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Research Article

Heuristic Evaluation and Usability Testing of G-MoMo Applications

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ABSTRACT

Financial technology (FinTech) has swiftly revolutionized mobile money as one of the ways of accessing financial services in developing countries. Numerous mobile money applications were developed to access mobile money services but are hindered by severe authentication security challenges, thus, forcing the researchers to design a secure multi-factor authentication (MFA) algorithm for mobile money applications. Three prototypes of native mobile money applications (G-MoMo applications) were developed to confirm that the algorithm provides high security and is feasible. This study, therefore, aimed to evaluate the usability of the G-MoMo applications using heuristic evaluation and usability testing to identify potential usability issues and provide recommendations for improvement. Heuristic evaluation and usability testing methods were used to evaluate the G-MoMo applications. The heuristic evaluation was carried out by five experts that used the 10 principles proposed by Jakob Nielsen with a five-point severity rating scale to identify the usability problems. While the usability testing was conducted with forty participants selected using a purposive sampling method to validate the usability of the G-MoMo applications by performing tasks and filling out the post-test questionnaire. Data collected were analyzed in RStudio software. Sixty-three usability issues were identified during heuristic evaluation, where 33 were minor and 30 were major. The most violated heuristic items were "help and documentation", and "user control and freedom", while the least violated heuristic items were "aesthetic and minimalist design" and "visibility of system status". The usability testing findings revealed that the G-MoMo applications' performance proved good in learnability, effectiveness, efficiency, memorability, and errors. It also provided user satisfaction, ease of use, aesthetics, usefulness, integration, and understandability. Therefore, it was highly recommended that the developers of G-MoMo applications fix the identified usability problems to make the applications more reliable and increase overall user satisfaction.

Keywords: Mobile money, industry 4.0, digital transformation, G-MoMo applications, blockchain, heuristic evaluation, usability testing, experts, participants.

INTRODUCTION

The evolution of the fourth industrial revolution has caused a substantial transformation in business through FinTech, such as mobile money. However, over a billion people in developing countries do not have formal bank accounts, forcing the unbanked population to incur high transaction costs and theft since they resorted to informal financial networks. Surprisingly, the unbanked population has access to mobile phones, making it easy to transfer money digitally, thus, giving rise to mobile money. As one of the essential financial innovations in developing countries, mobile money fills this gap by offering convenient digital financial services over mobile phones and improving financial inclusions (Ali et al., 2020a; Rwiza et al., 2020).

The mobile money subscribers perform mobile money services using either a dedicated mobile application or the unstructured supplementary service data (USSD) (Ali et al., 2020b; Ayeb et al., 2022). The current mobile money applications developed by the mobile money service providers only use a personal identification number (PIN) and one-time password (OTP) to authenticate mobile money subscribers. Though promising, this two-factor authentication (2FA) scheme is susceptible to many security attacks (Ali et al., 2020b). Much as the developed applications helped ensure mobile money security, more work is still needed to improve their algorithms. This prompted the researchers to develop a secure MFA algorithm for mobile money applications to overcome these security issues (Ali et al., 2021).

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Other emerging technologies such as blockchain are also used in mobile money systems to (1) prevent fraud and ensure the security of the mobile money transactions data; (2) ensure interoperability among the different mobile money service providers to permit cross-operators transactions; (3) create transparent and traceable data; (4) ensure auditability by allowing governments and regulators to access a cryptographically verifiable copy of an immutable ledger; and (5) address trusted third-party issues. These are achieved by storing the mobile money user's identity and the mobile money transactions data in a distributed and immutable ledger (Agbezoutsi et al., 2021, 2019).

Three prototypes of native G-MoMo were developed to prove the algorithm's feasibility and provide high security against attacks and threats (Ali et al., 2021). This study, therefore, validates the developed native G-MoMo applications using heuristic evaluation and usability testing to identify usability issues and provide feedback for improvement to achieve usability and satisfaction. The usability of applications due to user-friendly design enhances user experience, attracts and retains customers, increases profitability of services, allows users to attain their desired objectives and contributes to user satisfaction and loyalty. The critical task of mobile application developers requiring keen attention is improving the applications' design to appease user satisfaction through heuristic evaluation and usability testing. The heuristic evaluation uses the 10 heuristics established by Jakob Nielsen to identify any usability problems with the application interfaces and provide feedback for improving the early designs (Hertzum, 2020; J. Nielsen, 1994a). At the same time, usability testing is evaluated based on quality components such as effectiveness, efficiency, satisfaction, learnability, errors, memorability, understandability, attractiveness, and accessibility (Ammar, 2019; Chipa and Mwanza, 2021). Validating the native G-MoMo applications using heuristic evaluation and usability testing is crucial because it allows the application developers, experts, mobile money service providers, and end-users to test the G-MoMo applications' user interfaces to ensure usability and satisfaction.

The significant contribution of this study is the validation of the G-MoMo applications using heuristic evaluation and usability testing to identify usability issues and provide feedback for improvements. Both heuristic evaluation and usability testing were achieved through laboratory experiments. Experts and a few selected participants used the G-MoMo applications in the real environment to identify usability problems and provide feedback by filling the post-test questionnaire for improvements (Ammar, 2019).

The remaining contents of this article are structured as follows: The background to mobile application usability, usability evaluation, heuristic evaluation, usability testing, and G-MoMo applications are provided in Section 2, and Section 3 describes the materials and methods used. The analysis of the results is explained in Section 4, while discussions are presented in Section 5. Finally, the conclusion and recommendations are raised in Section 6.

BACKGROUND

Mobile Application Usability

(Weichbroth, 2020) defines a mobile application as a program developed for smartphones and tablets to perform specific tasks and functions. Mobile applications can either be installed on mobile devices or accessed using web browsers (Lynn et al., 2020). The installed mobile applications can be downloaded from mobile App Stores such as Google Play Store, Apple App Store, Amazon Appstore, Samsung Galaxy Apps, Huawei App Store, and Sony Apps (Byun et al., 2020).

Mobile application usability has attracted the attention of application users, software developers, and academics and is a crucial area of research in human-computer interaction (HCI) because it determines the application's success and reduces irritation during usage (Lynn et al., 2020; Weichbroth, 2020). The usability of mobile applications also determines the successful technology adoption depending on how users feel about the use of the application in terms of improving work performance (Byun et al., 2020). The user's feelings, understanding, desires, convenience, attitude, and achievement are assessed through mobile application usage (Bajcar et al., 2020). The successful adoption and usage of mobile applications depend on how users easily and efficiently perform services. When mobile applications are poorly designed, it results in low usage. Nevertheless, an application can only be used when it performs its functions effectively, efficiently, and satisfactorily. The usability of mobile applications is evaluated using expert-based methods and a standard questionnaire designed and administered to end-users to ascertain their satisfaction based on ease of usage of the applications, how they enable users to perform tasks efficiently and clearly, and so on (Salari et al., 2021).

According to (Ammar, 2019), usability is how specific people use a software product to attain stated goals effectively, efficiently, and satisfactorily. A usability evaluation is a sequence of a well-defined set of tasks for gathering relevant information related to end-user interaction with the application to determine how features of the software product add to earning a certain level of usability by identifying the usability problems (Kous et al., 2020; Lynn et al., 2020). Its main objective is to assess the quality of the interface designs of the system and mobile applications, ascertain the possible interaction issues with the applications, develop aesthetic interface designs and check them per the usability standards. Usability evaluation can be formative or summative, depending on the assessment goals (Salman et al., 2018). Formative evaluation collects feedback from users for additional development, while summative evaluation evaluates whether the set usability requirements are fulfilled (Hewett, 1986). Several factors such as screen size, storage capacity, interface design, and context of use are considered in the usability evaluation of mobile applications.

Usability Evaluation

The usability evaluation process is essential and includes many evaluation methods such as heuristic evaluation, cognitive walkthrough, interviews, log analysis, task analysis, eye tracking, perspective-based inspection, think-aloud usability testing, guideline reviews, focus group, questionnaires, and remote testing (Islam et al., 2020; Wahyuningrum et al., 2020). These usability evaluation methods are applied at any stage of

the software development process, and the evaluation process can be performed on prototypes and the final product. It helps reduce costs since changes are easy to implement and determine if the application meets an appropriate level of usability. They provide recommendations for improving the interface designs of the applications (Eliseo et al., 2017).

(Jeong et al., 2020) and (Putri et al., 2021) further added that the usability evaluation method measures software usability by testing it with selected users to identify any usability problems and give direct feedback and recommendations for improvement to achieve effectiveness, efficiency, and user satisfaction. Heuristic evaluation and usability testing are the primary methods for validating application interfaces (Ammar, 2019). By carrying out usability evaluation, it helps to identify defects in mobile applications by checking and inspecting the application interfaces, thus, allowing developers to produce suitable application designs to achieve usability evaluation goals (Lynn et al., 2020). It emphasizes the level users interact with mobile devices, ensures the acceptability of the application, provides ease of application usage, ensures effective and efficient application, and acts as an essential reference for improving the applications' design and features (Lynn et al., 2020). Heuristic evaluation is extensively used to validate system and application interfaces during and after development (Hussain and Omar, 2020). Jakob Nielsen proposed the heuristic evaluation method in 1994 and defined it as an evaluation method with between 3 to 5 trained HCI expert evaluators to examine a system or prototype according to established heuristic principles to check for problems and deficiencies with the application interfaces and rectify possible faults (J. Nielsen and Mack, 1994). It is performed by experts who rely on 10 heuristics established by Jakob Nielsen to serve as a framework for evaluating the user interface design of applications, and the experts are selected carefully (J. Nielsen, 1994a). The experts include usability specialists, fellow developers, and expert users who use heuristic rules, subjective judgment, and task-based evaluation to rate the severity of application interface issues. Then all problems and ratings are analyzed collectively to identify the most critical usability issues (Tremoulet et al., 2021).

Heurestic Evaluation

Heuristic evaluation's primary goal is to identify usability problems when some expert users operate the system or application interface at a relatively low cost, resulting in multiple enhancements to the mobile applications (Kumar et al., 2020). When the heuristic principle is violated, the expert determines the severity of the problem and suggests solutions (Paramitha et al., 2018). It can be carried out at any software development stage upon identifying the problem and usually presents the best practical results(Kumar et al., 2020). The expert goes through the system once to get familiar with it during the heuristic evaluation and then thoroughly assesses the specific heuristics (Ball and Bothma, 2018). A maximum of five experts can identify usability problems (J. Nielsen and Mack, 1994).

The 10 principles proposed by Jakob Nielsen to examine the usability problems with the interface designs are "visibility of system status"; "match between the system and the real world"; "user control and freedom"; "consistency and standards"; "error prevention"; "recognition rather than recall"; "flexibility and efficiency of use"; "aesthetic and minimalist design"; "help users recognize, diagnose, and recover from errors"; and "help and documentation" (J. Nielsen, 1994a). Heuristic evaluation offers numerous benefits, including simple, fast & efficient identification of usability problems, a cheap method to evaluate applications, easy to motivate people to do, and suitable for every life-cycle software phase (Kumar et al., 2020; Tremoulet et al., 2021) Due to these benefits, the heuristic evaluation approach is widely used in HCI to evaluate the effectiveness of mobile applications.

Usability Testing

The usability testing method defines the usability of a system and mobile application. It has been accepted as an essential activity in software design, implementation, testing, acceptance, and revision because it aims to determine user perception about the application by measuring convenience and efficiency and ensuring user satisfaction with the software product (Ramayasa and Candrawibawa, 2021; Wirasasmiata and Uska, 2019). Software developers must perform usability tests on mobile applications to achieve the quality of tasks and help improve application designs for higher market and competency (Byun et al., 2020; Lynn et al., 2020). It is also essential in developing an application to ensure that the various end-users can access, understand and identify gaps, and use it (Babatunde et al., 2020). Usability testing can be conducted throughout the development life cycle of the mobile application (Weichbroth, 2020). It consists of multiple facets commonly known as usability attributes, used to measure the quality of the applications (Putri et al., 2021; Zakaria et al., 2020). Internal and external attributes are the two types of usability attributes used to measure the quality of applications (Ammar, 2019). Researchers have identified many attributes for testing the usability of mobile applications, which include (a) learnability; (b) effectiveness; (c) efficiency; (d) memorability; (e) errors; (f) user satisfaction; (g) simplicity; (h) comprehensibility; (i) cognitive load; (j) ease of use; (k) understandability; (l) operability; (m) aesthetic; (n) accessibility; and (o) learning performance (Byun et al., 2020; Hussain and Omar, 2020; Kous et al., 2020; Lynn et al., 2020). Several usability testing methods used techniques, such as performance measurement, to evaluate effectiveness and efficiency. Retrospective think-aloud and post-study system usability questionnaires measure user satisfaction (Ammar, 2019).

Usability testing offers several benefits, such as identifying usability problems via user interaction observation; determining how easily a user uses an application's interface. Furthermore, usability testing reduces the cost of changes later in the software development life cycle (Burkard, 2020; Jeong et al., 2020).

G-MoMo Application

(Ali et al., 2021) designed a secure MFA algorithm for mobile money applications. The algorithm authenticates mobile money subscribers using a novel method combining PIN, OTP, and biometric fingerprint. The mobile money customer confirms money withdrawal by scanning their biometric fingerprint and the agent's QR code. In addition, the PINs and OTPs are protected by SHA-256; biometric fingerprints by FIDO, where the RSA encryption secures the public/private key pair and the fingerprint templates; and the QR codes, confidential

information in the databases, and all the data before transmission using Fernet encryption (Ali et al., 2021).

G-MoMo IT support application, G-MoMo agent application, and G-MoMo customer application prototypes were developed to prove the algorithm's feasibility and provide high security against attacks and threats. The applications' front-end was developed using the Vue JS framework, Python for the back-end, MySQL as a back-end database, and Twilio SMS to receive the OTP (Ali et al., 2021). The mobile money IT support staff uses the G-MoMo IT support application to register new mobile money IT support staff and agents, add new smartphones for registered mobile money agents and customers, display the enrolled subscribers' statistics, and manage their PIN and biometric fingerprint. G-MoMo agent application allows mobile money agents to enrol new customers, deposit money, display agent's QR code, check available float and manage their PIN and biometric fingerprint. While G-MoMo customer application allows mobile money customers to withdraw money, send money, pay bills, check electronic balances and mini statements, and manage their PIN and biometric fingerprint (Ali et al., 2021). The three G-MoMo applications were used to explain the enrolment, authentication, and transaction phases (Ali et al., 2021).

Mobile Money Agent Enrolment Phase

The enrolment phase involves the mobile money IT support staff downloading and installing the G-MoMo IT support application on their smartphones connected to the Internet. The mobile money IT support staff must log into the G-MoMo IT Support Application. Once they log in successfully, they can register a new mobile money agent by capturing their first name, last name, and phone number, and then confirm their registration. A 5-digit OTP will be generated and sent to the new mobile money agent's smartphone, where they are requested to read and tell the IT support staff. The mobile money IT support staff will enter the OTP to complete the registration. If the OTP matches, the information is saved in the database and the new agent is successfully registered but required to finish the enrolment process by installing and running the G-MoMo agent application; else, required to attempt three (3) times. **Figure 1(a)–(f)** illustrates the steps the mobile money IT support staff follows to enrol the new mobile money agent using the G-MoMo IT support application.

After installing the G-MoMo agent application, and when the mobile money agent runs the G-MoMo agent application for the first time, the system will require the agent's smartphone and phone number to be registered. The agent will be requested to enter their phone number, through which a 5-digit OTP will be sent to verify the phone number and smartphone. Once the agent receives and enters the OTP, it will be compared with the copy stored in the database, and if it matches, the smartphone and phone number are registered, and a universally unique identifier (UUID) is generated for the phone number and smartphone, and the UUID is encrypted with Fernet and saved in the main database. **Figure 2(a)–(d)** illustrates the steps the mobile money agent follows to register their smartphone and phone number. After successfully registering the phone number and the smartphone, the agent must complete the enrolment process by running the G-MoMo agent application, entering their five (5)-digit PIN, and re-entering the 5-digit PIN again. If the PINs match, the agent is requested to confirm the creation of the new PIN. Once the new PIN is approved, the mobile money agent can enroll their biometric fingerprint by scanning it using its biometric fingerprint sensor, and if it is successfully captured, the fingerprint template is saved, and the mobile money agent is successfully registered. The application then sends a notification to the mobile money agent for successful registration and is ready to use the G-MoMo agent application. **Figure 3(a)–(g)** illustrates the steps the mobile money agent must follow to complete the enrolment using the G-MoMo agent application.

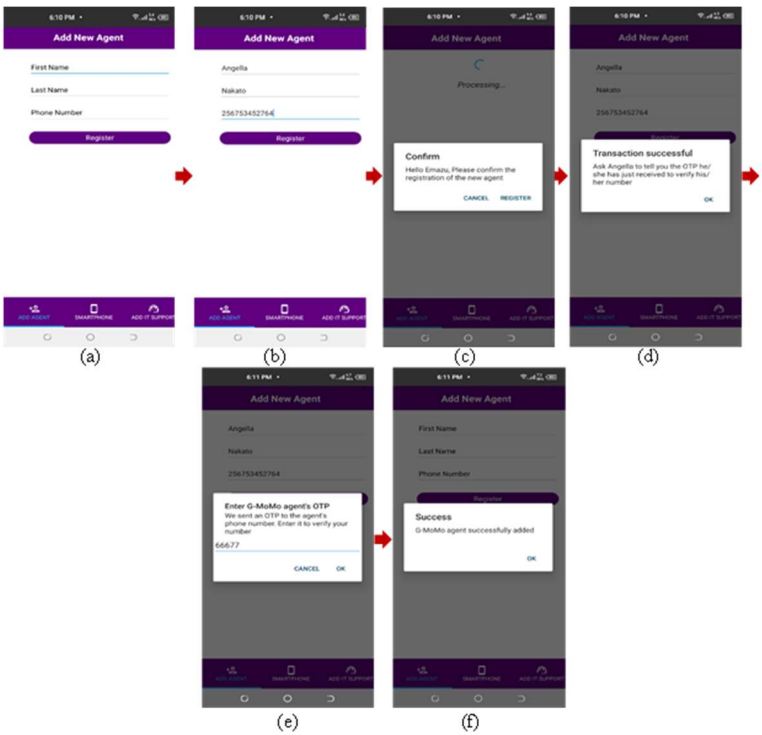

Figure 1(a)-(f). Illustrates the steps the mobile money IT support staff follows to enroll the mobile money agent using the G-MoMo IT support application.

Mobile Money Agent Authentication Phase

After the successful enrolment, the agent can log in to the G-MoMo agent application by entering the five-digit PIN. If the PIN is correct, a 5-digit OTP is generated and sent to the agent by SMS. Once the OTP is received, they must enter it, where the system will compare it with the template stored in the database. If it matches, the agent is requested to scan their biometric fingerprint. If the scanned fingerprint matches, the agent successfully logs in to the G-MoMo agent application and is presented with the menu to choose service(s). **Figure 4(a)–(d)** illustrates the steps the mobile money agent follows during authentication.

Mobile Money Agent Authentication Phase

After the successful enrolment, the agent can log in to the G-MoMo agent application by entering the five-digit PIN. If the PIN is correct, a 5-digit OTP is generated and sent to the agent by SMS. Once the OTP is received, they must enter it, where the system will compare it with the template stored in the database. If it matches, the agent is requested to scan their biometric fingerprint. If the scanned fingerprint matches, the agent successfully logs in to the G-MoMo agent application and is presented with the menu to choose service(s). **Figure 4(a)–(d)** illustrates the steps the mobile money agent follows during authentication.

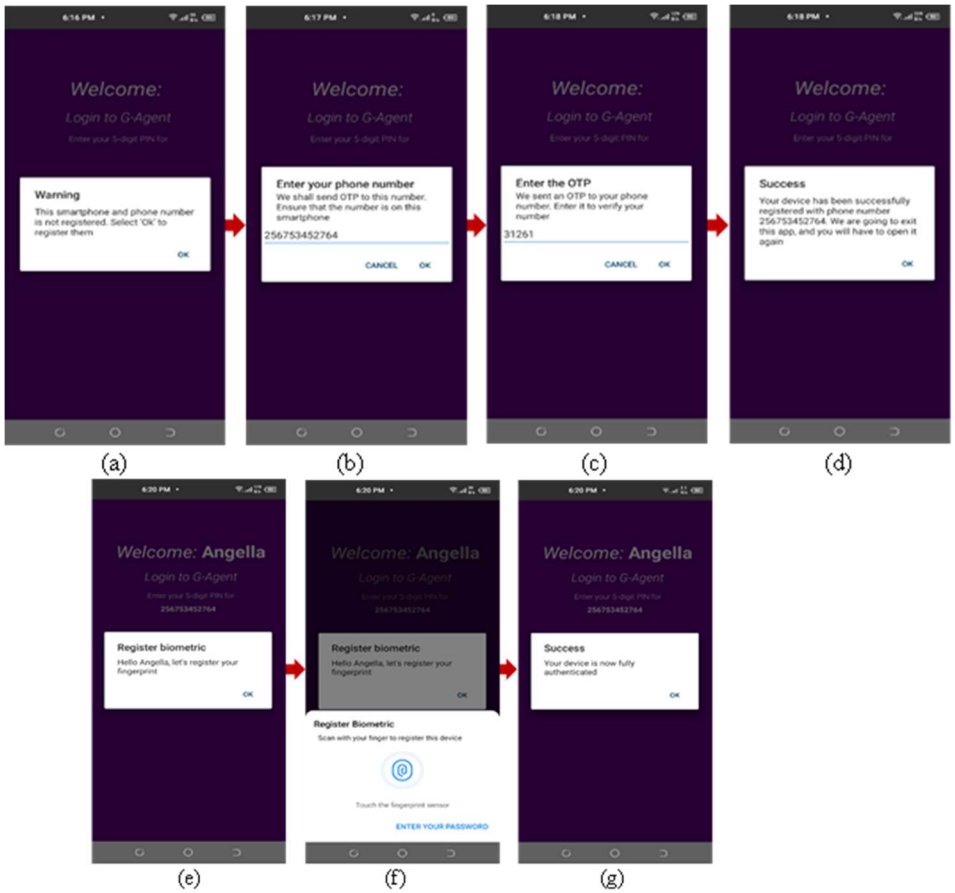

Figure 2(a)-(g). Illustrates the steps the mobile money agent must follow to register the smartphone and phone number using the G-MoMo agent application.

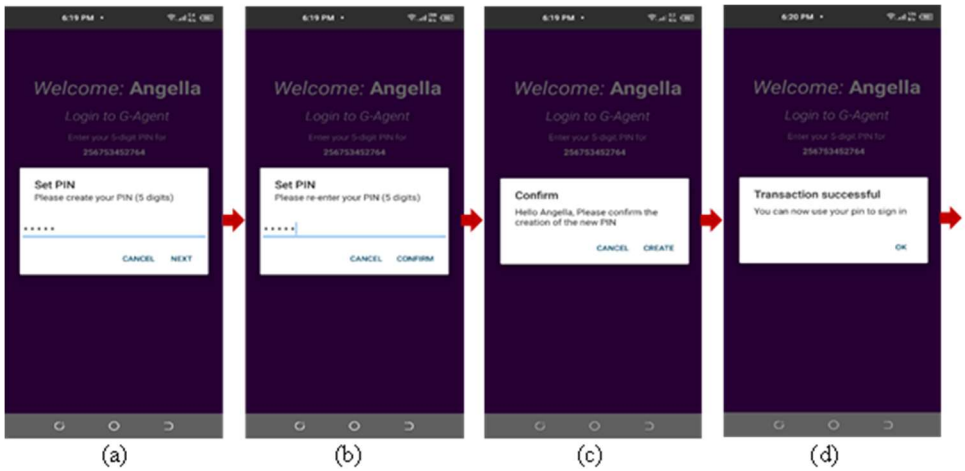

Figure 3(a)-(d). Illustrates the process of completing mobile money agent enrolment using the G-MoMo agent application.

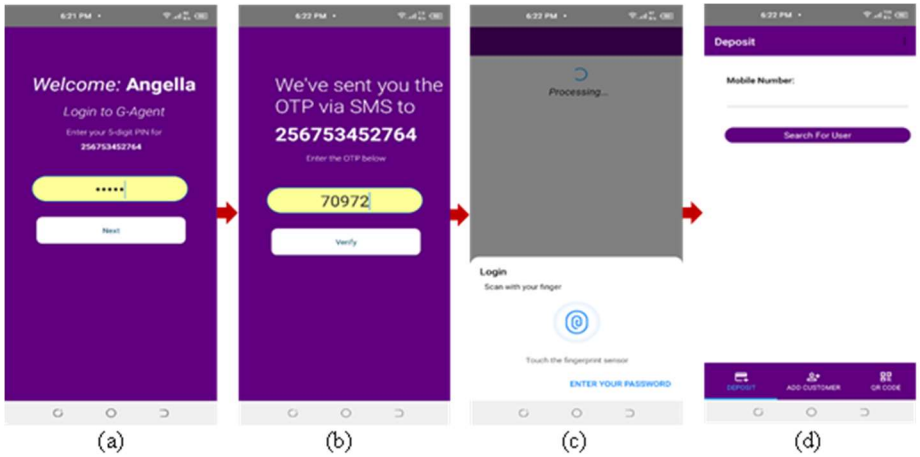

Figure 4(a)-(d). Illustrates the steps the mobile money agent follows during authentication using the G-MoMo agent application.

Transaction Phase

The transaction phase involves the mobile money agent using the G-MoMo agent application to enrol new customers, deposit money, and confirm money withdrawal through a QR code scan.

(a) Depositing Money

The mobile money agent begins depositing money into customers' accounts by running the G-MoMo agent application and signing in by entering their PIN and OTP and scanning their fingerprint. If the agent logs in successfully, their electronic balance is displayed. If they have enough float, they can select the deposit menu, enter the recipient's phone number, and search to confirm whether it is registered with the G-MoMo customer application. If the phone number is enrolled, the application will display the phone number and the name of the person who registered the phone number. The application will request the mobile money agent to enter the amount they want to deposit. The system will only accept the deposit amount less than the available float. The application will then request the agent to confirm whether they want to deposit the money into the recipient's phone number. If the agent clicks the deposit button, the system will deposit the funds into the recipient's account and display the successful money deposited notification. **Figure 5(a)–(d)** illustrates the steps followed by the mobile money agent to deposit money into customers' accounts using the G-MoMo agent application.

(b) Money Withdrawal

To withdraw money from their mobile money wallet, the customer must first log into the G-MoMo customer application by entering their PINs, OTP, and biometric fingerprints. The system will verify the PINs, OTP, and biometric fingerprints entered, and if they do not match, they are required to try again; else, they are successfully logged in. The mobile money customer must check their available electronic balance and ensure that it is withdrawable. The system only accepts the customer to enter an amount less than the available balance. After entering the amount, they can click the withdraw button, where the system will request them to scan their biometric fingerprint for authorization. The scanned biometric fingerprint is matched with the fingerprint template stored in the database, and if it matches, the customer is requested to scan the secure QR code of the mobile money agent using the customer's smartphone smart scanner for final confirmation. The system will then verify the scanned secure QR code, and if it is correct, money is withdrawn from the customer's account, and the electronic balance is updated. A notification for successful money withdrawal is displayed, authorizing the customer to collect money from the mobile money agent (Ali et al., 2021). **Figure 6(a)–(g)** illustrates the steps followed by the mobile money customer to withdraw money from their account using the G-MoMo customer application.

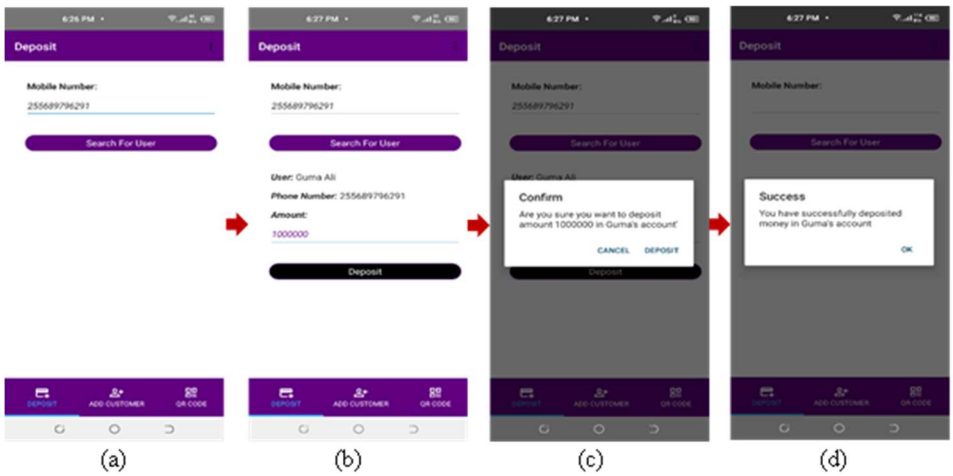

Figure 5(a)-(d). Illustrates the steps the mobile money agent follows during authentication using the G-MoMo agent application.

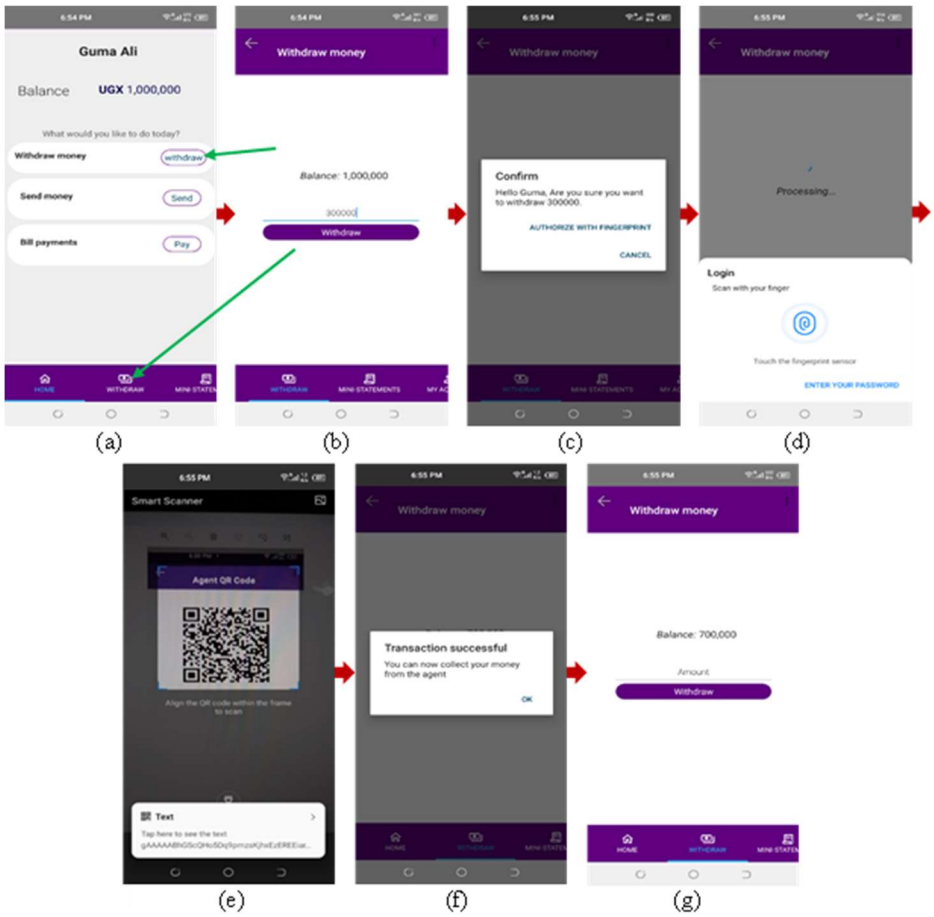

Figure 6(a)-(g). Illustrates the steps followed by the mobile money customer to withdraw money from their account using the G-MoMo customer application.

MATERIALS AND METHODS

Heuristic Evaluation

Heuristic evaluation and usability testing methods were used to evaluate the usability of the three G-MoMo applications, identify usability issues with their interface designs, and suggest recommendations for improvement. They were conducted for five months from December 2021 to April 2022. The application of the two methods is briefly described below.

The Heuristic evaluation method adopted the 10 heuristic guidelines established by Jakob Nielsen to serve as a framework for evaluating the user interface design of G-MoMo applications. Five experts conducted the heuristic evaluation of the interface designs of G-MoMo applications to identify usability issues and suggest recommendations for their improvements. The experts were selected based on the recommendation by Nielsen and Mack that requires 3-5 evaluators (J. Nielsen and Mack, 1994). Two of the selected experts have expertise in usability evaluation and knowledge base and three with the knowledge base. They consist of four males and one female between 28 to 40 years old. Three experts were web and mobile application developers who had used the G-MoMo applications for some days. The experts were chosen based on their profiles. The two experts were teaching staff who had experience in HCI and conducted research in usability testing and mobile applications. They had significant expertise in conducting heuristic evaluations on systems and applications and had used the G-MoMo applications for three weeks before analyzing them. The three experts in the second group included web and mobile application developers focusing on developing mobile-friendly web and mobile applications and had experience developing special-purpose mobile applications. The experts acquired two-hour training on using Nielsen's heuristics to assess the G-MoMo applications before conducting the evaluation. Each heuristic item was thoroughly explained with examples to help them accurately identify usability problems. The profiles of the experts are summarized in **Table 1**.

Table 1. The profile of the usability evaluation experts.

S/No	Participant	Gender	Age	Profession	Years of Experience
1	Expert 1	Female	37	PhD in Information Technology	8
2	Expert 2	Male	39	PhD in Computer Science	10
3	Expert 3	Male	30	Web and Mobile Application Developer	6
4	Expert 4	Male	31	Web and Mobile Application Developer	6
5	Expert 5	Male	29	Mobile Application Developer	5

Table 2. Participants' Social Demography Characteristics.

S/No	Variable	Frequency	Percentage (%)
1	Gender		
	Male	25	62.5
	Female	15	37.5
2	Age		
	Less than 20 years	0	0.0
	Between 20–29 years	19	47.5
	Between 30–39 years	16	40.0
	More than 39 Years	5	12.5
3	Level of Education		
	Bachelors	32	80.0
	Masters	6	15.0
	PhD	2	5.0
4	Category of Evaluation		
	Mobile Money IT Support Staff	4	10.0
	Mobile Money Agent	10	25.0
	Mobile Money customers	26	65.0

The heuristic evaluation post-test questionnaire contained five-point Likert scale statements developed based on the 10 heuristic guidelines to evaluate the prototypes of the G-MoMo applications (J. Nielsen, 1994a).

The experts were asked to install and test the three prototypes of G-MoMo applications on Android-based smartphones like Tecno Camon 16 Pro running Android 10 with a touchscreen having 720 x 1640 pixels and a rear-mounted fingerprint sensor. It was also tested on Samsung Galaxy S7 Edge running Android 7.0, with a touchscreen having a 2560 x 1440 pixels resolution and a front-mounted fingerprint sensor.

During the evaluation, the experts used the heuristic evaluation post-test questionnaire to evaluate the prototypes of the G-MoMo applications interfaces by giving their opinion about the usability issues with the interfaces after performing some tasks such as registration, authentication, transaction, and system logout. The usability issues' severity was rated based on applying the Jakob Nielsen scale of (0) no problem, (1) cosmetic problem only, (2) minor usability problem, (3) major usability problem, and (4) usability catastrophe (J. Nielsen, 1994b), which provided the experts with a better insight into the usability issues with their degrees of severity which the application developers can consider as a priority and make the essential corrections (Nabovati et al., 2014). The experts were also requested to give additional suggestions after the evaluation. After the evaluation, the results obtained using the post-test questionnaires were compiled and a consensus was generated for the ratings, and recommendations were provided. Descriptive statistics were calculated from the collected data about the usability issues and analyzed using the RStudio software.

This study also employed a usability testing method to ascertain the ease of use of the G-MoMo applications. The method was used to obtain quantitative data from the selected participants about the G-MoMo applications. Forty participants were chosen using a purposive sampling method to validate the usability of the G-MoMo applications. The selected sample size is enough to carry out usability testing because, according to Jakob Nielsen, the number of respondents to participate in usability testing is at least 20 people (Nielsen, 2021). Of the 40 participants, 25 were male (62.5%), and 15 (37.5%) were female. The participants were between the ages of 20 to 40. However, 19 (47.5%) of the participants were between 20-29 years, 16 (40.0%) between 30-39 years, while the remaining 5 (12.5%) were above 39 years. Among the participants, 32 (80%) had Bachelor's degrees, 6 (15%) master's degrees, and 2 (5%) had PhD. The selected participants were computer literate. Nevertheless, not all participants were familiar with the functioning of the G-MoMo applications. The participants were further divided into mobile money IT support staff, agents, and customers. 4 (10%) of the participants were grouped as mobile money IT support staff, 10 (25%) as mobile money agents, and 26 (65%) as mobile money customers. **Table 2** Summarizes the social demography characteristics of the participants.

Table 3. The frequency of severity of usability issues with the interfaces of G-MoMo applications.

ID	Heuristic Principles	Severity				Total		Average Severity
		Cosmetic	Minor	Major	Catastrophe	Frequency	%	
H1	Visibility of system status	0	1	0	0	1	1.6	2
H2	Match between system and the real world	0	4	0	0	4	6.3	2
H3	User control and freedom	0	8	3	0	11	17.5	2.2
H4	Consistency and standards	0	5	0	0	5	7.9	2
H5	Error prevention	0	3	0	0	3	4.8	2
H6	Recognition rather than recall	0	4	0	0	4	6.3	2
H7	Flexibility and efficiency of use	0	3	3	0	6	9.5	2.5
H8	Aesthetic and minimalist design	0	1	0	0	1	1.6	2
H9	Help users recognize, diagnose, and recover from errors	0	3	0	0	3	4.8	2
H10	Help and documentation	0	1	24	0	25	39.7	3
TOTAL		**0**	**33**	**30**	**0**	**63**	**100.0**	**2.2**
		0.0	**52.4**	**47.6**	**0.0**		**100%**	

Before the selected participants began performing tasks, the researchers conducted a quick pilot study to ensure a smooth usability testing session. The researchers began conducting usability testing by briefing and checking the participants' smartphones to ensure that they were connected to the Internet and that the fingerprint sensors functioned well. A functioning version of G-MoMo applications was downloaded and installed based on the participants' category. The participants were introduced to G-MoMo applications, their features, functionalities, and workflow. The G-MoMo applications were demonstrated to each category of the participants. Each participant was allowed to carry out tasks using the G-MoMo applications to learn what they were doing. Three moderators supervised the process to ensure the smooth running of the session. After completing tasks, the participants were required to validate the applications by filling out the post-test questionnaire. The questionnaire contained five-point Likert scale statements developed based on the usability testing attributes used to validate the usability of the G-MoMo applications. The agreement scale used in the post-test questionnaire was (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, and (5) strongly agree. After completing the tasks, the selected participants appraised their satisfaction with the applications and shared their experiences and recommendations with the moderators. Data collected using post-test questionnaires in the usability testing was analyzed in RStudio software. Percentages, means, standard deviations, and graphs were computed and analyzed to understand the general usability of the assessed G-MoMo applications. The results for the mean (M) ≥ 3.41 were considered statistically significant (Pimentel, 2010).

RESULTS

Heuristic Evaluation Results

Usability experts conducted the heuristic evaluation to ascertain the usability issues with G-MoMo applications using Jakob Nielsen's 10 principles of heuristic evaluation. Each of the five usability experts independently evaluated the G-MoMo applications using heuristic evaluation principles to find usability issues. The usability issues encountered by each usability expert were compiled to produce the report on the heuristic evaluation. Sixty-three (63) usability issues were identified, where 33 (52.4%) were minor and 30 (47.6%) were major. **Table 3** shows the frequency of severity of usability issues with the interface designs of G-MoMo applications based on the 10 principles of heuristics evaluation.

G-MoMo IT support application had 10 minor and 8 major usability issues compared to the G-MoMo agent application, with 10 minor and 10 major and the G-MoMo customer application with 13 minor and 12 major usability issues. **Figure 7** shows the distribution of usability issues across the three G-MoMo applications.

Table 3 and **Figure 8** show the regularity of severity of usability issues with the interfaces of G-MoMo applications. The severity rating results showed that the "help and documentation (H10)" principle was mentioned 25 times (39.7%) with a mean severity score of 3.0 and had the most frequency, where it is grouped as a major problem. This was followed by the "user control and freedom (H3)" principle which had a mean severity score of 2.2 and frequency of 17.5% where it was grouped as a minor problem. The principles of "visibility of system status (H1)" and "aesthetic and minimalist design (H8)" were each mentioned once (1.6%), with mean severity scores of 2.0, and they had the least frequency and were grouped as minor problems.

The G-MoMo IT support, G-MoMo agent, and G-MoMo customer applications had more usability issues related to "help and documentation (H10)", and "user control and freedom (H3)". However, they had few usability issues related to "aesthetic and minimalist design (H8)" and "visibility of system status (H1)". The results of usability issues are presented in **Figure 9**.

Five significant themes related to usability issues were identified through the qualitative analysis of the three G-MoMo applications. The identified usability problems were based on heuristics principles and are clearly explained.

- *Lack of forward navigation button:* The three G-MoMo applications have a backward navigation button for mobile

money subscribers but lack a forward button. This has made it difficult for the subscribers to navigate between the different pages of the applications, thus affecting user control and freedom.

- *Lack of search field options:* The G-MoMo applications do not have search field options, making finding the required services difficult. This lack of search field options affects the applications' flexibility & efficiency and user control & freedom.
- *Lack of actions needed for recovery:* The G-MoMo applications lack detailed steps essential for recovery in case the applications crush, thus affecting the applications' error diagnosis and recovery.
- *Lack of uniformity in the G-MoMo applications menu titles:* Some menu titles of the applications are aligned to the left, center, and justified. This has caused inconsistency in the applications' menu titles, thus affecting consistency and standards.
- *Lack of help and documentation:* The G-MoMo applications lack help and documentation components for the subscribers. The instructions on using the applications are not visible or clear. They also lack a panel of tips and tricks for the application, and it is not easy for new users to understand the navigation menu. This usability issue thus results in errors during the applications' usage and makes it difficult for the users to recall the steps involved in the application's usage.

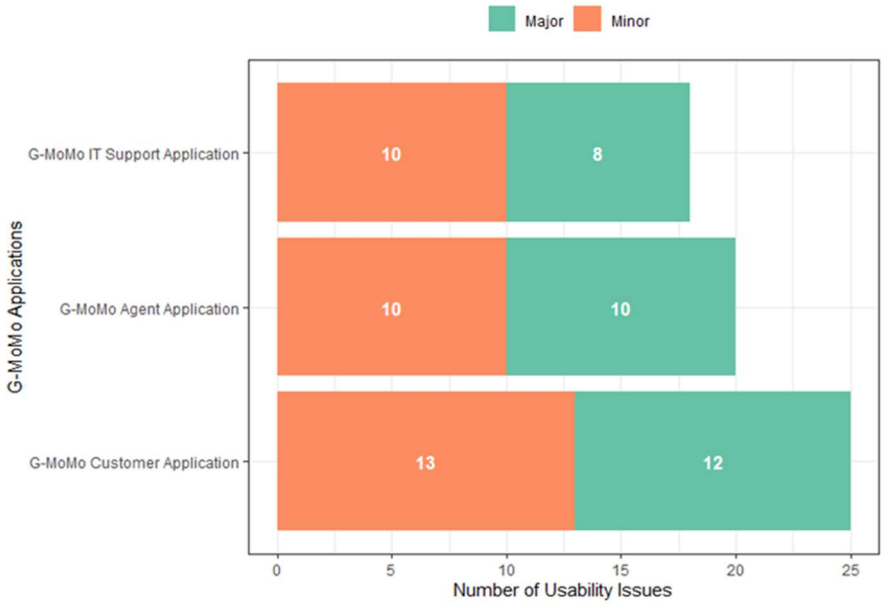

Figure 7. The distribution of usability issues across the G-MoMo applications.

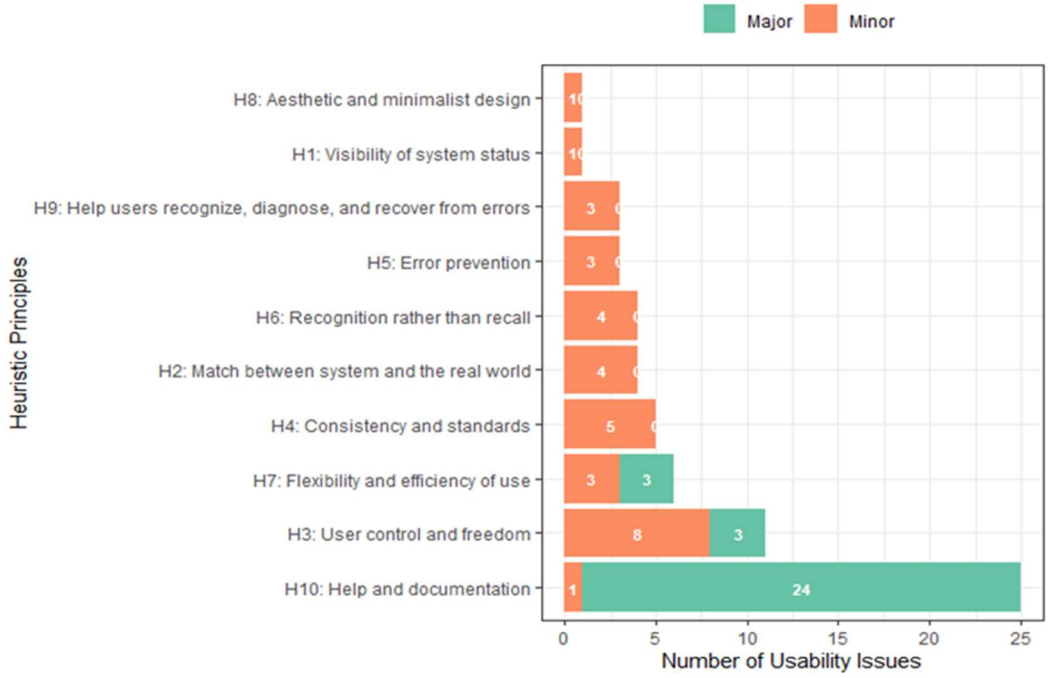

Figure 8. The frequency of severity of usability issues with the interfaces of the three G-MoMo applications.

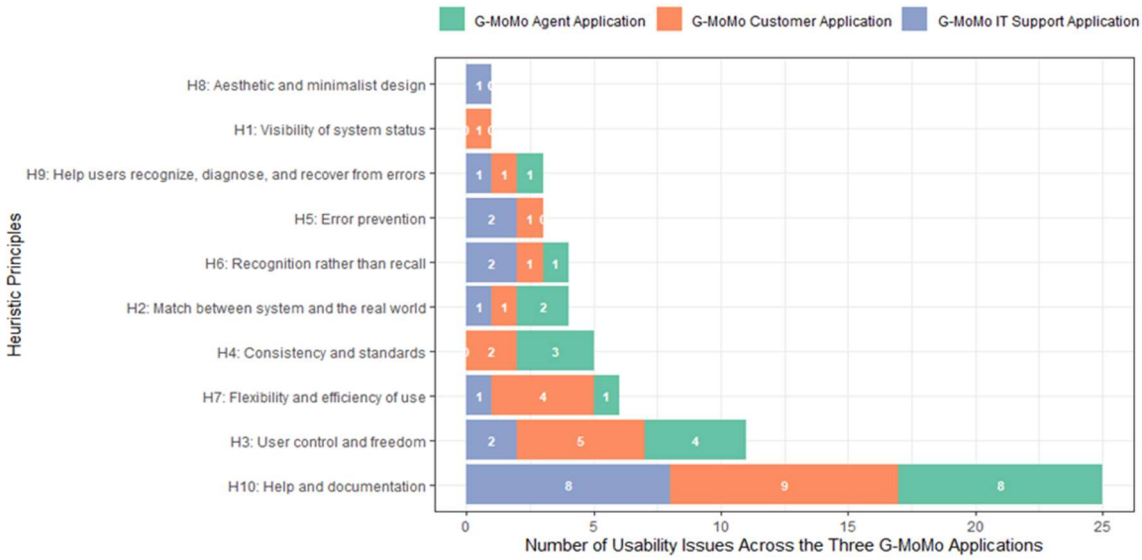

Figure 9. The usability issues with the user interfaces of the three G-MoMo applications.

Table 4. Opinion of participants about the usability of G-Momo applications.[1]

S/No	Usability Testing Attributes	SD	D	N	A	SA	M	Std Dev
1	Learnability	0.0	5.0	15.0	42.5	37.5	4.13	.853
2	Effectiveness	0.0	0.0	32.5	62.5	5.0	3.73	.554
3	Efficiency	0.0	0.0	7.5	42.5	50.0	4.43	.636
4	Memorability	0.0	0.0	17.5	70.0	12.5	3.95	.552
5	Errors	0.0	0.0	7.5	57.5	35.0	4.28	.599
6	User satisfaction	0.0	0.0	17.5	65.0	17.5	4.00	.599
7	Ease of use	0.0	0.0	15.0	67.5	17.5	4.03	.577
8	Aesthetic	0.0	0.0	17.5	62.5	20.0	4.03	.620
9	Usefulness	0.0	0.0	22.5	60.0	17.5	3.95	.639
10	Integration	0.0	0.0	10.0	57.5	32.5	4.23	.620

Usability Testing

The usability testing results presented are from the 40 participants selected to validate the G-MoMo applications by performing various tasks discussed in the materials and methods. The participants managed to submit 40 (100%) post-test questionnaires, which were analyzed. The percentages, mean, and standard deviations were calculated to assist in making decisions. **Table 4** depicts the participants' opinions regarding the usability of G-MoMo applications.

As shown in **Table 4**, majority of the participants agreed that, learnability (M = 4.13, Std Dev = 0.853), effectiveness (M = 3.73, Std Dev = 0.554), efficiency (M = 4.43, Std Dev = 0.636), memorability (M = 3.95, Std Dev = 0.552), errors (M = 4.28, Std Dev = 0.599), user satisfaction (M = 4.00, Std Dev = 0.599), ease of use (M = 4.03, Std Dev = 0.577), aesthetic (M = 4.03, Std Dev = 0.620), usefulness (M = 3.95, Std Dev = 0.639), integration (M = 4.23, Std Dev = 0.620), and understandability (M = 4.10, Std Dev = 0.496) were the usability testing attributes achieved while using the G-MoMo applications. Therefore, it was statistically significant to conclude that the above-mentioned attributes were achieved, and no issues were got with their usability because their means are greater than 3.41.

DISCUSSION

Before fully deploying the developed G-MoMo applications, the researchers needed to perform heuristic evaluation and usability testing to identify usability issues and suggest recommendations. Five experts and 40 participants were selected to participate in the validation. They were allowed to use the three G-MoMo applications to perform various tasks to identify usability issues, give recommendations for improvement, and assess their usability. The user interfaces design of G-MoMo applications was evaluated using Jakob Nielsen's proposed 10 usability heuristics, and usability testing was measured using essential attributes. The heuristic evaluation results revealed that many usability issues exist with the interface designs of G-MoMo applications, and most of the problems were ranked as minor and major. The usability issues identified are discussed as follows.

The G-MoMo applications lack forward navigation button, thus, forcing the users to either go back to the home page or select any service provided by the applications and then proceed to the required pages. This affected the user's control and freedom. This finding is similar to the studies by (Höhn and Bongard-

[1] *SD* = Strongly Disagree, *D* = Disagree, *N* = Neutral, *A* = Agree, *SA* = Strongly Agree, *M* = Means, and *Std Dev* = Standard Deviation.

Blanchy, 2020; Jeddi et al., 2020), where it was found that applications without backward and forward navigation buttons make it difficult for users to navigate between the pages. Most of the menu titles of the G-MoMo applications are not uniformly aligned. Some menu titles are aligned to the left, centre and justify, which shows inconsistency in the alignment. This has affected the consistency and standards in the design of the G-MoMo applications. This reaffirms the results of earlier studies by (Othman et al., 2018; Vingen et al., 2020), who observed inconsistency in heading and a lack of adherence to conventions, design principles, and application patterns with the applications.

The G-MoMo applications do not have search field options, making finding the required services difficult and affecting the applications' user control & freedom, flexibility & efficiency. This is in line with (Paramitha et al., 2018), who identified a lack of search features in the application. (Eliseo et al., 2017) recommended that search features be strategically placed on the application to search for required services. The G-MoMo applications lack the necessary steps vital for recovery in case the applications crush. This affected the applications' error diagnosis and recovery. It was well confirmed by other studies (Caro-Alvaro et al., 2018; Höhn and Bongard-Blanchy, 2020), who observed that the applications do not indicate the error occurrence and the error was not explained in plain language. (Eliseo et al., 2017) recommended that error messages be displayed clearly. The G-MoMo applications also lack help and documentation components for novice users. The instructions on using the applications are not clear, and they also lack a panel of tips and tricks for the application, thus making it difficult for novice users to understand the navigation menu. This usability issue then results in errors during G-MoMo applications' usage and makes it difficult for the subscribers to recall the steps involved in the application's usage. This outcome is consistent with the earlier studies by (Jeddi et al., 2020; Kekkonen and Oinas-Kukkonen, 2019), who mentioned that the applications lacked any features related to the help and documentation and tooltips/instructions that provide helpful guidance to users. In addition, (Abidin et al., 2019) suggested that applications should have a help and documentation feature to access help easily and be explained in plain language so that new users can understand.

The discussion of the results for the usability testing of the G-MoMo applications is: The users found it easy to learn how to use the G-MoMo applications, thus, enhancing their performance. This finding is also reported in earlier studies by (A'bas et al., 2021; Al-Gayar et al., 2021; Byun et al., 2020), where they found that the systems were easy to learn. The G-MoMo applications were highly effective because they allowed mobile money subscribers to complete the tasks accurately to achieve their specified goals. This finding is logical to the studies by (A'bas et al., 2021; Byun et al., 2020; Lowe et al., 2021). The overall usability testing result is positive for the effectiveness of applications. The G-MoMo applications are efficient since users take less time to complete tasks accurately. This reconfirmed the results of earlier studies by (A'bas et al., 2021; Hussain and Omar, 2020; Lowe et al., 2021; Zakaria et al., 2020), where they found the applications efficient for the users. The users also agreed that they would remember navigating between G-MoMo applications pages the next time they use it. This is supported by (Alturki et al., 2020; Putri et al., 2021; Sukmasetya et al., 2020; Zakaria et al., 2020), who reported that the users easily remember the steps followed while using the applications. The participants reported having encountered fewer errors while using the G-MoMo applications. This finding is consistent with the earlier studies by (Alturki et al., 2020; Putri et al., 2021; Zakaria et al., 2020), where it was mentioned that the total number of errors decreased while using the applications. The users achieved satisfaction with the features, functionalities, design, information and display quality of the G-MoMo applications. This finding was also reported in earlier studies by (A'bas et al., 2021; Al-Gayar et al., 2021; Lowe et al., 2021; Putri et al., 2021), where they observed that the users were satisfied with the applications' functionalities and design. The participants mentioned that the G-MoMo applications were easy to use, which helped them achieve satisfaction. This outcome is reported in studies by (Al-Gayar et al., 2021; Byun et al., 2020), where it was noticed that the applications had excellent content knowledge and were pretty easy to use. The G-MoMo applications have a high aesthetic rating because they are attractive to the participants. It is also affirmed by (Santesteban-Echarri et al., 2020), who observed that the applications are aesthetically designed. The G-MoMo applications were helpful for mobile money subscribers since they can perform the required services. It is further supported by (Al-Gayar et al., 2021; Kumar et al., 2020), who reported that the applications were useful in achieving their intended goals. Other usability attributes identified included integration and understandability.

CONCLUSION

With mobile money's wide adoption and usage in developing countries to foster financial inclusion, the current 2FA schemes suffer severe security issues. The researchers developed secure G-MoMo applications to resolve the security issues encountered. This paper, therefore, validated the developed secure G-MoMo applications using heuristic evaluation and usability testing. The three prototypes of the native G-MoMo applications were validated to identify usability issues and defects with the applications' user interface. The usability issues identified in the heuristic evaluation included lack of forward navigation buttons, lack of uniformity in the application's menu title, lack of search field options, lack of actions needed for recovery, and lack of help & documentation. While, the usability testing results confirm that the three G-MoMo applications' performance proved good in learnability, effectiveness, efficiency, memorability, and errors. It also provided user satisfaction, ease of use, aesthetics, usefulness, integration, and understandability. These validations were carried out independently with no biases that could have influenced the study's outcome. Therefore, the developers must improve the interface designs of G-MoMo applications by fixing the usability problems identified to make them more reliable and increase users' overall satisfaction.

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