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Perspectives on usability guidelines for smartphone applications: An empirical investigation and systematic literature review

Naveed Ahmad*, Aimal Rextin, Um E Kulsoom

Department of Computer Science, COMSATS Institute of Information Technology, Islamabad 44000, Pakistan

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ABSTRACT

Context: Several usability guidelines have been proposed to improve the usability of smartphone apps. These guidelines can be classified into three disjoint sets: platform specific guidelines, genre specific guidelines, and generic guidelines. However, smartphone applications are usually developed for multiple platforms and targeted for a variety of users. Hence the usefulness of existing guidelines is severally limited.

Objective: This study aims to develop a comprehensive list of usability guidelines suitable for multiple platforms and genres of smartphone applications.

Method: A controlled experiment was conducted, and it highlighted that even popular and established apps have usability problems. In order to identify different perspectives on usability a systematic literature review was conducted.

Results: Systematic literature review resulted in 148 studies that proposed a total of 359 usability guidelines. These guidelines were condensed into 25 guidelines in 7 categories by removing redundancy, repetition and similarity through a sequential and iterative process. Finally, usefulness of the proposed classification of guidelines is established by mapping these to usability issues identified earlier.

1. Introduction

Today's smartphones are so powerful that some authors believe smartphones are replacing personal computers [1–4]. Regardless of the platform and device itself, there are a wide range of mobile applications related to multiple aspects of our life, such as health [1], business [8,9], entertainment, communication [2,7,10], learning [3–6,12,15], and personal data management [16].

Usability is considered a key factor in achieving customer loyalty [10,13]. However, designing usable mobile interfaces is usually difficult due to their limited screen size. Therefore, on smaller screen sizes, developers need to make additional efforts to facilitate users in interacting with his/her application.

To aid developers in making usable smartphone applications various researchers have proposed usability guidelines. These usability guidelines range from general to very specific that are meant for specific applications. *Generic usability guidelines* include: Nielsen's general guidelines [12]; Shneiderman's Eight Golden Rules of Interface Design [14]; Gerhardt-Powel's Cognitive Engineering Principles [15]; and Weinschenk and Barker classification [17] etc. These set of guidelines were developed for desktop applications, but due to their generic nature they are applicable on smartphones as well. This limitation led to various smartphone specific usability guidelines which has two main types. The first type is *platform specific guidelines* that are designed by the vendors such as i*OS,* Android, Windows and Firefox. The other type is *genre specific guidelines* that target a specific category of app such as usability guidelines for health apps [19,39] and guidelines for news apps [22] etc.

There are various problems with the existing guidelines for example it is difficult to apply generic guidelines to mobile apps. Similarly, platform specific guidelines may not be applicable to other platforms and the problem with genre specific guidelines is that it is difficult to apply them to other types of applications [74]. Another problem with existing usability methods is that they are considered whilst evaluating the final product, hence often at a time where only minor modifications are possible. Holzinger et al., proposed the concept of *extreme usability* which advocates including usability guidelines from the very beginning [157]. Hence we believe that a comprehensive set of usability guidelines for smartphone apps is needed by combining the three aforementioned types of guidelines.

In order to address these limitations, we first conducted an empirical study to establish its need. Next, we aimed at developing comprehensive set of guidelines by starting from a *systematic literature review (SLR)*. More specifically, we did the following. We first conducted

* Corresponding author.
E-mail address: naveedahmad@comsats.edu.pk (N. Ahmad).

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an SLR to review usability guidelines presented by academic researchers. We then reviewed platform specific guidelines by smartphone OS vendors and finally, we grouped and merged these to form our final comprehensive list of usability guidelines. Our main contributions in this paper are the following:

- A controlled experiment establishing the need of comprehensive usability guidelines for smartphones.
- A systematic literature review to compile a comprehensive list of guidelines for smartphone apps
- A comprehensive list of guidelines is developed

The rest of the paper is organized into five sections. We first give a background of our study in the next study. In Section 3, we discuss our experiment to validate the need for this study. Section 4 discusses research method used for comprehensive literature review in detail. Section 5 discusses the results of literature review and formulates all guidelines found in literature. We then present our final set of guidelines and explain how we categorize our guidelines. In the end, we give our conclusions.

2. Background

This section explores existing literature reviews addressing usability in smartphone applications. It is important to note that the objective of this study is not to provide genre specific guidelines but to use these guidelines to bridge the gap between existing platform specific and generic usability guidelines. Moreover, this study does not include such studies for smartphone games. This is because some of the usability guidelines for smartphone games conflict with other mobile applications. For example, when designing games controls are unified to increase screen visibility [156], whereas this is contradicting with the guideline for other applications i.e. to use clear consistent navigation [1,4,7,12]. Similarly, reducing the button size is another option to address smaller screens of smartphones [156], but this also contradicts with another guideline i.e. to provide visible and well-defined buttons [40,113,134].

Some researchers have performed SLRs to identify usability evaluation techniques [44,53,153,154]. Zapata et al., performed a systematic literature review on empirical studies regarding usability of mHealth applications [44]. Another genre specific research to evaluate usability techniques was conducted by Hussain and Mkpojiogu [153]. Their findings showed that in heuristic evaluation, formal tests and think aloud are the most commonly used methods for testing usability of m-commerce applications. These studies were genre specific and there scope was also limited to usability evaluation.

In comparison to Zapata et al. [44] and Hussain and Mkpojiogu [153], Harrison proposed a new usability evaluation model for mobile applications by studying existing usability models [53]. This research was different from earlier ones because it was not meant for a specific genre. Another similar research was conducted to identify usability evaluation techniques for smartphone applications [154]. It identified experimental study, field study and hands on measurement as the main methods for evaluating usability. Although, these studies were generic in nature but they also only covered literature on evaluating usability. Finally, Baharuddin reviewed literature published (between 2000 to 2012) on factors affecting usability of smartphone applications [155]. The authors identified 18 dimensions and placed them in four contextual factors, namely: user, environment, technology and task. These dimensions can be considered as a unified model for mobile applications. It can be seen that few reviews have been conducted on usability in smartphone applications, but none of them aggregate and classifies guidelines published in literature into a framework.

Following sub-section compares and reviews two other comprehensive sources of usability guidelines: (1) generic usability guidelines; and (2) platform specific guidelines.

2.1. Generic usability guidelines

Generic usability guidelines are rules of thumb that should be followed by the all UI designers. They are termed generic as they are independent of type of system being developed, and their use is not only limited to developers but also evaluators [122]. Set of usability guidelines which this research considers generic include: Nielsen [12]; Gerhardt-Powals [15]; Shneiderman [14]; and Weinschenk and Barker [17] guidelines. A total of 11 studies were identified addressing the general usability aspects from which 4 studies were selected. These studies have comprehensive set of generic guidelines in contrast to others as they consider only one aspect of usability such as: provide limited options to user [124], building a grid [125], provide simpler solution [126], and make most appealing apps [127]. These studies were proposed for another field [125] but can be useful for app design due to their generic nature.

These guidelines were originally developed for desktop applications, and their main focus is the visibility of the system status, guidance about the terms used, and consistent representation of

Table 1
Generic guidelines.

Guidelines	Nielsen	Shneiderman	Gerhardt-Powals	Weinschenk and Barker
System status visibility	✓			
Simple and daily life terms	✓		✓	✓
Exit, undo and redo options	✓	✓		✓
Content consistency	✓	✓	✓	✓
Error avoidance	✓			✓
Object and option visibility	✓			
Flexibility	✓	✓		✓
Information relevancy	✓			
Error message simplicity	✓	✓		
Feedback and guidance	✓	✓		✓
Logical presentation		✓	✓	
Simplicity of layout		✓		✓
Avoidance of memory load			✓	✓
Information clustering			✓	
Graphics instead of text			✓	
Equitable use				✓
User mental model consideration				✓
Attractive design				✓
Focused and committed interface				✓
Result aware				✓

information. These principles usually discourage system dependency on user, extra burden on human memory for performing tasks. These guidelines are combined and summarized in Table 1.

2.2. Platform specific guidelines

As already discussed in Section 1, different platforms also specify usability guidelines for developers. Since the focus of this research was to gather perspectives on guidelines, so while building our comprehensive list of guidelines three well-established platforms (iOS, Android, and Windows) and an emerging (Firefox OS) platform were also included to identify guidelines. One key observation here is that these platforms while specifying guidelines do not consider type of applications being developed. There are also differences among these platforms in terms of usability guidelines.

Windows OS [129] provides very generic guidelines in nature. Window OS guidelines are mainly focused to content. Guides about the presentation of content, proper feedback to user, and adopt error avoidance policy for error handling. Android OS [131] mainly focus on the equitable use of app, so their guidelines emphasize on the visual data along with textual data, guidance for navigation, and readability. Firefox OS [130] is an emerging operating system. Their guidelines mainly focus on use of color, sizes and font in different area of app and have limited focus on navigation. Similarly, *iOS* [128] guidelines contains a wide variety of guidelines that are more comprehensive than others. It starts from content presentation, font and color selection, and layout, however the *iOS* guidelines do not consider error handling and navigation.

3. Investigating the need for a comprehensive list of usability guidelines

In this section, we will investigate if a comprehensive list of usability guidelines is needed. This is done by a two-step process:

1 We first conducted a controlled experiment that showed that smartphone apps, even ones with huge number of users, built using contemporary set of guidelines have usability issues.
2 We then mapped the usability problems found in the experiment discussed above to contemporary set of usability guidelines.

The controlled experiment was conducted to find the usability problems in the selected app, while the mapping was done to find out if the discovered usability problems are covered by existing usability guidelines. We will now discuss the experiment, its results, and the mapping in more detail below.

3.1. Experiment: design and results

We first selected our two apps; we wanted two well-known apps because it will imply they are widely accepted by smartphone users. We also decided that the two selected apps should be from a popular genre of apps. We selected two notes taking apps: (1) Evernote; and (2) Google Keep as both have more than 500,000 users.

Next, we selected participants for the experiment. Our only criterion for selecting participants was that they should be familiar with smartphones [34,35]. A total of 40 participants were selected including graduate and postgraduate students from a local university. Details of our participants are shown in, which shows that just 2 participants didn't use a smartphone and just 1 participant was an iPhone user.

Each participant performed the following sequence of tasks:

1 Add a note with a specified text
2 Set the color of font;
3 Adjust the font size;
4 Erase the note;
5 Undo the erase operation;
6 Save the note with a specific name;
7 Delete the note.

We designed our study as a *within subjects* experiment and hence all 40 participants were asked to perform the same set of 7 tasks that they needed to perform on both apps.

3.1.1. Threats to validity

We now discuss the different threats to validity of this experiment and how we handled them. We will first discuss some important threats to the internal validity of the experiment and then we will move to the external validity. Finally, we will discuss construct and conclusion validity threats. Below we discuss internal validity threats:

1 Ordering effect: To counter the effect of ordering, half participants first performed the given tasks on Google Keep and the rest started from Evernote.
2 Uncontrolled variation: To minimize uncontrolled variation in the experiment, the experiment was conducted at the same time of day and at the same location (a lab). Moreover, all participants used an Android phone provided by us for the same reason. Since a clear majority of the participants were users of Android phone and all participants used the same Android phone so variation due to OS of smartphone was minimized. Any uncontrolled variation due to the OS of the participant's personal phone was negligible as 93%% of the participants were Android users. .
3 Experimenter bias: The research team were neutral about both application as none of the team members had any association with either of them. Hence this threat was not present.
4 Selection bias: Selection procedure for participants was random representing both genders and mixed experience levels. We can see from Table 3 that although 62%% of the participants used a similar app, the participants told us that majority i.e. 60%% of them use at most a few times a month. Hence any uncontrolled variation due the participant's usage history was also small.

We now come to threats to external validity. We ensured training validity by giving a demonstration on how to add a note in each app to every participant of our experiment. They were also briefed on the task (s) they had to perform. They were also informed that they could ask any question during the experiment. However, the results of this experiment cannot be generalized as the participants were all students of the same university.

We now discuss conclusion validity. We did not try different hypothesis and our significance level was 5%%, hence the chance of Type I error is small. Hence our experiment has low fishing and error rate problem. However, we had a sample of size 40 and the sample was not randomly selected. So this is a threat to the conclusion of this test.

Construct validity is the degree to which an experiment correctly captures the intended measurements. The purpose of this experiment is to measure usability of apps. We note that although usability is a subjective concept, it is generally agreed that efficiency, effectiveness, and satisfaction captures this subjective concept. Although there are many definitions of *usability*, we adopted the definition that usability consists of three independent constructs: efficiency, effectiveness and satisfaction. Hence we decided to measure usability in terms of these easily measurable constructs. Below we discuss what each of these construct means in our context and how we measured it.

3.2. Results of experiment

Although there are many definitions of *usability*, we adopted the definition that usability consists of three independent constructs: efficiency, effectiveness and satisfaction. Below we discuss what each of these construct means in our context and how we measured it.

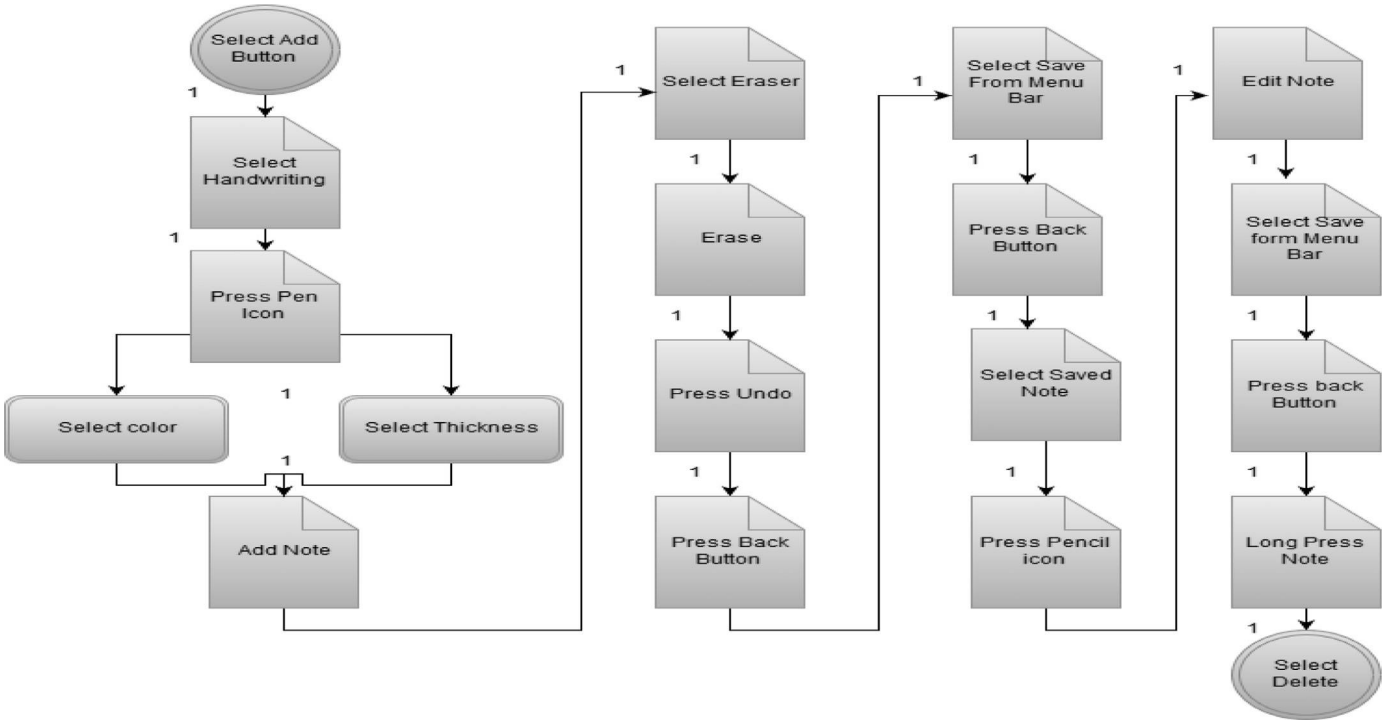

Fig. 1. Benchmark navigational cost for Evernote.

Efficiency is a measure of time taken to complete a task, it is calculated usually as the seconds taken by a user to complete a task. We define *navigational cost* as the number of steps (clicks) required to complete a task. We first note that the benchmark navigational cost for the 7 tasks above. Here we define *benchmark navigational cost* as the minimum number of steps or clicks required to complete the task. We found that benchmark navigational cost for Evernote and Google Keep was 17 and 13, respectively. As an example, the tasks of the participants can be completed with minimum number of clicks by following the flow shown in Fig. 1. We saw that users missed the bench mark navigation cost by 4.8 steps (s.d = = 6.19) and 1.27 steps (s.d. = = 2.05) for Evernote and Google Keep respectively. Moreover, only 2 participants completed the task in benchmark number of steps for Evernote; while for Google Keep only 3 users completed the task in benchmark number of steps.

Effectiveness refers to the degree to which a user successfully accomplished a task. We observed how each participant performed on each of the task and noted if he or she could complete a task or not. Almost 41%% in average for both apps user could complete all the tasks. More detailed results can be seen in Fig. 2.

Satisfaction measures the level of satisfaction of different users after using an app. To measure satisfaction a questionnaire was given to all the participants (Appendix B). This questionnaire was designed after conducting two focus group studies of 5 mobile phones users each to understand what a usable software means to them. The major themes that came up from these discussions was incorporated as a questionnaire. It included questions on a wide variety of aspects such as the participants' perception on overall satisfaction, how fun it was to use, the ease of using the software etc. All these questions were scored on a five point Likert scale from strongly agree till strongly disagree. The internal consistency of this questionnaire was tested by calculating Cronbach Alpha, which resulted in a value 0.772, suggesting that the survey questions have relatively high internal consistency. So, these set of questions can be reliably used to measure satisfaction. We then added the positive results of the questionnaire are shown in Fig. 3, where Fig. 3(a) shows summarizes the participant responses for Google Keep, whereas Fig. 3(b) shows the same for Evernote. Looking at these figures we can see that although people considered these apps useful and some even believed that these apps fulfil expectations, but generally people were not completely satisfied with these apps. An example of this that when participants were asked whether ``you are overall satisfied with these apps", only 40%% and 30%% participants responded by selecting ``strongly agree" or ``agree" for Evernote and Google Keep respectively.

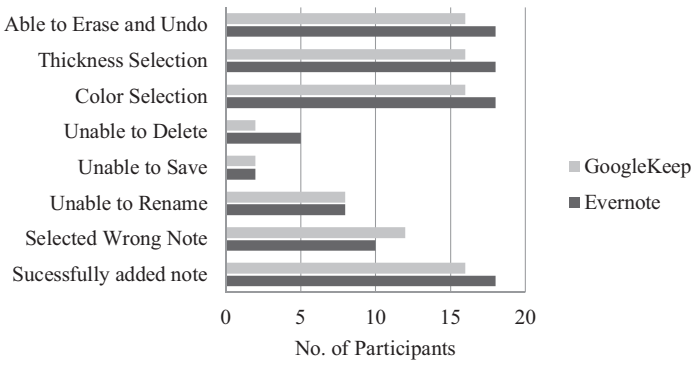

Fig. 2. Effectiveness Measurements. Note the number of participants who could complete a task is shown on the x-axis. The a-axis rages from 0 to 20 as a task was completed by not more than 20 users.

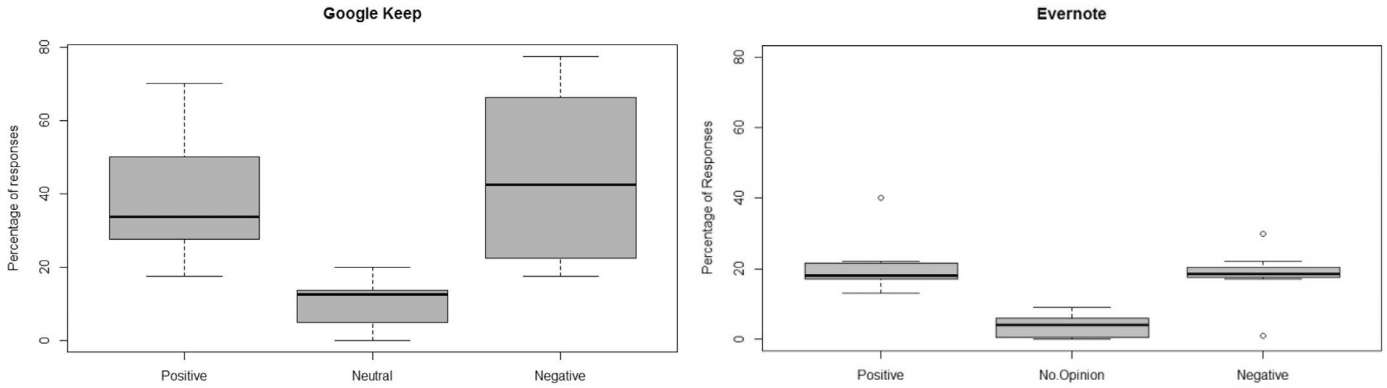

Fig. 3. User Satisfaction of Evernote and Google Keep. We can see that users generally more negative views about different aspects of the two-software system. Note that this figure aggregates Strongly Agree and Agree as *Positive* while Strongly Disagree and Disagree is aggregated as *Negative*.

3.1.2. Statistical significance of experiment results

We now test our hypothesis: ``*Smartphone apps, even ones with huge number of users, built using contemporary set of guidelines have usability issues*''. We have already discussed the results of satisfaction survey in reasonable depth, so here we will only test the hypothesis on effectiveness and efficiency. We will first discuss effectiveness and then we will talk about efficiency. Note that we used *t*-test for our hypothesis testing using R.

We define p as the proportional of users who can complete a task. Since our selected apps are generally considered to be well designed so it is reasonable to assume as our null hypothesis that $p = 1$, i.e. all users should be able to complete their task. Since not all users in our sample completed the given tasks so our alternative hypothesis is that $p < 1$. By testing this hypothesis at 1%% significance level we found that our results are statistically significant for both Evernote (p-value = = .000001) and Google Keep (p-value = = 0.000001)

Similarly let μ represent the mean difference between actual navigational cost minus actual navigational cost. Again, since we selected good quality apps so one would assume that $\mu = 0$. This leads to the following null and alternative hypothesis:

H_0: $\mu = 0$

H_1: $\mu > 0$

We applied the right tailed test at 1%% significance level and got p-values of 0.000000008 and 0.00005 for Evernote and Google Keep respectively. So, null hypothesis for efficiency is also rejected.

Given the hypothesis tests applied here and the discussion of the satisfaction results earlier, we can reasonably say that smartphone apps have usability issues.

3.3. Mapping

Several usability problems were identified in the experiment above which were mapped to the guidelines shown in Tables 1 and 2 by two coauthors of this paper. The usability problems revealed in the experiment and the mapping is shown in Table 4.

We can see from the table above that coauthor 1 was unable to map 46.67%% of usability problems and coauthor 2 was unable to map 53.33%% of the usability problems found. Moreover, both felt that the existing guidelines are either too high level in case of generic guidelines; or too low level in case of platform specific guidelines. Moreover, the problems that were matched didn't come from a single source of guidelines.

It was not easy to map the usability problems found in the experiment to the existing usability guidelines, probably because the platform specific guidelines are very low level while the generic guidelines were very high level as compared to the usability problems discovered. On the whole, the two step process indicated that even reputable apps have usability problems. One reason can be that appropriate usability guidelines are not available to the practitioner. Hence a comprehensive list of usability guidelines is needed. However, we note that since mapping was done by two coauthors, hence it is a risk to the construct validity of the mapping. In the rest of the paper, we will present how the comprehensive list was developed, we will then present the guidelines we developed. In the end, we will show that we could map all usability problems identified in the experiment to usability

Table 2
Usability guidelines by different platforms.

Guidelines	Windows OS	Android OS	Firefox OS	iOS
Content relevancy	✓	✓		✓
Content logical order	✓			✓
Content priority	✓	✓		✓
Guidance and feedback	✓	✓		✓
Consistent set of actions	✓			
Shortcuts	✓			
Error handling	✓			
Considering disabilities		✓		
Provide a return mechanism		✓	✓	✓
Provide buttons for frequent actions			✓	
Provide filtration option			✓	
Provide traversal mechanism among screen		✓		✓
Font standard			✓	
Provide large font for important content		✓		✓
Use color contrast to enhance readability		✓		✓
Provide visual alerts		✓		✓
Colors guide			✓	✓
Placement of input area			✓	
Clear consistent and working icons			✓	✓
Provide hidden controls				✓
Use full screen				✓
Use of dynamic font				✓
Use of borderless buttons for content area				✓
Provide hierarchies for information				✓
Provide app in both orientation				✓
Avoid setting change option for different user				✓
Provide edit option				✓
Start without any delay				✓
Don't ask rate app early		✓		✓
Provide model task for core functionality				✓
Provide app description				✓

Table 3
Details of participants in the experiment.

Category	Frequency	Count	Percentage
Gender	Male	25	62%%
	Female	15	38%%
Qualification	Undergraduate students	13	32%%
	Postgraduate students	25	62%%
	Professional developers	2	5%%
Age	Between 20–25 years	24	60%%
	Greater than 25 years	16	40%%
Smartphone	Android phone owners	37	93%%
	iPhone owners	1	3%%
	Do not own smartphones	2	5%%
Experience	Used similar apps	25	62%%
	Have not used similar apps	15	38%%

Table 4
Mapping of usability problems to guidelines.

Issues	Coauthor 1	Coauthor 2
Mandatory registration	x	✓
Absence of label	✓	x
Resemblance – Similar icons	✓	✓
Don't have proper buttons	x	✓
Additional clicks required	✓	x
Improper closing	✓	x
Unable to locate	✓	x
Lack of guidance and feedback	✓	✓
No option to delete notes – only done through long press	✓	x
User interface issues	x	x
Option unavailability on same page	✓	✓
Scrolling in note area	x	x
Undo option limited	x	✓
Redundant task	x	x
Don't ask before commit	x	✓

guidelines in our comprehensive list

4. Identifying usability guidelines from literature

In the initial literature search, it was observed that usability guidelines literature is spread across different genres of mobile applications, and there is a need to consolidate different terms used in literature for different aspects of usability. Moreover, the result of the experiment discussed in Section 3 also highlighted usability issues in existing applications further making the case for a comprehensive set of guidelines encompassing different genres and platforms. In order to identify usability guidelines in literature, a systematic literature review following Kitchenham and Charters SLR guidelines [123] was conducted. Key research question which guided the remaining review process was:

Question: What are the existing usability guidelines for smartphone applications?

This research question was further decomposed into a search string by identifying keywords from this question. Given below is the search strings derived from this research question.

Usability AND (guidelines OR principles OR heuristics) AND (``mobile application" OR ``smartphone applications" OR ``mobile apps" OR ``smartphone apps")

This search strings was used to search relevant literature from multiple digital sources including: ACM Digital Library, IEEE Xplore, Springer, Science Direct and Google Scholar. It resulted in a total of 1952 papers including: full papers, short papers, doctoral consortium, editorials, etc. These papers were scrutinized based on inclusion and exclusion criteria, mentioned in Table 5. Inclusion criteria were to include papers written in English, discussing usability guidelines, with potential to answer research question, and focus on smartphone applications guidelines. Exclusion criteria excluded all the papers not written in English, not discussing usability guidelines, not relevant to smartphone applications, related to game development, and duplicate papers. The data used for initial scrutiny included paper title, abstract. This was followed by full text filtration to identify literature with the potential of answering the research questions. After applying these criteria, a total of 131 papers were selected. This search process is summarized in Fig. 4.

Following the search process, guidelines proposed, and the context (app genre) in which these are used were identified from these 148 selected studies. Since, this information was not explicitly written in any specific section of these papers so it was extracted through full text filtration. For instance information extracted from Kaur and Haghigh [147] included: its genre (mobile health) and guidelines (provide error correction, simple error messages, provide simple and homogeneous information, status should be visible, consistent design, and provide control to the user so that they can exit or back at any stage). Similarly, guidelines were extracted from all the studies and this initial search for genre specific guidelines was performed by one author. This resulted in a total of 359 guidelines related to different genres. These results are explained in the following subsection.

4.1. Results of systematic literature review

Most of the literature on usability guidelines consists of papers on genre specific guidelines. It was found that about 104 studies from total 148 studies proposed the usability guidelines for a separate genre of an app which is 70%% of total studies. These studies have focused only on one type of app genre. More than one study may address a genre e.g. mobile learning studies was found in large numbers as compare to others. All genre addressed by these studies are shown in Table 6.

Mobile Health is a very popular genre of mobile apps. Given the penetration of smartphones and their increased usage potential usage of such apps have increased. Most popular among such type of applications are fitness apps and health monitoring apps (heart rate, blood sugar, blood pressure). Most of the studies found as a result of SLR were related to Mobile Health. In total 26 studies discussed usability related to Mobile-health applications [17,19,39,101,134,136,139]. It also included usability guidelines related to users with different disabilities, including visual impairment [151], and older users [23,70,138].

M-learning is enabled through a variety of apps such as: Moodle, mLearn, MDroid etc. Special attention is required when designing such apps, heeding to this new trend various researchers have proposed usability guidelines for m-learning apps. Out of 148 studies selected for this SLR, 18 were related to m-learning. Mainly, these guidelines concern simplicity, ease of understanding, and fitness of content [[7,9–11] [26,43,77,83,113]]. We also found 16 studies related to web interface apps (newspapers apps, browser apps etc.) which mainly deal with presentation of data [11,18,120]. More specifically, Serm et al. and Yu et al., emphasize on providing brief information to minimize scrolling [6,22]. Dharmasiri et al. and Shrestha propose guidelines about how to presentation data in a web browser along with navigation guidelines [12,105]. Mobile commerce emphasized on highly focused functions, where content and features are focused to a target market only [1,38,65].

Other than these more studied, we also found guidelines related to other genres including: email [90], tourist guides [60], data management apps [102], context aware apps [15], M-Ticket reservation [69], smarter touch interfaces [78], cultural info apps [13], mobile internet portal apps, data collection apps [16], and meta data management apps [102]. We used these genre specific guidelines and guidelines identified in Sections 2.1 and 2.2 to build our comprehensive list of guidelines.

5. Perspectives on usability guidelines

There are three different kinds of guidelines discussed in this article.

Table 5
Inclusion/Exclusion criteria.

Inclusion criteria	Exclusion criteria
All papers published in English language	Papers not published in English language
Papers focusing on smartphone app usability, usability issues and guidelines	Papers not capable of answering research question
Papers capable of answering research question	Papers focusing on smartphone game usability, usability issues and guidelines
All non-gaming apps papers that focus on usability guidelines	Grey papers i.e. papers without bibliographic information
Papers published between 2000 to 2017	Duplicate papers

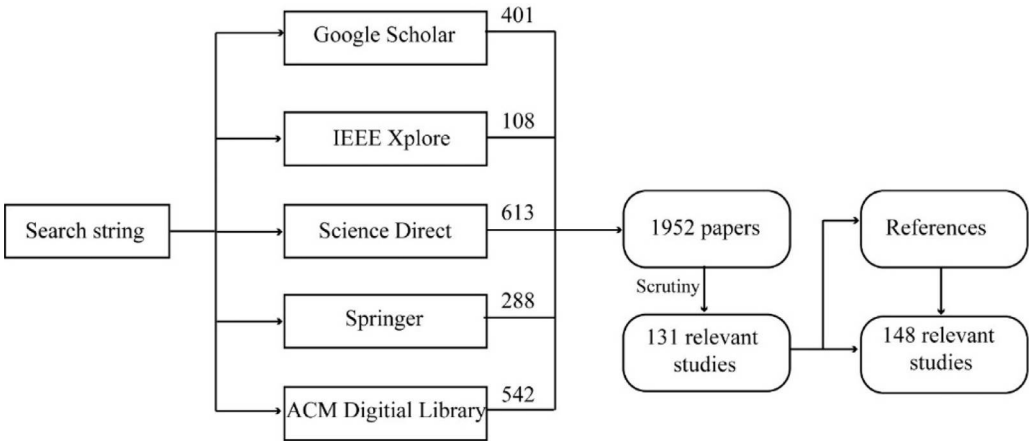

Fig. 4. Search process.

Table 6
Genre specific papers.

S.no	App genre	Number of studies	Number of guidelines
1	Mobile Learning	18	61
2	Web interfaces	18	53
3	Mobile Health	26	144
4	Mobile commerce	12	26
5	M-News paper	2	6
6	Web Browser	5	9
7	WAP	2	3
8	Mobile email	2	3
9	Context- aware apps	4	7
10	M-Ticket Reservation	2	6
11	Tourist guide	3	6
12	Smarter touch base interface for children	2	5
14	Cultural info apps.	1	5
15	Mobile Internet Portal.	3	17
16	Data collection apps.	2	2
17	Meta Data Management	2	6
Total		104	359

It includes: (1) generic guidelines in literature (independent of genre, platform, device discussed in Section 2.1); (2) platform-specific guidelines (Section 2.2); and (3) genre-specific guidelines in literature (Section 4.1). Fig. 5 shows the frequency of guidelines identified from these sources.

In this section, usability guidelines gathered from three sources are used to present perspectives on usability guidelines. The need to make this comprehensive list of usability guidelines for smartphone developers can be attributed to three reasons. Firstly, total number of guidelines is quite large (359 in total). Secondly, there is repetition and redundancy in these guidelines. Thirdly, there is similarity in various guidelines. So, the number of guidelines is reduced by removing redundancy, repetition and similarity following a sequential and iterative process. In order to ensure consistency and accuracy all the authors were involved throughout this process for defining perspectives on usability guidelines. This process is shown in Fig. 6.

As mentioned above building the list of guidelines was a sequential and iterative process. A sequence of steps was followed to identify key usability guidelines categories from Source 1 (platform-specific guidelines) and Source 2 (generic guidelines). Following this sequential process, seven main categories were identified, namely: (1) Navigation; (2) Content; (3) Error handling; (4) Input method; (5) Equitable use; (6) Cognitive load; and (7) Design. An iterative process was deployed to identify guidelines from Source 3 (genre-specific guidelines). In the first iteration guidelines were selected from individual studies and redundancies were removed. These redundancies included repetitive and similar guidelines. In second iteration, these guidelines were then grouped together. Finally, in iteration 3 these grouped guidelines were mapped to categories identified earlier. Details of these iterations are shown in Appendix C.

Following subsections presents main categories of usability guidelines.

5.1. Navigation

Navigation refers to the mechanism of moving from one screen to another and set of actions to complete a specific task [1]. Navigation includes the usage of buttons, menu tabs, links and images that leads you from one point to another within an app to perform set of actions. Various researchers emphasize on the importance of navigation for making an app useful [7,26,41,1,4,120,12,37,111], but ensuring effective navigation is a challenging task for mobile devices because of display limitations [9,13,26,29,30]. Many researchers have proposed navigation guidelines to overcome this challenge, which are grouped in following subsections.

5.1.1. Use clear consistent navigation

Navigation methods should be simple and clear enough so the user can easily grasp them [1,4,7,26,41,12,120,37,132,144]. Navigation can be made easily understandable by using a consistent navigation method throughout the app [1,4,7] e.g. using only swipe throughout the app. It is not difficult to see that multiple [1,4,12,120], and redundant navigation methods [98–100] e.g. usage of swipe and buttons within same screen, create confusion and drastically reduce usability. Providing the

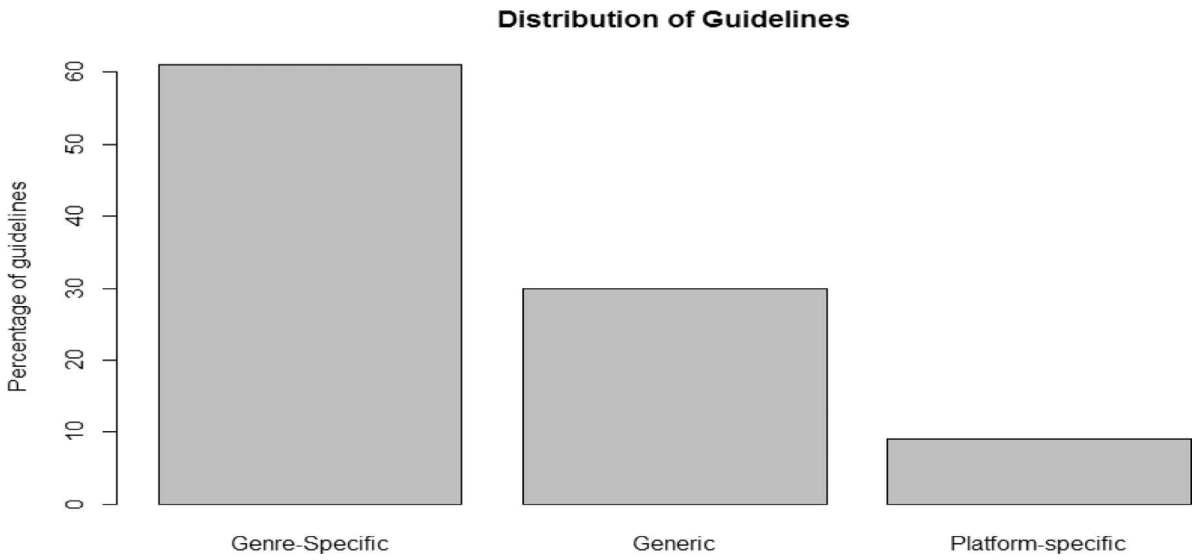

Fig. 5. Frequency of guidelines from three sources.

navigation method that users are using in their daily routine [18,20,33,59,108], e.g. back button, according to human mental model are easily predictable and help users to understand navigation well [80,81,94]. Another example of this is using pinch gesture for zoom [136–138,141]. Navigation should be easy enough to help user predict its current position [96].

5.1.2. Provide visible and well define buttons for easy navigation

Buttons are one way to provide easy navigation. Buttons should be distinguishable [40,113,134,136,138] e.g. buttons with border to make navigation easy. Similarly, it has been mentioned to highlight previously visited links [141]. Navigation provided through visible [40,41,60,65,78] and properly labeled [78] buttons enhance usability. In this regard, on-screen keyboard can be used [142]. Considering the limitation of screen size, buttons should be used carefully and overuse should be avoided. Button placement is also important, as Johnston and Pickrell suggest avoiding unintuitive button placements [146].

5.1.3. Reduce navigation by providing hierarchies and menu

Most of the smartphone apps have complex and multi-layer functionality. To cope with small display area for such type of apps develop navigation in the form of hierarchies is the best options e.g. hidden menu [11,41,68,83,77,117,137,143,144]. Providing functionality in multilayer, not only, make navigation easy but also address screen size limitation and increase user understanding [12,21,40,67,103]. It is also important to note that on one hand making hierarchies may increase usability but on the other hand deep hierarchies result in increased memory load [19,97,112].

5.1.4. Minimize scrolling through search button

Various researchers propose to minimize content on screen, as this results in less scrolling which enhances user satisfaction [6–9,36,60,66,68,83,93,117,120]. Considering limited display area, it's not possible to avoid scrolling at all. So, some authors suggest used of vertical and horizontal scrolling [18,36,113,117]. Search can also be used to avoid extensive scrolling [84,102,105,143]. Another option is to focus on the content important to a user [33,53–55].

5.1.5. Provide complete control to user so that they can exit or back at any stage

When designing apps it is important to make user feel in control. Controlled here is defined as enabling the user to close or to go back in an app. Inability to deliver this to the user will reduce user satisfaction. Various researchers have identified guidelines to exit a certain stage [[9,17,19,21,26,40] [97,113]], to exit altogether [4,41,65,69,112] and back button should be available all the time [15,132,143]. Closing mechanism should be easy and available as a button [2,20,27,95,147]. This is also in accordance with the guideline mentioned in Section 5.1.2. Similarly, some researchers argue the importance of providing undo, redo, and delete option at every stage [4,9,78].

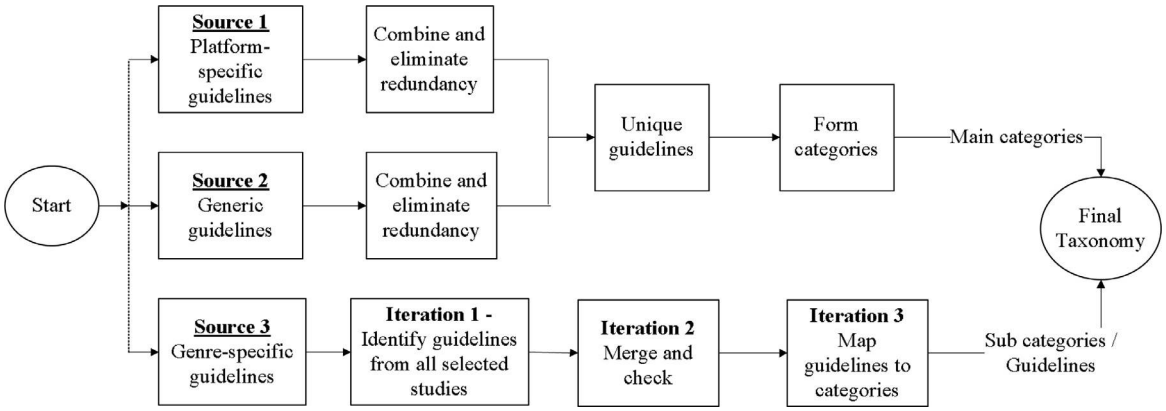

Fig. 6. Process for defining perspectives on usability guidelines.

5.2. Content

Content refers to information communicated to user(s). Content includes all expressive material either in the form of text or multimedia. Some apps do not require much content, but few apps are specifically content based apps, such as internet portal [2] and newspaper apps [6,22] etc. Independent to the amount of content on an app, it requires special attention from developers. Different researchers have proposed a variety of content-related guidelines, which are grouped into following subcategories.

5.2.1. Do not use object(s) which provide different meanings

First characteristic of the content is that it should be consistent in term of their meaning [9,23,28,144,148]. Using multiple terms to convey something similar may challenge user's understanding [33]. Different objects should be used to show redundant information [17]. Moreover, information should be presented traditionally, the way people are used to seeing it [19].

5.2.2. Use terms that are related to real world

Conveying information in the language used by target audience will enhance users' understandability [7,19,20,28,33,39,61,62,120,119,145]. The language should be simple, friendly and have lenient tone [23,41,42]. Although, terms used in daily life have a greater influence on app's usability, but it is important to not use terms that are considered negative [9,28,38,66,77,83,113,78]. It is also desirable to use familiar terminology for hyperlinks [141].

5.2.3. Content should be brief and specific

Considering the limitation of small screen, very limited information should be provided on the screen [1,3,4,6,8,10,19,42,60,67,69,76,120,132,139,141,148]. At the same time, it is important not losing the important information, so information should be brief and specific [2,7,13,18,78,116,115,118]. Overloading mobile screen with lots of information may affect user's ability to interpret and understand it [1,42,60,69]. Key thing to remember here is that reducing amount of information means, only providing highly relevant information. In data intensive apps this can be achieved by providing visualizations to show historical information [134,135].

5.2.4. Avoid use of fast moving objects and animations

Animation is also part of content, but it is important to remember that if the user does not have sufficient time to read the content than providing it is useless [120]. Provide ample time to read the text [19], and avoid fast moving objects specifically for older adults [19,121,148].

5.2.5. Visited item should be distinguishable

All objects used as content should be prominent specifically active/inactive objects [9,21,132,144]. User should be capable to identify the object or links s/he has selected or visited [4,21,141]. Mark that link or object with different color so the user can identify it. It is suggested in literature to use black and white as a better option to distinguish active and inactive objects [19].

5.2.6. Provide thumbnail at each page

To accommodate the limited view of mobile devices providing less information is one solution but at times it's not an option. In such cases, summary of the detailed content may be provided at the top in form of concise description [[6][65]], short story format [117] or summary [36]. Thumbnails can used to summarize information in a very short form [22].

5.3. Error handling

There is always a chance of error in human developed software. Errors cannot be eliminated at all instead they could be minimized by taking some precautionary measures. These measures are referred to as error handling.

5.3.1. Provide error prevention by confirming before commit an action

Any application that does not deal with errors committed by the user reduce its usability, as users feel that the app is not handling mistakes from user's aspect [132,143]. Some errors can be avoided by asking through alerts before a user can commit an action [147,148]. This will notify the user about their action, and may alert them [133,142]. System should be designed in such a way that it provides alerts [18,90] and feedbacks [17,40,113,76] related to action(s). System should ask before committing any action by providing conformation specifically for critical actions such as deletion/updating [78,142].

5.3.2. Error messages should be simple and easy to follow

In accordance with the guideline mentioned above (5.3.1), alerts should be simple, short and easy to understand [19,40]. They do not lead to any confusion or difficulty. Select simple brief and comprehensive sentences for alerts [9], avoiding long and confusing phrase [78,113,120,132]. Providing only error messages is not sufficient, user should also be guided to recover/fix the error [133]. Hence, it is important to clearly state actions that can lead to error(s) and provide methods to recover [120].

5.4. Input method

Due to small keyboards it is very difficult for user to provide input in mobile devices. Input methods available for mobile devices are different from desktop devices and require certain level of aptitude. This problem increases the rate of erroneous input.

5.4.1. Minimize number of keystrokes while taking input

As mobile input method are limited and can cause the inaccurate input so avoid taking input unless it is very critical [18,41,52]. Avoidance may not be the solution, so another option is avoiding manual input by providing dropdown menu or list [3,16,50,65,66,77,83,102,113,117]. Multiple ways of input may also be used to enhance usability, as users with different experience may use different methods [146,148]. Although, introduction of data loaded automatically reduce the input limitations, but it does mean to overuse drop down menus and lists [97]. Especially, for data driven applications it is important to clearly differentiate between required and optional fields [132].

5.5. Equitable use

An app cannot be considered useful, if it is not equally usable for all type of users. These differences are attributed either to users themselves or mobile devices they are using. An app should be capable to cater these differences to meet usability goal.

5.5.1. Provide relevant graphical and voice assistance

Many users have disabilities or develop disabilities with age (elderly people). So, an inclusive app, equally usable by people with different abilities, should be able to address different disabilities [144,150]. This can be in the form of acoustic and graphical assistance with text [[13,17,19,26,41,42,64,65,68,83], [142]] e.g. screen readers may be used for interaction [142]. Multiple researchers have emphasized on the use of colors to tackle color blindness [3,18,24,120]. Equitable use is not only mentioned in terms of making an inclusive app but also in terms of making an attractive app to attract different types of users [17,144,150].

5.5.2. Provide same functionality for different screen orientation and size

Smartphones allows user to change screen orientation from vertical to horizontal and vice versa. Smartphone users, over time, develop a preference for anyone of these orientations, so an app should be available in both orientations [8,39]. It should be adjustable to changing orientations [137]. Moreover, interface should adapt to different screen sizes [17,21,151].

5.6. Cognitive load

Cognitive load refers to total amount of mental effort in working memory. Working memory is the system responsible for processing information [120], it helps in reasoning, learning and understanding process. Instructional design should minimize the cognitive load [4,10,19,78], as higher cognitive load may lead to error(s) [10]. Similarly, minimizing cognitive load can maximize users' satisfaction and performance [133].

5.6.1. Provide little and homogenous information in modules to avoid cognitive load

To minimize cognitive load, an option is to provide very little and homogeneous [4,9,10,17–19,49,77,78,120,144,147] information that depict some pattern [77,21]. Another option is to partition the information into modules [25,27,30,66,71–75,79,84–87] and chunks [88,89,91,92,110,114] that are related [[7,21] [26,66,113,102]]. Similarly, hierarchies can also be used to group similar things together [60]. At the same time it is important to keep menu structure simple [139,152]. Another aspect is to group information and presenting different groups on different screens [65] or interfaces [136].

5.6.2. Similar and minimal steps or actions should be required to complete a task

Not only the information be little and homogenous, but also the actions required to complete a task should be minimal [2,10,17,18,31,64,66,78,121,151]. This will avoid extra load on a user's working memory. An interface which enables users to complete different tasks in minimal steps is considered usable as it is easier to understand [66,78]. Moreover, these steps should be consistent, simple and focused [7,14,77]. It is also important to help the user in tracking his/her progress through a task [32,44–48,51,82,119].

5.6.3. System status should be visible through proper feedback

System should always inform the user, regarding the system status, through proper feedback and within appropriate time [4,10,17,43,63,76,78,83,104,106,120,132,133]. It can be achieved through automated feedback [134]. This is also in accordance with the previous guideline, as it also emphasizes on guiding the user at each step [10]. It is believed that feedback enhances system status visibility [[9,19,41] [76,78,113]]. Again, it is important to mention that feedback should be comprehensive, simple, and relevant [4,147,152]. When designing inclusive apps spoken feedback may be used to enhance usability [142].

5.7. Design

To grasp the user attraction an app should be aesthetically pleasant [144]. The use of color(s) and object(s) should attract the user. An attractive interface will mean more traction, but it is not limited to colors, art work it is also related to integration of app function with its appearance.

5.7.1. Design should be attractive but avoid using too many colors and animation

To make design attractive colors, graphics and animation should be used rationally [4,17,21,19,113,132,140,143,144]. Graphics and animation should be relevant and for relevant assistance [120]. The goal is to make an easy to learn interface [133], so app users should not be exposed to too many new and fancy design elements [135]. For users with visual impairment it is important to use physical landmarks such as edges of the screen [142].

5.7.2. Color contrast of background and front content should be visible

There should be a proper balance between background and foreground content to make an app more attractive and useful [139,143,144,146,149]. Color contrast of background and front content should be visible [64,146,149], it should enable all types of user to read information presented [19,21]. Using pure white colors or changing background(s) may affect readability [19,120]. Choice of colors should be done in accordance with app genre [28,40]. It is important to avoid using annoying colors [132]. An alternative is to enable users to configure colors of interface components [142], this is especially applicable for the users with visual impairments.

5.7.3. Avoid fancy font styling

Most of the information in an app is in the form of text, so selection of font style is extremely important. It should be selected in a way that it does not hamper the visibility of text [105,148]. Multiple researchers have mentioned to not use fancy font styles, as they reduce readability [107,120]. They recommend using simple and standard fonts such as: Arial, Courier, Times New Rom [107,120,135]. Moreover, there is also problem of unavaiilablility of a font in a device [109]. Smaller font size should be avoided [132].

5.7.4. Design should be consistent and should follow conventions

As has been mentioned earlier as well, consistency is very essential for app usability and this is also imperative while designing apps. Design should be consistent throughout the app [19,37,113,147] and also follow the conventions [66,78]. This consistency applies to the use of objects, colors and content [19,66,78,113]. Design should enable user to easily identify features and options provided in an interface [142].

5.7.5. Limit number of screens and provide title for each

An app usually consists of many screens. Each screen should have a unique title, this title should be informative (conveying content of the screen) and unique [2,21,112,113,120,143,148]. Number of screen is also very important, for example, in case of health apps it is recommended to use four screens (authentication, home, blog/comments, chat) [68].

5.7.6. Direct physical touch enhance user satisfaction

Maximize the use of touch interface that enable users to directly touch objects. Various researchers have recommended providing an interface where user can directly touch objects in comparison to interacting through buttons [17,18,56–58,148]. It has also been reported that this will increase the user satisfaction [11,21,41]. It is important to ensure interface deals with problems such as fat finger allowing all users to physically interact with apps [132]. In case of users with disabilities it is important to avoid or keep physical interaction as simple as possible [142].

The proposed classification of usability guidelines is shown in Fig. 7. Considering the amount of literature published on smartphone application usability, it was not easy to identify guidelines from literature. To summarize, initially 359 guidelines were identified by one author, and as explained earlier all the authors were involved in the process of defining usability perspectives. However, there is a threat to conclusion validity because of human bias in the initial search and the authors' subjective opinion in defining usability perspectives.

5.8. Usefulness of proposed list of guidelines

In this section, we map the usability issues faced by participants

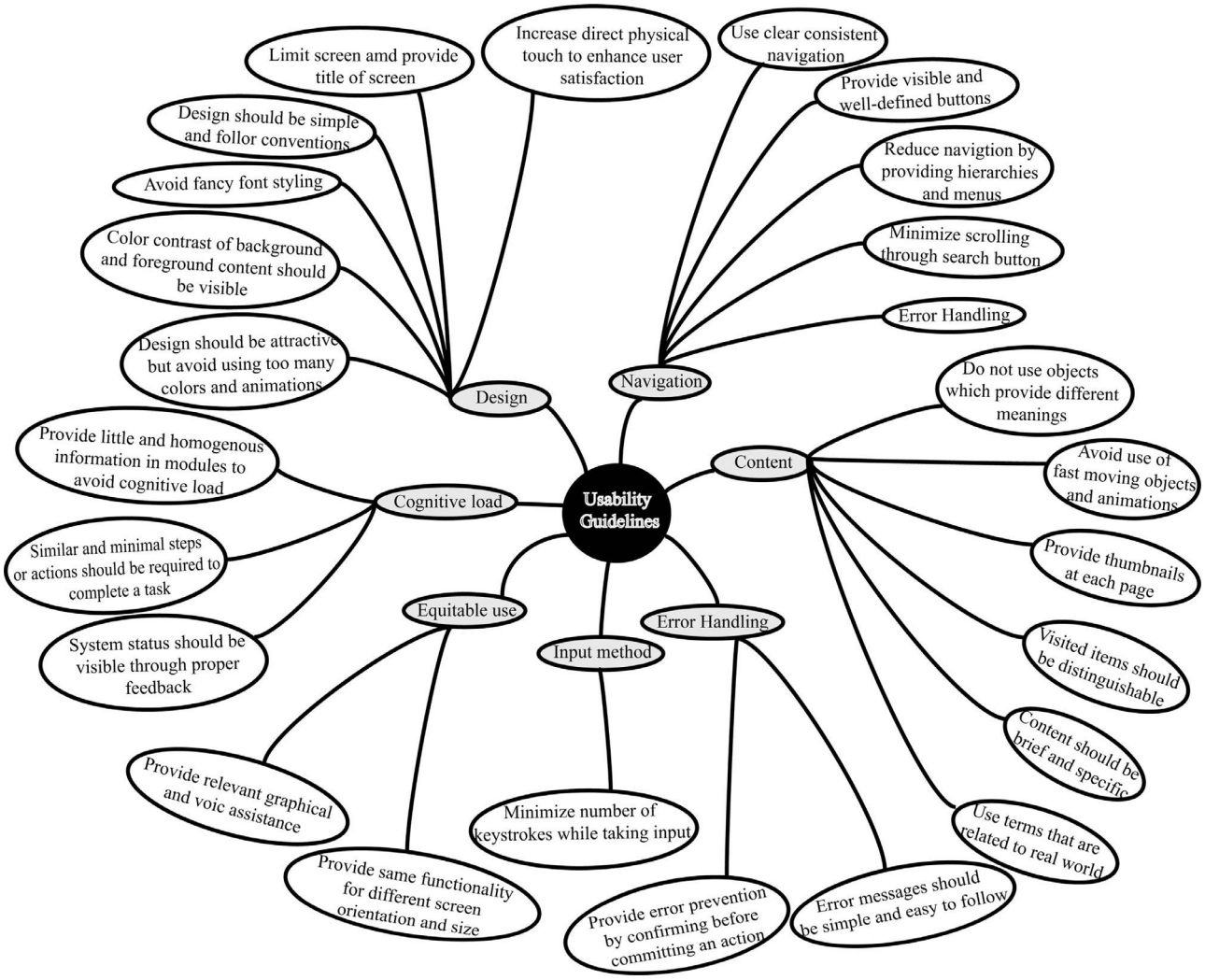

Fig. 7. Perspectives on usability guidelines.

during experiment (Section 3), and map these to the guidelines identified in earlier subsections. These issues were identified by noting the feedback of our participants and by observing where they are making mistakes. For example, some usability problems are discussed in detail below, while a more comprehensive list is given in Table 7.

1 **Mandatory registration**: Both these apps required registration through email address and a password. However, most users were irked that it was mandatory. This issue could have been avoided by following the guideline to minimize input from the user (Section 5.4.1).
2 **Absence of label:** Notes were added through a `plus' sign, which was troublesome for some users as they anticipated a button with a clear label for it. We note that the guidelines mentioned in Section 5.5.1 deal with this issue.
3 **Resemblance – Similar icons:** Another issue was use of one object for multiple purposes. Selecting color and thickness is combined in the same button for Ever note app. Pressing pen icon opens a hidden menu from which thickness and color can be selected at the same time, labels were also missing here. For Google Keep different pen icons are used to present different categorize, writing, highlighting and marker. Sliding upward provides different colors and thickness available for these pens without any label. New users took a lot of time to select desired colors and adjust thickness. In the proposed list multiple guidelines emphasize on using distinct objects 5.2.1, 5.2.2, and 5.2.3.
4 **Lack of feedback** was another issue identified during the experiment, as often users clicked multiple time in confusion that icon is selected or not. Although color changed in both apps for selected items but due to small size of icon color change went unnoticed. Guidelines mentioned in Section 5.6.3 highlight the need for feedback.

Table 7 clearly shows that both apps do not provide sufficient guidance and feedback mechanism. Different task performed by users, whether it is saving something or changing or closing of apps, are done without any status information. We also note that the proposed list of guidelines in Section 5 clearly specifies guidelines for issues identified during this experiment, and may serve well to enhance usability of smartphone apps.

6. Conclusion

Usability guidelines are developed to help develop software with minimum usability issues. There are several usability guidelines that are proposed for smartphone apps. These guidelines can be classified into three disjoint sets: platform specific guidelines, genre specific guidelines, and generic guidelines. This study aimed to develop a comprehensive set of guidelines to serve multiple platforms as well as multiple genres. We achieved this through three step process: (1) establishing the need for the proposed list of guidelines; (2) a systematic literature review to gather guidelines from literature and platforms; (3)

Table 7
Issues found and recommendations.

Issues	Ever note frequency	Google frequency	Addressed by the proposed list of guidelines
Mandatory registration	40	40	Input methods (5.4.1)
Absence of label	18	16	Relevant assistance (5.5.1)
Resemblance – Similar icons	16	18	Content should be consistent and brief (5.2.3) Avoid object provide different meanings (5.2.1) Use terms that are related to real world (5.2.2)
Don't have proper buttons	8	9	Provide visible and well defined buttons (5.1.2)
Additional clicks required	12	15	Provide similar and minimal steps (5.6.2)
Improper closing	35	38	Provide exit and back mechanism (5.1.5)
Unable to locate	12	14	Provide title (5.6.1) Provide thumbnail (5.2.6) Consistent number of steps (5.6.2)
Lack of guidance and feedback	25	30	System status should be visible through proper feedback (5.6.3)
No option to delete notes – only done through long press	12	14	Provide one click delete option (5.1.5)
User interface issues	23	20	Make app attractive (5.7.1)
Option unavailability on same page	12	11	Provide hierarchies and menu (5.1.3)
Scrolling in note area	12	10	Minimize scrolling as not needed in app (5.1.4)
Undo option limited	12	13	Provide undo, redo and delete option at every stage (5.1.5)
Redundant task	11	10	Visited item should be distinguishable (5.7.4)
Don't ask before commit	40	40	Ask before commit (5.3.1)

forming perspectives based on the gathered guidelines. The results obtained from the literature review reinforced the importance of generic set of usability guidelines. We found that about 104 studies from total 148 studies proposed the usability guidelines for a separate genre of an app which is 70%% of total studies. Our systematic literature review resulted in a total of 359 usability guidelines. We note that since we used expert judgement to identify guidelines from the literature, there are chances of some human bias.

In future, we would like to validate these guidelines, i.e. develop an app using this comprehensive list and compare it with another version of the same app that was developed without it. Another area of further research is to develop heuristics from this classification. These heuristics would be used to test usability of applications based on the proposed classification. Once, these heuristics are developed they could be automated. This would facilitate developers in testing usability of their apps, and result in more usable smartphone apps.

Appendix A. : Proportion of tasks completed

Evernote:

User id	Select note	Select color	Adjust thickness	Erase	Undo	Save	Delete	Task performed	Proportion
U1	1	1	1	1	1	1	1	7	1
U2	1	1	1	1	1	1	1	7	1
U3	1	1	1	1	1	1	1	7	1
U4	1	1	1	1	1	1	1	7	1
U5	1	1	1	1	1	1	1	7	1
U6	1	1	1	1	1	1	1	7	1
U7	1	1	1	1	1	1	1	7	1
U8	1	1	1	1	1	1	1	7	1
U9	1	1	1	1	1	1	1	7	1
U10	1	1	1	1	1	1	1	7	1
U11	1	1	1	1	1	1	1	7	1
U12	1	1	1	1	1	1	1	7	1
U13	1	1	1	1	1	1	1	7	1
U14	1	1	1	1	1	1	1	7	1
U15	1	1	1	1	1	1	1	7	1
U16	1	1	1	1	1	1	1	7	1
U17	1	1	1	1	1	1	1	7	1
U18	1	1	1	1	1	1	1	7	1
U19	0	0	0	0	0	0	0	0	0
U20	1	1	1	1	1	1	0	6	0.857143
U21	0	0	0	0	0	0	0	0	0
U22	0	0	0	0	0	0	0	0	0
U23	1	1	1	1	1	1	0	6	0.857143
U24	0	0	0	0	0	0	0	0	0
U25	1	1	1	0	0	0	0	3	0.428571
U26	0	0	0	0	0	0	0	0	0
U27	1	1	1	1	1	0	0	5	0.714286

U28	0	0	0	0	0	0	0	0	0
U29	0	0	0	0	0	0	0	0	0
U30	1	1	1	0	0	0	0	3	0.428571
U31	0	0	0	0	0	0	0	0	0
U32	1	1	1	0	0	0	0	3	0.428571
U33	0	0	0	0	0	0	0	3	0.428571
U34	1	1	1	1	1	0	0	5	0.714286
U35	0	0	0	0	0	0	0	0	0
U36	1	1	1	1	1	0	0	5	0.714286
U37	1	1	1	1	1	0	0	5	0.714286
U38	1	1	1	0	0	0	0	3	0.428571
U39	1	1	1	1	0	0	0	4	0.571429
U40	1	1	1	1	1	0	0	5	0.714286

Google Keep:

User id	Select note	Select color	Adjust thickness	Erase	Undo	Save	Delete	Task performed	Proportion
U1	1	1	1	1	1	1	1	7	1
U2	1	1	1	1	1	1	1	7	1
U3	1	1	1	1	1	1	1	7	1
U4	1	1	1	1	1	1	1	7	1
U5	1	1	1	1	1	1	1	7	1
U6	1	1	1	1	1	1	1	7	1
U7	1	1	1	1	1	1	1	7	1
U8	1	1	1	1	1	1	1	7	1
U9	1	1	1	1	1	1	1	7	1
U10	1	1	1	1	1	1	1	7	1
U11	1	1	1	1	1	1	1	7	1
U12	1	1	1	1	1	1	1	7	1
U13	1	1	1	1	1	1	1	7	1
U14	1	1	1	1	1	1	1	7	1
U15	1	1	1	1	1	1	1	7	1
U16	1	1	1	1	1	1	1	7	1
U17	0	0	0	0	0	0	0	0	0
U18	1	1	1	0	0	0	0	3	0.428571
U19	0	0	0	0	0	0	0	0	0
U20	1	1	1	0	0	0	0	3	0.428571
U21	0	0	0	0	0	0	0	0	0
U22	0	0	0	0	0	0	0	0	0
U23	1	1	1	1	1	0	0	5	0.714286
U24	0	0	0	0	0	0	0	0	0
U25	1	1	1	0	0	0	0	3	0.428571
U26	0	0	0	0	0	0	0	0	0
U27	1	1	1	0	0	0	0	3	0.428571
U28	0	0	0	0	0	0	0	0	0
U29	0	0	0	0	0	0	0	0	0
U30	1	1	1	1	0	0	0	4	0.571429
U31	0	0	0	0	0	0	0	0	0
U32	1	1	1	0	0	0	0	3	0.428571
U33	0	0	0	0	0	0	0	0	0
U34	1	1	1	1	1	1	0	6	0.857143
U35	0	0	0	0	0	0	0	0	0
U36	1	1	1	1	1	0	0	5	0.714286
U37	1	1	1	1	1	1	0	6	0.857143
U38	1	1	1	0	0	0	0	3	0.428571
U39	0	0	0	0	0	0	0	0	0
U40	1	1	1	1	1	0	0	5	0.714286

Appendix B. : Questionnaire

Evaluation of usefulness of taxonomy
Satisfaction questionnaire
Name_____

Sr. No.	Questions	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	I am satisfied with it.	○	○	○	○	○
2	It is simple to use.	○	○	○	○	○
3	It is fun to use.	○	○	○	○	○
4	It does everything I would expect it to do.	○	○	○	○	○
5	I do not notice any inconsistency as I use it.	○	○	○	○	○
6	It is very user friendly.	○	○	○	○	○
7	Its look is attractive.	○	○	○	○	○
8	I needed to learn a lot of things before I could get going with this app.	○	○	○	○	○

Appendix C: Iterations – during taxonomy construction

Iteration 1	Iteration 2	Iteration 3
Provide flat navigation	Use clear consistent navigation	Navigation
Repetition of navigation should be avoided at every page		
Use consistent navigation		
Provide consistent gesture navigation		
Avoid using complex navigation		
Navigation should help the user to locate their current position		
Navigation should be clear		
Navigation should meet the user mental model		
Navigation should be easy to understand		
Extra and bolder navigation cues should be provided		
Clear navigation should be provided		
Provide navigation through back buttons	Provide visible and well define buttons for easy navigation	
Menus and buttons should be clearly labeled that help user navigation and information memorization		
Provide physical buttons		
Provide submenu and hidden buttons to increase display		
Provide clickable link on each page to navigate to internet		
use the buttons for navigation or performing some actions it increase usability but button's look should be real		
Menus and buttons should be clearly labeled that help user navigation and information memorization		
Button's look should be real		
Provide displayable menu sub menu and button		
Minimize hierarchical structure	Reduce navigation by providing hierarchies and menu	
Keep navigation simple narrow and straight forward		
Provide functionality in multilayer format		
Use step by step navigation		
Keep navigation simple narrow and straight forward		
Use linear navigation and navigation bar		
Use navigation tree in depth five and in breath five stages		
Provide dropdown menu for each action		
Use tree view navigation		
Provide vertical navigation		
Reduce navigation by providing hierarchies and menu		
Minimize number of steps in navigation		
Use simple hierarchies for navigation.		
Providing navigation in vertical form enhance the view		
Add search option to avoid extensive scrolling	Minimize scrolling through search button	

Reduce vertical scrolling		
Support searching and browsing of content in group		
Provide double scrollbar for top to down and left to right navigation		
Minimize or avoid scrolling		
Provide complete control to the user so that they can exit at any stage	Provide control to the user so that they can exist or back at any stage	
Back and exist options should be available		
Navigation should be clear that help user to locate their current position		
Provide a back button and home screen button at each page/screen		
Back button should be available at each stage		
Provide dialogues for exit		
Ensure presence of back button		
Provide navigation through back buttons		
If user actions is delayed provide exit mechanism		
Provide once click cancel button at each stage		
Provide a back button		
User should be able to move back forth and exit at any stage		
Provide clear closing mechanism		
Provide undo, redo, and exit at every stage		
Provide one click delete input		
Delete option should be available		
Provide appropriate way for backward navigation		
Provide consistent terms to convey same meanings	Do not use objects which provide different meanings	Content
Use different objects for redundant information		
Use elements according to conventions		
Use self-explanatory icons		
Do not use text or names of buttons links and menu which contradict any religion or society	Use terms that are related to real world	
Language of interaction should be match to real world		
Use real world language		
Use natural and easily understandable language		
User should take few minutes to understand working of app		
Write user familiar terms		
Writing style of the content should be simple and informal		
Use simple and friendly language		
Unique and well known term should be used that are easily understandable		
Use simplified text format		
Use easily understandable daily routine language		
Language should be simple and clear		
Provide gestures that are related to daily life		
System should me matched to real world		
Provide small and consistent information	Content should be consistent, brief and specific	
Avoid unnecessary information		
Provide only useful and relevant content.		
Provide only location based information		
Reduce the amount of information so the user can easily interpret		
Keep interface simple by providing less information		
Don't provide content in table		
Displayed content should be simplified		
Provide accurate content		
Layout should be concise		
Place most important information or link at the top		
Content related to main functionality should be accessible all the time		
Provide ample time to read information	Avoid use of fast moving objects and animations	
Avoid use of fast moving objects and animations		
Content should not all be in color and avoid moving text		
Disable inactive objects	Visited item should be distinguishable	
Highlight selected text		
Visited link should be marked with different colors		
Distinguish selected item from others		
Provide thumbnail of each page at start	Provide thumbnail at each page	
Provide news in short story format		
Provide thumb nail design instead of list view		
Provide summarized information with few keystroke		
Provide thumbnail of information with detailed information		
Ask user before execution of action	Provide error prevention by confirming before commit	Error

	an action	Handling
Provide conformation massages but that are necessary		
Provide error prevention by confirming before commit an action		
provide alerts and feedbacks related to action		
Provide guide in form of tutorial at state of the app		
System should warn user about critical information		
Provide warnings for errors		
Error messages should be simple and easy to follow	Error messages should be simple and easy to follow	
Provide error prevention and simple error handling method		
Everyday language should be used for alerts and feedback		
Provide clear and simple error massages		
Display error message in user understandable language and solution as well.		
Provide concise error messages to recover		
Malfunctioning should be clearly stated and procedure for recovery of error should be stated		
Everyday language should be used for alerts and feedback		
Minimize the number of keystrokes while taking input	Minimize the number of keystrokes while taking input	Input method
Avoid taking textual input		
Provide summarized information with few keystrokes		
Minimize input, use list selection instead of text input		
Provide fastest data entry method		
Provide default input value		
Avoid taking manual input from users		
Limit keypad input		
Reduce number of strokes to take input		
Input should require minimal keystrokes		
Data should be loaded automatically whenever needed		
Provide data automatically, whenever possible, instead of entering by user		
Avoid login unless it is not a critical action		
Provide visuals with text	Provide relevant graphical and voice assistance	Equitable use
Provide graphical assistance		
Provide voice annotation		
Provide same functionality for each user		
Provide visual, textual and auditory feedback		
Use pictures to explain content instead of text		
Provide information in audio form		
Provide non-speech information		
Use an avatar by combining multiple modals to represent a user with different emotions		
Provide sound with each button that notify the user		
Do appropriate use of graphic symbols		
The older adult should not be expected to double click		
Provide both orientation	Provide same functionality for both types of orientation	
Accommodate different screen sizes		
Application should be available in both orientations		
Page/interface should be fit to the display area		
Provide mechanism of recognition rather than remembrance		
Content should be broken into easily understandable chunks to avoid cognitive load	Provide little and homogenous information in modules to avoid cognitive load	Cognitive load
Divide content in partials		
Provide homogeneous information to avoid cognitive load		
Visuals should be provided in grouping to show relationship		
Content should be organized in modules or units		
Provide widgets in non-overlapping groups		
Partition information on separate pages		
Provide content in meaningful group		
Learning content should be in small files		
Provide little information to avoid cognitive load		
Similar steps or actions should be required to complete a task	Similar and minimal steps or actions should be required to complete a task	
Minimal number of steps should be required to perform a task		
Provide consistent set of actions and commands		
Avoid repetitive actions		

Avoid continued actions		
Minimize number of steps to complete a task		
Action should be simple and focused		
Provide information about user's current state and number of remains steps to complete a task		
Minimize number of steps to perform an action		
User should take few minutes to understand working of an app		
Provide user guidance at each step	System status should be visible through proper feedback	
System status should be visible		
Provide appropriate feedback to the user		
System should provide feedback in form of alerts		
Provide feedback during and after completion of a task		
Provide feedback at each stage/step		
Provide informative feedback		
An online help tutorial should be provided		
Design should be attractive but don't use too many colors	Design should be attractive but don't use too many colors and animations	Design
Make attractive design considering all users		
Graphics should be relevant and not for decoration		
Animations add to good design but avoid using too many animations		
Don't use pure white and changing background	Color contrast of background and foreground content should be visible	
Use high contrast colors for text and background to ensure readability		
Color contrast should distinguish between types of content		
Background should not be pure white or change rapidly in brightness		
Black colors is considered as repulsive		
Don't use red color in heath apps		
Blue and green tones should be avoided		
Select the font that do not hamper the visibility of text	Avoid fancy font styling	
Use standard styles		
Use san serif type font i.e. Helvetica, Arial of 12–14 point size		
Avoid using fancy font types		
Use following fonts for web apps to provide easy viewing: Arial, Time New Roman, Courier New		
Design should follow conventions	Design should be consistent and should follow conventions	
Use elements according to conventions		
Use consistent colors throughout the app		
Applications should follow convention and should provide consistent set of actions		
Provide title of screen	Limit number of screens and provide title for each	
Each screen should display title		
Provide a unique title to each page		
Provide informative title		
Use minimal screens		
Try to maximize direct physical touch	Direct physical touch enhance user satisfaction	
Provide direct touch		
Interface should be responsive to user touch and selection		

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