Research Article

Towards Understanding the Usability Attributes of AI-Enabled eHealth Mobile Applications

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Mobile application (app) use is increasingly becoming an essential part of our daily lives. Due to their significant usefulness, people rely on them to perform multiple tasks seamlessly in almost all aspects of everyday life. Similarly, there has been immense progress in artificial intelligence (AI) technology, especially deep learning, computer vision, natural language processing, and robotics. These technologies are now actively being implemented in smartphone apps and healthcare, providing multiple healthcare services. However, several factors affect the usefulness of mobile healthcare apps, and usability is an important one. There are various healthcare apps developed for each specific task, and the success of these apps depends on their performance. This study presents a systematic review of the existing apps and discusses their usability attributes. It highlights the usability models, outlines, and guidelines proposed in previous research for designing apps with improved usability characteristics. Thirty-nine research articles were reviewed and examined to identify the usability attributes, framework, and app design conducted. The results showed that satisfaction, efficiency, and learnability are the most important usability attributes to consider when designing eHealth mobile apps. Surprisingly, other significant attributes for healthcare apps, such as privacy and security, were not among the most indicated attributes in the studies.

1. Introduction

The recent exponential advancement in technology has ushered in a new era of artificial intelligence- (AI-) enabled mobile applications (apps) that are used globally by people from all walks of life. AI is increasingly becoming a significant part of people's everyday lives [1, 2]. The global adoption of smartphones and tablets has led to widespread use of AI in mobile applications ranging from healthcare systems to finance to entertainment [3]. Healthcare patients are the most important recipients and users of AI-based applications; therefore, they should be ensured that using AI in the context of healthcare will not harm them but, rather, benefit them [4]. Therefore, AI systems should be effective and efficient and capable of providing patient satisfaction in multiple healthcare environments [5].

Usability is the scope to which software technology has a user-friendly interface and how easily the end users can effectively use the interface [6–8]. User satisfaction, convenience, efficiency, effectiveness, and learnability are some of the most common attributes considered when defining usability. For researchers or clinicians whose work focuses on those populations, usability testing unique to that population might be especially useful [9–11]. One of the most significant barriers to mobile application adoption is usability. Examining the usability of mobile health (mHealth) apps can expose issues, aid in system redesign, save time and money, and boost users' willingness to use them [12]. New health IT interoperability efforts are concentrating on a few well-defined application programming interfaces (APIs) [5]. However, more advanced applications are being developed with little end-user feedback and continue to grow with little

user participation in terms of usability. Usability evaluations must focus on user experience evaluation, which includes user emotions, values, and motives [13]. When poor-quality applications are shared, they can be hard to use or easily misused, eventually failing to fulfill their intended purpose. The conventional usability guiding principle used in desktop applications is not very much pertinent to mobile apps. Mobile app usability attributes are distinct. It is essential to identify usability attributes that are vital and essential. Therefore, evaluating the usability of an app will assist designers and developers to identify usability problems and presenting better design solutions. [8, 14]. This study investigates the literature on the usability attributes of various AI-enabled mobile applications and evaluates the findings, analysing the most recent and significant usability qualities that have emerged from the research. As such, the study seeks to contribute to future guidelines for developing AI-enabled mobile applications using evidence-based essential usability attributes.

The rest of this paper is organised as follows: Section 2 discusses the performance attributes of various eHealth apps, Section 3 details the data collection process, and Section 4 presents the outcomes of the research, followed by a conclusion in Section 5.

2. Selected Literature

AI software and devices have the ability to automatically learn from real-world environments and can improve in performance over time [12, 15]. This characteristic of AI software distinguishes it from other software used in healthcare and presents novel monitoring challenges. It is an objective of governing authorities, health services, and health practitioners to deliver safe and quality healthcare apps to patients [16–19]. Algorithmic decision making is inscrutable, involves continuous updates with use, and requires specific policies and guidelines [20].

The key challenge in the eHealth applications domain is accurately handling the input, analysis, and application of patient eHealth data [21–24]. In the future, the great amount of eHealth information produced and collected will need a sharp adaptation on the health organisations to the new technologies and their development. To provide a solution to these points, it is believed that the AI methods, applied in a convenient way to the eHealth data collected, would be a fascinating and convenient option [25, 26]. The aim of an AI-based eHealth application is to develop a healthcare system strengthened by a series of approaches based on the mining of knowledge accumulated in the large amount of data that the system generates about the patients [27].

In an AI-enabled eHealth system, data collected by wearable sensors and devices can be conveniently treated to be sent and integrated into the patient's medical history, which is stored in the hospital's server system or computing cloud [28, 29]. Moreover, data related to electronic prescriptions can provide medical experts privileged information about the patient's condition and health status [30].

AI-based eHealth applications aim to integrate knowledge about a given disease into an algorithmic set. After the learning process of the eHealth system is completed, it can be generalised to all those cases that it has never analysed before [31–35]. This knowledge is extracted from the analysis of the corresponding data and is accumulated during the learning process. Depending on the type and quantity of treated data, the learning of AI-based eHealth applications is divided into supervised, nonsupervised, and semisupervised applications [36–38]. Table 1 provides a summary of articles investigating AI-enabled mobile apps' usability published between 2015 and March 2021. These systems are categorised on the basis of different attributes, such as effectiveness, efficiency, attractiveness, learnability, size, cost, and ease of use.

3. Data Extraction and Categorisation

A comprehensive examination of peer-reviewed studies was conducted to evaluate the usability and attributes of AI-enabled mobile applications. To identify the relevant studies, we conducted searches on Google Scholar, JSTOR, PubMed, and ResearchGate. We only included articles published after 2015. The search results were compiled from the first five pages of each database. We used the terminology in Table 2 to search for articles on the usability attributes of AI-enabled mobile applications filtered by the title and abstract. These articles were sorted to include all related terms whose search results could provide articles relevant to this topic.

We also conducted an all-encompassing poll on app usability to identify the critical features mentioned in these studies. In the database record, 213 relevant research articles were identified by the search engine; 117 duplicate records were eliminated, and 96 unique publications were selected. Of these 96 articles, 64 were accessible in full text and were downloaded. On the basis of quantitative analysis, 39 peer-reviewed and published articles were highlighted and included in the review (Figure 1).

4. Results and Discussion

In this section, the discussion is divided into four main themes: the usability attributes within AI-enabled mobile apps in general, the specific attributes of eHealth mobile apps, data security and privacy in eHealth mobile apps, and AI in mobile health apps.

4.1. AI-Enabled Mobile Apps. The development of novel applications, new technologies, and huge investment in AI applications can be seen every day. AI has assisted health risk identification and fast patient diagnosis in hospitals, in the form of AI apps executing at a smartphone or computer unit, separating healthy and unhealthy people. AI will replace healthcare workers to avoid disease infection. Caregiver robots will mimic the behaviours of healthcare workers in performing basic housekeeping operations. The usability of mobile health apps is an evolving area of research because of the widespread use of mobile systems all over the world. Mobile healthcare app development is a difficult task because each app has its own specific function and each individual patient has different requirements and expectations from the apps. There are numerous health apps available for each purpose, and the

TABLE 1: Details of articles investigating the usability of AI-enabled mobile apps published between 2015 and March 2021.

Studies (years)	Usability attributes	Summary
[15–19] (2015)	Efficiency Attractiveness Learnability Operability Satisfaction	These studies illustrate the validity and efficiency of a healthcare mobile app assessment method. The assessment methods developed and tested are suitable and widely available tools for measuring the reliability and utility of healthcare smartphone applications
[20–26] (2016)	Size Visibility Comprehensibility of buttons and symbols	In these studies, eHealth applications are developed for diabetes, weight loss, HIV, and CVD. They examine factors that influence the usability of mobile applications to determine which mobile machines are excellent and which usability characteristics are highly significant
[10, 27–35] (2017-2018)	Learnability Efficiency	In these articles, the learnability and efficiency of Challenger app, fitness app, mobile learning apps, the MoomMae app, and new mobile apps are discussed
[36–42] (2019)	User star ratings Privacy policy Ability to delete data Costs	These studies look at characteristics of common mobile health apps and methods such as iterative convergent and hierarchical usability methods. Moreover, usability of different mobile health apps was also examined
[43–47] (2020)	Ease of use Acceptability	These studies compared content with the targeted users to assess ease of use and acceptability of mobile health apps using a rating scale
[48–52] (2021)	Efficiency Learning Satisfaction	These articles examined efficiency and offered developers some guidance on the consumer criteria that must be addressed when creating cardiopulmonary resuscitation (CPR) support applications by assessing the CprPrototype app and discussed how different authentication structures are meant to enhance security

TABLE 2: Keywords that were considered to describe the usability of mobile applications.

Keywords used to search the databases
Mobile Devices OR Mobile Phones OR Smartphone
Applications OR Apps
Usability
Mobile Application/App Usability
App Usability Attributes

success of the apps depends on their usefulness. Most of the studies included in this review assessed the usability attributes of mHealth apps in meeting their end-user demands. Some studies tested the usability attributes of a single application, while others compared various mobile applications with an emphasis on certain attributes. The major purpose of this study is to identify the user's satisfaction, learnability, and memorability, on this mobile app. We also evaluated other attributes such as efficiency, effectiveness, and usefulness. Figure 2 shows the modal distribution of the various usability attributes of the mobile apps examined in the included studies. Satisfaction was the most frequently occurring attribute (22 times). The user's satisfaction analysis shows that the respondents were highly contented with the mobile apps, followed by efficiency which occurred 18 times. Next to satisfaction and efficiency, the learnability was encountered 14 times. Learnability denotes how easy it is for the user to learn to use the app and its features. Likewise, the effectiveness was counted 12 times, errors 10 times, memorability 10 times, and usefulness 6 times. The next were operability, flexibility, and consistency (5 times each); privacy, acceptability, understandability, and simplicity (4 times each); accuracy, interactivity, aesthetics, and universality (2 times each); and reliability and objectivity (1 time each).

4.2. eHealth Mobile Apps. Many AI-based eHealth applications are based on machine learning models that decode the meaning and behaviour behind sensors' data and implement accurate predictions about the health status of patients. In eHealth application development, machine learning provides a wide-ranging solution of the AI mechanism to provide a widespread approach to solve health issues. The algorithms of AI are based on incessant learning mechanisms so that the user can get a better experience. Machine learning supports mobile applications to predict the same pattern entered by the user, and it constantly relies on those patterns. Machine learning techniques can increase the organization of the data generated by the eHealth activity, allowing taking more improved decisions on the treatment and supervision of the patients. Deploying machine learning in eHealth applications improves performance. Findings in this study suggest that, with the rapid growth of the number of eHealth applications, the number of studies that report usability testing findings in eHealth app development is also increasing.

Figure 3 shows the various usability attributes that focus on eHealth applications. Satisfaction was again the most frequent attribute, encountered 15 times, followed by efficiency (11 times). The next were learnability and errors (9 times each); effectiveness (7 times) and operability (6 times); memorability, usefulness, flexibility, consistency, and understandability (5 times); privacy and acceptability (4 times); simplicity, interactivity, and aesthetics (3 times); accuracy and universality (2 times); and reliability and objectivity (1 time).
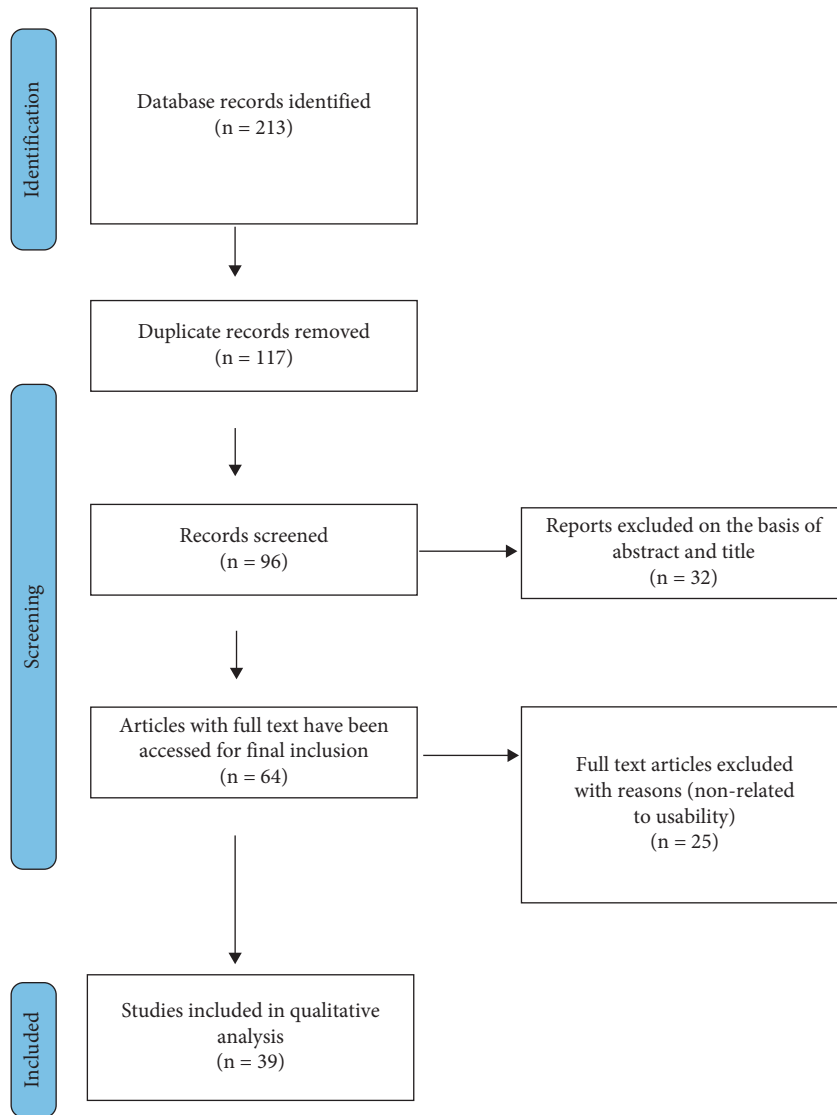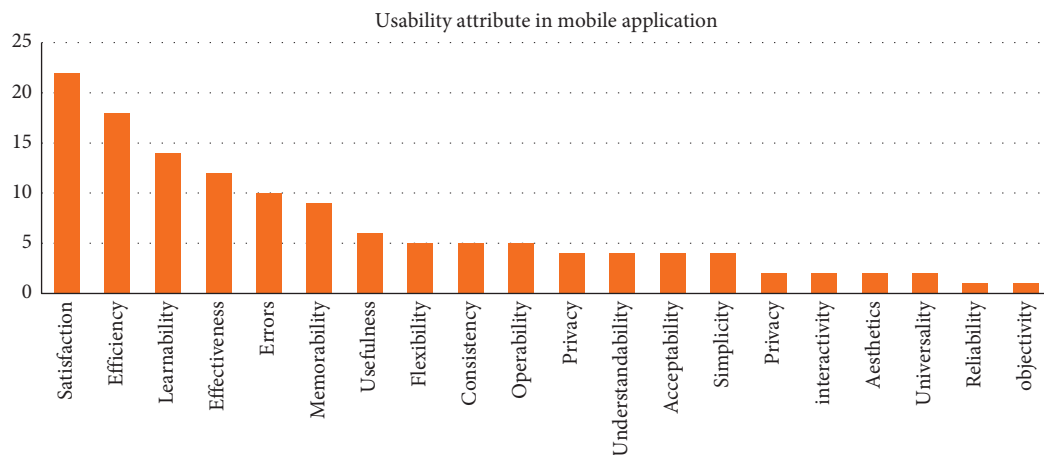
FIGURE 1: PRISMA flow diagram for this study.

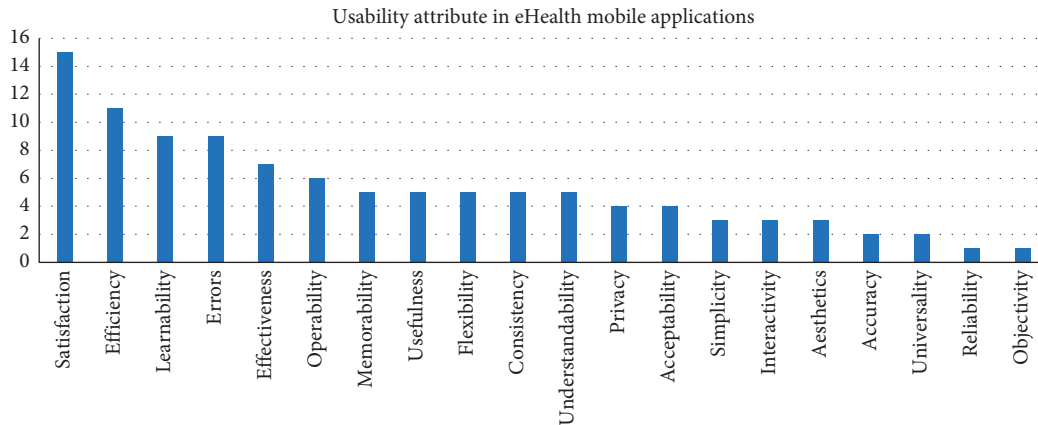FIGURE 2: Most mentioned usability attributes of AI-enabled mobile apps.

FIGURE 3: Most mentioned usability attributes of AI-enabled mobile apps in eHealth.

This shows that, in order to further enhance the capabilities of mobile eHealth applications, it is essential to enhance the accuracy and reliability of the eHealth applications.

4.3. eHealth Mobile Apps' Data Privacy and Security.

The eHealth services can enhance individuals' self-management, performing lifestyle-related events, and decision making, to keep good health, or to decrease the influence of illness on their health. Developments in information and communication technologies provide the potential to increase many aspects of recent healthcare services. The employment of electronic health records systems is an essential part of an eHealth system. Regardless of the potential improvements, there are few complications that restrict the widespread use of eHealth apps. Among these are the apparent threats to the security and privacy of patients' data and a generally held faith that these cannot be sufficiently addressed. It was found that privacy is an important usability attribute, especially for mobile health apps. However, it was only mentioned in four out of the 39 studies. Therefore, this is a critical issue, especially when dealing with patients' sensitive electronic health data. It is essential to implement privacy in eHealth apps, especially those that store patient information. Privacy is a major concern in the health sector [53]. Data privacy defines who can access information, whereas data protection provides tools and policies to enhance data [54]. Data and information apply to personal data or information to health information and other identifiable contact information. It is recommended that the app should include a clear privacy policy that outlines the reasons data are being gathered, permissions and privacy statements, and required information about the app's developers. The app's privacy policy may be found in the settings menu, which can be accessed through the app.

Security is also important in the context of eHealth apps; however, in the 39 studies, it was only mentioned once. Like privacy, security has singular importance, especially in health applications that store patients' electronic health records. The security of health status information is an individual's right to control the acquisition, loss, usage, or exposure of health data. Confidentiality refers to the responsibilities of those who obtain information to protect the privacy interests of those to whom the data are related. Security is different. It refers to the physical and technological tools used to protect recognizable health data from unauthorized access or disclosure.

Mobile health app security is a method of safeguarding software from external attacks, unauthorized access, or viruses, such as Trojan horses and malware, which can uncover sensitive personal information to hackers. Data security and privacy in mobile health apps are correlated. When mobile apps store insecure data, data breaches are possible. However, securing the data that mobile health apps collect from patients promotes confidentiality and data integrity [55]. Therefore, data security facilitates data privacy in mobile health apps.

4.4. AI in Mobile Health Apps.

AI-based healthcare apps are a great way to help with health management. Many aspects of healthcare are being transformed by AI, including diagnostics, medication, and follow-ups [56]. AI and machine learning are expected to play significant roles in developing mHealth apps, perform additional general practitioner (GP) duties, and exhibit a greater number of their characteristics [57]. AI can aid in the development of intelligent interactive eHealth systems that can engage users and develop meaningful and healthy connections with them over time [58]. AI processes real-time information and learns through continuously processing information, thus building its understanding. AI in mobile health apps is an invaluable tool [59]. It employs machine learning components to handle big data and assist medical professionals in performing other tasks. AI in healthcare apps means using large amounts of data via AI-driven tools such as machine learning algorithms to complete particular tasks automatically and create more effective remote healthcare operations and delivery outcomes. These outcomes help in successful patient recovery, nursing, positive drug research outcomes, and assistance in administrative tasks. Consequently, patients can access medical services in their homes and can play an effective role in their treatments. Mobile healthcare apps handle vast amounts of data. AI uses algorithms to process large volumes of data and automate tasks. Automation of tasks promotes

efficiency in remote healthcare operations. Thus, it facilitates patient monitoring, successful patient recovery, and assistance in administrative tasks. According to the work in [60], AI can perform critical healthcare tasks even better than humans. AI cuts the cost of implementing healthcare apps. Mobile health apps have the ability to cut costs [61]. AI can change the healthcare delivery model into a proactive approach. The change of the healthcare delivery model enables medical professionals to focus less on disease control and more on healthcare management and prevention, thus reducing treatment costs and the number of hospitalisations.

5. Conclusions

Mobile apps, including mHealth apps, have become pervasive. After developing a mobile health application, it is crucial to evaluate its usability prior to releasing it to the public. In this study, a detailed review of the usability attributes of AI-enabled health applications was presented. This study demonstrated the various usability attributes that end users want in AI-enabled mobile applications. According to this review's findings, satisfaction is the most frequently encountered usability attribute, followed by efficiency, learnability, errors, and effectiveness in mobile health apps. Other important usability attributes in mHealth apps, such as privacy and security, were unexpectedly absent from the list of the most often cited attributes. Most studies, however, used only questionnaires and interviews rather than automated evaluation tools to assess applications. Using automated, scientific, and systematic approaches will encourage the use of evidence-based frameworks for future usability studies on the development of mobile applications. Therefore, it will be difficult for designers to incorporate all these attributes into one mobile app. Future work should focus on finding a way to include a reusable requirement catalogue for app developers for the minimum usability attributes they should incorporate in mHealth apps. Having a reproducible requirement catalogue will offer a source of information that can be adopted and refined by software developers of AI-enabled mobile applications.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] A. I. Alharbi, V. Gay, M. J. AlGhamdi, R. Alturki, and H. J. Alyamani, "Towards an application helping to minimize medication error rate," *Mobile Information Systems*, vol. 2021, Article ID 9221005, 7 pages, 2021.

[2] K. Komalavalli, R. Hemalatha, and S. Dhanalakshmi, "A survey of artificial intelligence in smart phones and its applications among the students of higher education in and around Chennai city," *Shanlax International Journal of Education*, vol. 8, no. 3, pp. 89–95, 2020.

[3] R. Alturki and V. Gay, "The development of an Arabic weight-loss app Akser Waznk: qualitative results," *JMIR formative research*, vol. 3, no. 1, Article ID e11785, 2019.

[4] P. Esmaeilzadeh, "Use of AI-based tools for healthcare purposes: a survey study from consumers' perspectives," *BMC Medical Informatics and Decision Making*, vol. 20, no. 1, pp. 1–19, 2020.

[5] C. M. Cutillo, K. R. Sharma, L. Foschini, S. Kundu, M. Mackintosh, and K. D. Mandl, "Machine intelligence in healthcare—perspectives on trustworthiness, explainability, usability, and transparency," *NPJ digital medicine*, vol. 3, no. 1, pp. 1–5, 2020.

[6] R. Alturki, N. Awan and M. Alshehri, Privacy, security and usability for IoT-enabled weight loss apps," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 4, https://www.researchgate.net/profile/Valerie-Gay, 2020.

[7] R. Alturki, V. Gay, N. Awan, M. Alshehri, M. J. AlGhamdi, and M. Kundi, "Analysis of an eHealth app: privacy, security and usability," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 4, 2020.

[8] A. A. Arain, Z. Hussain, W. H. Rizvi, and M. S. Vighio, "Evaluating usability of M-learning application in the context of higher education institute," in *Proceedings of the*, Springer, ON, Canada, July 2016, https://link.springer.com/conference/lct.

[9] R. Alturki and V. Gay, "Usability testing of fitness mobile application: methodology and quantitative results," in *Proceedings of the 7th International Conference on Computer Science, Engineering & Applications*, Copenhagen, Denmark, September 2017.

[10] D. E. Jake-Schoffman, V. J. Silfee, M. E. Waring et al., "Methods for evaluating the content, usability, and efficacy of commercial mobile health apps," *JMIR mHealth and uHealth*, vol. 5, no. 12, p. e190, 2017.

[11] T. Kallio and A. Kaikkonen, "Usability testing of mobile applications: a comparison between laboratory and field testing," *Journal of Usability studies*, vol. 1, no. 4-16, pp. 23–28, 2005.

[12] R. Khajouei, A. Ameri, and Y. Jahani, "Evaluating the agreement of users with usability problems identified by heuristic evaluation," *International Journal of Medical Informatics*, vol. 117, pp. 13–18, 2018.

[13] Y. Inal, J. D. Wake, F. Guribye, and T. Nordgreen, "Usability evaluations of mobile mental health technologies: systematic review," *Journal of Medical Internet Research*, vol. 22, no. 1, Article ID e15337, 2020.

[14] S. Reddy, S. Allan, S. Coghlan, and P. Cooper, "A governance model for the application of AI in health care," *Journal of the American Medical Informatics Association*, vol. 27, no. 3, pp. 491–497, 2020.

[15] B. C. Zapata, J. L. F. Alemán, A. Idri, and A. Toval, "Empirical studies on usability of mHealth apps: a systematic literature review," *Journal of Medical Systems*, vol. 39, no. 2, pp. 1–19, 2015.

[16] L. Al-Wakeel, A. Al-Ghanim, S. Al-Zeer, and K. Al-Nafjan, "A usability evaluation of Arabic mobile applications designed for children with special needs--Autism," *Lecture Notes on Software Engineering*, vol. 3, no. 3, p. 203, 2015.

[17] M. Jin and J. Kim, "Development and evaluation of an evaluation tool for healthcare smartphone applications," *Telemedicine and e-Health*, vol. 21, no. 10, pp. 831–837, 2015.

[18] Q. Wei, Z. Chang, and Q. Cheng, "Usability study of the mobile library App: an example from Chongqing University," *Library Hi Tech*, vol. 33, no. 3, pp. 340–355, 2015.

[19] C. Zhang, X. Zhang, and R. Halstead-Nussloch, "Validating the assessment metrics for mobile health apps: preliminary outcomes from a pilot study," New York, NY, USA, September 2015.

[20] M. Isaković, U. Sedlar, M. Volk, and J. Bešter, "Usability pitfalls of diabetes mHealth apps for the elderly," *Journal of diabetes research*, vol. 2016, Article ID 1604609, 9 pages, 2016.

[21] V. V. S. M. Chintapalli, W. Tao, Z. Meng, K. Zhang, J. Kong, and Y. Ge, "A comparative study of spreadsheet applications on mobile devices," *Mobile Information Systems*, vol. 2016, Article ID 9816152, 10 pages, 2016.

[22] R. Schnall, M. Rojas, S. Bakken et al., "A user-centered model for designing consumer mobile health (mHealth) applications (apps)," *Journal of Biomedical Informatics*, vol. 60, pp. 243–251, 2016.

[23] Q. Xiao, Y. Wang, L. Sun, S. Lu, and Y. Wu, "Current status and quality assessment of cardiovascular diseases related smartphone apps in China," *Nursing Informatics*, vol. 225, pp. 1030-1031, 2016.

[24] S. Zaidan and E. Roehrer, "Popular mobile phone apps for diet and weight loss: a content analysis," *JMIR mHealth and uHealth*, vol. 4, no. 3, p. e80, 2016.

[25] K. Anderson, O. Burford, and L. Emmerton, "App chronic disease checklist: protocol to evaluate mobile apps for chronic disease self-management," *JMIR research protocols*, vol. 5, no. 4, p. e204, 2016.

[26] E. Eraslan, Y. T. İç, and M. Yurdakul, "A new usability evaluation approach for touch screen mobile devices," *International Journal of Business and Systems Research*, vol. 10, no. 2-4, pp. 186–219, 2016.

[27] C. Stiles-Shields, E. Montague, E. G. Lattie, S. M. Schueller, M. J. Kwasny, and D. C. Mohr, "Exploring user learnability and learning performance in an app for depression: usability study," *JMIR human factors*, vol. 4, no. 3, p. e18, 2017.

[28] R. Alturki and V. Gay, "Usability testing of fitness mobile application: case study Aded Surat app," *International Journal of Computer Science and Information Technology*, vol. 9, no. 5, pp. 105–125, 2017.

[29] N. Asaddok and M. Ghazali, "Exploring the usability, security and privacy taxonomy for mobile health applications," in *Proceedings of the 2017 International Conference on Research and Innovation in Information Systems (ICRIIS)*, July 2017.

[30] R. Nouri, S. R. N. Kalhori, M. Ghazisaeedi, G. Marchand, and M. Yasini, "Criteria for assessing the quality of mHealth apps: a systematic review," *Journal of the American Medical Informatics Association*, vol. 25, no. 8, pp. 1089–1098, 2018.

[31] H. Cho, P. Yen, D. Dowding, J. A. Merrill, and R. Schnall, "A multi-level usability evaluation of mobile health applications: a case study," *Journal of Biomedical Informatics*, vol. 86, pp. 79–89, 2018.

[32] B. A. Kumar and P. Mohite, "Usability of mobile learning applications: a systematic literature review," *Journal of Computers in Education*, vol. 5, no. 1, pp. 1–17, 2018.

[33] R. Schnall, H. Cho, and J. Liu, "Health Information Technology Usability Evaluation Scale (Health-ITUES) for usability assessment of mobile health technology: validation study," *JMIR mHealth and uHealth*, vol. 6, no. 1, p. e4, 2018.

[34] S. Stonbraker, H. Cho, G. Hermosi, A. Pichon, and R. Schnall, "Usability testing of a mHealth app to support self-management of HIV-associated non-AIDS related symptoms," *Studies in Health Technology and Informatics*, vol. 250, pp. 106–110, 2018.

[35] C.-J. Wang, P. Chaovalit, and S. Pongnumkul, "A breastfeed-promoting mobile app intervention: usability and usefulness study," *JMIR mHealth and uHealth*, vol. 6, no. 1, p. e8337, 2018.

[36] M. F. Alwashmi, J. Hawboldt, E. Davis, O. Image, and M. D. Fetters, "The iterative convergent design for mobile health usability testing: mixed methods approach," *JMIR mHealth and uHealth*, vol. 7, no. 4, Article ID e11656, 2019.

[37] H. Wisniewski, G. Liu, P. Henson et al., "Understanding the quality, effectiveness and attributes of top-rated smartphone health apps," *Evidence-Based Mental Health*, vol. 22, no. 1, pp. 4–9, 2019.

[38] L. Zhou, J. Bao, I. M. A. Setiawan, A. Saptono, and B. Parmanto, "The mHealth APP usability questionnaire (MAUQ): development and validation study," *JMIR mHealth and uHealth*, vol. 7, no. 4, Article ID e11500, 2019.

[39] R. Alturki and V. Gay, "Usability attributes for mobile applications: a systematic review," *Recent Trends and Advances in Wireless and IoT-Enabled Networks*, pp. 53–62, 2019.

[40] A. S. Dahri, A. Al-Athwari, and A. Hussain, "Usability evaluation of mobile health application from AI perspective in rural areas of Pakistan," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 13, no. 11, 2019.

[41] F. A. Kasali, O. O. Olaniyan, I. O. Akinyemi, and O. B. Alaba, "An enhanced usability model for mobile health application," *International Journal of Computer Science and Information Security*, vol. 17, no. 2, 2019.

[42] M. S. Liew, J. Zhang, J. See, and Y. L. Ong, "Usability challenges for health and wellness mobile apps: mixed-methods study among mHealth experts and consumers," *JMIR mHealth and uHealth*, vol. 7, no. 1, Article ID e12160, 2019.

[43] P. Azad-Khaneghah, N. Neubauer, A. M. Cruz, and L. Liu, "Mobile health app usability and quality rating scales: a systematic review," *Disability and Rehabilitation: Assistive Technology*, pp. 1–10, 2020.

[44] M. N. Islam, M. M. Karim, T. T. Inan, and A. K. M. N. Islam, "Investigating usability of mobile health applications in Bangladesh," *BMC Medical Informatics and Decision Making*, vol. 20, no. 1, p. 19, 2020.

[45] K. Khowaja and D. Al-Thani, "New checklist for the heuristic evaluation of mHealth apps (HE4EH): development and usability study," *JMIR mHealth and uHealth*, vol. 8, no. 10, Article ID e20353, 2020.

[46] J. Nabi, E. B. Cone, A. Vasavada et al., "Mobile health app for prostate cancer patients on androgen deprivation therapy: qualitative usability study," *JMIR mHealth and uHealth*, vol. 8, no. 11, Article ID e20224, 2020.

[47] A. van Haasteren, E. Vayena, and J. Powell, "The mobile health app trustworthiness checklist: usability assessment," *JMIR mHealth and uHealth*, vol. 8, no. 7, Article ID e16844, 2020.

[48] M. H. Afif, "Evaluating PSAU mobile application based on people at the center of mobile application development (PACMAD) usability model: empirical investigation," *Journal of Computer Science*, vol. 17, no. 3, pp. 275–283, 2021.

[49] M. Aji, C. Gordon, E. Stratton et al., "Framework for the design engineering and clinical implementation and evaluation of mHealth apps for sleep disturbance: systematic review," *Journal of Medical Internet Research*, vol. 23, no. 2, Article ID e24607, 2021.

[50] F. Kasali, O. Adekola, I. Akinyemi, I. Ebo, and J. Balogun, "A model for ranking the usability attributes of mobile health applications in Nigeria (MCDM approach)," *Covenant*

Journal of Informatics and Communication Technology, vol. 8, no. 2, 2021.

[51] S. D. Müller, K. G. Lauridsen, A. H. Palic, L. N. Frederiksen, M. Mathiasen, and B. Løfgren, "Mobile app support for cardiopulmonary resuscitation: development and usability study," *JMIR mHealth and uHealth*, vol. 9, no. 1, Article ID e16114, 2021.

[52] Z. Teng, P. Zhang, X. Li, and W. Nock, "Authentication & integration approaches for mHealth apps from a usability view," *Advances in Electrical and Electronic Engineering*, vol. 19, no. 1, pp. 74–89, 2021.

[53] J. Benjumea, J. Ropero, O. R. Romero, E. D. Zubiete, and A. Carrasco, "Privacy assessment in mobile health apps: scoping review," *JMIR mHealth and uHealth*, vol. 8, no. 7, Article ID e18868, 2020.

[54] K. J. Giri, S. A. Parah, R. Bashir, and K. Muhammad, *Multimedia Security: Algorithm Development, Analysis and Applications*, Springer, Singapore, 2021.

[55] J. Müthing, R. Brüngel, and C. M. Friedrich, "Server-focused security assessment of mobile health apps for popular mobile platforms," *Journal of Medical Internet Research*, vol. 21, no. 1, p. e9818, 2019.

[56] D. Impedovo and G. Pirlo, *eHealth and Artificial Intelligence*, Multidisciplinary Digital Publishing Institute, 2019, https://www.google.com/search?rlz=1C1GCEB_enIN982IN982&q=Basel&stick=H4sIAAAAAAAAAOPgE-LSz9U3ME7OqyivVOIAsQ2zTdK0tLKTrfTzi9IT8zKrEksy8_NQOFYZqYkphaWJRSWpRcWLWFmdEotTc3awMgIAFOERwk8AAAA&sa=X&ved=2ahUKEwi_ycfDzb_0AhUCzDgGHaBgDTkQmxMoAXoECEcQAw.

[57] A. Wattanapisit, C. H. Teo, S. Wattanapisit, E. Teoh, W. J. Woo, and C. J. Ng, "Can mobile health apps replace GPs? A scoping review of comparisons between mobile apps and GP tasks," *BMC Medical Informatics and Decision Making*, vol. 20, no. 1, pp. 1–11, 2020.

[58] G. L. Kreps and L. Neuhauser, "Artificial intelligence and immediacy: designing health communication to personally engage consumers and providers," *Patient Education and Counseling*, vol. 92, no. 2, pp. 205–210, 2013.

[59] S. Berrouiguet, M. L. Barrigón, J. L. Castroman, P. Courtet, A. A. Rodríguez, and E. B. García, "Combining mobile-health (mHealth) and artificial intelligence (AI) methods to avoid suicide attempts: the Smartcrises study protocol," *BMC Psychiatry*, vol. 19, no. 1, pp. 1–9, 2019.

[60] T. Davenport and R. Kalakota, "The potential for artificial intelligence in healthcare," *Future healthcare journal*, vol. 6, no. 2, p. 94, 2019.

[61] S. M. H. M. Jazayeri and A. Jamshidnezhad, "Top mobile applications in pediatrics and children's health: assessment and intelligent analysis tools for a systematic investigation," *Malaysian Journal of Medical Sciences: MJMS*, vol. 26, no. 1, p. 5, 2019.