An Enhanced Usability Model for Mobile Health Application

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Abstract- Mobile health applications (mHealth apps) which are currently used for improving human body fitness and overall quality of life are becoming available. Designing and assessing the usability of these tools are major issues as evaluating them normally demands an already finished product that would have been in use for a long period of time. Moreover, evaluating the usability attributes of these apps require substantial efforts from a wide range of knowledge domains and prospective users. Existing usability models possess limited attributes that can be adequately used to assess these apps, hence, the main objective of this work was to design a usability model specifically for mHealth apps assessment. Current evaluation of mHealth apps models based on usability were examined. A model that fully captured usability attributes of mHealth apps was developed based on the Integrated Measurement Model (IMM) and People at the Center of Mobile Application Development (PACMAD) model. Identified attributes which included efficiency, effectiveness, satisfaction, learnability, operability, user interface aesthetics and universality were all broken down into 23 corresponding sub-factors and all these were integrated into the developed model. The applicability of the model was tested using GoogleFit and MyFitnessPal mHealth apps. In conclusion, the usability model presented in this work could help mHealth apps developers make efficient, reliable and valid decisions when it comes to designing and assessing highly usable apps. It is recommended that the study could be extended further by increasing the number of usability attributes in the model and for such attributes to be ranked effectively using adequate mathematical techniques.

Keywords- *Mobile health applications; PACMAD model; IMM model; Usability models.*

I. INTRODUCTION

There has been a proliferation of various mobile platforms for communication. Mobile health applications (mHealth apps) have been attracting a lot of attention from software designers, researchers and users at large, as well. Mobile health applications provide convenient access to a wide range of health information. Thirty one percent (31%) of mobile phone users check health related news with mobile devices, while 20% of smartphone users possess at least one health application downloaded and installed [11]. About half a billion of the population of smart phone users downloaded at least one healthcare app in 2015 and by 2018, fifty percent (50%) of the more than 3.4 billion projected mobile technology users will download mHealth apps with fitness applications accounting for 36% of such downloads [3]. The mHealth application market is almost reaching its saturation point. Developers and vendors are finding it difficult to realize viable achievements in an already congested market [37].

One of the factors for assessing mHealth apps is usability [26]. Evaluating the usability of mobile apps will aid designers to detect usability problems easily and to produce better design solutions [18]. There is the need for increased attention to usability of a product at the developmental stage [24]. A common challenge amongst these apps is that they lack proper usability evaluation [20] as research data on the usability of mHealth apps is scarce and about 95% of mobile apps usability are yet to be evaluated [19]; [38]. Usability construct has been identified as a significant factor to be considered by users and developers of any information systems [12].

Evaluating the usability of any mHealth app requires substantial efforts from a wide range of knowledge domains and prospective users. The focus of this study therefore is to develop a model that can be used to design and evaluate the usability of mHealth apps based on existing usability models.

II. LITERATURE REVIEW

A. Overview of Some Specific Usability Models for mHealth Apps.

Several conceptual frameworks have been proposed to measure usability such as the International Standard Organization (ISO) model which identifies effectiveness, efficiency and satisfaction as the main usability evaluation constructs. Jacob Nielson, a consultant, leading and foremost usability researcher identified five usability evaluation constructs although it is argued that Nielson's usability model constructs are included implicitly in the ISO model and more so, the model was developed mainly for telecommunication systems rather than for computer software. [16] proposed the PACMAD model by integrating the ISO model with Nielson model and added the Cognitive load attribute as depicted in Figure 1.

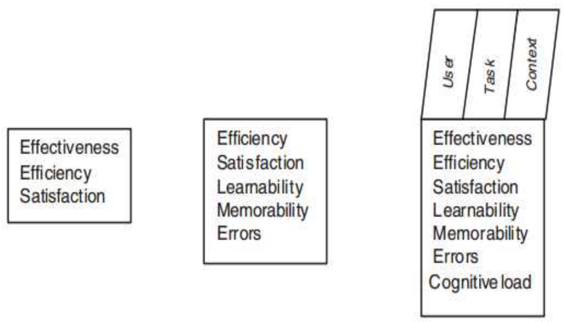

Figure 1: Comparison of Usability Models [16]

[32] tried to improve the PACMAD model by including low level metrics in it. [17] developed the Integrated Measurement Model (IMM) based on the integration of previous models of usability. The main goal of this approach is to be able to notice and identify usability issues at every stage, manage them with fewer usage of resources and also evaluate the usability of a fully developed system as usability measurement has been identified as a difficult task for software developers and researchers. Detailed descriptions of usability factors identified in the IMM model is found in [2]. The IMM is a novel approach at indicating which usability attributes to be considered at every stage of system development although the efficiency of this model is yet to be proven using an original case study.

[6] developed the Health Information Technology Usability Evaluation model (Health-ITUEM) as a result of the dearth of available models that can be used to rigorously evaluate the usability of mHealth applications. The model took advantage of the constructs identified in Technology Acceptance model (TAM), ISO 9241-11 model, Nielsen's ten heuristics, Shneiderman's eight rules for user interface design and Norman's seven principles for design. Other usability attributes in existing usability models are indicated in Table 1.

TABLE 1: USABILITY ATTRIBUTES IDENTIFIED IN OTHER EXISTING MODELS

Author	Usability Attributes Proposed
[25]	Operability, training, communicativeness
[5]	Type of product, type of user, ease of use, acceptability
[35]	Effectiveness, learnability, flexibility, subjectivity, pleasing
[33]	Effectiveness, efficiency, satisfaction, learnability
[29]	Safety, effectiveness, efficiency, enjoyableness,
[27]	Efficiency, satisfaction, learnability, memorability, errors
[30]	efficiency, satisfaction, learnability
[8]	Learnability, flexibility, robustness
[9]	Efficiency, effectiveness, productivity, satisfaction, learnability, safety, trustfulness, accessibility, universality, usefulness
[4]	Modifiability, scalability, reusability, performance, security
[34]	Effectiveness, efficiency, satisfaction, productivity, universality, learnability, accessibility, user error protection
[1]	Knowability, operability, efficiency, robustness, safety, subjective satisfaction
[23]	Effectiveness, efficiency, satisfaction, learnability,
[10]	Effectiveness, efficiency, satisfaction, learnability
[6]	error prevention, completeness, memorability, information needs, flexibility/customizability, learnability, performance speed, competency and other outcomes
[16]	Effectiveness, efficiency, satisfaction, learnability, memorability, errors, cognitive load
[14]	Effectiveness, efficiency, satisfaction, productivity, universality
[17]	universality, learnability, appropriateness recognizability, accessibility, user interface aesthetics, user error protection, efficiency, effectiveness, productivity and satisfaction

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[36]	Understandability, Learnability, Operability, Attractiveness, Usability Compliance
[13]	Efficiency, Effectiveness, Satisfaction, Memorability, Security, Universality, Productivity
[15]	Efficiency, effectiveness, satisfaction, memorability security, universality

It is obvious that quite a number of models exist that can be used to evaluate the usability of different information systems. Different usability techniques exist which can be applied on any of the identified models as seen from literature to evaluate usability of mHealth applications and as also specified in the usability technical report [21]. These techniques are broadly categorized as:

i. Techniques that require active inclusion of users (A)
ii. Techniques that does not require active inclusion of users (B) which are used either when it is not possible to gather usage data due to non-availability of the users or where they provide complementary data and information.

TABLE 2: USABILITY METHODS: TECHNICAL REPORT [21]

Usability Technique	**Users Inclusion**	**Brief description of usability technique**
Users observation	A	This is when a system information is collected in an accurate and organized way based on users' context of use.
Performance-related measurements	A	This is the gathering of performance measurements that can be quantified so as to have a deeper knowledge on the influence of usability related problems.
Critical incidents Analysis	A	This is the logical gathering of certain or uncertain particular usability events.
Questionnaires	A	This is a form of indirect assessment technique that is aimed at gathering users view by using a list of questions. Different types of usability questionnaires are currently available in literature such as the System Usability Scale (SUS) which has 10 questions, Questionnaire for User Interactive Satisfaction (QUIS): 24 questions, Software Usability Measurement Inventory (SUMI): 50 questions, Computer System Usability Questionnaire (CSUQ): 19 questions amongst others.
Interviews	A	This is identical to questionnaires but with more open and accommodating questions. It involves face-to-face interaction with respondents.
Thinking aloud	A	This require users to repeatedly express their views, prospects, reservations and findings about a system under investigation.
Collaborative design and evaluation	A	These are techniques that encourage various stakeholders involved in a system development and usability to all work together to achieve a better product and hence increase its usability.
Creativity methods	A/B	These are techniques that require extracting information about a new product and its features. It is usually a group work and in HCI context, group participants normally comprise of users.
Document-based methods	B	In this technique, a usability expert will critically but objectively analyze systems document and form a proficient opinion about such system under study.
Model-based approaches	B	These techniques make use of models that are developed to give a hypothetical or speculative idea of a systems performance. It allows the usability of a particular product to be predicted.
Expert evaluation	B	This technique relies on expert knowledge to be able to ascertain the usability of a particular product either through experience or other methods.
Automated evaluation	B	This technique makes use of algorithms that are aimed at identifying usability issues based on some criteria or using ergonomic knowledge-based systems that can effectively diagnose the inherent limitations of a product based on some predefined rules.

Table 2 gives a detailed analysis of various methods for usability evaluation and it is observed that most of the methods involve direct users involvement in making decisions about the usability of a particular technology being investigated.

Some recent works in which the usability of mobile apps was evaluated include the research done by [31] who evaluated an app called AAL@MEO using the Post-Study System Usability Questionnaire (PSSUQ) together with International Classification of Functioning based Usability Scale I and II (ICF-US I and ICF-US II). The PSSUQ consists of 19 items aimed at addressing five usability characteristics of a system:

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rapid completion of the task, ease of learning, high quality documentation and online information, functional adequacy and rapid acquisition of productivity. A sample size of 30 female was used for data gathering purpose and results of analysis showed that elderly users have a high degree of satisfaction towards the interaction with the app. Another one is the work done by [39] in which they assessed the usability of myPEEPS mobile, an app for HIV prevention curriculum from both informatics experts and users of the app perspectives. A heuristic evaluation was done using 5 experts and 20 end users which constituted only men. Results of the analysis showed that the mean scores of the overall severity of identified heuristic violations rated by experts ranged from 0.4 to 2.6 (0 = no usability issue to 4.0 = usability catastrophe). End users results showed that all the users successfully completed the tasks given to them based on the developed app and it was concluded that both the experts and users comments would be used to further refine the app in further developments for increased usability.

Observing usability evaluation based on Table 2, [7] ascertained that the model based method yields a more logical, systematic and scientific estimates of usability attributes although it was also affirmed that such approach tends to measure only one component of usability at a time which could lead to limited task applicability. This work tends to approach usability evaluation from a wider perspective, taking numerous attributes into consideration.

III. METHODOLOGY

A. Method to Develop the Hierarchical Model

This section depicts the methods used in identifying relevant usability criteria and sub-criteria that were used in developing the model.

Usability Factors/Attributes Identification

Numerous researchers have come up with different usability models over the years to identify and evaluate factors/attributes that can be used to evaluate specific systems based on the user, the task which the system is intended to perform and the context under which the system is to be used. For the purpose of this study, two usability models were adopted as a result of their integration with other widely known usability models, attention to important system usability evaluation factors during and after system development, mobile context, reasonably recommended metrics for evaluating identified usability factors and level of acceptance and popularity among other usability researchers. [16] proposed the PACMAD model by combining the ISO 9241-11 [22], Nielson's model [28] and added the Cognitive load attribute which directly affects the mobile context in which an application is being used.

The other usability model that was considered is the Integrated Measurement Model (IMM) by [17], which combined different qualitative and quantitative usability constructs from numerous models. The IMM is structured in a way that it identified usability attributes that can be measured during and after system development. The model also simplified the evaluation process by defining various metrics that are suitable for each identified factors. Identified usability factors include satisfaction, efficiency, effectiveness, learnability, operability, universality and user interface aesthetics as illustrated in Table 3.

TABLE 3: USABILITY CRITERIA AND SUB-CRITERIA

Satisfaction (D1)	This is the perceived level of comfort the user experienced through the use of the app.	Comfort (D11)	Measures how comfortable users are when using the app
		Trust (D12)	Measures to which extent users trust the system
		Pleasure (D13)	Measures to which extent users derive pleasure from using the app.
		Usefulness (D14)	Measures how helpful and practical the app is
Efficiency (D2)	Ability of the user to complete their task with speed and accuracy	Task efficiency (D21)	Measures the ratio of the goals which are achieved by users per unit of time
		Time efficiency (D22)	Measures the time required to complete a task compared with the actual time
		Relative task time (D23)	Measures the time users take to complete a specific task and comparing this time with the time it takes an expert to complete the same task
Effectiveness (D3)	Ability of a user to complete a task in a specified context	Task completion (D31)	Measures the ratio of tasks executed and completed

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			correctly
		Task effectiveness (D32)	Measures the ratio of tasks' goals that are achieved correctly
		Error frequency (D33)	Measures the frequency of errors that result from users, and compared it with the target value
Learnability (D4)	This is the ease with which a user can learn how to use an app within a sufficient time.	Time to learn (D41)	Measures the average time the users spend to learn specific functions in the app.
		Memorability (D42)	Measures the average time the users spend to remember over time the steps of using specific functions without the need to relearn them from scratch
		Easy to understand error messages (D43)	Measures to make sure any error message clarifies the cause of the error occurrence and the ways to resolve it
		Completeness of user documentation (D44)	Measures to make sure that all the apps functionalities or any help facilities are complete and correctly described
		Cognitive Load (D45)	This is the amount of reasoning required by the user to use the application
Operability (D5)	This assesses the level at which users can easily operate the app.	Understandable I/O (D51)	Measures the number of app messages that are clearly described and can be easily understood by users
		Message clarity (D52)	Measures the number of app messages that are clearly described and can be easily understood by users
		Operational consistency (D53)	Measures to ensure all the similar app tasks are working in a consistent way
Universality (D6)	This is the app's tendency to accommodate various users with different cultural backgrounds	Cultural universality (D61)	Measures the ability in using the app by those people who have different culture background
		Standard compliance (D62)	Measures to which extent the app is in compliance with the international standards, regarding usability
		Accessibility (D63)	This measures the tendency at which the application can be accessed by different users with various abilities and uniqueness.
User Interface Aesthetics (D7)	This evaluates the users' satisfaction and pleasure with regard to the mobile application user interfaces aesthetics.	Customizability (D71)	Measures the ratio of interface items that can be customized in appearance by users to be convenient for them

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		Attractiveness of user interface (D72)	Measures the extent at which the app is found attractive by its users (e.g. through the interface color)

IV. RESULTS AND DISCUSSION

A. Developed Usability Hierarchical Model

Figure 2 shows the developed model hierarchically consisting of 7 criteria and 23 sub-criteria

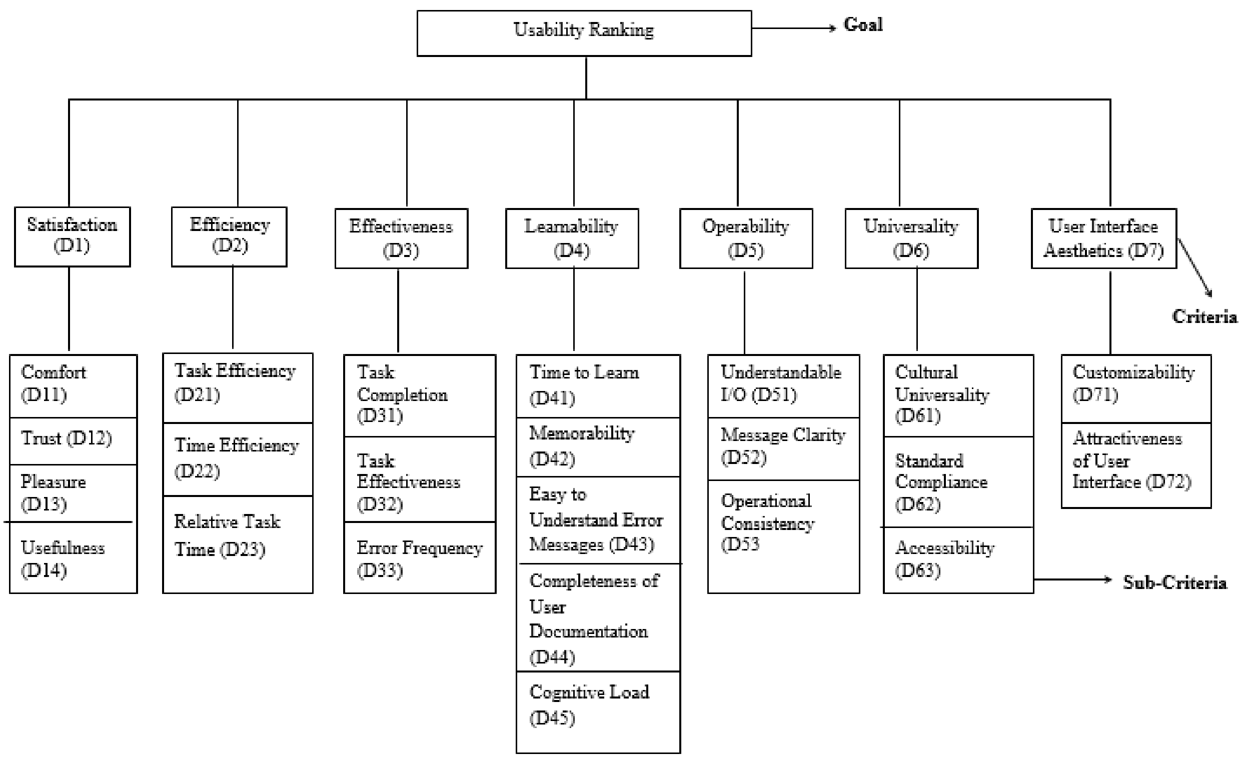

Figure 2: Developed Usability Hierarchical Model

B. Evaluation of the developed model

In other to ensure the validity, effectiveness, applicability and reliability of the developed model, a survey was conducted to assess the usability attributes in the developed usability hierarchical model by using it to compare the usability of 2 fitness apps. Data was gathered from fifteen users that were chosen purposively and randomly. The data was collected quantitatively through the use of a measuring tool that was validated by 4 experts on usability studies. The measuring scales were developed using psychometric scales and the variables consisted of Likert's scale.

The reliability of the measuring instrument was done using Cronbach's alpha reliability coefficient which yielded 0.905 depicting the tool as a highly reliable one. Statistical Software Package (SPSS version 21.0) was used to evaluate the data gotten from the users and descriptive statistics was used to analyze the information gotten from the users who participated in this study.

In designing the measuring tool, some of the usability questions proposed by [32] in their Goal Questions Metrics model (GQM) were also used but on Likert's rating scale. In other for respondents to correctly answer some questions in the tool, the metrics identified in the GQM were used for Efficiency, Effectiveness, Learnability, Memorability, Errors and Cognitive Load attributes.

Two popular mobile health apps were downloaded from google play store based on their level of popularity and high user ratings. The apps used include MyFitnessPal, and Google Fit. The users downloaded the apps on their android smartphones and used them interchangeably for a period of 3 months so as to be able to ascertain their usability level based on the designed measuring instrument. This type of test is known as the field evaluation test to get a more realistic opinion about the apps being evaluated objectively. For the subjective measurement (Satisfaction attribute), some questions were adapted from the IBM Computer System Usability Questionnaire (CSUQ) and these were used to measure users' satisfaction of the apps in the context of use as also used by Saleh et.al., (2015).

C. Result of Analysis

Results of demographic data indicated that 6.7% of the users were less than 25 years old, 40% were 26-35 years old, while 36-45 and 46-55 age range had 26.7 respectively. 46.7% of the users were single while 53.3% were married. 66.7% were male while 33.3% were female. 40% of the users had a doctoral certificate or its equivalent in the industry, 33.3% were masters holders while 26.7% had first degree or its equivalent.

The reason for this is because it was stipulated that users who were to participate in the study should have obtained at least a first degree or its equivalent academically, must possess an android smart phone and the free version of the two apps evaluated were downloaded from Android play store (Google Fit is basically free but the premium version of MyFitnessPal comes with a price). Table 4 and Table 5 give the detailed statistics of the users' gender and age respectively while Table 6 gives the participants statistics.

TABLE 4: GENDER OF RESPONDENTS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	10	66.7	66.7	66.7
	Female	5	33.3	33.3	100.0
	Total	15	100.0	100.0	

TABLE 5: AGE OF RESPONDENTS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	<=25	1	6.7	6.7	6.7
	26-35	6	40.0	40.0	46.7
	36-45	4	26.7	26.7	73.3
	46-55	4	26.7	26.7	100.0
	Total	15	100.0	100.0	

TABLE 6: PARTICIPANTS' STATISTICS

		Gender of Respondents	Age of Respondents	Marital Status of Respondents	Highest Educational Qualification
N	Valid	15	15	15	15
	Missing	0	0	0	0
Mean		1.33	2.73	1.53	3.13
Median		1.00	3.00	2.00	3.00
Mode		1	2	2	4

Table 7 shows the results of the usability hierarchy based on users' response

TABLE 7: USABILITY HIERARCHY RESULTS

Level 0	Level 1	Level 2:	GoogleFit	MyFitnesPal
	D1 G=3.65 M= 3.44	D11	3.90	3.64
		D12	4.03	3.83
		D13	3.57	3.37
		D14	3.10	2.94
	D2	D21	3.67	3.40

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Overall Usability G= 3.43 M= 3.23	G= 3.49 M= 3.22	D22	3.13	2.87
		D23	3.67	3.21
	D3 G= 3.52 M= 3.35	D31	3.40	3.27
		D32	3.57	3.40
		D33	3.54	3.33
	D4 G= 3.38 M= 3.18	D41	3.33	3.14
		D42	3.34	3.10
		D43	3.47	3.27
		D44	3.25	3.12
		D45	3.48	3.24
	D5 G= 3.70 M= 3.43	D51	3.53	3.33
		D52	3.87	3.53
		D53	3.56	3.48
	D6 G= 3.09 M= 2.87	D61:	2.87	2.73
		D62:	3.47	3.20
		D63:	3.00	2.77
	D7 G= 3.04 M= 2.80	D71:	2.67	2.41
		D72:	3.40	3.13

G= GoogleFit M= MyFitnessPal

It is evident from the result of the analysis that GoogleFit has a higher usability value than MyFitnessPal based on all the criteria and sub-criteria evaluated. This is not surprising as some of the participants' confessed to have used GoogleFit before and never heard of MyFitnessPal before the study.

V. DISCUSSION, CONCLUSION AND RECOMMENDATIONS FOR FURTHER STUDIES

In order to design and assess the effectiveness of a mHeath app, the study had proposed a hierarchical usability model with 7 criteria and 23 sub-criteria. Identified factors include efficiency, effectiveness, learnability, satisfaction, user interface aesthetics, operability and universality. These factors were chosen from the PACMAD and Integrated Measurement model as a result of their integration with other widely known usability models, attention to important system usability evaluation factors during and after system development, mobile context and level of acceptance and popularity among other usability researchers.
This research presents a hierarchical model that can be used to effectively assess the usability of persuasive mHealth apps during and after development to minimize developmental resources and for increased usability.

It is recommended that software/apps designers could use the developed model to evaluate the usability of other types of software applications or systems aside mHealth apps to predict and ensure their usability during and after system development to save developmental resources and cost. For further studies, all the attributes in the hierarchical model would be ranked and prioritized using a mathematical model that has the ability to capture both the subjective and objective attributes simultaneously for a reliable and better results. Such model would also be able to capture the inherent ambiguity involved in human decision making process.

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