LRAP: Layered Ring Based Adaptive and Personalized Usability Model for Mobile Commerce Apps

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Abstract—Usability is one of the most important characteristics of software applications, especially when it comes to mobile shopping applications. There is a great deal of shift from traditional shopping to online shopping because it benefits both parties i.e., customers as well as businessmen. In such a scenario, the usability factor can play a very vital role in the business industry. If a client stops using a mobile shopping app because it is not user-friendly, it can badly damage the annual revenues especially when hundreds of alternatives are available and there is tough competition. Therefore, to keep existing customers intact and to attract new customers, it is very important to provide a user-friendly mobile app to customers. This paper considers a large variety of online customers with diverse requirements. background and constraints and evaluate the usability of existing mobile e-commerce apps to identify the problems people face with existing applications and do a systematic review of existing shopping apps. Then, we propose a personalized and adaptive usability model for mobile commerce apps considering the neglected user type i.e., illiterates and people with tactile disabilities. The proposed model LRAP is a layered approach from generalization to specification and it can be considered an extension of the famous PACMAD usability model. Besides this, we also suggest a combining score tool which will be helpful in measuring the usability of any app. Participant-based usability evaluation is the major technique used to identify the design problems in existing mobile commerce apps. Major design issues identified in mobile commerce apps include poor navigation and lack of personalization for illiterates and people with tactile disabilities.

Keywords—usability model, online shopping, m-commerce, mobile apps

1 Introduction

1.1 Background and motivation

A good interaction between technologies and their users not only improves user satisfaction but also helps in fostering effective communication between them [1]. Failure to satisfy its users or customers will create dissatisfaction among them eventually leading to quitting the system. Hence, the provision of an effective, user-friendly, and interactive system design for customers is vital to prolonging the business [2]. This is where the concept of Usability Engineering comes in. *"Usability engineering"* [3]is a discipline focused on creating user-friendly and highly usable computer interfaces. It is generally concerned with human-computer interaction.

Technology has seen a lot of progress during the last few decades. Today when mobile Internet is the most popular form of the Internet among users, the concept of e-commerce has taken the more popular name of m-commerce [4]. Just like e-commerce, m-commerce offers huge potential to its customers as well as business owners [5]. After the sudden outbreak of COVID-19 as schools and colleges shifted towards online learning platforms [6] traditional shopping also hugely shifted towards online shopping platforms.

1.2 Problem definition

While m-commerce is making well-paced progress and lots of mobile shopping apps are available to customers, several issues need attention and, in this work, our target is one issue that has been largely neglected among researchers as well as developers i.e., usability and the user interface experience. It is accepted that usability is the biggest cause of frustration for net users [7]. Because a user's decision to stop using a mobile shopping app due to a bad user experience would directly affect the business owner's annual income, it is important to understand that in m-commerce, the user experience of mobile apps is directly tied to annual revenues.

1.3 Contributions

Mobile app usability has attracted a lot of attention from researchers recently and many have worked on proposing usability guidelines [8], [9] and usability models [10], [11]. In order to fill the research gap for the usability of mobile commerce apps, this paper adds three major contributions in this regard which are listed below:

- As our first contribution to this paper, we perform a systematic review of mobile commerce apps which reveals the market share, range of functions and user ratings, etc.
- Participant-based usability evaluation is our second major contribution to this paper. This step is very important in our work because it lays the foundation for the most important contribution of LRAP i.e., a usability model by identifying the major design issues in existing mobile commerce apps.
- Finally, as part of our major contributions, we propose an adaptive and personalized usability model (LRAP) to address the concerns identified during usability evaluations. The proposed LRAP usability model is unique and novel in its nature. It is a layered ring-based model which shows an approach from generalization to specification. In addition, LRAP is navigationally adaptive and is personalized in terms of content display. Both of these features make it very suitable for people with tactile disabilities.

1.4 Research objectives

The following is a description of the main research goals of the work that was presented:

- To pinpoint the actual usability challenges in m-shopping apps by means of performing detailed user-based evaluations,
- To evaluate the user experience of a wide diversity of participants from participants with tactile deformities to illiterates to reflect a real-world evaluation of the mobile apps,
- To identify the gender-based usability problems in mobile shopping apps,
- To identify which usability factors are more important for users and which are being neglected in the design of mobile shopping apps,
- To propose an adaptive and personalized usability model for mobile commerce apps.

The structure of this paper is as follows: We describe some relevant work in the section that follows the experimental section, in which we describe our experimental settings in a detailed manner, and then the results of the experiments are discussed. In the next section to this, we propose a personalized usability model for mobile shopping apps.

2 Related work

Here, we provide a quick summary of the relevant work. i.e., we highlight some works that have proposed usability evaluation models in the literature.

Baharuddin et al [12] introduced a usability evaluation model that involves ten dimensions to measure mobile applications' usability. The dimensions proposed are dependent on the level of significance that is affected by four major factors in terms of context. These four contextual factors involve task/activity, technology, environment, and use which are in the principles of HCI.

Mobile commerce has become an indispensable aspect of diverse industries. Shin et al [13] examined unique behavioral aspects of customers by conducting a theoretical study dependent on the integrated framework. It includes the B2C channel preference model, web satisfaction, and IS success.

The effectiveness of various smart devices has enhanced mainly in current years per-permitting customers to do chores in the mobile framework. This enhancement in the context of use has resulted in the usability of such devices in some contexts. Mobile usability models have been evaluated and it has been identified that usability gets measured mainly in three terms that are satisfaction, efficiency, and effectiveness. Other factors like cognitive load get overlooked in the usability model despite having a major influence over the failure or success of an application. To overcome this issue, the "PACMAD" (*People at the Centre of Mobile Application Development*) model [14] has been introduced.

This model has been introduced to conquer the shortcomings of present usability models. It has not involved any such attributes that are new, but the attributes that get neglected by other usability models. This results in an incomplete evaluation of usability. The major downfall of the proposed model was that it was considered that the people who are using the mobile application are literate or illiterate. The literacy of the users should also be considered important while evaluating usability. This factor should also be considered while performing the evaluation.

3 Systematic review of mobile commerce apps

In this section, we discuss how a systematic review of mobile commerce apps is performed. It includes searching and screening of mobile apps and a discussion of the results of a systematic review of mobile commerce apps.

3.1 Strategy of search and screening

The primary step in reviewing and evaluating the usability of mobile commerce apps is data collection. The Android operating system is the main focus of the data collection for these particular apps. The Google Play Store is where Android OS-related apps are gathered. Mobile commerce shopping apps with English as a language are our primary targets. To choose any app related to e-commerce or online shopping, it is first necessary to determine the keywords. Thus, the keywords "online shopping apps in Pakistan", "free shopping apps", and "buying and selling apps" were chosen in English. Each app was evaluated based on its relevancy to prevent spam or misleading descriptions. All the selected apps were evaluated based on the presence of effective functions and sub-functions to check their impact on the rating of the apps.

3.2 Systematic review results

The strategy of search and screening. A total of 187 apps were assessed as part of the search and screening process, including 124 apps for Android and 63 apps for iOS. Three data sets were produced in total. One sheet contains apps for the Android platform (124) and the other sheet carries apps for the iOS platform (63 apps), with the final sheet containing all of the apps available on both platforms (56).

Market share of both platforms. The market share of Android versus iOS apps is seen in Figure 1 by which we can see that Android maintained its position as the leading mobile operating system. The market share of Android versus iOS apps is shown in this pie chart. Android contributes significantly to the market in terms of mobile shopping apps with 73%, compared to 27% for iOS apps.

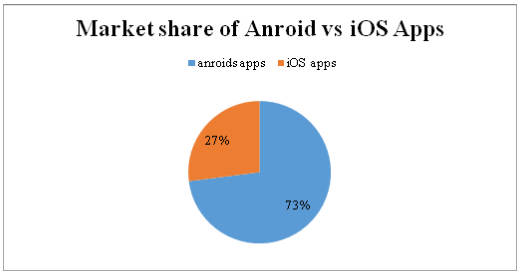


Fig. 1. Market share of Android v/s iOS Apps

Acquisition cost. From the gathered results the ratio of free apps vs paid apps, the acquisition cost showed significant variance when compared between Android and iOS. Android offers an almost free version of every app (661) where payment is required for many iOS apps, around 62% percent of apps in iOS are free (38/100). Thirty-eight percent of mobile shopping apps are paid apps and 23 offer a lite version, In contrast to 2 percent of paid apps on Android.

Range of functions. The detail of functions and their effective sub-functions present in mobile shopping apps on which we evaluated the apps are as follows:
F1. Registration: with no. with mail id, F2. Product Search: QR/Barcode scanner, image search, voice search, F3. View and reviews: VR/AR, 360-degree view, recommendations, F4. Offers for customers: sales discounts, gaming points, vouchers/coupons, F5. Communication: chat boxes, helpline, social media integration, F6. Placing order: Autofill info, payment methods, F7. Product-related services: order tracking, return, refund

A thorough examination of every function has revealed it. Few applications actually offer all of the functionalities needed for customers to easily and seamlessly continue their online shopping. In general, iOS with average functions per app of 2.43 has more functionalities than Android on average (2.01), as shown in Figure 2. The presence of effective sub-functions has a great impact on user ratings, so iOS apps have more ratings as compared to android apps.

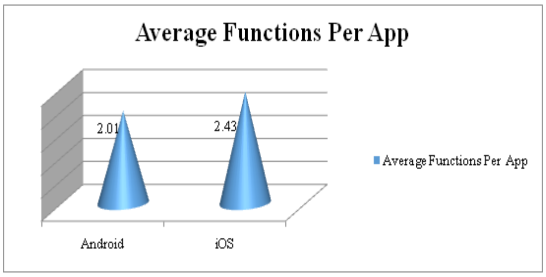


Fig. 2. Average Functions per Apps in two Platforms

Average user ratings. Figure 3 displays the average rating for iOS apps at 4.28 and for Android apps at 4.26. From the detailed review of the apps, it has been seen that iOS apps have more user ratings as compared to Android due to the presence of more effective sub-functions in apps.

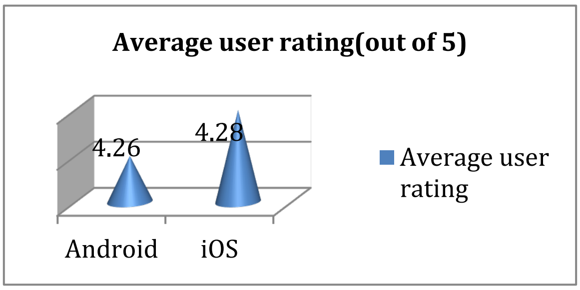


Fig. 3. Average Functions per Apps In two Platforms

4 Usability experiments

In this section, we explain our usability experiments in detail. We add details on participant selection and their further categorization according to age and gender, selection of mobile apps, and complete the usability evaluation process.

4.1 Participants-based usability evaluation

Participation-based usability testing is the practice of evaluating an application's user interface and interactivity while interacting with actual users. [15]. In this approach to usability testing, several tasks are given to a set of users while they are being observed by an observer. The user's actions are attentively observed in a secure setting, usually a lab equipped with cameras. The entire scenario was designed with the intention of collecting subjective, qualitative, and quantitative data that could be used to assess usability and identify interface problems [16]. Consequently, this method of measuring total user satisfaction.

4.2 Participants selection

The nature of the problem and the questions we seek solutions to make the participant selection process in our situation a challenging one. Because of the nature of our issue, we must aim our attention to a variety of people. Globally, we require carefully chosen individuals who are: 1) educationally literate, 2) educationally illiterate, 3) digitally literate, 4) digitally illiterate, and 5) physically deformity of hands.

For a fair review, we must also select an equal number of individuals from each gender for each of these participant categories. We must be very careful when selecting the total number of participants because a lesser number may not accurately reflect the views of the entire public while an excessively high number will add to our workload [17]. We must, however, select a sufficient number of participants from each of the participant categories stated above. using the literature as a guide to find a baseline for the number of chosen participants [18], We chose to choose six people for each group, for a total of 30 participants.

Gender consideration. We decided to keep a 50% gender distribution among all categories i.e., we will choose 3 male participants and 3 female participants from each category.

Age binning. we set 3 age boundaries for each category, i.e., we choose an equal number of participants from each age boundary for each category. Group A ($20 \leq Age \leq 35$), Group B ($36 \leq Age \leq 50$), and Group C ($51 \leq Age \leq 65$).

We selected a total of 30 people are used to perform the usability testing. The reason for selecting this number of participants is based on previous papers' references. For instance, in [19] a total of 5 people were used to perform usability testing. Similarly, in the paper [20] 8 people were chosen to perform the usability analysis. Based on the previous work we chose 6 participants from 5 different categories of participants and hence making it a total of 30 participants

Mobile application selection. For usability analysis of mobile applications, we decided to select 20 percent of the total applications as selected for a systematic review of mobile commerce apps. The decision of selecting only 10 percent of apps is not a random decision but, in the literature, there exists such precedence [18],[21]. However, we make sure that we select those apps that contain all relevant functions to represent their population in a true sense. From the collected data of 180 apps (120 apps in android, 60 apps in iOS), we select a total of 36 apps. Out of 36 apps, 24 apps are selected from android and 12 apps are selected from iOS i.e., 20 percent of the total apps from each platform are selected.

- Apps that are relevant i.e., they are a commerce application and used by the common audience and not by a particular group of users,
- The main language of the Apps is English,
- Apps include the maximum no. of functions as selected in the systematic review process.

Based on the criteria defined above, we choose the following apps for the usability review. Table 1 consists of 3 columns. The first column contains the types or categories of apps that is in which category that particular app exists, then column 2 and 3 contains the selected apps for usability evaluation on both platforms.

Table 1. List of selected mobile shopping apps and their categories

Category	Android Apps	iOS Apps
All in one	Daraz, Amazon, Ali Express, Ebay, Bangggod, Naheed.pk	Alibaba,11 Street, Econox
Fashion Shopping	Namshi, Clicky, Elo, Meesho, Karma, Fashion Nova	Negative Apparel, Patpat, unze
Grocery & Electronics	Airlift, Metro online, Grocer App, Alfatah, Gahak, Krave Mart	Maf Carrefour, Noon, Talabat
Clothes and brands	Outfitter, LimeLight, Beechtree, j., Bonanza, Maria. B	Zara, Khaadi, Ethenic

4.3 Test material preparation

Pre-test questionnaire. A pre-test questionnaire generally consists of questions related to participants.

Post-test questionnaire. The post-test questionnaire is based on usability criteria. We create this set of usability criteria which is based on the study of existing literature and our observation of online shopping applications.

4.4 Usability evaluation process

Usability evaluation is a time-taking process with several tests to be conducted on several applications using selected participants. In our case, we have a total of 1080 (36 x 30) tests to be performed. We have to test 36 applications using 30 selected participants. Keeping in mind the easiness of the participants and the time it takes to conduct a test; we plan to conduct tests in several sessions. After a detailed discussion with the participants, we decided to conduct all experiments in four sessions for each participant. The details of each session are given below in the table.

It is unanimously decided with participants to complete all 4 sessions within two days. We decided to allocate morning and evening timings for separate sessions. Even a few participants expressed their willingness to complete the test within a day, but we did not want to let their fatigue overcome during the usability testing process and hence we requested 4 separate sessions. We also made sure that participants are invited on those days when they are totally free. We keep a participant engaged even when he/she is not performing usability tests to keep him thinking in the same space. We take the following precautions for all tests.

- Before the test begins, all participants receive a briefing on usability testing.
- All testing is carried out in a controlled setting with appropriate lighting arrangements and a WIFI facility in case it's required.
- On the appropriate cell phones, every mobile app is already installed.
- Mobile phones are introduced to participants in order to prepare them for testing. They are instructed on how to use the back and home buttons, as well as the virtual keyboard on the phone.
- Time of start and end of each test is noted down,
- To prevent any learning effects on the outcomes, we ensured that no participant had ever used any of the chosen apps.
- Before the first session, everyone signs a "letter of consent."

4.5 Identified design problems in mobile commerce apps

The main objective of conducting usability testing was to identify the problems in the user interface of mobile shopping apps available for Android platforms and iOS. The idea behind this is to find out the design problems in existing mobile commerce apps so that identified design issues can be targeted in the proposed usability model.

We have conducted a very extensive set of usability experiments and conclusively following problems have been identified in mobile commerce apps:

- Men and women behave very differently when evaluating mobile shopping apps because women are more engaged in online buying.
- In terms of usability evaluation, the app "daraz. pk" received the highest ratings, while "maria. B" received the lowest ratings from participants and in the play store rankings.
- It is concluded that an app's usability is substantially influenced by its effective usability features.
- It has been discovered that the ratings for the usability of shopping apps for iOS and Android are significantly different.
- Due to the cultural gap and their resistance to technological advancement, people in rural areas are reluctant to shop online.

Usability evaluation represents the following negative characteristics in mobile shopping apps.

- No visual presentation for the loading process
- Too many navigational delays
- Lack of personalization and optimization (old people and people with tactile disability unable to select small icons or buttons that are in corners)
- Many apps have no local language option due to which the app is not learnable for illiterates.
- Access to category products is challenging.
- Home button is not accessible in most apps.
- Problem in selection according to exact feature or requirement
- No proper help was provided.
- There is not any error message in case of wrong input.
- Not sufficient information on what functions apps offer.
- It is hard to use the app for a prolonged time.
- Security problems related to payment.
- Most apps didn’t have proper reviews about the product.
- Apps icons are complicated to operate.
- No return policy for faulty products
- Even digitally illiterate people are not able to know the proper way of searching for payment.

The following is a list of some positive features as revealed from the ratings of participants.

- The Apps offer easy scrolling.
- The App uses easy language.
- The Screens throughout the app are consistent.

5 Usability model

This is an era of technology and advancement that keeps all information in the palm of a hand. So currently developers are trying to develop easy-to-use interfaces that fulfil the needs of users and give them a good experience. Same the existence of an e-marketplace on mobile phones growing rapidly with the passage of time users can make transactions anytime anywhere with just a few clicks on mobile. This makes m-commerce more common, especially after COVID-19. Usability is an important aspect of m-commerce because today's users are not satisfied with the mobile app that simply allows them to shop, but the experience must also be pleasant [92]. In this section, we describe one of the major contributions of this paper i.e., personalized, and adapted usability models for mobile commerce apps. Other contributions of this paper include a systematic review of mobile commerce apps, usability evaluation of mobile commerce apps, and heuristic guidelines development for mobile commerce apps. The proposed layer usability model for mobile commerce apps is adaptive as well as personalized in terms of its navigation, tactile disability, illiteracy, and visualization. It can customize the UI whenever it senses any wrong clicks (adaptive) and random navigation according to the user's needs (personalized). Furthermore, the proposed model gives the liberty of having audio accessibility and versioning to address different disabilities like tactile disabilities or illiteracy.

5.1 Existing models and deficiencies

While all models consider several usability factors in their approaches, they still lack on many fronts. Table 2 gives the description of previous usability models with their attributes and domain area for which they are proposed and the possible deficiencies in them.

Table 2. Existing Models and Deficiencies

Model	Attributes	Domain	Deficiency
Shackle (1991) [22]	Effectiveness Flexibility Learnability Attitude	LMS	Greatly emphasizes on consideration of environments in which the system is used.
Neilson (1993) [23]	Efficiency Learnability Satisfaction Memorability Errors	Web usability	These attributes are specifically for websites. do not consider the issues of mobile apps.
ISO-9241-11 (1998) [24]	Efficiency Learnability Satisfaction	Interactive systems	Basically, international standard attributes but not according to apps.
ISO-9126-1 (2001) [25]	Portability Functionality Reliability Usability Maintainability Efficiency	General and Web-based applications	The modified version considers the issues of mobile apps but not for a specific domain.
PACMAD (2013) [14]	Efficiency Learnability Satisfaction Learnability Memorability Errors Cognitive Load	Mobile Apps	Specifically for mobile apps and greatly acceptable. but it is not personalized according to different domains and diverse users.

The PACMAD model has been popular among the research community and mostly it has served as a seed model for many newer usability models. As in [26] researcher used the PACMAD model for testing the mobile application. Studies like [27], [28] also used the PACMAD model in their empirical investigation of apps. The study based on demographics [29],[30] also used the PACMAD model for the usability evaluation of mobile applications. Therefore, we chose the PACMAD model as our base for personalized models due to its popularity and acceptance for mobile application development. While all existing usability models including the PACMAD model are found to be very effective on many fronts, however, all these usability models lack richness on some ends as given below:

- Specificity (especially for m-commerce apps which is the focus of this paper
- Personalization
- Adaptability in navigation

6 LRAP: Layered ring-based adaptive and personalized usability model

In order to solve the shortcomings of current usability models when used with mobile devices, the PACMAD model [31] was proposed. To develop a more complete model, PACMAD combines key characteristics from many usability models. None of the characteristics it offers are novel, but one or more of them are disregarded by the popular usability models now in use. This can result in an incomplete usability assessment. Figure 5 displays the PACMAD model's attributes.

In this section, we describe the proposed LRAP (layered ring adaptive and personalized) mobile shopping apps usability model by providing details on its every component along with diagrams where necessary. The proposed model is unique in its contribution. The added components in the proposed model target the various deficiencies found in existing usability models or frameworks. These components also reflect the findings of usability evaluations we performed. In Figure 4 three gray arrows in the model with directions from outside to the inside of the model show the specificity of the model i.e., these are indications of a voyage from generalization to a more specific set of applications. The outer blue layer is showing the PACMAD model with its contextual factors (user, task, and context) and the extensions of the PACMAD model i.e., LRAP shown in the inner green and red layers. The green layer consists of three components which are generic and used for other domains also, but the 3rd red layer is domain specific which consists of the attributes based on 3 basic commerce sites elements. In the following, we describe all the proposed components of the LRAP model.

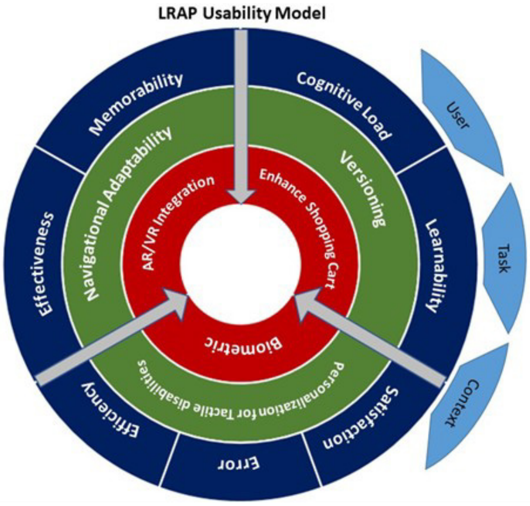
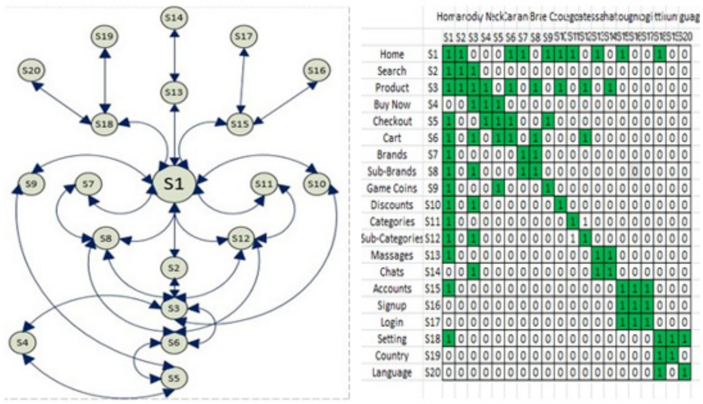


Fig. 4. The Proposed LRAP Model

6.1 Components of LRAP

Navigational adaptability. It has been found from our usability evaluations that people can get confused when they are navigating between different mobile screens especially when they are searching for a particular product or when they are trying to reach some service information. It becomes more severe when mobile commerce apps are being used by some illiterate person no matter whether educationally illiterate or digitally illiterate [32]. Therefore, we suggest a graph-based module that can aid in anticipating the upcoming screens a client would be looking for. For the client's fastest access to the screen of his choosing, all potential candidate screens are enlarged and displayed at the bottom of the current screen. This becomes possible when an adjacency matrix for all screens of the mobile app is created. We know that in graph theory, "an adjacency matrix is a square matrix utilized to describe a finite graph". The components of the matrix convey whether the pairs of a finite set of vertices (also called nodes and in our case mobile screens) are adjacent in the graph or not. In graph description, the networks are stated with the help of nodes and edges, where nodes represent the vertices and edges represent the finite set of ordered pairs [33], [34].

In our case, we present all possible screens of the mobile app as a directed graph which is further represented as an adjacency matrix. An entry in a cell (i, j) represents a directed edge from the screen i to screen j. Figure 5(a) shows the directed graph for screens of a particular mobile commerce app. Each node represents a screen and the edges between these nodes represent a directed link between screens. Screen S1 shows the home screen and its links to all other screens are shown by arrows in Figure 5(a). Figure 5(b) is the representation of a directed graph in the form of an adjacency matrix which shows the possible navigation from 1 screen to another and from which screen we can move back to the home screen the green box with value 1 shows the link between screens while 0 shows that there is no direct link between these screens.



		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
Home	S1	1	1	0	0	0	1	1	0	1	1	1	0	1	0	1	0	0	1	0	0
Search	S2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Product	S3	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0
Buy Now	S4	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Checkout	S5	1	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cart	S6	1	0	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Brands	S7	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Sub-Brands	S8	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Game Coins	S9	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Discounts	S10	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Categories	S11	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Sub-Categories	S12	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Massages	S13	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Chats	S14	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Accounts	S15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
Signup	S16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
Login	S17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
Setting	S18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Country	S19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Language	S20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Fig. 5. (a) Network of links Between Pages and (b) corresponding Adjacency Matrix

Weighted adjacency matrix. We propose to update the adjacency matrix of Figure 5 by replacing the 1s in each cell with a navigational weight. The navigational weight is indirectly a kind of recommendation for the link to be followed from the existing or current screen. This navigational weight is computed by monitoring all sessions of previous interactions of any client with the mobile app. Each time a user follows a particular link the relevant weight increase by 1. Therefore, once a user is on a particular screen, he or she is presented with relevant magnified screens for the cells which are highly weighted.

$$P_{SiSj} = \frac{C_{SiSj}}{T_{SiSn}} \quad (1)$$

Where P_{SiSj} is the probability of navigating from screen Si to screen Sj computed over all previous interactions of any user. C_{SiSj} is the total number of navigations from screen Si to Sj while T_{SiSj} is the total number of navigations from screen Si to any screen Sn.

Let's assume that Nij denotes the total number of links between screen Si and Sj then in a case where P_{SiSj} are equal for any two screens from a specific screen then we will give preference to Nij i.e., we will show the screen with a greater number of links in-between to reduce the overall number of navigational clicks. It is also to be noted that screens like Order Placement and Shipping Details etc. are excluded from these calculations because each client completing his/her order will is always going to visit these pages hence increasing their P_{SiSj} which will cause a bias and will result in recommending these screens to the clients always.

Personalization for tactile disabilities. One of the deformities we focused on in our work is tactile disability i.e., people with different and special hand formations like thick fingers, cut fingers, big hands, small hands, etc. Normally such hand formations cause problems in navigation when using buttons or links to switch screens.

We propose this module to tackle this problem in future mobile application developments where we focus on this problem and propose a solution by combining evidence from previous session interactions of a particular user and visual interaction.

Let us take the example of people with thick fingers, which is very common among our population. It has been observed during our usability evaluation process that people with thinking fingers find it difficult to interact with a rather smaller screen of mobile. It creates unfocused and untargeted clicks on mobile screens because of their inability to click a relatively smaller button or link.

The proposed solution for this problem is magnified visual buttons see Figure 6(a) which shows the previous screen with a small corner button and 6(b) with visualized button after magnification based on the previous interaction history of a particular user. Our navigational soft agent will keep an eye on previous interactions of users with the mobile app. This soft agent has all the information about the size and locations of all buttons or text links. It gathers information about all unfocused clicks in a certain perimeter around the buttons and links in all previous sessions. It waits for a specific threshold to reach (as fixed by our agent) and once the number of unfocused clicks surpasses this threshold mentioned in Table 3 which is based on the calculation of no. of useless clicks on a specified pixel location on a specific screen, this agent passes the message to Visual Magnifier to magnify those specific buttons in their next interactions. The user will always have the choice of restoring the original visual display in case he/she does not want to continue with magnified buttons.

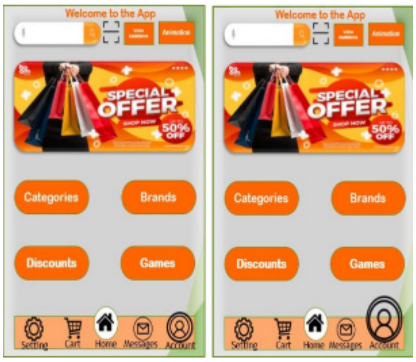


Fig. 6. (a) Normal Visualization, (b) Versioning with Magnification

Table 3. Useless Clicks Calculator Table Maintained for Each user overall Sessions

Object	Screen	Location	Useless Clicks
Button 1	S1	Pixel Locations of Corners	1
Button 2	S1	Pixel Locations of Corners	2
Button 3	S1	Pixel Locations of Corners	2
Button 4	S2	Pixel Locations of Corners	0
Button 5	S2	Pixel Locations of Corners	1
Button 6	S3	Pixel Locations of Corners	3
Button 7	S4	Pixel Locations of Corners	2
Button 8	S4	Pixel Locations of Corners	3
Button 9	S4	Pixel Locations of Corners	4
Button 10	S5	Pixel Locations of Corners	2

Versioning. This module is designed for app users who are illiterate since their ability to interact with the app may be limited by content that is not tailored to their cognitive capacities. For instance, the user may be presented with a localized version of the mobile app in his or her native language, a more graphical version of the app may be shown if necessary, or in another situation, the user may be given a more wizard-based interaction. In short, versioning can provide a very effective alternative solution to many problems the general audience faces and effectively increase the mobile app hits. Figure 7(a) shows the app interface in English as a general public view and 7(b) shows the interface in Urdu version in terms of personalized versioning so to increase the learnability of the interface.

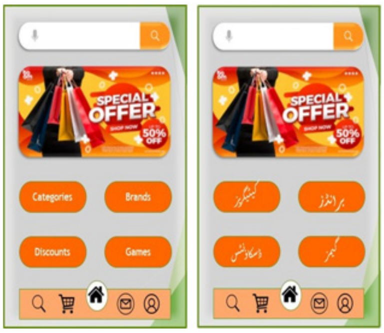


Fig. 7. (a) General Public View, (b) Personalized Versioning (In Urdu)

AR and VR integration. Virtual commerce transforms online shopping from 2D product catalogs to 3D immersive virtual places by integrating immersive technologies like augmented reality and virtual reality. [35]. To encourage the purchase of goods and services in virtual commerce, it is critical that application design principles and the factors driving customer behavior align [36]. Their link must be clarified, and there may be room for improvement in the way applications are designed [37]. According to the findings, anthropomorphizing AR-mediated m-commerce positively influences customer confidence, perception of innovation, and subjective norms assigned to AR-mediated m-commerce [38], all of which have a positive impact on attitudes toward AR-mediated m-commerce [39].

Biometric payment. Biometrics will authenticate more than $3 trillion in payment transactions in 2025, up from approximately $404 billion in 2020, according to a recent Juniper Research. According to the survey, as mobile payments take over the payments landscape, biometrics like fingerprint, iris, voice, and facial recognition are more important for creating engaging app experiences.

Enhanced shopping card payments. The functionality of a retailer's shopping cart might influence or dissuade a customer from making a purchase. With mobile commerce, cart abandonment is a significant problem, thus certain features are crucial to ensuring that customers come back to buy the item they are interested in [2]. To make it simple for shoppers to return and buy an item later, shopping carts should save all product data and metadata. Customers should be able to access their order, the retailer's catalog, and customer management through the cart so they can locate everything they require in one location [40]. A company can make the checkout process simpler for customers by improving shopping cart features, ensuring they won't encounter any difficulties or annoyances that will cause them to remove items from their cart.

6.2 Combining scores

This component is very important in combining different heterogeneous evidence to mark the overall usability of a mobile app. The idea is to integrate all possible evidence possibly available to compute the final usability score. The main challenge in this task is how to combine the scores on different scales and whether all scores should be given equal weightage, or whether some should be given preference over others. The main sources of different scores are:

- Usability score as computed as a result of Participant based Usability Evaluation
- User Ratings of the app
- Scores (positive) obtained as a result of mobile app reviews mining

A simple linear or weighted combination after a suitable normalization measure can be used to combine these scores.

7 Conclusion

In this paper, we performed a comprehensive usability evaluation of mobile commerce apps. In the literature, we cannot find any work which has performed usability testing on such a large scale to find usability problems in mobile commerce apps (to the best of our knowledge). A total of 1080 experiments have been performed for 36 apps using a total of 30 participants from various categories. We discuss the results in detail and as a conclusion, we identify some usability problems as, too many navigational delays, Lack of personalization, especially for tactile disabilities related to hands, Unavailability of local versions of apps, and Access to the exact category of product is problematic. In addition to all this, we describe our major contribution in this paper i.e., the LRAP usability model which is an adaptive and personalized usability model for mobile commerce apps. It targets most of the challenges as far as interaction with mobile shopping applications is concerned. Its layered-based ring design encompasses generic to specific approaches in it. In last we proposed a system of combining scores from heterogenous sources, to set criteria for measuring the usability of applications.

We list a few tasks as our future work.

- To consider the use of blockchain technology to be part of mobile commerce apps and to analyze its impact on the usability of mobile commerce apps,
- To see how VR and AR are integrated into mobile commerce app development and to see how they affect the usability of mobile commerce apps.

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