness		
Safety		
Reliability		
Accessibility	Accessibility	[32],[28, 33]
Functionality		

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An initial examination of table 1.1 shows that efficiency, effectiveness, user satisfaction, learnability and ease of use are the most common usability dimensions in the empirical usability evaluation studies. Similarly, most of these usability dimensions were incorporated in the recent usability studies such as [18, 21, 24]. One of the reasons the above mentioned usability dimensions are broadly used in usability studies is their direct relationship to the technical capabilities of the system. These dimensions are also comparatively easy to measure. However, the emphasis on these usability dimensions suggests that other usability dimensions such as learnability, security, and accessibility are not easy to evaluate, and this may be why their assessment is often overlooked [34]. Therefore, the purposed model includes learnability, security, and accessibility in the context of chronic disease management apps and requirements of intended users.

Selection of criteria

The usability dimensions are broken into measurable criteria. The measurement of usability dimensions depends on their corresponding criteria with their consistent metrics assigned to it. Twenty-four criteria were identified from the empirical usability studies following QUIM model[12], [21] and mGQM [20] along with other empirical usability studies. However, some of the usability dimensions introduced in the literature are not clearly defined and may not be able to measure a particular aspect of interface usability [12] Therefore, such dimension needs to be broken into criteria to provide a clear description of which aspect of usability it is going to measure.[12] and [21] classified many of such usability measures as criteria by hypothesizing specific usability dimension to its corresponding criteria. Therefore, the criteria that have the same meaning and direction with others but different in words are combined as a single criterion to avoid duplication as recommended by[12].

Criteria	Efficiency	Effectiveness	Satisfaction	Learnability	Security	Accessibility
Self-tracking	✓					
Push notification	✓					
Loading time	✓					
Accuracy		✓				
Completeness		✓				
Fault tolerance		✓				
Aesthetic			✓			
Content			✓			
Simplicity				✓		
User guide				✓		
Confidentiality					✓	
Integrity					✓	
Availability					✓	
Non-repudiation					✓	
Operability						✓
Presentation						✓

Accessibility and security are given higher consideration as an independent usability dimension in this model which differs from previous usability evaluation model that are too general in terms of user's needs, application evaluation platform and are focused on desktop instead of mobile applications which are being widely used nowadays [35].The selection of the criteria is based on the relationship that exists with their corresponding usability dimensions as described by[12] and[21] .

Selection of metrics

The usability metrics are used as an instrument or mechanism to evaluate the usability of a software or mobile application products using the defined set of dimensions and their associated criteria. Figure 1.1 below represent the model development phases.

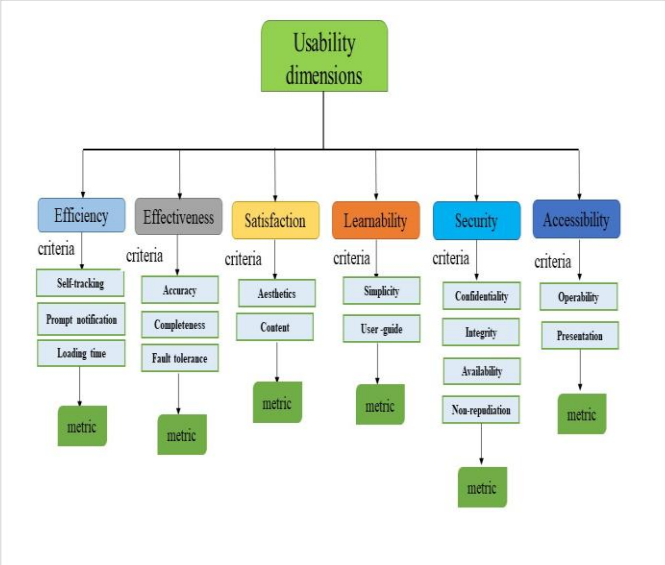

Fig. 1 Model development phases

According to ISO 9126, metrics measures or asses dimension assigned to it during the software development or usability evaluation process [30] [36]. Therefore, based on the review conducted on the selected studies, a total of 60 metrics was included in the proposed model. However a verification process was done through expert review (see for example) [37]. Results were analyzed from expert review and changes were made according to the comments and suggestions received from experts. The revised model includes fifty-three (53) metrics which comprise of twenty-seven (27) objective metrics and twenty-six (26) subjective metrics. The metrics were chosen based on the function of the usability dimensions and their associated criteria, relationship and features of the intended application[12, 20, 21] . The metrics comprise of performance (objective) and preference (subjective).

The objective metrics are used to collect data concerning actual users 'performance when carrying out a task, whereas subjective metrics are used to measure the level of satisfaction of end users. Thus, requirements identified through interviews with the chronic disease patients were analyzed before adapting into related metrics as part of the usability studies in order to make this model focused on chronic disease patient needs. Metrics in this study are generated to provide information on user performance and satisfaction level.

Table. 3 Metrics and criteria selected for the proposed model after expert verification

Criteria	Objective Metrics	Subjective metrics
Self -tracking	A number of activities user can input on a daily basis.	Satisfaction with the accuracy of data back up
		Satisfaction with the accuracy of live data fetch from tracking devices such as smartwatch
		Satisfaction with goal achievement
Push notification	Total number of delivered notifications	
	Total number of dismissed notifications	
Loading time	Time taken to load application	
	Time taken to respond to a command	
	Time taken to load help menu	
Accuracy	Number of successful tasks	Satisfaction with the accuracy of the functions
	Total time spend on executing the task	
Fault tolerance	Total number of error(s)	
	Number of times application crash	
	Number of times user undo actions that may lead to errors	
	Total time spend on errors by users	
completeness	Time taken to complete a task	
	Total number of tasks to complete a goal	
	Total Number of interactions	
Content		Satisfaction with the content display (images/captioning)
		Satisfaction with multimedia content
		Satisfaction with the touchable menu
		Satisfaction with the usefulness of the app
Aesthetics		Satisfaction with the touch screen input
		Satisfaction on colour and font
		Satisfaction on layout presentation
Simplicity	Time taken to learn using the application	Satisfaction with the navigation structure
	Number of errors while key in data	Satisfaction with help provided
	Time spend while key-in data	
	Total number of times help menu used	
User guide		Easy to revert error (s)
		Satisfaction with the self-explanatory information provided to understand medical jargon*
		Satisfaction with the video help provided*
Confidentiality	Total failed log in attempts for specific user(s)	Satisfaction with username, password style, and format.
	Time spend on successful log-in	Satisfaction with session continues without active user interaction such as time-out.

Integrity	Number of interaction while key in user id and password.	Access denial support.
	Number of authentication check per user such as device and location	
Insurance		Require authentication code for each software update
Operability	Time taken to select a task	Satisfaction with virtual keyboard
	Number of clicks to find call to action button	
	Number of errors during navigation	
	Total number of failed commands	
Presentation		Satisfaction with information organization
		Satisfaction with menu names and icons
		Satisfaction with the text presentation
		Satisfaction with finding content
		Satisfaction with screen optimization

IV. CONCLUSION

This model covers all the usability issues and special needs of CDM applications and integrates those issues in the form of usability dimensions and metrics to design the user-friendly interfaces. A comprehensive review of various usability models, past studies related to mobile health and usability of CDM applications have been done to develop dimensions, criteria, and metrics. The developed metrics can be used as evaluation instruments such as checklists, heuristics, and guidelines. The proposed metrics will help evaluators and usability practitioners to acquire quantitative and qualitative data for evaluating the usability of chronic disease applications. This model can be modified by adding more usability dimensions based on future technological advancements and needs of the user. However, the proposed model needs to be verified and validated by experts. Moreover, Usability testing of any CDM application with a large group of participants in a real-time and controlled environment by using the proposed model is also recommended as a future work.

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