Mobile Application Software Usability Evaluation: Issues, Methods and Future Research Directions

Blessing Iganya Attah[1] and John Kolo Alhassan[2][0000-0002-9289-0404], Ishaq Oyebisi Oyefolahan[3], Sulaimon Adebayo Bashir4

[1,2,3&4] Federal University of Technology, Minna, Nigeria
blessingiganya@gmail.com
{jkalhassan,o.ishaq,bashirsulaimon}@futminna.edu.ng

Abstract. Recently, the growth and advancement in mobile technology (such as mobile devices, smartphones, mobile wireless networks) have cushioned everyday lives of peoples across the globe. Interestingly, this can be attributed to the greater ease of developing mobile applications for diverse usages such as healthcare, finance, and agriculture. Another reason for this is that, there is the quest to rollout mobile device tailored application software having lower budget, quicker time of delivery, and top-quality product from the developers and the end-user's perspectives. The challenges of appropriate designs frameworks; and the understanding of the needs of users (that is, the end users) have persisted long after their eventual rollouts. The concept of mobile app usability and accessibility evaluation were developed to enable developers to ascertain the level of usages and relevance of mobile applications in-use or prior release under diverse criteria such as maintainability, understandability, comprehensibility, as well as parameters specified by Usability Standards of ISO 9241-11 (that is, effectiveness, efficiency, and satisfaction). This study undertakes a systematic literature review (SLR) to discuss the subject of mobile application software usability under the specific scope of issues, methods and future research directions. To achieve these, a total of forty (40) peer-reviewed articles from diverse databases/sources of records were selected. The outcomes of this study revealed that, mobile applications usability evaluations and processes are domain-specific (or locality-dependent). Also, there are no generic approaches identified or developed for performing usability and accessibility of mobile applications due to the non-deterministic nature of the domain, and context-of-use.

Keywords: Usability, Mobile Application, mobile devices, quality, software product, users, developers.

1   Introduction

Mobile application is type of software application built particularly for use on small and wireless computing devices such as tablets and smartphones [1]. According to estimates for 2020 by [2], mobile applications are projected to produce nearly $189 billion in proceeds from app stores and in-app commercials. The outburst of mobile

apps spans a wide range of industries including media, retail, education, travel, finance, healthcare, and social [1, 3]. This is attributable to the use of mobile apps to deliver services with improved access, high quality, reduced cost, and increased safety. But, the attitudes of users and end-users towards these new technology needs to assessed urgently in order to redress it [3]. Software quality evaluation is an activity targeted at maintaining, managing and controlling a piece of software. The usability evaluation of software has been directly linked to the levels of software usability [4].

Besides, usability attributes are dissimilar, the mobile Apps lay more emphasis on the usage and accessibility when compared to conventional desktop applications. Again, the range of users as well as scope is larger in mobile apps than conventional application. The number of apps developers and builders are on the increase across the globe, but the prospective users continue to diminish over the years owing to several issues to include: proof of product claims unsupportive, behavioral changes, unsupportive of existing media, poor human touches and app features [5].

The International Standard Organization (ISO) established five core characteristics in which every mobile application is built upon including: reliability, usability, portability, maintainability, and accessibility. Ideally, usability relies on what the user wants to do and their goals in the context of the user's action [6]. Usability models for mobile applications are relatively unexplored and unproven, still evolving, isolated or disintegrated [7]. Mobile Apps have huge pervasiveness in e-commerce, financial solutions, and mobile shopping experiences, as well as diverse integration and support for several lifestyle applications such as health, banking, fashion, etc. [8, 9].

This paper investigates the following research questions including:

1. What is the present state of usability evaluation of mobile applications?
2. What usability and accessibility evaluations models or methods are identified in existing studies?
3. What are the problems with usability and accessibility evaluation of mobile applications?
4. What is the future focus of mobile application usability?

The remaining four sections include: literature review, research methodology, results of the study, and conclusion.

2   Literature Review

2.1   The concept of software usability

The quest to create good quality software products is evolving over time in the field of software engineering. A number of factors have been specified in the efforts to ascertain the quality of software products by ISO including: reliability, usability, effectiveness, efficiency, etc. [10]. In general, software products are referred to as top quality after using factors such as functionality, reliability, efficiency, usability, portability, and maintainability. According to study in [4], usability is the most profound quality factors of software products, which are expected to be strictly observed during the developmental phase of software. Usability is coined from the concept of user-

friendliness that is often used among software professionals to explain the ease of use, satisfaction, efficiency and effectiveness, learnability, and remembrance of man-made items such as website, software application, machine, tool, process, book, and any object with capability of interacting with humans. The tasks of conducting usability assessments on software products are performed by usability experts, writers, end-users, marketing personnel, technical writers, designers, etc.

Though, majority of usability models rely largely on the perspectives of end-users with regards to the functionalities and operations of certain parts of the application [8]. According to the study in [11], the context of use is essential for assessing usability of mobile apps, which involves efforts capable of affecting quality of interactions of end-users with the mobile apps [11]. Again, user interface is regarded as key metric of software system, which directly impacts on the subsequent effectiveness. The usability concept is often related to user-friendliness and ease of use of a software system. As a result, the efforts of usability evaluation are geared towards the design of intuitive user interfaces in order to make software system effective, satisfaction, and efficiency by relying on the user's perspective [12, 13, 14]. In fact, the human-computer interaction (HCI) community has evolved several usability concepts including: inspection methods, frameworks, and heuristics approaches for the purpose of improving the understanding, measure and assess usability that targets the eventual delivery high quality software products and software quality assurances [9, 15]. The benefits of usability evaluation include [9, 8, 11, 16, 17]:

1. To enable better human computer interaction in which end-users of a software product have ease communicating and utilizing the functions of software systems.
2. To promote loyalty and acceptance of customers and Apps respectively.
3. To evolve better versions of mobile Apps and experience of end-users.
4. To improve on the sales and usages of the mobile Apps.
5. To report bugs and areas of negative concerns.
6. To enable HCI practitioners to concentrate on the basic components of software, this can be problematic for end-users.
7. To enhance the software quality assurances for present and future projects.
8. To create online business opportunity for marketers and consumers.

The common usability standards consider software systems [1, 18]; software product [10, 18, 19]; and service and information systems [20, 21]. These standards provide guidelines for developing systems and application software for optimal user experience and continuous relevance of the software product for both desktop and mobile platforms. The process and practice of software usability evaluation models were derived from basic attributes defined by the ISO 1924-11 standards for conducting usability evaluations of mobile applications similar to desktop applications. The metrics focus on the users' experiences [4] the developers and external experts [11, 13] to measure the successes or failures during usage or prior releases. Msweli & Mawela in [16] identified usability enablers of financial mobile apps to include: Perceived value, perceived ease of use, convenience, and consumer attitudes. The barriers are trust, privacy, security, personalization, and technical knowledge of users.

2.2   Mapping Studies

The mobile applications usability testing and evaluation ensure the effectiveness on the users' perceptive with regards to satisfactions of the running application. it affords users the capability to identify and address issues during the course of the developmental processes [22]. The majority of the studies surveyed cover healthcare and related mobile apps [22, 23, 24, 25]. While, few of the mapping articles discussed usability characteristics under general scope including the mobile websites and apps, mobile computing [12], software development, and mobile software development [26, 27, 28].

Weichbroth [1] identified the most widespread usability attributes including: efficiency, satisfaction, effectiveness (adapted from usability definition of ISO 924-11); fewer occurring attributes were learnability, memorability, cognitive load, errors; and least occurring attributes are simplicity, and ease of use.

The concepts of eWOM and UX provide valuable information for the purpose of evaluating the usability of mobile apps using a number of criteria [29]. Mixed methods usability approaches were adopted to guarantee software quality assurances of the present and future projects in a more reliable and valuable manner [9]. Jha et al. in [30] identified software maintainability as a performance or usability attribute of software product, which can be adopted for mobile apps developments. Recently, the deep learning approaches have found to hold great potentials in accurately and autonomously predicting maintainability of software. A study in by Msweli and Mawela [16], key enablers for financial mobile apps usability were found to include: satisfaction, usefulness, attitude, accessible, suitable, understanding, familiarity, easy to use, prior experience and user-friendliness.

2.3   Justification for the New Study

The justification for the new study is generated from the connected papers prior and derivative works graph built indicating the influence and connection is shown in Fig. 1.

The distinctions between connected papers or articles and the new study in terms of author(s), title of article, type of article, period of study, and category of work are presented in the Table 1.

Fig. 1. Towards usability evaluation of hybrid mobile user interfaces [14].

Table 1. The differences between connected papers and studies to the new study.

S/No.	Author(s)	Title of the article	Type of article	Period of study	Category of study
1.	[1]	Usability of Mobile Applications: A Systematic Literature Study	SLR	1990-2018	Derivative work
2.	[16]	Enablers and Barriers for Mobile Commerce and Banking Services Among the Elderly in Developing Countries: A Systematic Review	SLR	2009-2019	Derivative work
3.	[9]	A mixed-methods measurement and evaluation methodology for mobile application usability studies	SLR	1992-2018	Derivative work
4.	[31]	Set of Usability Heuristics for Quality Assessment of Mobile Applications on Smartphones	SLR	1932-2018	Prior work
5.	[32]	A Systematic Literature Review: Opinion Mining Studies from Mobile App Store User Reviews	SLR	2000-2015	Prior work

In Table 1, the new study covers the period from between 2019-2020, which is not reviewed in the prior and derivative works obtainable. This provides the justification for a new study in the subject area uncovered by previous studies.

3   Research Methodology

This study presents a systematic literature review on peer reviewed and published journals using comprehensive searches of record sources/databases. A total of fifty-two (52) papers out of the initial search of 1550 were identified to have direct answers to the questions of usability and assessments of mobile applications usability and accessibility, models for conducting mobile application usability and accessibility, and research areas of mobile application in the future time. This study is to provide answers to the following research questions (RQ):

RQ1. What is the present state of usability evaluation of mobile applications?
RQ2. What usability and accessibility evaluations models or methods are identified in existing studies?
RQ3. What are the problems with usability and accessibility evaluation of mobile applications?
RQ4. What is the future focus of mobile applications usability?

The purpose of the Systematic Literature Review (SLR) is to orderly chart the concise phases of the proposed research. The method including Planning and specifying research questions, conducting the review (that is, an identification of search string and data sources, selecting studies, quality assessment, and data extraction and finally reporting the review [28]. In order to achieve this, the preferred reporting item as reported by [28] was adopted. The review procedure adopted the Preferred Reporting Items for SLRs and Meta-Analyses (PRISMA) statement [33] in conjunction with the standard guidelines for conducting computer science SLRs by [34] as illustrated in Fig. 2.
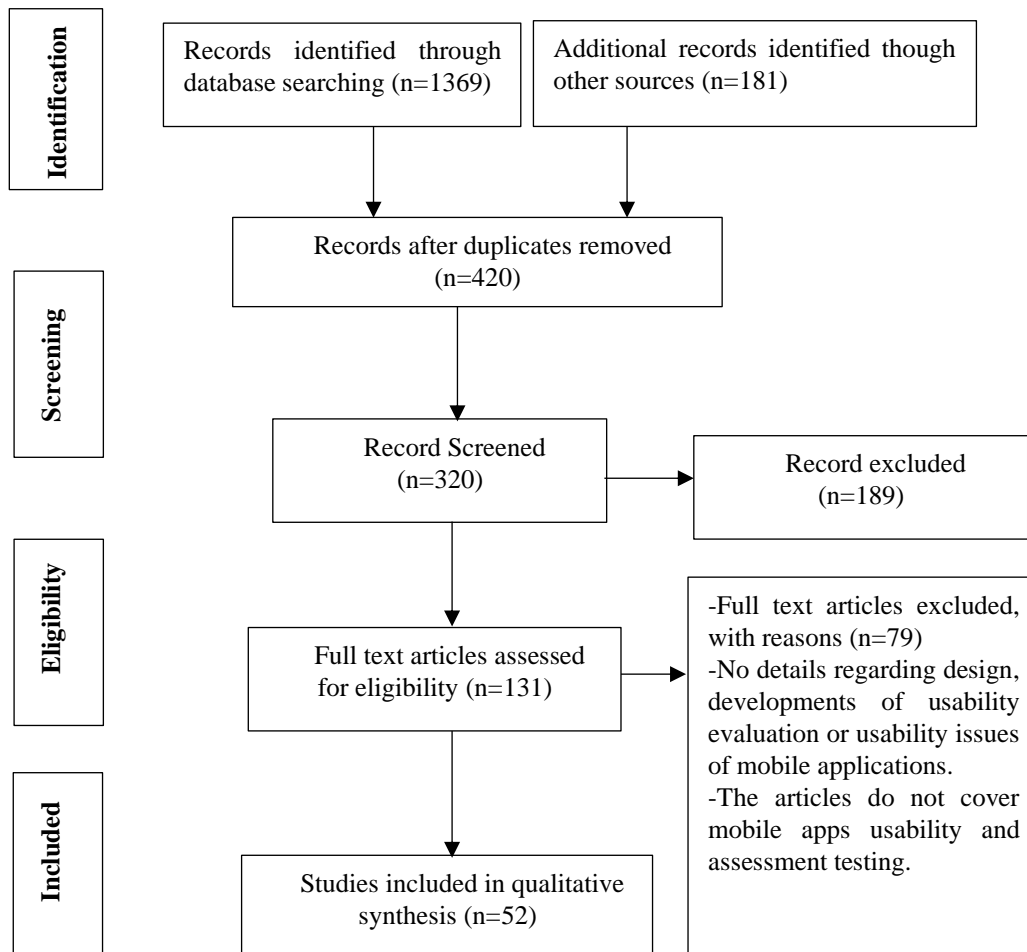
Fig. 2. The process of study using Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).

From Fig 2, the item selection was divided into phases with associated criteria as shown in Table 2. The Identification phase collected 1550 peer-reviewed from different database listed in Table 4 and other sources. The screening phase used 420 articles for identifying and removing of duplicate from previous phase to arrive at 320 screened articles. Eligibility phase considered 131 eligible articles and excluded 79 due to no details regarding design, development of usability evaluation or usability issues of

mobile apps. The articles do not cover mobile apps usability and assessment testing. The last phase is the Included phase that provided items or articles included in the qualitative synthesis of the new study.

The inclusion and exclusion criteria include all published peer reviewed articles from five major criteria established for this study as indicated in Table 2.

Table 2. Criteria Inclusion and Selection and Matching Justification.

S./No	Criteria	Justification for Inclusion/Exclusion in the Study
1.	Titles of articles	To investigate and eliminate studies unrelated to the present area of research.
2.	Abstract and keywords	To review abstract and keywords in studies from above step to ensure information provided is relevant to the study.
3.	Clearly stated findings to the research questions set for the study	The primary studies offer analysis of mobile apps trends, methods, issues and future directions.
4.	Reference list	To cross-check the reference list of the mapping studies to find supplementary studies relevant to the records searches.
5.	Language of articles	To review articles written in English, that is, authors' language of communication for the study.
6.	Peer-reviewed articles	To review articles such as presentations, blog posts, books, journals, conference papers.

Data extraction is concerned with opinion mining for search strings for the distinct research questions RQ1, RQ2, RQ3, and RQ4. The information synthesis took account of the findings and methods, repetition, contradictions, and inconsistencies. The main criteria for data extraction process include:

1. The studied details of the first author, country and type of article.
2. Description of the methods for mobile application usability and accessibility.
3. Application areas of mobile applications and prospects in real world.
4. The issues and gaps of usability and accessibility of mobile apps.

This study generated diverse data from various records sources including: ResearchGate, Clarivate WoS, SpringerLink, ACM Digital Library, AISeL, ScienceDirect, Google Scholar, Connected Papers, and Semantic Scholars. The different records included in this study are generated from distinct word/phrases or keyword search using the criteria of keyword, year, article title, abstract and subject area as presented in Table 3.

Table 3. Records word/phrases/keyword or search strings.

S./No	Subject area	Search string
1.	Mobile applications	((mobile apps) OR (mobile applications))
2.	Software development	((software application) OR (software lifecycle) OR (software development))
3.	Usability evaluation	((definition of usability) OR (standards for usability evaluation) OR (usability assessment techniques))

4.	Accessibility	((mobile accessibility techniques) OR (methods of mobile accessibility))
5.	Financial mobile apps	((what is financial mobile apps, what are problems of financial mobile apps?) OR (Issues of financial mobile apps usability) OR (issues of financial mobile apps accessibility))
6.	Usability Methods	((methodology of usability and accessibility evaluations) OR (trends in usability evaluations) OR (main usability evaluation methods))

This study generated diverse data from various records and corresponding URL addresses are under-listed in Table 4.

Table 4. Record sources and databases

S/No.	Source/Database of Articles	URL address
1.	ResearchGate	https://www.researchgate.net/
2.	Clarivate WoS	http://wokinfo.com/
3.	SpringerLink	https://link.springer.com/
4.	ACM Digital Library	https://dl.acm.org/
5.	AISeL	https://aisel.aisnet.org/
6.	ScienceDirect	https://www.sciencedirect.com/
7.	Google Scholar	https://scholar.google.com/
8.	Connected papers	https://www.connectedpapers.com/
9.	Semantic scholars	https://www.semanticscholar.org/

4   Results of the Study

4.1   Present State of Mobile Application Usability Evaluation

This subsection answers the RQ1 which reveals the popularity of concept of usability evaluations researches over the period under review as shown in Fig. 3.
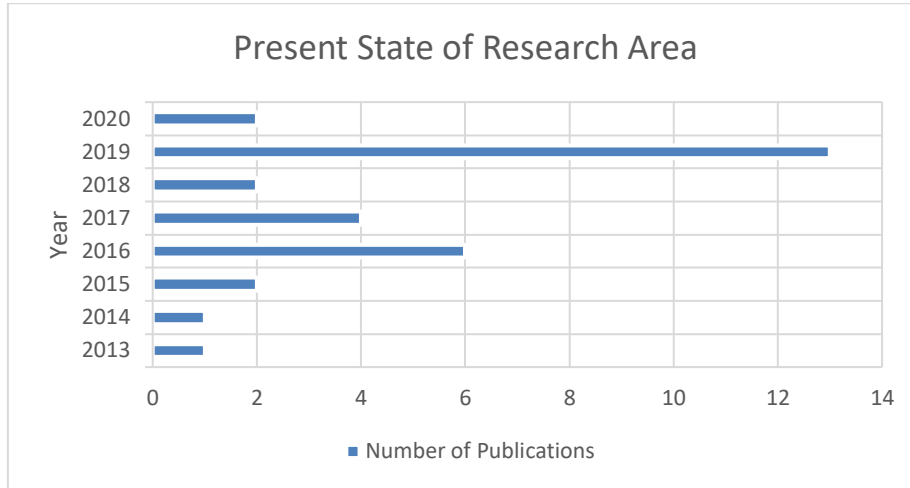
Fig. 3. Current position of research area on the included studies.

From Fig. 3, the popularity of the concept of usability evaluations of mobile apps is most in year 2019 due to the growth of mobile computing and technology. The studies are still evolving especially in the current of review or study in which more studies are expected by end of the year after ease of lockdowns.

4.2 Usability and Accessibility Evaluation Methods

This study found a list of the usability models measures for the categories of mobile apps as presented in Table 5.

Table 5. The usability and accessibility evaluation models.

S./No	Author(s)	Category	Methods
1.	[3, 9, 24, 27, 29, 35, 42]	Product	ISO 9241-11 and SIO/IEC 25010 usability guidelines, Product usability guidelines, Use case point, Mobile Apps user development model, Mobile Apps Rating Scale (MARS), Accessibility evaluation and reporting using visualisation of bugs identified in the source code, Electronic word of mouth (eWoM), Mixed-methods methodology for mobile application usability measurement (3M$MAUME).
2.	[23, 36]	Expert	5-Point Likert scale, Maintainability Index (MI) model, Expert evaluation of usability and accessibility.
3.	[22, 25, 39]	User	Classical Test Theory (CTT), Agile model of user experience, Frame mode using questionnaire, Machine learning models for user behavioural traits of interactions, Mobile Apps user ratings with a 5-star scale, Automatic and manual/visual analytical tools for user experience of mobile app, Affect-Behaviour-

			Cognition (ABC) model, User dimension-based usability testing; SUS to assess the experience of user.
4.	[26, 30, 32, 40]	Heuristic	People at the Centre of Mobile Application Development (PACMAD), PACMAD UE framework, App store spam review detection, Hybrid of Experience Sampling Method and logging methods, Extending usability Heuristics for smartphone apps, Deep learning for software maintainability metric prediction, Cognitive walkthrough and Heuristic evaluation/expert reviews.

From Table 5, the methods for evaluating usability and accessibility of mobile apps are broadly categorized into four with associated models/techniques/methods. These include: product, user, expert and Heuristic, which answers the RQ2.

4.3   Problems of Usability and Accessibility Evaluation of Mobile Applications

The main challenges facing usability evaluation processes for three categories of mobile apps (namely: native apps, web apps and hybrid apps) are presented in Table 6.

Table 6. The challenges identified with usability and accessibility of mobile applications.

S./No	Author(s)	Specific issues
1.	[3, 28, 35, 36]	No formal model or technique for usability testing. Subjective appraisal-based model.
2.	[23, 26, 42]	Omission of usability on the part of the developers on the part of the benefactors.
3.	[9, 14, 16]	Compatibility of mobile platforms and user interface designs arising from bugs, errors, designs and performance.
4.	[1, 9, 24]	Majority of models targeted at user experience contexts such as product quality, user beliefs, preferences, and emotions. There is little on developers.
5.	[22, 38, 39, 40]	Metrics/methods are incomprehensive and unreflective of user experience and behaviours towards Apps due to poor communication and large budgets incurred during tests.
6.	[25, 30]	Non-compliance with standards such as WCAG 2.1 due to difficulty in choosing relevant metrics.
7.	[16, 30]	Trust, security, digital literacy, access to electronic services, complicated menu, fears and privacy.

From Table 6, the main issues militating against the practice of usability and accessibility evaluation of mobile apps include: perception of users, metrics/parameters inadequacies, over-reliance on user experience alone, omission of developers or benefactors in the process, product compatibility, lack of well-defined model or technique for conducting tests and the subjective appraisal approach deployed by many usability evaluations. These provided the answers to the RQ3.

4.4 Future Focus of Mobile Applications Usability Evaluations

This subsection explained the answer to the RQ4. Recently, models of usability assessments for mobiles apps favor the autonomous and self-regulated approaches rather than the traditional or manual approaches for effectiveness of process. Hence, new research works must consider new measuring attributes concerning users' interactive and behavioral characteristics (user logs and interactions with mobile apps). Again, new studies should create new parameters and design usability evaluation model, which are dynamic, automated and comprehensive (machine learning supportive) for increased usability evaluation of mobile applications [42, 43].

Developing usable application software remains daunting challenges because of peculiarity of conditions of environment, networks, sizes and controls. Then, there is need to establish a common ground for the theory and practice of mobile applications usability assessments [1]. There is need to consider mixed methods of usability evaluation in order to enhance obtainable software quality assurance schemes [9].

There is need to perform usability evaluation on more mobile apps especially within their local contexts [43]. And, the usability heuristic should be developed for domain-specific situation in order to effectively detect issues in the user interfaces and functionality [36]. A study on financial mobile applications among adult population shows drastically poor usages and adoption. This is expected to be redressed to benefit maximally from the potentials of mobile applications [16].

5   Conclusion

This paper found that, the general usability of mobile applications depends on the continuous users' feedbacks, which are valuable for designers in adjusting the product for the purpose of accommodating user's behavioral issues. Shah et al. in [24] argued that usability evaluation or measures must take into account user behavior issues, motivation retention to unceasingly utilize mobile applications through the provision of the right and optimal services.

The usability and accessibility of mobile applications approaches cover diverse user experiences which are inconsistent with the present-day reality. Actors such as designers/developers and external usability experts are tremendously valuable, which has led to new kinds of approaches to enable appropriate estimation of usability before release of system or software products.

Usability evaluation of software product or system increases its quality assurances, and improved user experiences. However, there is no consensus on the generic usability measurement method for mobile apps. Therefore, a number of usability methods are developed from prior techniques or for domain-specific. The next generation of usability techniques must leverage on the user behaviors by adopting advanced machine learning or modeling models [30] for faster, accurate and appropriate outcomes.

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2

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