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Preventing accessibility barriers: Guidelines for using user interface design patterns in mobile applications☆

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ABSTRACT

Mobile applications play an important role in many aspects of life. It is essential to be aware of the software development approaches that can support the design of accessible applications. Their main goal is to ensure that the interactive applications are available to everyone, including people with disabilities, reduced skills, or momentarily induced impairments. This paper aims to identify the accessibility barriers that occur when using design patterns for building user interfaces of mobile apps and propose guidelines to prevent the problems most often encountered. We start by conducting a gray literature review in professional forums and blogs to reveal the difficulties developers face when using mobile user interface design patterns. We thus compiled a catalog which contains the descriptions of 9 user interface design patterns, the accessibility barriers linked to the use of each pattern and the guidelines that can be followed to prevent the problem of these barriers. We carried out an evaluation of the use of the catalog with 60 participants. Our results show that in most cases, the guidelines were correctly applied for the prototyping of mobile user interfaces. The findings also revealed the usefulness and ease-of-use of the guidelines from the perspective of the participants.

1. Introduction

Accessible software design is not yet a reality (Lopes et al., 2010) owing to a number of factors, such as the difficulty of following the available guidelines constructively throughout the software lifecycle (Fogli et al., 2014) and the lack of technical knowledge on the part of the designers and developers (Rau et al., 2014). Thus, researchers and software engineers have adopted approaches which involve incorporating accessibility into the software design process. These approaches have the aim of ensuring that the accessibility requirements are correctly adhered to and include into the phases of design, implementation, testing, and maintenance (Sanchez-Gordon et al., 2019; Quintal and Macías, 2018; Reichling and Cherfi, 2013).

As is well known, there has been an increase in the use of mobile devices for Internet browsing around the world. In some areas, these devices have even started to replace personal computers, laptops, and tablets because of their cost effectiveness, greater mobility and convenience. Currently, mobile devices represent approximately 52% of the mobile market when compared with desktops.[1] However, the accessibility barriers that face users with disabilities in desktop platforms, can also be a problem for users of mobile devices (Yesilada et al., 2011) It suggests that there is still a good deal of scope for improving the developmental processes and the final products with regard to accessibility.

While smartphones provide mobility, convenience, and access to information, there are physical and contextual features that hinder access to information such as the small size of the screen (and the wide range of resolutions), processing limitations, Internet service shortages, difficulty in entering information, and navigational problems (Patch et al., 2015; Nilsson, 2009). In addition, in many cases problems with the user interface can lead to accessibility barriers that are conditions that make the interaction more difficult. Consequently, these barriers bring problems to people achieve a goal when using the web on mobile or desktop devices (Brajnik, 2008).

Designing mobile applications is a challenge on account of their special features and, thus several design patterns have been

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[1] StatCounter Global Stats, accessed in Feb 2021: https://gs.statcounter.com/platform-market-share/desktop-mobile-tablet.

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0164-1212/

examined in the literature to describe experiences and assist in the design of new applications (Cruz and Abreu, 2019). In general, a design pattern names, abstracts and identifies the key features of a common design structure and enables it to create a reusable design. Each design pattern focuses on a problem and describes when it should be applied and if it can be applied in light of other design limitations, as well as the implications and benefits of its use (Gamma et al., 2009).

There are several user interface design patterns for mobile devices that are available in libraries (Ribeiro and Carvalhais, 2012); however, sometimes these patterns do not attach much importance to the accompanying accessibility features. For this reason, the main objective of this work was to investigate the accessibility barriers that occur when using design patterns for building user interfaces for mobile applications. Considering the accessibility barriers, we intend to propose guidelines that can help to prevent, or at least mitigate, the problems that are most often encountered. To achieve this objective, we defined two research questions (RQ) for this study:

RQ1 — *What are the accessibility barriers that developers/designers reported when using mobile User Interface Design Patterns (UIDP) in practice?*

RQ2 — *What are the guidelines that can assist developers in using UIDP by preventing the problem of accessibility barriers?*

To answer our research questions, we first had to decide about the accessibility definition we adopted in our work. According to Petrie et al. (2015), accessibility should not be confused with usability. Usability refers to the inherent characteristics of a product to be used by any user, encompassing criteria of efficiency, ease, practicality, and satisfaction. In literature, accessibility is usually considered a subset of usability, where accessibility problems are particular cases of usability problems. The perspective we adopt is that accessibility is also related to the concept of "universal usability" (Shneiderman, 2000, 2002), a term coined by Shneiderman (Shneiderman, 2000) to encompass both accessibility and usability. Universal usability is about creating and offering products and services to the broadest possible range of people, regardless of whether they have special needs or not. In our work, we explored the accessibility guidelines to be applied to the maximum possible set of users (Petrie and Bevan, 2009) that fits into the *universal design* or *design for all* concept.

On investigating the accessibility barriers, we decided to perform a gray literature review to explore the practitioners' experiences on the use of user interface design patterns in the perspective of accessibility. Gray literature has been considered a source of evidence in academic research, including software development (Garousi et al., 2019). The contents available in different sources of gray literature (e.g., blogs, websites, and news articles) are produced by practitioners who report their practical experience on adopting some method or technique (Garousi et al., 2019; Kamei et al., 2020). Therefore, we understood that the gray literature is a rich source of practical knowledge which could support us in identifying and creating guidelines that were more suitable for being applied by software practitioners in industrial settings.

Our research method consisted of four key activities outlined below and illustrated in Fig. 1:

1. A Gray literature review was conducted with regard to professional forums and blogs concerning the difficulties faced by software professionals when using UIDP. The gathered documents reflected the state-of-practice, since they reported several issues, and not premeditated any words related to this research.
2. Based on the detected difficulties it was possible to determine the accessibility barriers that the use of UIDP might involve. The documents about difficulties were examined by filtering the issues regarding accessibility barriers reported during UIDP use.
3. A set of guidelines was drawn up to prevent the occurrence of accessibility barriers when designing mobile applications; and
4. Finally, an evaluation of the usefulness was carried out of these guidelines.

Since the guidelines raised up from practical issues faced by the developers, we are confident that our research contribution includes both academic and practical approaches. Moreover, we believe that the results of this study will be of significance for the area of user interface design that can contribute to Software Engineering (SE) as well as Human–Computer Interaction (HCI) areas. This is because many researchers are investigating the means of including accessibility features in the software process and many challenges need to be addressed. There is an important agenda to be covered with regards to accessibility features in the user interface design process (Paiva et al., 2021). By considering our guidelines, developers and designers can avoid introducing the accessibility barriers on the applications and consequently reduce the problems that users have to overcome during the interaction, which set contributions to the HCI area.

This article is structured as follows: Section 2 defines the concepts related to accessibility, and design patterns. Section 3 examines the research on accessibility barriers in practice. Section 4 sets out accessibility guidelines for mobile user interface design. Section 5 outlines the evaluation of the guidelines; Section 6 presents the results of the evaluation. Section 7 discusses our main findings. Section 8 presents the related work and Section 9 concludes with some final remarks.

2. Background

According to the ISO/IEC 25010 (ISO, 2011) accessibility is a sub-characteristic of usability. It can be defined as the "degree to which a product or system can be used by people with the widest range of features and capabilities to achieve a specific goal in a specific context of use". Additionally, it states that this requirement can be met when a product or system is used by people with specific disabilities so that they can achieve their objectives effectively and efficiently.

It is worth noting that usability is defined in the framework provided by ISO 9241 standard (Organization, 1998) as "the extent to which a product (service or environment) can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". The usability of systems is thus largely focused on the interaction of users who have information system interfaces that are designed to maintain quality in the interactions. Thus, both usability and accessibility are criteria that are wide-ranging and adopt a "quality in use" perspective, that is, they should be applied in practical contexts.

Petrie et al. (Petrie et al., 2015) provided a unified definition of web accessibility based on an analysis of 50 studies from the literature. The detailed study stated that web accessibility means that "all people, particularly disabled and older people, can use websites in a range of contexts of use, including mainstream and assistive technologies; to achieve this, websites need to be designed and developed to support usability across these contexts". The authors stated that this definition may be considered to be long, but they believed accessibility is a complex concept with a number of different components (for example, users, assistive

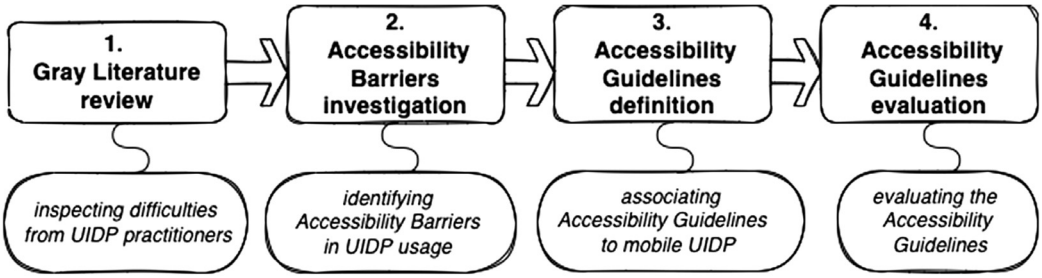

Fig. 1. Overview of the research method.

technologies, etc.) that are seldom represented together in any single definition. Additionally, the authors state that accessibility, like usability, can be applied to the maximum possible set of specified users covered (Petrie and Bevan, 2009), i.e., it fits into the *universal design* or *design for all* concept.

From another standpoint, Yesilada et al. (2011, 2008) investigated the question of accessibility barriers. In general, the authors examined a number of barriers that people with disabilities experience when interacting with web content. They showed how these barriers are similarly addressed in the W3C Web Content Accessibility Guidelines (WCAG) (Caldwell et al., 2008). The barriers were divided into four principles: *perceivable* (information and user interface components must be presentable to users in ways they can perceive); *operable* (user interface components and navigation must be operable); *understandable* (information and the operation of user interface must be understandable); and *robust* (content must be robust enough to be interpreted reliably by a wide variety of user agents, including assistive technologies).

The software accessibility guidelines outlined in the literature represent prescriptive knowledge in an abstract way, and serve as guidelines of good practices that developers should follow. However, owing to the wide range of possible combinations, developers often have to struggle to create user interface designs and meet the rapid demands for the construction of new applications (Cabrera-Umpiérrez, 2016; Babu et al., 2010). In light of this complexity, the technique used to represent and communicate knowledge, known as design patterns, can be regarded as very useful as it can be applied during the software development process (at different levels of abstraction) (Gamma et al., 2009) and can enable software designers to manage design knowledge for later reuse (Sanchez-Gordon et al., 2019). As well as this, it should be noted that, design patterns can only capture the essential details of design knowledge in a specific setting and abstract superfluous information. The designer must be informed when, how, and why the pattern can be applied (Javahery et al., 2011).

In addition to the concept being widely used by software developers, design patterns have been adopted in HCI domain to assist in the creation of the user interface design, and are known as UIDP (*User Interface Design Pattern*). A recurring challenge in this domain is how to design efficient documentation and knowledge-sharing techniques for user interaction with an interface, and to apply them in certain circumstances (Fincher et al., 2003).

According to Folmer (2002), UIDP is a general and repeatable solution to a common usability problem in the design of an interface, and consists of the following features: design pattern name, definition of a problem, solution, consequences, and examples. There are different opinions about what elements are needed to form the UIDP structure. Van Welie and Van der Veer (2003) recommended including the "Reasoning" category in the "Solution", for example. The purpose of this alteration is to explain how the adoption of the pattern would improve the usability of the software product, by taking account of attributes such as learning and user satisfaction. Despite the divergences, this provides a basic framework defined for UIDP, which is similar to the system adopted by Gamma et al. (2009).

3. Investigating the accessibility barriers that occur in practice

To begin with, we carried out an *ad-hoc* review of the academic literature by concentrating on the keywords *accessibility*, *mobile*, and *UI design patterns* in different combinations. In a broader exploration, we looked for systems that involved the use of UIDP in different platforms (i.e., web mobile, android, or iOS) for the construction of user interfaces and those where accessibility featured as an extension of usability (Petrie et al., 2015).

Our findings revealed that little has been discovered about *UI mobile design patterns* and *accessibility*, especially in a practical context. In view of this, we decided that as the aim of our investigation was to highlight problems arising from the practice of software development, we should conduct a literature review. It would enable us to detect the real problems from sources based on the experiences of software developers.

The literature makes clear that handling accessibility in different mobile platforms is a complex activity (Rieger et al., 2020). Nonetheless, we decided to focus on the Android UIDP platform which was Operating Systems mostly used in smartphones. According to Statcounter website (Stats, 2021), from June 2020 to July 2021, 72.18% of mobile phones used Android, and 26.96% used iOS. As well as their native applications, Android users also access web applications from their smartphones. Moreover, several research studies have made a comparison between iOS and Android, which are the most popular Operating Systems for smartphones. Indeed, according to Garg and Baliyan (2021), 72.95% of mobile phones use Android, and 26.25% use iOS. Taking into account the popularity of Android, our investigation was concentrated on Android UIDP so that we could reach a large number of the developers and designers of this platform.

In light of the discussion above, when seeking to answer our RQ1 (*What are the accessibility barriers that developers/designers reported when using mobile User Interface Design Patterns (UIDP) in practice?*), we decided to investigate the gray literature about user interface development in Android.

3.1. The gray literature

According to Kiteley and Stogdon (2014), gray literature (GL) can be produced by the government, academics, or the business and industrial world, in both print and electronic formats. It is available from different types of sources such as blogs, social networks, annual reports, wiki articles, news articles, and so on. GL has been recognized as a source of valuable information for SE practices and is often characterized as a means of providing knowledge derived from practical experience (Garousi et al., 2019; Kiteley and Stogdon, 2014; Kamei et al., 2020).

Table 1
Q&A to decide whether we should use the GL in our work.

Questions (based on Garousi et al. (2019))	Our answers
(1) Is the subject "complex" and not solvable by considering only the formal literature?	No
(2) Is there a lack of volume or quality of evidence, or a lack of consensus of outcome measurement in the formal literature?	**Yes**
(3) Is the contextual information important to the subject under study?	No
(4) Is it the goal to validate or corroborate scientific outcomes with practical experiences?	No
(5) Is it the goal to challenge assumptions or falsify results from practice using academic research or vice versa?	No
(6) Would a synthesis of insights and evidence from the industrial and academic community be useful to one or even both communities?	**Yes**
(7) Is there a large volume of practitioner sources indicating high practitioner interest in a topic?	**Yes**

Garousi et al. (2019) drew up a list of questions to assist researchers in deciding whether or not to use GL (see Table 1). The authors state that, if at least one answer was *yes*, it is an indication that GL should be included in the SE review. In the case of our own investigation, three out of the seven questions were answered as *yes*. Our review of the academic literature revealed that there is little evidence in the formal literature and most of it is not directly related to our proposal (see Section 2). The summary of the evidence obtained from GL sources will be useful to both industrial and academic communities. The lessons learned about the use of UIDP (or related issues) are often being widely discussed in blogs and other types of websites, for instance. In the case of the SE practitioner, it would be valuable to have a catalog with good practices to avoid having to face accessibility problems regarding the application of UIDP in the Android platform (i.e. both website and native). Finally, we noted that the large volume of practitioner sources suggests that there is a great interest in the topic. By referring our answers to the questions in the checklist (see Table 1), we proceeded to examine the GL by following the guidelines set out in Garousi et al. (2019), Kiteley and Stogdon (2014).

3.2. Planning

We decided to investigate the GL in online spaces since these are sources that are often accessed by designers and developers. As there are a large number of available online sources about our research topic, we began by carrying out a brief survey (in both Portuguese and English) with developers and designers concerned with mobile development. We asked them to provide us with basic information about their experience and to pinpoint the relevant keywords required for our main topic, i.e. mobile platform of development, UI design patterns, and accessibility issues Besides, we asked them about what online sources they often accessed when searching for practical information about mobile development and accessibility.

The survey was posted to the mailing lists of universities, partners, and social network groups devoted to design and reached a total number of 44 participants (i.e. designers and developers) from 14 different countries (i.e Brazil, Colombia, Chile, Germany, USA, Republic of Ireland, Japan, Spain, Portugal, France, Britain, Mexico, Peru, and Italy). From the total, 25 of the participants were developers and 19 designers, and out of these, 15 developers and 18 designers had had more than 3 years of practical experience in software development. With regard to the more experienced developers, 8 and 2 (of 25) had 5–10 and 10+ years of experience, respectively. 11 and 6 (out of 19 designers) had 5–10 and 10+ years' experience, respectively. Out of 44 participants, 30 stated that they had a fair knowledge of mobile UIPD, while 27 stated that they were novices in accessibility issues. As a result, information about 72 online sources, i.e. websites, forums and blogs, was informed by the participants (see the list in Appendix A).

We defined three inclusion criteria (IC) as follows: (IC1) the reference contains a description of UIDP for Android web and native applications; (IC2) the reference describes practical information about the use of mobile UIDP; and (IC3) the document (i.e. blog and forum posts or forum discussions) was published after 2012. We discovered that most of the interface patterns have undergone modifications following the dissemination of smartphones in the world since 2012 when the sale of these devices began to grow (Statista, 2021). Our exclusion criteria (EC) were as follows: (EC1) no text-based content like videos or slide presentations; (EC2) not related to Android UIDP; (EC3) the online source was not available, and (EC4) duplicated content.

We decided not to narrow our search to the Android UIDP field because there would be a risk of losing important gray references. Moreover, as the search mechanism available in the blogs and websites is often not as smart as in the academic databases, broader strings are usually applied (Garousi et al., 2019; Kiteley and Stogdon, 2014). Our search string was based on the keywords selected by the participants in the survey. After some testing, we were able to compile a list with 10 terms: Mobile Design Patterns, Mobile Accessibility, Design Patterns, Inclusive Mobile, Inclusive Design Patterns, Android Accessibility, Android Design Patterns, Mobile UI, Mobile UI Accessibility, and Interface Design Patterns.

3.3. Selection of documents

We noticed that out of 72 online sources provided by the participants, 31 were replications. After applying EC4 to eliminate the replications, we obtained 41 unique online sources. We then proceeded by checking the other exclusion criteria (EC) and another 23 of the 41 were eliminated as a result of the following: (i) 2 addresses or names were not found (i.e. EC2); (ii) 12 were not blogs and websites that were text-related and only provided a UI description (EC1), e.g., Android documentation; (iii) the web UI pattern libraries are not related to Android, examples of UI designs or slides presentations; and (iv) 9 sources were only concerned with iOS development (EC2). After carrying out a previous examination of the online sources, we decided to only include the ones which have information about mobile accessibility and UI design patterns (i.e. IC1 and IC2). In Appendix A is available the complete list of sources informed by the survey participants and the exclusion criteria applied. After this preliminary analysis, 18 information sources were selected and used in the study (see *the online source column* in Table 2).

After establishing the online sources, we explored each of them with the aid of our 10 terms (see Section 3.2). None of the 18 online sources had sophisticated search controls, which meant that we had to create a set of expressions in plain text and search each of them. Each online source (see Table 2) was explored by using a search query formed of the keywords in the database. Every blog post or forum discussion that matched the inclusion criteria (i.e. IC1 and IC2) was analyzed with regard to its topic, importance, and the value of both its raw content and

Table 2
Online sources explored and number of documents collected from each one.

Online source	No. of documents collected
1 — medium.com	46
2 — smashingmagazine.com	21
3 — nngroup.com	12
4 — stackexchange.com	10
5 — reddit.com	9
6 — creativebloq.com	7
7 — uxpin.com	6
8 — torresburriel.com	2
9 — grihotools.udl.cat	2
10 — uxmovement.com	2
11 — usabilitygeek.com	2
12 — bradfrost.com	2
13 — androiduipatterns.com	1
14 — visualhierarchy.com	1
15 — lmjabreu.com	1
16 — mobile-ui-design.ionicthemes.com	1
17 — linkedin.com	1
18 — jamesarcher.me	1

comments. Our search was also filtered and took into account the publications that had appeared since 2012.

Since online sources can have volatile data, we adopted a safety through redundancy strategy to prevent content from being lost. In our computer, we created local storage for the documents by generating a ".png" image of the entire page with the help of a plugin for Chrome browser to maintain the original state of the page. We also produced two other copies of the information in ".pdf" files (one generated with the browser's pdf saving tool and another with a special plugin that creates ready for print .pdf files) alongside a ".txt" file containing the URL of the page. We arranged all the files by subject and date; we also compiled a portfolio containing a domain folder, sub-domain folder (if present) and publication title.

After analyzing all the 18 domains, we selected 127 publications (see the list of publications in Appendix B). Table 2 shows the total number of documents collect by the online source. It is clear from Table 2 which shows the number of publications from online sources that some of them (for example, medium.com and smashingmagazine.com had a greater concentration of documents. This can be explained by the fact that these pages publish articles from different authors, and thus have higher publication rate than the other sources.

3.4. Analysis

When analyzing our data, we employed the two steps of the Grounded Theory (GT) approach. GT is a qualitative research method that follows a systematic set of procedures to derive a theory inductively that is, it is grounded on a phenomenon based solely on the data collected (Strauss and Corbin, 1997). In our analysis, we followed two steps of the GT approach defined by Strauss and Corbin (1997): *(i)* open coding and *(ii)* axial coding, and these can be described as follows (see Fig. 2).

Open coding relates codes to chunks of text. These codes are assigned labels that give a certain meaning to the chunks of texts they refer to Strauss and Corbin (1997). Among the different coding techniques, we adopted in this study, one is called incident-to-incident coding. In this approach, any amount of text in any location of the document can be coded. Incident-to-incident coding is mostly used for low density documents, that is, documents that are not derived from direct interviews and may contain portions of text that are not relevant to the research as they address other subjects (Charmaz, 2014). Axial coding is the process of relating the codes which emerged from the open coding step and provide a visualization of their relationship (Strauss and Corbin, 1997). *Nvivo 11* (Richards, 1999) was the tool that supported our qualitative analysis. All of the 127 documents in PDF format were imported in NVivo.

Fig. 2 illustrates our analytical procedure. It was conducted by two researchers hereinafter called R1 and R2. R1 had a master's degree in Computer Science and was a full stack mobile developer, and had expertise in Software Engineering research. R2 was a senior researcher with academic and practical knowledge in User eXperience and Software Engineering, and experience in carrying out empirical studies in industrial context.

First, in Step1, R1 carried out the open coding process in all the 127 documents. Each document was analyzed so as to find the text snippet that provided evidence that there were accessibility barriers in the use of mobile UIDP. The four principles (*perceivable*, *operable*, *understandable*, and *robust*) defined by Yesilada et al. (2011) (see Section 2) were applied to find the snippet that provided information about accessibility barriers. We thus found out evidence that the use of some UIDP led to difficulties which prevented people from achieving their goal. This snippet might be a line, a sentence, several lines or an entire paragraph. As soon as some snippet which had a significant meaning for our work was found, it was labeled by the researcher. As a result, we created 243 codes. Additionally, considering the open coding process, all the previous codes were reviewed and all the documents revisited by R2. Thus, it was possible to identify codes that were very similar. In these cases, some codes were created, some were removed, and others were merged. At the end of Step1, R1 and R2 reached an agreement meeting to obtain the open coding results. By the end of the second step 189 codes were left.

Subsequently, the axial coding process (Step2) was conducted. R1 revisited the documents and the codes to search for intersecting codes in the text. By using the snowball sampling technique for the set of documents, we were able to discover the relationship between the different codes. In Step2, R1 and R2 worked together to find out the link between one accessibility barrier with the different mobile UIDP. In addition, R1 and R2 explored the 189 codes and their links. Finally, in Step3, R1 and R2 created a set of categories in which the codes were classified. In this step, the 189 codes were divided into 27 categories 9 of which were directly related to the mobile UIDP. The others were crosscutting categories which means they affect the whole UI design. These 9 categories were the most cited among the GL documents we have explored. The two researchers, i.e. R1 and R2, had a discussion about how to label these 9 categories. The researchers thus assigned the respective UIDP name to each category and linked them to accessibility barriers that could be triggered from the use of those UIDP on mobile devices. The 9 UIDP categories we worked on were: *Hamburger Menu*, *List and Pagination*, *Carousel*, *Select and Dropdown*, *Input*, *Slider*, *Icon*, *Data Tables*, and *Tab Navigation*. Fig. 3 shows two examples of extractions (i.e. A and B) that we obtained from the GL, the respective categories for UIDP and the code assigned to the extraction.

Our qualitative analysis was supported by memos which are created and compiled by R1, and refined by R2. Memos are notes about the data, codes, relationships between codes or even summaries that the researchers find useful to define the accessibility problems more precisely (Birks and Mills, 2015). The creation of memos is extremely important as these annotations are the first attempt to communicate the results of each coding step in textual format. Table 3 shows a memo from which we summarised our findings about problems in the *List and Pagination* UIDP.

After completing all the three analytical steps, we obtained 20 memos that list several of the accessibility problems that are cited in the documents (see Fig. 2). All the memos are available in a Google Drive document.[2]

[2] https://drive.google.com/drive/folders/1yVERzqSmdaEQ9QdMDZEC_XT2vYvNYVNv?usp=sharing.

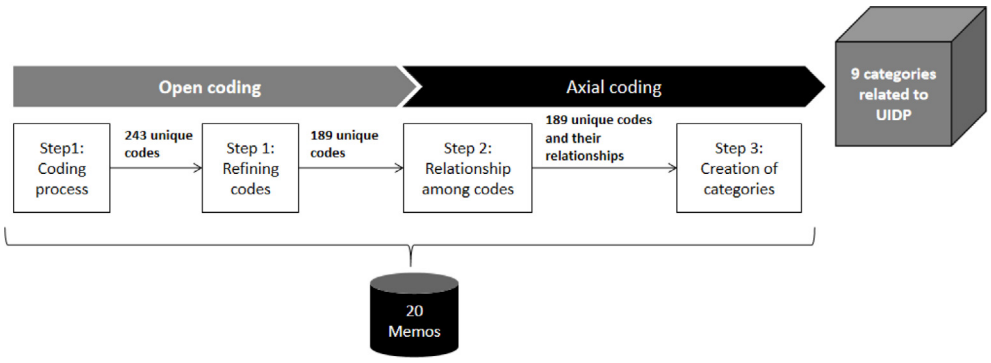

Fig. 2. Steps of analysis — partial and final results.

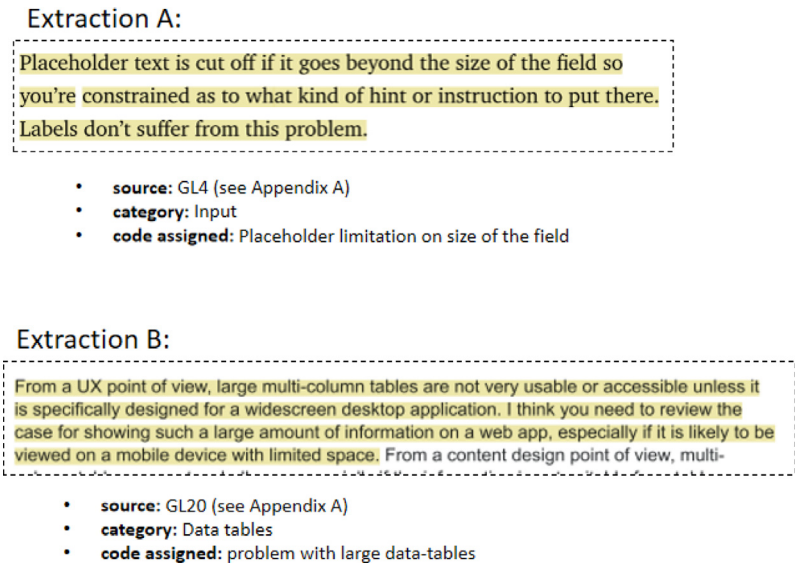

Fig. 3. Examples of extractions from GL.

Table 3
Example of memo on UIDP list and pagination.

Navigation list on mobile
On desktop, a list navigation is usually implemented with a wide range of options in the bottom of the list in which the user can chose to go back and forth one, two, three or more pages and usually, there are options for the first and last pages too. On mobile, a pattern that is widely used for list navigation is the infinite scroll, i.e., by reaching the end of the loaded items, new items from the list are loaded and displayed automatically for the user that continues to scroll until he or she reaches the end of the list. There are several problems with the infinite list pattern: • On situations with low bandwidth, the loading of new items may cause lack of responsiveness • While scrolling down, and loading new items, a loading icon must appear and the user may have problem identifying the meaning of the icon • Infinite list does not provide any information regarding the position on the items in the list • As infinite list does not have pagination, it is difficult to share or save the position of an item in the list • The concept of loading new items when reaching the end of the list may be difficult to understand by some people • Infinite scrolling on large lists may discourage users • It is difficult to find an item in a ordered infinite list (even more difficult when the item is at the end)

3.5. Results

UI issues and accessibility barriers arose from an analysis of each memo. We found out that there was a set of crosscutting problems that were not directly linked to UIDP — for instance, issues regarding the use of gestures when interacting and the application of screen readers. Although we are aware of the importance of these kinds of topics, we think that they have a high level of complexity and need to be investigated in greater depth, including the elements from the context of the interaction (Zhuang et al., 2017). In view of this, we concentrated on the nine categories directly related to the mobile UIDP. Table 4 summarises these categories and each of the respective numbers of GL documents in which we found evidence of accessibility barriers. We also show the codes assigned to each category and the number of occurrences of these codes. Our findings were arranged into 2 sets, the *Navigation group* and *Content interaction group*.

Table 4
Mobile UIDPs and the codes assigned to them.

Category	Codes assigned	Number of documents	Total of codings
Hamburger menu	Description of Hamburger menu	8	8
	Hamburger menu takes less space	1	1
	Hamburger menu icon hides context	13	22
	Hidden Navigation with Hamburger menu	14	27
	Greater number of clicks with Hamburger menu	5	9
Tab nav	Current location is shown on tab bar	1	1
	Limited number of navigation options with tab bar	2	4
	Tab bar doesnt hide navigation	2	2
	Tab bars remain on the screen	3	3
	Tabs accessibility	4	13
	Tabs on Screen Reader	3	5
	Use of tabs for menu is better	5	7
List and pagination	Good applications of infinite list	1	7
	Image for list item can be unnecessary	2	4
	Image list item position	2	4
	Images for list items can be helpful	2	3
	Hybrid infinite list	2	4
	Infinite list involves in loosing position control	2	13
	Infinite list makes you waste time	2	2
	Infinite scroll hides footer	1	2
	pagination with clicks	2	4
	Provide meaningful and clear titles for thumbnails	1	1
Carousel	Advantages of carousel pattern	1	4
	Bad examples of carousel (Problems)	1	3
	Explaining a carousel	1	3
	Lack of satisfying carousel implementation	1	1
	Tips for a good carousel pattern	1	5
	Usage of carousel patterns	1	3
Sliders	Discrete slider can be better	1	4
	Problems with sliders	1	6
	Usage of slider	2	5
	Importance of hit area on forms	1	3
	Small fonts and touch targets (small screens)	2	2
	Tap area	6	8
Select and dropdown	Dropdown lists	2	5
	select menu cons	1	5
	Select menu pros	1	3
Input	Benefit of labels	5	5
	Benefits of placeholders	1	1
	Correct usage of placeholder + label	9	13
	Example of bad form	1	2
	Example of label	2	3
	Form filling for motor impaired users	2	2
	Hit area reduced by missing label	2	4
	Lack of context without labels	5	6
	Missing label impact on Motor impaired users	4	6
	Negative impact of placeholder problems on users	2	3
	Placeholder limitation on size of the field	1	1
	Placeholder not recognized by Screen Readers	1	1
	Problem with usage of Label AND placeholder	2	2
	Problems with forms	2	2
	Problems with placeholders	3	18
	Example of good link texts	1	1
	Meaningful text for links	1	3
	Use more than just text to present a button	1	1
Data tables	Concern with accessible data-tables	3	4
	Importance of data-tables	1	1
	Problem with large data-tables	2	4
	Show the minimum amount of information on data tables	1	4
Icons (*)	Icons are difficult to decipher	4	6
	Use color and icons to show information	5	5

The *Navigation group* contains the UIDPs that focus on general interactive navigation with mobile interfaces. It was the subject that was most often found in the GL documents. We discovered that only *Hamburger Menu* and the *Tab Navigation* were referred to explicitly by the term "navigation" in 28 documents. However, we were able to determine that other UIDPs were related to this category by examining the GL documents and realized from the use of terms that it meant some kind of "navigation". For instance, when we looked at Table 3, we noticed that the memo reports movements of navigation on the mobile interface (e.g., *go back and forth one, two, three or more pages...*). Following this examination, we decided to include the UIDP *List and Pagination*, *Carousel*, *Slider*, and the *Select and Dropbox* in the *Navigation group*. As a result of our snowball sampling technique, we discovered that the UIDP *Input* had a relationship with *Slider*, and thus this was added to the *Navigation group*.

Our *Content interaction group* covers two UI elements which enable the accessibility barriers to be related, as well as to handle a large amount of data and give some meaning to the interaction; these are *Data Table* and *Icon*, respectively. *Data Table* became a prominent feature of accessibility because of the limited space available on mobile screens. Since we recognised that discussing accessibility barriers that can come from the use of the *Icon (*)* element is a complex matter, we decided to avoid laying stress on the issues linked to it. However, we included it in our list, so that icons could be used in combination with other UIDP and hence affect the question of accessibility.

With regard to our coding and memos for each category, we would like to point out the accessibility barriers or accessibility problems which emerged from the analysis. These results enabled us to answer our RQ2 which will be discussed in the next section.

4. Accessibility guidelines for mobile UI design patterns

The following section provides an answer to our RQ2 (*What are the guidelines that can assist developers in using UIDP by preventing the problem of accessibility barriers?*).

After mapping the accessibility barriers, we drew up a set of guidelines called "AccessGuide" (**Access**ibility **Guide**lines). When we designed the guidelines, we followed three steps that were repeated for each of the 9 categories. Three researchers took part in compiling the catalog. R1 and R2 were the same researchers that conducted the GL analysis (see their profile in Section 3.4). Another researcher, hereinafter called R3, was a senior researcher in Software Engineering with expertise in UIDP and accessibility.

R1 and R2 carried out meetings to discuss the codes and their respective extractions. To begin with *(i)*, the researchers examined individually all the chunks of text linked to the codes assigned for one category (Table 4). After this, *(ii)* R1 and R2 discussed and compiled all the chunks of texts to thus together draw up a draft with the guidelines linked to a given category (i.e. UIDP). For instance, in the case of *Data Table category*, *(i)* the researchers individually read the chunks of text linked to all 4 codes assigned to this category (see Table 4). By reading the excerpts of the text, they first understood individually the problems about the use of data tables. After that, *(ii)* in a collaborative discussion based on their understandings, they constructed a draft with advice on how to avoid the occurrence of accessibility barriers for this UIDP. The bias on the interpretation of the excerpts was mitigated by R1 and R2 having the same background on the definition of accessibility (Petrie and Kheir, 2007; Petrie et al., 2015) and accessibility barriers (Yesilada et al., 2008, 2011). Furthermore, the meetings allowed R1 and R2 to collaboratively build the draft of the guidelines based on previously labeled extractions which were done taking into account the grounded theory principles.

Finally, *(iii)* R1 and R2 wrote up the guidelines for each category considering the draft resulted from *(ii)*. R3 conducted a review of the first version of the guidelines. Due to R3 having experience in design patterns and accessibility, R3 carried out the guidelines refinement in such a way that their descriptions are as close as possible to the ordinary language used for software developers. Since our target audience consists of practitioners (i.e. developers and designers of UI mobile applications), we employed simple and practical language when writing the catalog. A brief identification was assigned for each UIDP (i.e. id), and described its name, characteristics, the accessibility barriers related to it, and the guidelines adopted to prevent the occurrence of accessibility barriers on the mobile user interface. As well as this, we added animated GIFs[3] to illustrate the accessibility barriers and the related guidelines. The whole catalog is available at http://uxleris.net/accessguide/. In the next subsections, we will examine each UIDP.

4.1. AG1 — Hamburger menu

Definition — Hamburger menu is a kind of UIDP in a navigation system that is mainly used for mobile applications that involve displaying navigation options that are initially hidden and that can be triggered by the click of a button.

Accessibility barriers — sometimes when the Hamburger Menu is used, the navigation is hidden from the users who lacks previous knowledge of this UIDP, if they do realise that the menu can be accessed by clicking a button. The menu icon has little information scent and, even with a label called "Menu", users may still not be able to navigate as they do not know which options are available and may even fail to click the button.

Guidelines — when dealing with patterns that directly affect the discovery of content, the solution is not always simple. However, some guidelines are effective such as the following:

- When using the hamburger menu, use appropriate and explanatory terms for menu items;
- Avoid creating too many menu items. This can lead to an extensive list of options that are easily overlooked and, sometimes, not well displayed on mobile devices;
- Although the menu is displayed, it is worth telling the users the main navigation options that are available on the front page.

4.2. AG2 — Tab navigation

Definition — Tab navigation is based on the folder metaphor that displays content across different screens and datasets, and makes other interactions. The main advantage of using the tab bar as a feature of tab navigation is that it does not hide the navigation options. These can be available all the time and the user has easy access to the navigation bar without needing to open a drawer in order to locate which navigation options are available. Another significant benefit of tab navigation is that the tabs communicate with the user about the current location by displaying the current position in the related navigation option.

Accessibility barriers — although tab navigation may seem to be the perfect navigation feature for mobile devices, it can only hold up to 5 navigation options in order to be able to fit in the screen with a suitable font size.

Guidelines — in situations where the number of navigation options is too large, there are two approaches that we can be adopted to solve this problem:

- The first approach is to add a last option called "more" (or other appropriate label) that will make it possible to open a navigation drawer;
- The second approach involves using a horizontally scrollable navigation tab bar. If this approach is adopted, the navigation bar can hold more options while keeping the optimal touch-target size.

However, the downside of both approaches is that they still involve issues over discoverability.

4.3. AG3 — Icon

Definition — Icons are pictographic representations of something and are widely used in combination with UIDP. They are meaningful and their representation should be informative to users.

[3] They have not been added in this manuscript because of the limited space for visualizing their movements.

Accessibility barriers — sometimes, icons are not displayed correctly because an image o color is not the best way to represent their meaning. New users or users that have some kind of disability like color blindness, for example, will have trouble using the application.

Guidelines — the follow guidelines can assist in mitigating the problem of the occurrence of barriers:

- There is one effective way of using meaningful icons that will actually help the user is choosing one that is available in the mobile platform. As the icon often appears to users, it is easy to associate the image with the meaning;
- Always remember to include a text that explains what the icon means, because if it is just an image, this can sometimes cause confusion. Moreover, the text can assist the screen readers by describing the icon.
- Neutral colors are the best way to represent an icon, because the color does not usually convey a meaning. At the same time, it must be remembered that in the case of people who are colorblind, the use of colors can cause confusion.

4.4. AG4 — Input

Definition — Input is generally used solely and in combination with other UIDPs. Its main role is to make it possible to incorporate data.

Accessibility barriers — one of the accessibility concerns is the correct use of placeholders and labels in input fields. The use of placeholders alone saves the designer space for other features. However, when an input field does not have a label, the menu hint area for that feature is reduced. A placeholder disappears when the user starts typing, which instantly removes the whole context of the input field. Placeholders are shown with low color contrast to the background, which may spoil the experience of users with visual impairments or users with situational disabilities caused by screen reflection.

Guidelines — a solution for most of these barriers is to ensure the appropriate use of the label and placeholder together as described below:

- Labels are not textual aids and thus should be succinct, short, and descriptive so that users can quickly find out what information is required;
- Labels should only provide necessary information for the user;
- Placeholders that are used with labels should contain information about the format expected in the input field or other necessary information required for the fulfillment of the task;
- In the case of both placeholders and labels, the text should never be on all the caps, as it is more difficult to read and harder to scan quickly.

4.5. AG5 — Data tables

Definition — Data tables are widely used elements to display sets of data across rows and columns.

Accessibility barriers — the most common problem found when deciding how to display large amounts of data in the form of a table, is estimating the space that the table requires. In the case of the mobile, the problem is more evident as the screen is significantly smaller. There are several guidelines for this that can be found in research projects, such as making sure that only necessary and pertinent information is displayed and thus reducing the number of columns. This approach is helpful, but does not solve the whole problem as, often all the information is necessary. As mobile phones are usually used in portrait mode, the main problem faced when showing data, is how to display vertical information and maintain the necessary spacing between the rows. A number of factors can cause problems to screen readers, such as the following: the absence of table borders and the use of the correct minus Unicode symbol for negative numbers.

Guidelines — there are guidelines which should be followed when displaying the data:

- Table borders are used by screen readers to identify a data table. This means that if a screen reader locates a table that does not have defined borders, it will possibly parse the table as a layout table and thus not read its contents correctly;
- Some screen readers have difficulty in identifying basic types of operands and characters that are usually used in data. One example is the use of hyphens to show negative numbers (for example −99.99). The screen reader will not read the hyphen in most cases, and for this reason, it is essential to use the correct minus Unicode character;
- In the implementations of some frameworks, tables are not defined with the usual table HTML tag, but defined with div or custom tags instead. This means that the screen reader will not be able to understand the content;
- Data tables, like any other content, should have well defined Accessible Rich Internet Applications (ARIA) attributes;
- There are other questions regarding how to display a data table so that screen readers can read it at Web Accessibility in Mind website.[4]

4.6. AG6 — List and pagination

Definition — a UIDP that has been widely used for list navigation is an infinite list. In this pattern, the user does not have to click on any button in order to load more items, but instead, when reaching the bottom of the page, a new set of results is automatically loaded and displayed for the user. This process continues until the end of the list has been reached.

Accessibility barriers — in situations of low bandwidth, which are common when using mobile devices outside a Wi-Fi network, the infinite list may involve long waiting times while loading new items that have to be displayed. One of the major problems with infinite scrolling is that it does not provide any information regarding the position on the list. In the same way, the lack of information about location during the navigation of mobile applications can cause serious problems for people with different disabilities (and even people without disabilities). In some implementations, the infinite list is sorted by date or alphabetically. This situation causes a further problem if t is extremely difficult to find an item at the end of the list, as it is not possible to jump to the end. Moreover, the list implementations often fail to provide any kind of filtering options, which aggravates the problem.

Guidelines — with regard to accessibility issues, the better navigation list pattern is pagination, even on mobile devices, provided that it follows the guidelines set out below:

- A few navigational controls should be made available because of the small viewport;
- Filtering and ordering options should be included to reduce the number of items in the list.

4.7. AG7 — Select and dropdown

Definition — Select and Dropdown display a list of options (i.e. contents, navigation points) and allow users to select one of them.

[4] http://webaim.org/techniques/tables/data.

Accessibility barriers — when a dropdown has a large number of items, this gives rise to problems regarding the best way to display the list on mobile devices when there is limited space on the screen.

Guidelines — the adaptation of select and dropdown patterns for mobile applications can cause some difficulties which the guidelines set out below can help to overcome:

- Dropdown items can be affected by context and the way they are arranged should take account of this. For example, in a list of drugstores, the list should be ordered in terms of their proximity to the user. In other contexts, the list could be ordered by the item that is most often selected or any other classification or rank that may be reasonable;
- Another solution when there is a large number of items is to split the list into two or more "selects". However, this is not the best strategy and is often not meaningful, although it is effective in some cases;
- A different approach to the dropdown situation when there are many items, is to provide filters or categories to reduce the number of items displayed. It is already being used in many of the examples found, although it increases the number of clicks that the user has to make;
- Another approach that can be adopted is to make a hybrid search together with a select implementation where the select box is also a search input and the user can type a request to filter the items. This approach is of great value as it can be faster than manual searching. However, there is a "downside" which is that in mobile devices, the input entry may lead to complications for some users, because of the small screen.

4.8. AG8 — Sliders

Definition — Sliders allow users to make a selection from a wide range of values. In mobile applications, the slider is implemented by means of touch screen interaction.

Accessibility barriers — there are two possible types of sliders: the continuous and the discrete slider. While in the case of continuous sliders, users select a value along a subjective range, the discrete type can be set to a specific value by referencing its value indicator. The continuous control can also have a harmful effect as, often, it is difficult to select a specific value in a large interval, and thus with a continuous slider, there may not be a satisfactory degree of precision. In addition, another factor that arises with continuous sliders, is that the user has no idea of what sizes and values are currently available. This can lead to unwanted results. Another variation is the slider with two selections. In this kind of implementation, the user may make a selection by using the same interval at a lower and higher boundary for the filter. However, the problem with this implementation, is that in some cases, when the range of values is too wide, the user may have trouble selecting a small interval, as the slider selection icons can be overlaid or it might not be possible to carry out this task. Discrete sliders are preferable to continuous sliders, but there are concerns about their implementation too. In the case of discrete sliders, the user is able to choose predefined values and thus avoid the kind of precision problems that can arise in a continuous range.

Guidelines — the two implementations, i.e. discrete and continuous with discrete sliders, should follow the guidelines to prevent accessibility problems:

- The values of the slider selection should appear above the pegs so that, when the user clicks to select, the user's fingers will not cover the value;
- There should be an alternative form of selection that is different from sliding a peg. This can be provided by adding an input element on top of the slider, where the value can be manually changed by typing a new value or the value can be automatically changed when moving the selection along the slider's range. This option is useful for many disabled users with motor impairments and for those who use screen readers;
- The user could be given more control over the selection, and the slider could be provided with more information regarding the number of items available in a single position. One way of implementing this is to divide the slider positions by the number of items in a range. As a result, a certain distance from the movement on the slider axis will represent an equal absolute change in value;
- Another way of providing the user with more information regarding the range of results, is to create a histogram based on the number of items in stock attached to the slider.

4.9. AG9 — Carousel

Definition — Carousel is a collection of images used to show featured items with pictures and descriptions, but unfortunately, many mobile app implementations do not offer a satisfying carousel experience. In this pattern, the user is able to view several images across a row and navigate from one item to another by means of a horizontal swipe. Generally, an arrow indicates the direction of the carousel and apart from the featured item, there are other items that are partially hidden. Carousel is a typical pattern for illustrating the use of gestures to swipe and navigate through the carousel items in a mobile device.

Accessibility barriers — although the carousel operates in an intuitive way, it is necessary to provide visual information regarding the direction of the carousel and also alternative buttons for the swiping gesture. The pat tern works well in small devices because it uses screen space efficiently, but there are some implementations and variations that can cause accessibility problems.

Guidelines — accessibility issues can be avoided by complying with the following guidelines:

- At the end of a carousel, it is necessary to give the user the opportunity to see more results to avoid overloading items. A link called "See more" can be added and this can redirect the user to a page by listing more items;
- Some implementations include vertical scrolling that is not smooth. The scrolling of this pattern should offer the users the chance to employ fast and precise scrolling, without being "user stuck" or having their navigation limited;
- The implementation should always indicate the direction of the scrolling. In addition, the carousel must include a single starting-point, and show the far-left item first;
- An infinite carousel makes the user tired and is not recommended. An ideal number of items might range from 8 to 20;
- A carousel does not replace any kind of list of items;
- It is important to maintain consistency in the structure of the items, which means that if one item has an image and description, all the items should have the same information. The items should also have meaningful images and descriptive texts in a few words.

These nine guidelines (Sections 4.1 to 4.9) were drawn up with the aim of enabling developers to use UIDP while preventing the occurrence of accessibility barriers, which meant they had to be arranged by the investigated UIDPs. Thus, the AccessGuide Catalog is designed to assist developers/designers in using the UI mobile design patterns while being conscious of the accessibility barriers.

5. Evaluation of the guidelines

To evaluate the guidelines, we first searched for proposals that were similar to AccessGuide, i.e., those which contain guidelines that are focused on the use of mobile UIDPs and at the same time are concerned with preventing the occurrence of accessibility barriers. We noticed that most of the proposals set out guidelines to help visualize the content and were not mobile UIDP-related accessibility guidelines. We decided not to conduct a controlled study, because we could not find any similar guidelines that allowed a fair comparison with our proposal. Google Material Design, for instance, presents a set of accessibility guidelines; however, they do not make a relationship between accessibility and the use of UIDP. Moreover, since we had drawn up a set of guidelines to assist developers in their practice, we decided to carry out an evaluation that could measure/observe variables as they naturally occur (either in the lab or the real world) when the developers used our system. We thus decided to conduct a "non-experiment" (Lazar et al., 2010; Robson and McCartan, 2016) to measure and observe the way the guidelines were handled and complied with by software developers. This type of study allowed researchers to collect evidence that emerged from the developer's perspective with regard to the use of the evaluated object.

According to Lazar et al. (2010) there are two factors that define a non-experiment: (i) it does not involve multiple conditions; and (ii) there is only one observation group or one measure involved. As we did not find similar guidelines in the literature to our proposal, our study focused on evaluating a single object, i.e., the guidelines. Therefore, our study did not involve either multiple conditions (cause and effect) or different groups that had been randomly assigned to the different conditions. Moreover, we only observed one group, i.e., the software developers.

We also followed the guidelines of Lazar et al. (2010) to order the assessment into the steps of planning, execution, and analysis. We employed recommendations of Robson and McCartan (2016) to divide our evaluation into different stages — i.e. its purpose, variables, and the time of data collection. In later sections, we will examine the subjects involved in the evaluation, and the planning, execution, and analysis steps.

5.1. Subjects

The subjects of the evaluation were 60 participants who took part in a 10-hour non-fee paying extension course about UI mobile design patterns. The course was run 5 days a week with 2 h of teaching per day. It was approved by the Extension Board of the Federal University of São Carlos, Brazil as part of an extension program that is aimed at disseminating the technical knowledge produced in the university to society at large. Both members of the internal and external community could be enrolled in the course, i.e. students and software professionals. We promoted the course from social networks like Twitter and Facebook. The course covered concepts about accessibility, UI mobile design patterns, and low-fidelity prototyping. Moreover, it made use of Proto.io,[5] a low-fidelity prototype tool.

During the course, we invited the participants to take part in evaluating the catalog which took place at the end of the course. We informed the course participants in advance: (i) about the purpose of the evaluation; (ii) that the data collected would be strictly used for scientific ends; (iii) that their participation was voluntary and without any remuneration; and (iv) they had the right not to participate and to discontinue their participation at any time without incurring any penalty.

[5] https://proto.io/.

The course was offered twice. Two groups of individuals took part in each session, and are labeled hereinafter as Group 1 and Group 2, with 34 (i.e. P1–P34) and 26 (i.e. P35–P60) participants respectively. We applied a questionnaire to gather background information about participants and form a profile (see Table 5). Figs. 4–6 show an overview of the self-assessment of each of the 60 participants, as well as their knowledge about the main areas of this research. Before answering this questionnaire, the participants accessed an online consent form and then gave an assurance that their profile data would only be used for academic purposes.

All the participants also supplied information about their Educational Level, and it was found that there were 87% undergraduates, and 13% software practitioners (it should be pointed out that these included: an intern in software organization, a graduated without experience in software development, and a post-graduate student with experience in software development). Finally, Fig. 7 provides an overview of the self-declared knowledge of all the 60 participants, broken down into the areas of interest of each of them.

In short, the average amount of self-declared knowledge of all the 60 participants, can be seen in Fig. 8.

5.2. Planning

We divided our study planning into the aspects that characterized the non-experiment (Robson and McCartan, 2016), and the instruments and procedures adopted by our analytical study and data collection (Lazar et al., 2010) which are shown in the next sections.

5.2.1. Non-experiment characteristics

According to Robson and McCartan (2016), a non-experiment can be defined by its *purpose*, *time dimension* (i.e. the data collection over time or at a specific time), and the *explanatory* and *outcome variables* which have a similar purpose to the independent and dependent variables of the controlled experiments. Unlike of the controlled experiments, there is no manipulation or controlling of two or more variables. The explanatory variable can be a single element which is the focus of the researcher investigation. The outcome variables are those that can enable the researcher to observe the results.

Considering our study aspects, we defined our non-experiment *purpose* as the evaluation of the AccessGuide Catalog, hence the guidelines, from the standpoint of the software developers, i.e. the target subjects. In our study, the course participants formed a subset of target sample that represented the novice software developers. We planned the time dimension of our data collection at a single point in time and regarded it as a task to be carried out at the end of the courses of the two groups (i.e. Groups 1 and 2). In our non-experiment, we treated the catalog and the guidelines as a single *explanatory* element. We observed two *outcome variables*: (i) the application of the guidelines and (ii) the acceptance of the guidelines by the participants.

5.2.2. Data collection instruments and methods

We prepared an online consent form which had to be filled in before the study started. This sought permission to use the participants' data collected from the prototypes as well as their feedback. We used three instruments for the data collection which were related to the two *outcome variables* that are described below.

With regard to examining (i) the application of the guidelines, we took account of the low-fidelity prototypes produced by the participants. Low-fidelity prototypes focus on producing high-level visual design artifacts quickly which display the contents

Table 5
Participants profile.

Id	Edu	des	dev	low	SE	pat	Udp	Tap	Uio	Mat	fro	And	iOS
[P1]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	¬	¬	¬
[P2]	✓	¬	¬	tp	tp	¬	¬	¬	¬	¬	¬	¬	¬
[P3]	✓	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬
[P4]	✓	t	¬	¬	t	t	t	¬	¬	t	tp	¬	¬
[P5]	✓	p	p	tp	tp	p	¬	¬	¬	p	tp	¬	¬
[P6]	✓	¬	¬	t	t	¬	¬	¬	¬	¬	¬	¬	¬
[P7]	✓	t	p	¬	tp	¬	¬	¬	¬	¬	p	¬	¬
[P8]	✓	tp	t	tp	tp	t	t	t	t	¬	tp	¬	¬
[P9]	♠	¬	tp	t	tp	t	¬	¬	¬	t	tp	tp	¬
[P10]	⊙	¬	¬	p	t	p	¬	¬	¬	p	p	¬	¬
[P11]	✓	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬
[P12]	✓	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬
[P13]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	tp	¬	¬
[P14]	⊙	p	p	tp	tp	t	t	¬	t	¬	tp	¬	¬
[P15]	✓	t	t	t	t	t	t	¬	¬	t	tp	t	¬
[P16]	⊙	¬	¬	¬	t	¬	¬	¬	¬	¬	¬	¬	¬
[P17]	✓	¬	¬	t	t	¬	¬	¬	¬	¬	p	¬	¬
[P18]	✓	t	p	¬	tp	¬	¬	¬	¬	¬	p	p	¬
[P19]	✓	tp	¬	tp	tp	¬	¬	¬	¬	¬	tp	¬	¬
[P20]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	p	¬	¬
[P21]	✓	t	¬	tp	t	t	t	¬	¬	¬	tp	¬	¬
[P22]	✓	t	t	p	t	t	¬	¬	¬	t	t	¬	¬
[P23]	✓	t	t	¬	t	t	t	¬	¬	¬	t	¬	¬
[P24]	✓	p	p	t	tp	t	t	¬	¬	¬	tp	¬	¬
[P25]	✓	p	p	tp	tp	t	¬	¬	¬	t	tp	¬	¬
[P26]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	¬	¬	¬
[P27]	✓	¬	¬	t	tp	¬	¬	¬	¬	¬	tp	¬	¬
[P28]	✓	tp	¬	tp	tp	¬	¬	¬	¬	¬	tp	¬	¬
[P29]	✓	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬	¬
[P30]	♠	t	t	p	tp	tp	¬	¬	¬	tp	tp	t	¬
[P31]	✓	t	t	tp	tp	¬	¬	¬	¬	¬	tp	¬	¬
[P32]	✓	¬	p	¬	t	p	¬	¬	¬	p	t	t	¬
[P33]	✓	t	tp	t	t	t	t	¬	¬	¬	tp	tp	¬
[P34]	✓	p	tp	t	t	p	t	¬	¬	p	tp	tp	tp
[P35]	✓	p	p	p	tp	tp	t	¬	¬	tp	tp	p	p
[P36]	⊗	¬	t	¬	t	¬	¬	¬	¬	¬	¬	¬	¬
[P37]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	p	¬	¬
[P38]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	tp	¬	¬
[P39]	⊙	p	¬	tp	tp	¬	¬	¬	¬	¬	tp	¬	¬
[P40]	✓	¬	p	¬	tp	¬	¬	¬	¬	¬	t	t	t
[P41]	✓	t	t	t	t	¬	¬	¬	¬	¬	tp	t	¬
[P42]	✓	¬	t	¬	¬	¬	¬	¬	¬	¬	p	p	¬
[P43]	✓	¬	¬	¬	tp	¬	¬	¬	¬	¬	¬	¬	¬
[P44]	✓	¬	t	t	t	¬	¬	¬	¬	¬	t	t	¬
[P45]	✓	t	¬	p	t	p	¬	¬	¬	p	tp	¬	¬
[P46]	✓	¬	¬	t	t	¬	¬	¬	¬	¬	¬	¬	¬
[P47]	✓	t	t	t	tp	t	t	¬	¬	¬	t	tp	¬
[P48]	✓	t	t	tp	t	t	¬	¬	t	¬	tp	t	t
[P49]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	t	¬	¬
[P50]	✓	¬	p	¬	t	¬	¬	¬	¬	¬	¬	p	¬
[P51]	✓	¬	p	¬	t	¬	¬	¬	¬	¬	¬	¬	¬
[P52]	✓	¬	¬	t	t	¬	¬	¬	¬	¬	tp	¬	¬
[P53]	✓	¬	¬	t	tp	¬	¬	¬	¬	¬	¬	¬	¬
[P54]	✓	t	¬	t	tp	t	t	¬	t	t	t	¬	¬
[P55]	⊕	t	p	p	tp	p	¬	¬	¬	p	tp	p	t
[P56]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	¬	¬	¬
[P57]	✓	t	p	¬	tp	tp	¬	¬	¬	tp	¬	¬	¬
[P58]	✓	t	¬	¬	t	p	¬	¬	¬	p	p	¬	¬

(*continued on next page*)

and the interactive features (Sharp et al., 2019). When exploring (ii) the acceptance of the guidelines, we gathered data from (a) focus group sessions and (b) a feedback questionnaire.

The focus group (a) was chosen because it provides ways of encouraging the participants to prepare their feedback collaboratively by means of a dynamic discussion where one person

Table 5 (*continued*).

Id	Edu	des	dev	low	SE	pat	Udp	Tap	Uio	Mat	fro	And	iOS
[P59]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	tp	¬	¬
[P60]	✓	¬	¬	¬	t	¬	¬	¬	¬	¬	t	¬	¬

Education level: undergraduate student (✓); intern in software organization (⊙); graduate with experience in software development (⊕); graduate student and no experience in software development (⊗); graduate student with experience in software development (♠)
Soft eng. & HCI: design (des), app development (dev), software low-fidelity prototyping (low), Software Engineering (SE)
Design pattern: pattern CAT (pat), UI pattern (Udp), pattern tap (Tap), UI pattern io (Uio), Material design (Mat)
Web & mobile programming: Web front-end (fro), native Android (And), native iOS (iOS)
Participants' knowledge: *I have never heard of it* (¬); *I have only theoretical knowledge* (t); *I have only practical knowledge* (p); *I have both theoretical and practical knowledge* (tp); *I have in-depth theoretical and practical knowledge* (ttpp).

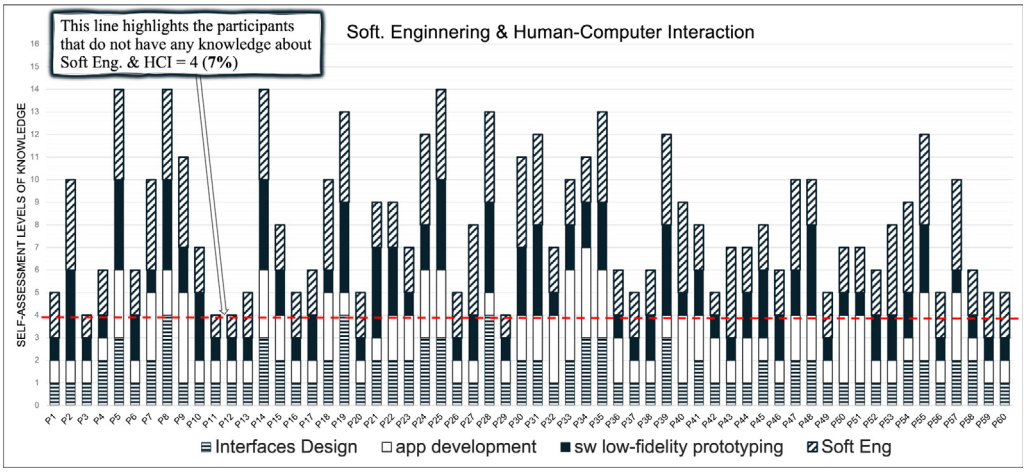

Fig. 4. Knowledge of each one of the 60 participants about Software Engineering and HCI.

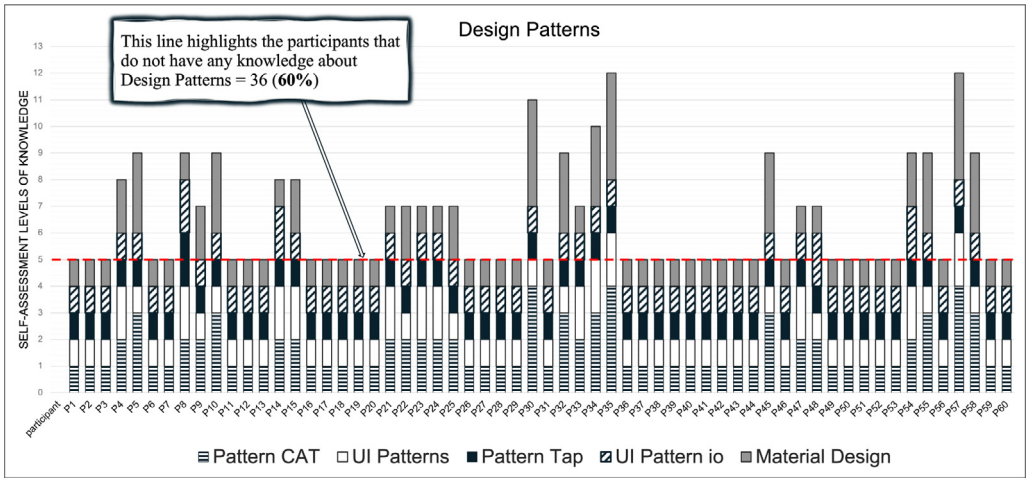

Fig. 5. Knowledge of Design Patterns of each one of the 60 participants.

gives his own ideas in response to the other's comments. Unlike individual interviews, a focus group provides a setting from which the participants can form their ideas either in agreement or disagreement with the views of the other participants. In addition, the focus group participants can stimulate each other to explore issues that might not have arisen in the individual interviews (Lazar et al., 2010). As our study was carried out in a course, the participants were used to sharing their ideas in a group. We prepared four questions to stimulate a discussion about the positive and negative reasons for using the guidelines.

The feedback questionnaire (b) enabled us to collect the individual viewpoints of the participants with regard to the guidelines. We prepared a questionnaire that was based on the Technology Acceptance Model (TAM) (Davis, 1989). TAM provides questions to measure the degree of acceptance of a particular technology by a group of participants. We added two questions to the TAM questionnaire regarding the frequency with which a participant complied with a particular guideline and the usefulness they thought each guideline had in finding a solution to a particular problem.

5.2.3. Data collection procedures

The script of our study was planned in three steps: (i) a training session, (ii) the preparation of the low-fidelity prototyping by the participants and (iii) the collection of the participants' feedback. Our data collection was carried out in step (ii) by gathering the prototypes, and in (iii) collecting the participants' feedback.

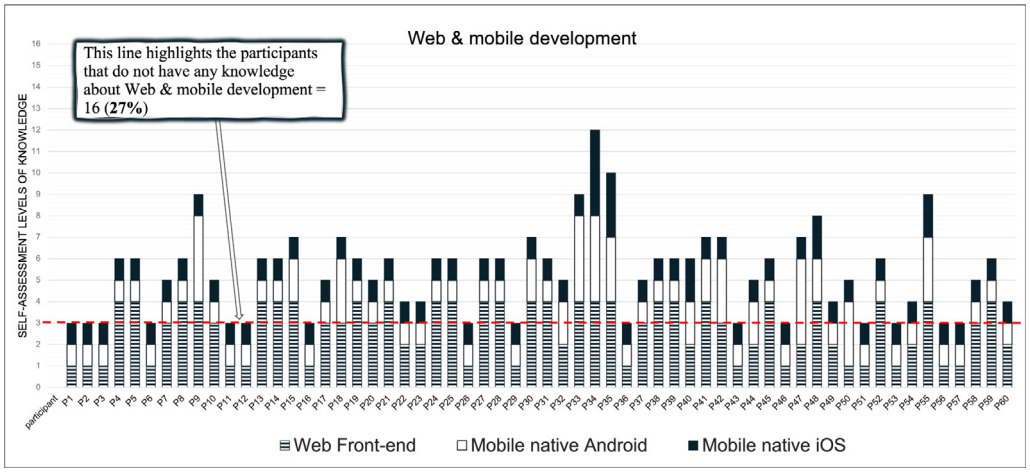

Fig. 6. Knowledge of Web and Mobile Programming of each one of the 60 participants.

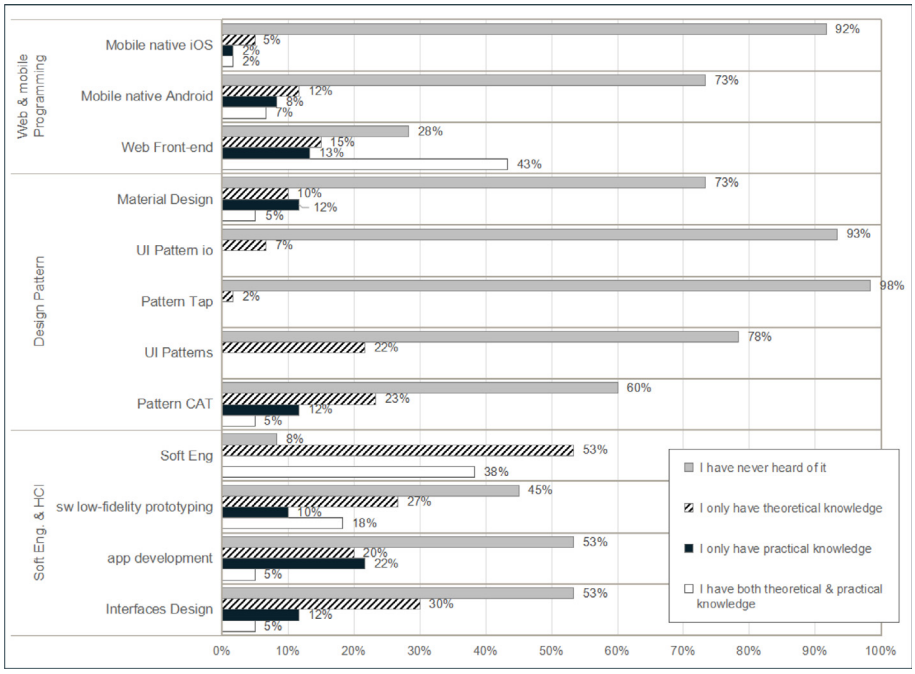

Fig. 7. The self-declared knowledge of the main topics of interest by the participants in our research.

A training session (i) was designed for the participants so that they could become familiar with the AccessGuide Catalog and the application of the guidelines for creative low-fidelity prototyping. In this session, a designed scenario was planned for the participants for finding a solution, i.e. a low-fidelity prototype. During the session, the participants had to clarify any doubts or uncertainties they had. Since the use of the application of the guidelines was the purpose of our study, no in-depth explanation of them was provided to the participants.

To the study execution (ii), we prepared a new scenario to develop the prototype which was different from the one used in the training session. At the end, we applied the questionnaire and conducted focus group sessions to collect feedback from the participants (iii).

5.3. Execution

We conducted two evaluation sessions with the 60 participants involved in the two courses, namely 34 in Group 1 and 26 in Group 2. The two sessions followed the planning that was outlined in Section 5.2 above. The sessions were held in the same location as the course, an informatics lab at the Federal University of São Carlos, Sorocaba, Brazil. Each evaluation session was held in a period of 2 days after the 10-hour course had been completed and lasted 4 h and 30 min in total. All the participants had to complete the consent form and signed an agreement with regard to the data collection, before the evaluation session could be conducted.

To eliminate the bias of understanding the study procedures, we created slides containing all information and procedures for the participants to follow during the study. Besides these slides, the researcher could answer any doubts at any moment. The researcher presented the slides from a multimedia projector while s/he explained the study steps. We also made the slides available in a folder on Google Drive. Therefore, the participants could have access during the study. In this way, all participants followed the same procedures during the study.

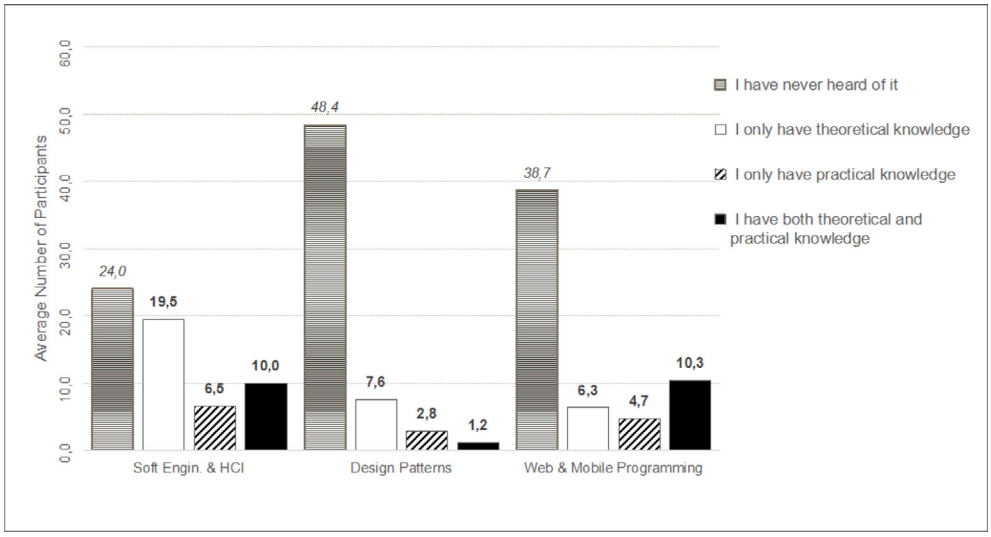

Fig. 8. The average of participants knowledge about three main topics: Software Engineering and HCI, Design Patterns and Mobile Programming.

A training session that lasted 2 h was conducted on the first day. First, the participants explored the Proto.io tool to learn about its features. Next, the online AccessGuide catalog[6] was introduced to the participants so they could briefly examine the elements presented in the catalog (i.e., the UIDP description, the guidelines, the examples in images). After this, a hands-on exercise was carried out, and the participants learned how to apply the guidelines from the catalog. During the training session, the participants were able to clarify any doubts they had about the use of the catalog; however, the researchers could not interfere in the participants' decisions about what and how to design their "solution" (i.e. how to use the UI mobile patterns and their guidelines).

The second day was divided into 2 h to create the prototypes and answer the feedback questionnaire, and another 30 min for the focus group. The prototypes were produced in a scenario where they could follow the same procedures as in the training session. We provided two different scenarios for Group 1 and 2, as shown in Table 6. The participants created their own prototype "solutions" individually by means of the Proto.io tool. They were allowed to design as many user interfaces as they wanted to find their final solutions. We asked the participants to add comments about the prototypes they had designed so that they could give information about the exact guidelines (i.e. id, AG-1, AG-2) they had followed in finding their solutions. We obtained 60 solutions in total (i.e. 34 for Group 1, and 26 for Group 2) from which 168 user interface prototypes were produced by Group 1 and 120 by Group 2. In Group 1, a solution had a minimum of 3 user interface prototypes and a maximum of 7; and in group 2, a minimum of 4 and a maximum of 7. Fig. 9 shows examples of what was produced by the participants. After this, the participants answered the feedback questionnaire individually.

Finally, we conducted six focus group sessions of 30-minute each — three sessions for each study group, i.e. Group 1 and Group 2. All the conversations were recorded in audio for further examination. During the sessions, two researchers asked questions to encourage the participants to engage in the discussion. The questions focused on collecting information about: (a) the difficulties the participants faced on understanding and using the guidelines, (b) the flexibility and agility that guidelines provided to support the creation of prototypes, and (c) any suggestions the participants might have to improve the guidelines.

5.4. Analysis

We conducted a qualitative analysis that involved 60 solutions (i.e. 288 user interface prototypes), as well as the feedback questionnaire and the focus group conversation. Two researchers (i.e. R2 and R4) carried out the data analysis. R2 was a senior researcher with experience in UX and Software Engineering and has taken part in the GL analysis and in drawing up the guidelines. R4 was a post-graduate student with expertise in the area of HCI.

We explored the two *outcomes variables*, i.e. (i) the application of the guidelines and (ii) the acceptance of the guidelines, in two steps as will be discussed in the next sections.

5.4.1. Application of the guidelines

We downloaded the 288 user interface prototypes (i.e. 168 from Group 1 and 120 from Group 2) in HTML and PDF formats. From the HTML version, we were able to browse and interact with the prototypes and examine the navigational design. As the version of Proto.io we were using did not allow us to download the comments found in the prototypes, we also got a images of the screens in "pdf" format. We developed two baseline solutions for each scenario (see Table 6) to strengthen our analysis of the participants' solutions. Taking into account the participants were able to provide different solutions, our baseline worked as a reminder of the essential requirements that should be implemented so that it would not be regarded as a unique solution.

We inspected the prototypes by employing the Defect-based Reading (DBR) technique. DBR is a software inspection technique that focuses on detecting specific classes or types of defects (Porter et al., 1995). We defined a six-point scale classification for the inspection: AC — *Applied Correctly and Cited* when the use and the citation of a guideline were conducted correctly; AP — *Applied Partially Correct and Cited* when not all the guideline was applied; AI — *Applied Incorrectly and Cited* when the guideline was applied in a wrong way; NA-*Not Applied and Not Cited*; and NC — *Applied Correctly and Not Cited*.

The prototype inspection was carried out in two rounds. First, R4 examined the solutions per participant individually. In the case of each UIDP that was used, R4 followed the guidelines and took into account the comments added by the participant regarding their use. The researcher thus assigned the classification by

6 http://uxleris.net/accessguide/.

Table 6
Scenarios used in the study sessions.

Studies	Description of the scenarios
Scenario 1	*Felipe is a student that likes to run different music styles from apps on his mobile phone. He is used to creating playlists to listen to while he is getting ready to go out, catching the bus, going to the gym or even studying. Felipe wants a music app with several features. Some examples of features are music playback, managing playlists, having a list of his favorite songs, setting the features of the app, and being notified about new songs from the app. The app should be flexible enough to allow Felipe to find and set options that satisfy his demands. Now, imagine you are the developer who will design this music app and want to provide a good experience for Felipe as well as preventing the occurrence of accessibility barriers when using the app.*
Scenario 2	*Júlio often used Internet Banking apps for all his banking tasks and thus avoided having to go in-person to the bank. He generally carries out the bank transactions by means of a mobile phone. Júlio wants an Internet banking app with several features. Some examples of features are a visualization of his bank account, checks future transactions, credit card invoices, statements, bank transfer transactions and the method for setting the app. The app should be flexible enough to allow Felipe to find and set options that satisfy his requirements. Now, suppose you are the developer who will design this internet banking app and want to provide a good experience for Júlio as well as preventing the occurrence of accessibility barriers when using the app.*

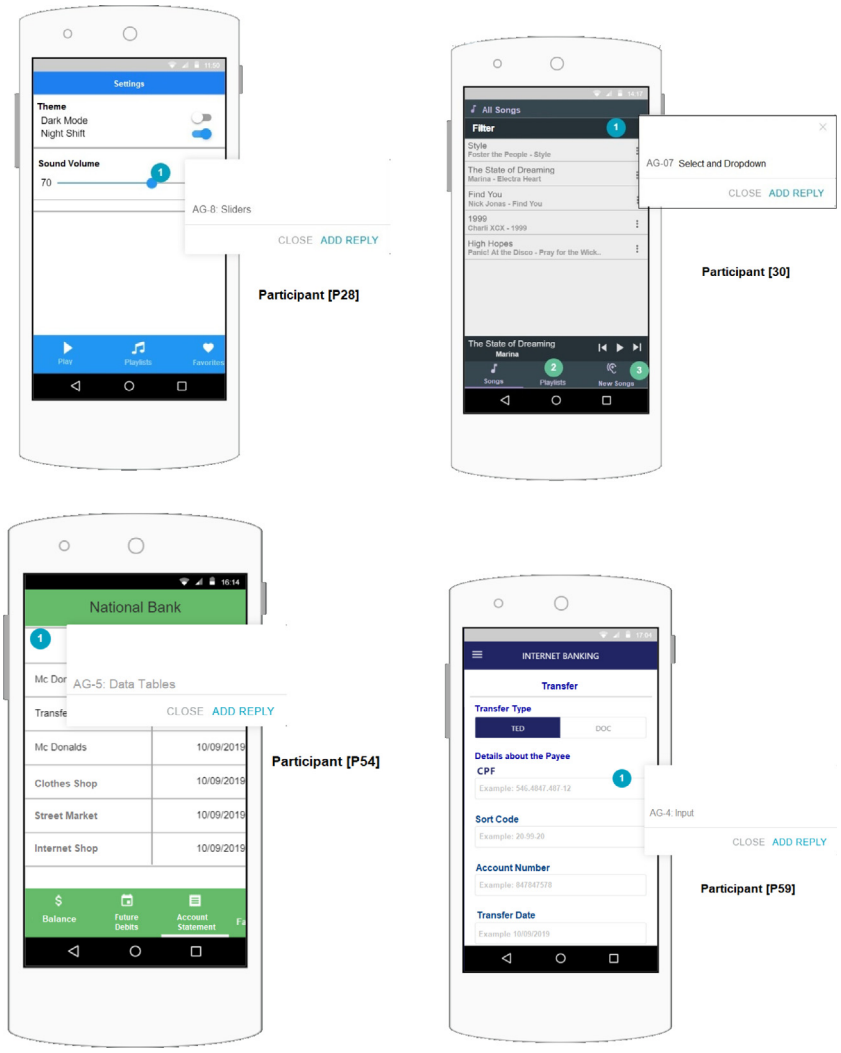

Fig. 9. Prototypes and identification of the guidelines that were set out.

referring to the scale described above (i.e. AC, AP or AI). If there were no comments, but the participant used a UIDP, R4 checked whether the participant had applied the guidelines, and assigned the NA or NC classifications. The whole analysis was recorded on a spreadsheet. After this, R2 proceeded with the second inspection round by double-checking each classification. R2 considered the spreadsheet verifying the classification assigned to each UIDP and reading the comment associated with it. R2 made notes in the spreadsheet line in case of doubts for clarification with R4 afterwards.

5.4.2. Acceptance of the guidelines

The answers to the acceptance questionnaire were compiled in descriptive quantitative data by R2. The questionnaire was based on the TAM model (Davis, 1989). TAM made it possible to analyze the individual's acceptance and attitudes with regard to the use of

the technology. It is divided into two areas, the usefulness of perception technology and its ease-of-use. The usefulness dimension represents to what extent a person believes a specific technology can improve his/her performance. The ease-of-use is related to the perception that technology can be employed with little effort.

The six focus group sessions were divided into three stages and took account of whether the participants' comments about the guidelines were positive or negative. All the audios were listened to at least twice in each stage. In the first stage, R4 analyzed the audios per question for all the groups. After this, the researcher listened to the audios again, session by session. All the relevant comments of the participants were transcribed to text format with their ID. Finally, R2 refined the results of the first and second stages.

5.5. Threats to validity

In the case of the non-experiment, we discussed the perspectives of threats to validity with regard to the categories *validity*, *generalizability*, *objectivity*, and *credibility* based on Robson and McCartan (2016).

Validity refers to the reliability of the data collected about the participants. Factors such as tiredness and motivation could affect the performance of the participants in their evaluation. In light of this, we decided to split the training session and the low-fidelity prototyping activity into two days to mitigate the tiredness factor. During the training sessions, the participants constructed some examples of how to use the UIDPs which kept the participants sufficiently motivated to carry out the experimental activity. By doing different exercises, the participants had the opportunity to request clarification about the UIDP and prototyping activity during the course. The participants were able to obtain expertise in using the prototyping tool (i.e. Proto.io) as well as the guidelines that were set out in a catalog format which contained explanations and examples. Hence, we believed that the sample of artifacts we inspected (i.e. the user interface prototypes) were of good quality.

Generalizability concerns the sample of the participants selected. Our sample consisted of participants with different levels of knowledge of the subject areas related to the evaluation (see Figs. 4 to 8). We discovered hat most participants did not have much knowledge in UIDP, even those who had extensive experience in software engineering and HCI. Salman et al. (2015) provide evidence that there is little difference in the performance of students or novice developers and practitioners when they carry out an activity in which they do not have previous knowledge. The literature shows that developers often have little contact with accessibility principles or guidelines (Vendome et al., 2019; Alshayban et al., 2020). In view of this, the works mentioned above suggest that the findings obtained from our sample, can be extended to more experienced developers who have never complied with accessibility guidelines when using UIDP. However, we are conscious that we need to carry out further studies to accurately mitigate the threat of generalization. In particular, the guidelines evaluation might present different results whether it would be conducted with professionals that have more experience working with UIDP or accessibility issues.

Objectivity refers on the strict principles employed when gathering and analyzing data. In our study, we collected different data (i.e. prototypes, and the feedback of the participants obtained from the questionnaire and focus group) which allowed us to investigate the application and the acceptance of the guidelines. The data were collected electronically and were not influenced by the researchers. All the data analysis followed a rigorous system with two researchers involved in double-checking procedures. Moreover, the analysis of the 288 user interface prototypes, i.e. 60 solutions produced by the participants, was not conducted in an ad-hoc way. We followed a sequence of steps and adopted a six-point scale of classification to determine whether the guidelines had been applied or not.

Finally, *credibility* relates to the rigor of the method employed for reporting the experimental steps and the extent to which the study replicates the work of other researchers. We provided explanations in detail regarding the characteristics of our non-experiment, its preparation (i.e. the instruments used to data collection and the procedures to conduct the study), its execution and the steps of the data analysis. In addition, we used well-known instruments and methods, i.e. TAM and a focus group, to obtain the feedback of the participants.

6. Results of the evaluation

Our results are examined in the next sections and include the two *outcomes variables* of our evaluation. As our analysis was conducted on the basis of categorical data, our results are obtained from descriptive data.

6.1. Application of the guidelines

Table 7 shows the results per participant, i.e. P1–P34 and P35–P60 from Group 1 and Group 2 respectively. Figs. 10 and 11 show the results on the correct, incorrect or non-application (see X axis) of the guidelines (see Y axis) for each participant group.

In the case of Group 1 (see Fig. 10), we found that some of the guidelines had not been correctly applied, since there were problems in the use of the *Inputs*, *Sliders* and *Data table* (i.e. AG-4, AG-5 and AG-8) and their respective guidelines. For instance, the participants only designed the *placeholders* to show the information requested in the *Input* element and did not follow the guidelines which required the inclusion of labels (see *Input* guidelines in Section 4.4). In the case of *Sliders*, we discovered that the Proto.io tool did not supply the participants with resources for their respective guidelines. Additionally, we discovered that the participants needed more examples to obtain a better understanding of the *Slider* guidelines. In contrast, the *Data table* was not adopted because the participants preferred to use other patterns instead, as they stated during their focus group sessions.

Considering the Group 1 findings, we decided to develop more examples of the use of the *Input*, *Slider* and *Data Table* UIDPs including animated GIFs and to make them available in the guidelines. We found that these improvements had a positive effect on the application of the guidelines of these UIDP in Group 2. Looking at Figs. 10 and 11, we see that the correct application of the *Input* guidelines increased in Group 2. In addition, it is clear that in Group 2 there was a decrease in the number of times the *Slider* was used. However, there was an increase in its correct application. In contrast, the *Data table* was applied for more participants in Group 2.

6.2. Acceptance of the guidelines

The acceptance of the guidelines results were discussed from two perspectives, the results of the TAM questionnaire and the focus group sessions.

Figs. 12 and 13 show the responses of TAM for each group. As shown in Section 5.4.2, the TAM questions are separated into two categories, the perception of the usefulness of the technology and the perception of its ease-of-use (see Table 8). In the case of each question, the participants chose the option that best represented their degree of agreement based in a 6-point Likert scale from "Fully Agree" to "Fully Disagree".

Table 7
Application of the guidelines in the prototypes: AC-*Applied Correctly and Cited*; AP-*Applied Partially Correct and Cited*; AI-*Applied Incorrectly and Cited*; na-*Not Applied and Not Cited*; NC-*Applied Correctly and Not Cited*; and NU-*Not Used*.

Id	AG-1	AG-2	AG-3	AG-4	AG-5	AG-6	AG-7	AG-8	AG-9
[P1]	AC	NU	AP	AP	NU	AI	AI	AI	AP
[P2]	NU	AC	AC	AC	NU	na	AC	AP	NU
[P3]	AP	NU	AP	na	NU	AP	AP	AI	NU
[P4]	NU	AP	AC	AI	NU	na	AP	NU	NU
[P5]	AP	NU	NC	na	NU	na	NU	AP	NU
[P6]	NU	AP	AP	AI	NU	na	NU	AI	AI
[P7]	AP	NU	na	NU	NU	na	AP	AI	NU
[P8]	NU	na	NC	AC	NU	na	AP	AP	NU
[P9]	NU	AC	AP	AP	NU	na	AC	AI	AP
[P10]	NU	na	AP	AI	NU	na	AP	AP	NU
[P11]	AP	NU	na	NU	NU	AI	NU	AI	AP
[P12]	NU	AP	AP	AP	NU	AI	AP	AP	NU
[P13]	AC	AP	AP	NU	NU	na	NU	NU	NU
[P14]	AC	NU	AP	AP	NU	AP	NU	AI	AP
[P15]	AC	AP	na	AC	NU	na	NU	AP	NU
[P16]	NU	AC	AP	AI	NU	na	NU	AI	NU
[P17]	NU	AP	AP	AC	NU	AI	NU	NU	AI
[P18]	NU	AP	AI	AI	NU	AI	AP	AP	NU
[P19]	NU	AC	AP	AC	NU	na	AC	AP	AC
[P20]	NU	AC	AP	AP	NU	na	NC	AI	AP
[P21]	NU	AC	AC	NU	NU	NU	NU	NU	AP
[P22]	NU	AP	na	na	NU	NU	AC	na	NU
[P23]	NU	AP	AC	AI	NU	na	NU	NU	NU
[P24]	NU	AP	AC	AI	NU	AP	NU	NC	NU
[P25]	AP	NU	na	na	NU	na	NU	AP	AP
[P26]	AI	na	AP	AI	NU	na	NU	NU	NU
[P27]	AC	NU	na	AP	NU	na	NU	AP	NU
[P28]	NU	AC	AP	AC	NU	AC	NU	AP	AC
[P29]	NU	AP	AC	na	NU	AI	NU	NU	AP
[P30]	NU	AC	AP	NU	NU	na	AC	NC	NU
[P31]	AP	NU	AC	AC	NU	na	NU	NU	NU
[P32]	NU	AP	AP	AI	NU	NU	NU	AI	AI
[P33]	NU	AP	AC	AI	NU	na	AP	AI	NU
[P34]	AI	AP	AP	na	NU	na	NU	AP	NU
[P35]	AC	NU	AC	AC	AP	AC	AP	AI	NU
[P36]	NU	na	na	NU	AP	NU	NU	NU	AP
[P37]	NU	AP	AC	AC	NU	na	AC	NU	NU
[P38]	AP	AC	AC	NU	NU	NU	NU	NU	AP
[P39]	NU	AP	NC	AP	NU	na	NU	NU	AI
[P40]	NU	NU	AI	AC	NU	na	NU	NU	NU
[P41]	NU	na	NC	na	NU	na	NU	NU	NC
[P42]	AP	NU	NU	AP	AI	na	NC	NU	NU
[P43]	NU	AC	AC	NC	NU	na	NC	AP	NU
[P44]	NU	NU	AC	NU	NU	NU	AP	AP	AP
[P45]	AP	na	AP	AI	NU	NU	AP	NU	AP
[P46]	NU	AC	NU	NU	NU	AI	AP	AI	AI
[P47]	NU	AP	NC	AC	AP	NU	NU	AC	NU
[P48]	NU	NU	AP	NU	NU	na	NC	NU	AP
[P49]	AP	NU	AP	NC	NU	AI	NU	NU	NU
[P50]	AC	na	AP	AP	NU	NU	NU	AP	NU
[P51]	NU	na	AC	AC	NU	AI	NU	AP	NU
[P52]	NU	AC	AP	AP	NU	na	AP	NU	NU
[P53]	NU	AP	AP	AC	NU	AP	NU	NU	NU
[P54]	NU	AC	AC	AP	AP	na	AP	NU	NU
[P55]	NU	AC	na	AI	NU	AC	NU	AP	AP
[P56]	NU	AC	AC	AP	NU	AI	NU	NU	NU
[P57]	AC	NU	AP	AP	AP	AI	NU	NU	NU
[P58]	AC	NU	AI	NC	NU	AP	AP	NU	NU
[P59]	AC	NU	AC	AC	NU	AP	AP	AP	NU
[P60]	NU	AP	AC	AC	NU	AI	NU	NU	NU

Guidelines: AG-1:*Hamburger menu*; AG-2:*Tab Navigation*; AG-3:*Icons*; AG-4:*Input*; AG-5: *Data Tables*; AG-6:*List and Pagination*; AG-7: *Select and Dropdown*; AG-8:*Sliders*; e AG-9: *Carousel*.

The results revealed that there was a high level of agreement between the usefulness and ease-of-use categories with only two "disagree" answers in Group 1 and three in Group 2. These results demonstrated that the guidelines had a positive acceptance on the part of the participants.

As well as looking at the TAM answers, we examined the participants' responses from a clustering perspective. We calculated the degree of agreement for a question (DAQ — see Eq. (3)) on the basis of the conceptions of Relative Strength Index (Wilder, 1978). In the equation, there is a balance between the frequency of agreement responses (i.e. *Agr*) and disagreement responses (i.e. *Dis*). These elements are formed by adding up the frequency of the different agreement and disagreement degrees (see Eqs. (1) and (2)). The final DAQ value is 100 if the *Dis* is zero.

$$Agr = FullyAgree + LargelyAgree + PartiallyAgree \quad (1)$$

$$Dis = FullyDisagree + LargelyDisagree + PartiallyDisagree \quad (2)$$

$$DAQ = 100 - \left(\frac{100}{\frac{Agr}{Dis} + 1}\right) \quad (3)$$

In addition to the DAQ, we calculated the factor of agreement degree (FAD). This factor is obtained from the arithmetic mean of the DAQ values. Each TAM dimension was regarded as a factor

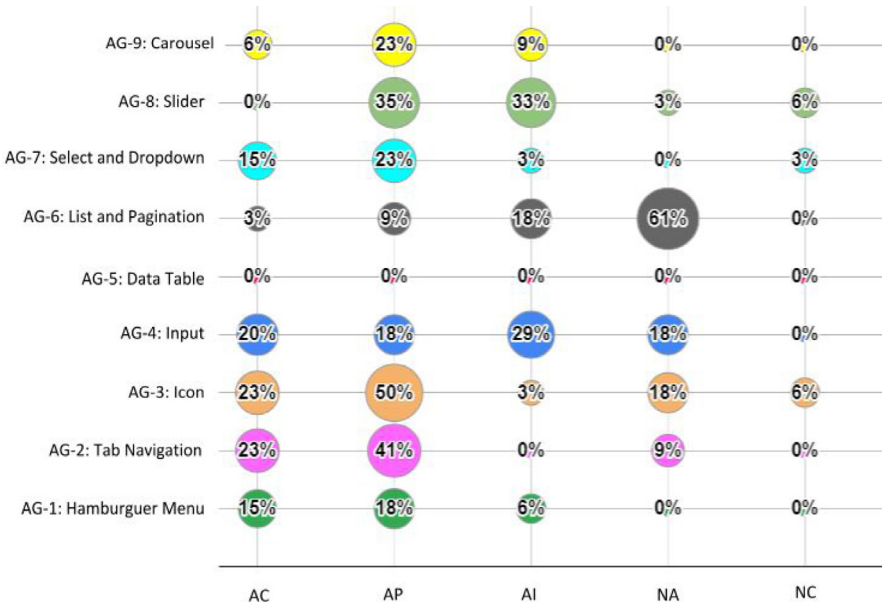

Fig. 10. Application of guidelines in the prototypes of Group 1 — AC:*Applied Correctly and Cited*; AP:*Applied Partially Correct and Cited*; AI:*Applied Incorrectly and Cited*; NA:*Not Applied and Not Cited*; NC:*Applied Correctly and Not Cited*.

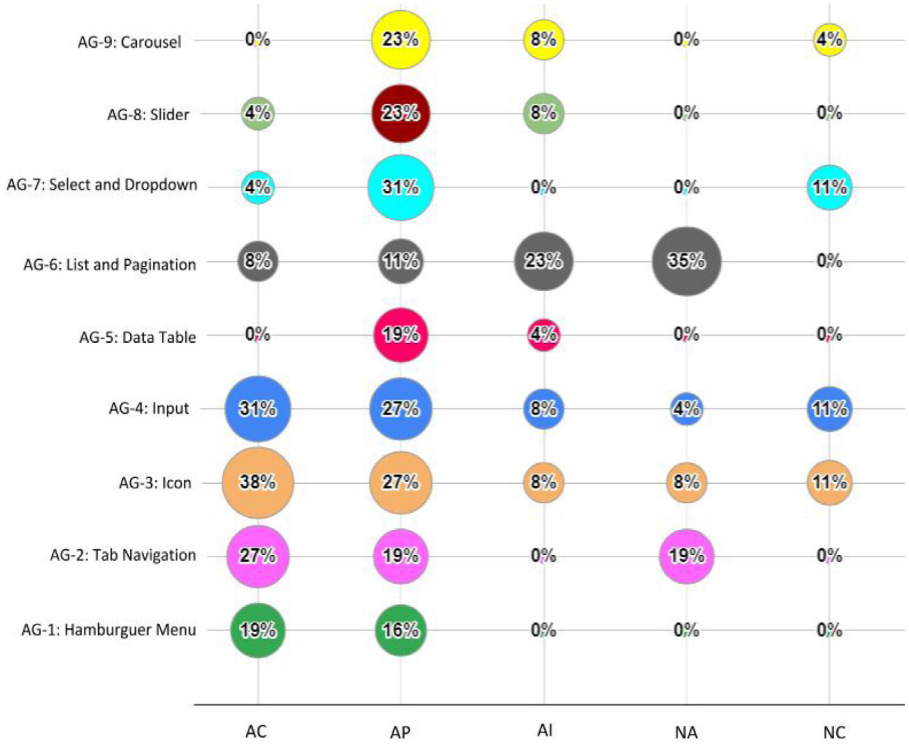

Fig. 11. Application of guidelines in the prototypes of Group 2 — AC:*Applied Correctly and Cited*; AP:*Applied Partially Correct and Cited*; AI:*Applied Incorrectly and Cited*; NA:*Not Applied and Not Cited*; NC:*Applied Correctly and Not Cited*.

(FAD). Therefore, the FAD of usefulness for the guidelines is the arithmetic mean of the DAQ of questions U1–U6 (see Table 9). On the other hand, the FAD of the ease-of-use is the arithmetic mean of the DAQ of questions F1–F7. Table 10 supports the interpretation of the results.

Even though we obtained positive results from the TAM responses, we examined the focus group sessions to supplement our findings. On the basis of these findings, it was possible to explain the disagreements found in the TAM responses (see Figs. 12 and 13). The results from the focus group sessions enabled us to understand the difficulties the participants faced when using the guidelines. The results were shown in the order of the four questions (Q) applied during the focus group sessions.

First, the participants discussed *Q1 — "What difficulties did you have in understanding the use of the guidelines? Were there any guidelines you could not apply in the way you wanted?"*. [P6], [P13], and [P14] reported no difficulties in applying and understanding the guidelines except for those that did not fit in with the scenario. On the other hand, [P11] had doubts about the number of items that should be used in the *Hamburger Menu*. The

Table 8
TAM-based questions.

Dimension		Question
Usefulness	U1	By using the guidelines, I was able to design the solution more quickly.
	U2	By using the guidelines, I was able to enhance my ability to design the solution.
	U3	By using the guidelines, I was able to increase my efficiency during the design of the solution.
	U4	By using the guidelines, I was able to more effectively design the solution.
	U5	By using the guidelines I was able to improve my perception of good practices for designing the solution.
	U6	I consider the guidelines are useful to prevent the occurrence of accessibility barriers.
Ease-of-use	F1	It was easy to learn to use the guidelines.
	F2	I was able to use the guidelines in the way I intended to.
	F3	The guidelines for the use of the guidelines were easy to understand.
	F4	I understand what happened during my interaction with the guidelines.
	F5	It was easy to learn how to use the guidelines.
	F6	The guidelines made it possible to design the prototypes in a flexible way.
	F7	It is easy for me to remember how to use the guidelines.

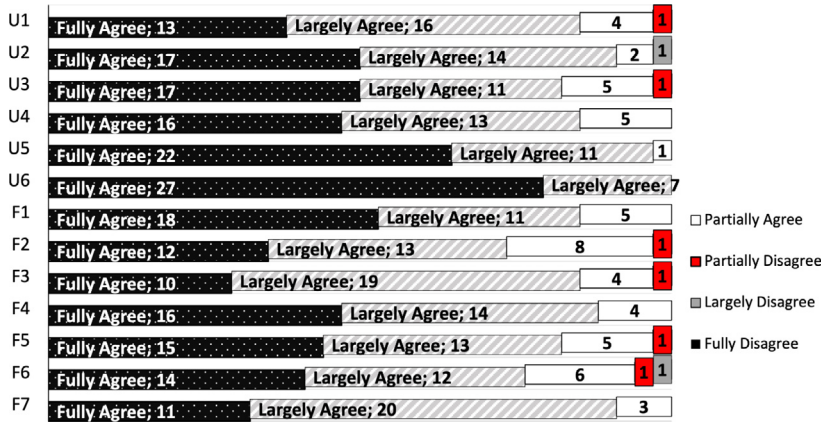

Fig. 12. Results of the Acceptance questionnaire — Group 1.

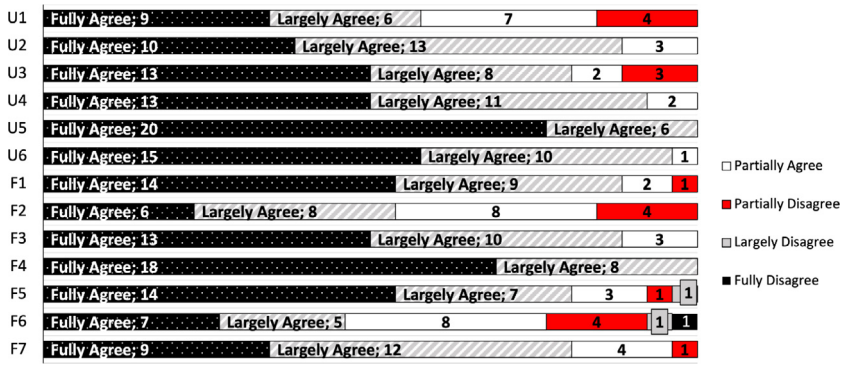

Fig. 13. Results of the Acceptance questionnaire — Group 2.

participant stated that the vast majority of applications available in the market, use many of the items in the menu; however, the guidelines suggest the opposite. The other participant, [P11], argued that usually menus have many items because the applications do not apply accessibility guidelines. [P20] argued that there were difficulties in handling *Tab Navigation* if it had five options or less. [P14], [P25], [P28], [P36], [P42], and [P45] stated that they had to struggle when using some of the guidelines because of the limitations in the Proto.io resources. [P22] highlighted the importance of having examples to help understand how to use the guidelines.

The participants also discussed *Q2 — "The guidelines were nimble and flexible enough to improve my abilities and an efficient way to create the solution. Is this statement true?"*. There was a general agreement about the need to obtain more expertise to create the solution; however, they pointed out some problems regarding the flexibility of the guidelines. The issues about guidelines flexibility matched with the disagreements about the TAM question F6 (see Figs. 12 and 13). [P7], [P22], [P47], [P56], and [P60] stated that the question of nimbleness came just after they read the guidelines more than once and hence obtained an understanding of the issues linked to the guidelines. These comments explained the disagreements in U1, U3, F1, F5 and F7 (see Table 8). [P2], [P8], [P31], and [P41] agreed with the statement and emphasised that there was an improvement in their skills when finding solutions to overcome accessibility issues.

With regard to *Q3 — "Did you use any pattern without following its guidelines? Please explain this decision?"*, the participants stated that there were two type of problems. First, in some cases they could not completely understand how to apply the guidelines. For instance, [P8] thought the *Slider*'s guidelines were not clear when attempting to show the current value. Others pointed out they did

Table 9
Clustering perspective of the acceptance feedback.

Question	FA	LA	PA	PD	LD	FD	Agr	Dis	DAQ	FAD
U1	22	22	11	5	0	0	55	5	91.67	
U2	27	27	5	0	1	0	59	1	98.33	
U3	30	19	7	4	0	0	56	4	93.33	97.22
U4	29	24	7	0	0	0	60	0	100.00	
U5	42	17	1	0	0	0	60	0	100.00	
U6	42	17	1	0	0	0	60	0	100.00	
F1	32	20	7	1	0	0	59	1	98.33	
F2	18	21	16	5	0	0	55	5	91.67	
F3	23	29	7	1	0	0	59	1	98.33	
F4	34	22	4	0	0	0	60	0	100.00	95.48
F5	29	20	8	2	1	0	57	3	95.00	
F6	21	17	14	5	2	1	52	8	86.67	
F7	20	32	7	1	0	0	59	1	98.33	

FA:Fully-Agree; LA:Largely-Agree; PA: Partially-Agree; PA:Partially-Disagree; LD:Largely-Disagree; FD:Fully-Disagree; Agr: Frequency of agreement responses; Dis: Frequency of disagreement responses; DAQ: Degree of Agreement for a Question; FAD: Factor of Agreement Degree.

Table 10
Interpretation of the clustering results — adapted from Wilder (1978).

Agreement/disagreement degree value	Meaning
$\geq$ 90	Strong agreement
80 to 89.99	Significant agreement
70 to 79.99	Medium agreement
60 to 69.99	Low agreement
50 to 59.99	Not significant agreement
40 to 49.99	Not significant disagreement
30 to 39.99	Low disagreement
20 to 29.99	Medium disagreement
10 to 19.99	Significant disagreement
$\leq$ 9.99	Strong disagreement

not apply some guidelines because they believed that keeping to the applications available in the market would provide a more natural interaction for the end-users ([P17], [P28], [P34], [P52], and [P55]). These comments reiterated the disagreements found in the TAM question F2 (see Table 8).

Finally, the participants were encouraged to make suggestions about the catalog (i.e. Q4). Most of the suggestions were related to the addition of examples to illustrate what someone should do and not do ([P6], [P9], [P20], [P28], [P49], [P50], [P51], [P59], and [P60]). [P3], [P22], and [P24] suggested action should be taken to encourage the developers to make a greater use of the catalog and think more about accessible design rather than concentrating on designing a "solution" based on their own individual preferences. [P55] highlighted the importance of the AccessGuide Catalog as a means of heightening awareness of accessibility issues among developers and designers.

7. Discussion

Considering our results, we answered the two research questions raised in Introduction (see Section 1). To answer RQ1, we conducted an investigation of 18 different online sources in a search for the issues that developers and designers faced when using UIPD. After a preliminary exploration, we focused on the UIDP web and native Android platform. By adopting the GL approach, we collected 127 documents from the online sources and carried out a qualitative analysis by following two GT steps — open and axial coding. The findings from the qualitative analysis allowed us to map out the accessibility barriers and thus draw up a set of guidelines, and hence we were able to answer RQ2.

RQ1 — *What are the accessibility barriers that developers/designers reported when using mobile UIDPs in practice?*
— The results of the GL review allowed us to list and map a set of accessibility barriers for 9 UIDPs that software developers might face when using UIDP for the development of Android mobile applications. We found the most significant number of accessibility barriers in UIDP were related to navigational issues (e.g. *Hamburger Menu* and *Tab Navigation*). Our findings demonstrated that an accessibility barrier that was included in one UIDP, could affect other UIDPs. *Icon* and *Input* are often used in combination with *List and Pagination*, for instance.

RQ2 — *What are the guidelines that can assist developers in using UIDP by preventing the problem of accessibility barriers?*
—- With regard to accessibility barriers, we compiled a set of guidelines for the UIDPs. To provide a better overview for software developers, we first pointed out the barriers and, subsequently, the guidelines that help to mitigate the problem or eliminate the barriers (see Section 4). In the next step, we created the AccessGuide Catalog,[7] which is a catalog that put together the barriers, guidelines and examples of how to use the guidelines. AccessGuide Catalog shows our findings in a straightforward way and thus software developers can apply them. We conducted an evaluation of the guidelines with 60 participants with experience in the level of novice developers. The results reveal that most of them found the guidelines were characterized by usefulness and ease-of-use. Moreover, the participants reported that the AccessGuide Catalog can assist them in improving their skills when dealing with UIDP for mobile development.

As far we know, there are no other studies that have carried out a study similar to ours and which address accessibility problems raised from a comprehensive investigation of the experiences of practitioners. We explored these matters in-depth by examining different online sources and pointing out where good sources of information could be found about UIDP.

8. Related work

In this section, we present the studies related to ours. We also point our work in relation to the other studies.

As shown by Vendome et al. (2019) and Alshayban et al. (2020), there has not previously been any large-scale research into the implementation of universal design principles and accessibility features in mobile apps. This area only began to be the subject of small-scale research a few years ago. Despite this, our work builds upon prior research into mobile application accessibility, and highlights some of the significant results described in the literature.

Vendome et al. (2019) conducted a qualitative analysis to investigate the accessibility features discussed by developers and determine to what extent they can be implemented in Android apps. On the basis of an analysis of 13,817 Android apps from

[7] http://uxleris.net/accessguide/.

GitHub and 810 discussions about universal design and accessibility from StackOverflow, the authors were able to establish lessons that could guide future work in the area of mobile development and accessibility features: (a) developers are able to leverage existing tools to support accessibility; (b) mobile developers lack background knowledge and exposure to accessibility features/tools; (c) there is limited support for automated accessibility testing of various disabilities; (d) there is a lack of support for developers with regard to implementing the automation of accessibility features; (e) accessibility APIs are utilized for more purposes than just accessibility; and (f) mobile app accessibility is not only about screen reading.

Alshayban et al. (2020) examined the results of an empirical study aimed at understanding the accessibility of Android apps from three perspectives: apps, developers, and users. In general, they investigated the prevalence of accessibility issues (the apps), the reasons why developers create apps with accessibility issues (the developers), and how accessibility issues affect user perception (the users). The authors adopted an empirical approach, that followed five stages, and the following important conclusions could be drawn from this study: (a) accessibility issues are widely prevalent in Android apps; (b) individuals with different kinds of disability are affected; (c) accessibility issues can even be found in the Android templates; (d) developers are generally unaware of the accessibility principles; (e) apps do not get worse over time; and (f) tools can operate in different ways. The research contribution made by this study centers on its examination of a wide range of accessibility issues (for example, text contrast, touch target size, and speakable text) across 33 different application categories and a discussion of current practices and challenges arising from accessibility (for example, the fact that developers are generally unaware of accessibility principles).

Another empirical study, carried out by Di Gregorio et al. (2020), investigates how the existing accessibility guidelines are implemented in mobile applications. The authors combined three set of content requirements guidelines to create a comprehensive set of accessibility guidelines, i.e. Android developer's documentation, World Wide Web Consortium (W3C) community and BBC Standards and Guidelines academy. The authors outlined a detailed strategy for: (i) inspecting 50 Android apps to check whether these apps implement or not of the set of accessibility guidelines; (ii) surveying the developer's opinions on the adoption of accessibility guidelines in their practice.

Ballantyne et al. (2018) carried out a study to determine the current state of accessibility in the mobile app industry. They compiled a list of guidelines to evaluate mobile app accessibility and made an assessment of the most popular 25 apps from Google Play Store. In general, with regard to their compliance with the accessibility guidelines, the results showed low rates of violations at the system level, and a high rate of violations at the design and content levels. The main violations related to the guidelines were as follows: (a) live videos with captions; (b) on-page control for changing text sizes; (c) videos with either text transcripts or audio description; (d) audio files with text transcript; (e) live audio with text transcript; either real-time closed captioning or a prepared script that is linked to the audio content; (f) the text can be resized without assistive technology up to 200% in a way that does not require the user to scroll horizontally when reading a line of text on a full-screen window; (g) users are offered a range of display options. Users can select colors from both the foreground and background; (h) videos have extended audio description that gives the narrator adequate time to describe what is happening in the video; and (i) videos have a full text transcript and audio description that is linked to the original content. Finally, the authors found that while many applications complied with most of the guidelines, the violations prevented a basic task from being completed and made the application inaccessible.

In a short term view, a number of points were made in the state-of-the-art that contrasted with those in our own scheme. First of all, Vendome et al. (2019) recommended that a set of lessons could be learned about mobile development and accessibility features, while in our study a catalog of guidelines is compiled which can assist in the practice of accessibility implementation in future mobile development projects. Alshayban et al. (2020) carried out a large-scale empirical study about accessibility issues in Android Apps. In our study, we carried out a similar investigation about the implementation of accessibility in mobile apps using gray literature review, focusing on the experiences of the developers. Then, we drew up a set of guidelines with the aim of providing designers and developers with a practical strategy.

The strategy drawn up by Di Gregorio et al. (2020) inspired our work, and they focused on two research questions: *(i)* How are the current accessibility guidelines implemented in mobile applications? and *(ii)* What are the developer' opinions about implementing accessibility guidelines in mobile applications?. On the other hand, we conducted a gray literature review and a follow-up evaluation of the usefulness of these guidelines while Di Gregorio et al. did not mention they had the goal of assessing the usefulness of the guidelines.

Ballantyne et al. (2018) evaluated mobile applications in terms of the guidelines laid down in the literature. Unlike these authors, we compiled and evaluated a catalog which contains (a) a description of 9 user interface design patterns, (b) the related accessibility barriers, and (c) a set of guidelines designed to prevent these barriers from occurring.

Finally, during our study of related work, we read four works in detail. Two of them discussed guidelines and lessons learned about the implementation of universal design principles and accessibility features in mobile apps (Vendome et al., 2019; Alshayban et al., 2020) but they were not focused on UIDP. The third work revealed the current status of accessibility in the mobile app industry, and recommended a set of guidelines to evaluate mobile app accessibility (Ballantyne et al., 2018). Despite these studies, we became aware that additional research is needed, including a number of related features (for example, an extensive evaluation of mobile apps).

In our opinion, our current results make a significant contribution to the growing amount of research in the HCI and SE areas for the following reasons: (i) we detected accessibility barriers related to mobile apps, and have drawn up a set of nine guidelines (AGs) that can assist developers in preventing their occurrence and (ii) we determined alternative ways of improving the design and development phases of the software process with regard to accessibility.

9. Conclusions

In this work, a set of guidelines has been drawn up with the aim of mitigating or eliminating accessibility barriers that can occur during the use of UIDP when designing mobile applications. First of all, we explored the Internet for international and national forums, blogs, and general discussions regarding accessibility and UIDP in the area of mobile development. We gathered a considerable amount of qualitative data which was analyzed through the lens of the grounded theory. As a result, we found out the accessibility barriers and mapped the guidelines. These guidelines were evaluated by 60 participants who provided us with positive feedback about their use.

Our study seeks to make two key contributions. First, we carried out a wide-ranging study of Internet communities following

Table A.11
Sources obtained from survey and the respective EC (exclusion criteria) applied.

Number of times	Link to the source	Application of EC
1	https://www.uxpin.com/	Accepted
1	https://uxplanet.org/basic-patterns-for-mobile-navigation-d12a87686efe	Accepted
2	https://nshipster.com/	EC2
1	http://www.grihotools.udl.cat/mpiua/recursos/recursos-patterns/	Accepted
1	http://mobileapps.umich.edu/design	EC3
1	http://uxmovement.com/buttons/9-guidelines-for-clear-and-intuitive-icons/	Accepted
1	https://visualhierarchy.co/blog/how-to-design-for-different-age-groups/	Accepted
2	https://blog.crazyegg.com/2015/04/24/web-usability-tips/	EC2
1	http://usabilitygeek.com/official-usability-user-experience-user-interface-guidelines-from-companies/	Accepted
1	https://www.nngroup.com/search/?q=mobile	Accepted
1	http://www.torresburriel.com/weblog/?s=mobile	Accepted
2	https://www.measuringu.com/blog.php	EC2
1	Smashingmagazine.com	Accepted
3	https://developer.apple.com/ios/human-interface-guidelines/	EC2
1	http://www.creativebloq.com/	Accepted
2	http://ui-patterns.com/patterns	EC2
2	http://www.disenomovil.mobi/	EC3
2	http://www.nosolousabilidad.com/	EC2
1	stackexchange.com	Accepted
2	https://developer.android.com/guide/practices/ui_guidelines/index.html	EC1
2	https://guides.codepath.com/android/Android-Design-Guidelines	EC1
2	https://developer.android.com/design/patterns/index.html	EC1
2	http://ui-patterns.com/	EC1
2	https://dribbble.com/	EC1
4	developer.android.com, developer.android.com/design	EC1
2	https://www.uplabs.com/	EC2
1	http://arquiteturadeinformacao.com	Accepted
4	http://materialdesignblog.com	EC1
4	http://pttrns.com/patterns	EC1
2	http://inspired-ui.com/	EC2
2	https://developer.android.com/guide/topics/ui/index.html	EC1
2	iOS Human Interface Guidelines — Apple Developer	EC2
2	http://www.mobile-patterns.com/	EC1
1	https://getmdl.io/	EC1
2	https://www.youtube.com/watch?v=7OSkB4BCx00	EC1
1	Reddit	Accepted
1	Medium	Accepted
1	bradfrost.com	Accepted
4	androiduipatterns.com	Accepted
1	lmjabreu.com	Accepted
1	mobile-ui-design.ionicthemes.com	Accepted

systematic guidelines. Our investigation of the 18 different online sources was strictly confined to studies in the gray literature that can be replicated by others. The results of this investigation provided data for the key feature of our study: the set of accessibility barriers related to UIDP and their respective guidelines for mitigating the effects of the barriers. In view of the fact that our results can be used by software developers in their daily activities, we compiled a catalog which contains a definition of UIDP, as well as descriptions of the barriers and guidelines supplemented by practical examples. While the results from the investigation on online sources provided significant academic findings, the catalog displayed the guidelines in a more suitable format so that they could be used by software developers. In addition, the guidelines were carefully evaluated from different perspectives and conformed to a thorough protocol which is described in detail and hence can be replicated in other studies. Additionally, we believe that our methodology is of great benefit as long as a systematic and original approach is adopted.

In future work, we intend to conduct a case study in industrial settings to collect feedback from software teams that is using our catalog. We also consider conducting an in-depth study to verify how the different accessibility definitions have applied to the conduction of user research and the proposal of mobile UIDP guidelines.

CRediT authorship contribution statement

Luciana A.M. Zaina: Conceptualization, Methodology, Writing – original draft, Supervision, Funding acquisition, Writing – review & editing. **Renata P.M. Fortes:** Methodology, Supervision, Writing – review & editing, Funding acquisition. **Vitor Casadei:** Formal analysis, Methodology, Investigation, Data curation, Writing – original draft. **Leornardo Seiji Nozaki:** Formal analysis, Investigation, Data curation. **Débora Maria Barroso Paiva:** Methodology, Writing – original draft, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

See Table A.11.

Appendix B

See Table B.12.

Table B.12
List of GL.

Id	Title	Available at
GL1	Pagination, Accessibility and UI.	https://goo.gl/ad8uYF
GL2	"It's Alive!"- Apps That Feed Back Accessibly.	https://goo.gl/J8FvJi
GL3	108 million web users are color blind. Tips for designing keeping them in mind.	https://goo.gl/xHbDkw
GL4	11 reasons why placeholders are problematic.	https://goo.gl/fpzFtY
GL5	5 Simple Guidelines To Improve Your Websiteś Accessibility.	https://goo.gl/9LeRgW
GL6	6 Principles Of Visual Accessibility Design.	https://goo.gl/BNVRM4
GL7	6 Surprising Bad Practices That Hurt Dyslexic Users.	https://goo.gl/x96BLa
GL8	7 Things Every Designer Needs to Know about Accessibility.	https://goo.gl/xvGRPZ
GL9	8 Website Accessibility Best Practices to Improve UX	https://goo.gl/wxzzW3
GL10	A color wheel for the color-blind.	https://goo.gl/Q2xHRZ
GL11	A Definitive Guide To The Android Carousel Design Pattern.	https://goo.gl/7AwQAG
GL12	A designer's guide to color and accessibility.	https://goo.gl/AqCjzz
GL13	A Study of Trends in Mobile Design.	https://goo.gl/YbJdA5
GL14	Accessibility — beyond the screen reader.	https://goo.gl/MG2Nqn
GL15	Accessibility APIs — A Key To Web Accessibility.	https://goo.gl/eGAxrS
GL16	Accessibility for mobile.	https://goo.gl/XRJdC9
GL17	Accessibility for mobile apps. Just go for it.	https://goo.gl/cgKSd9
GL18	Accessibility — Improving The UX For Color-Blind Users.	https://goo.gl/qDyd5m
GL19	Accessibility Is Not Enough.	https://goo.gl/Jeiuwx
GL20	Accessible and Responsive Tables.	https://goo.gl/VZ3Weq
GL21	Accessible data tables.	https://goo.gl/2ew5sG
GL22	Accessible Interface Design.	https://goo.gl/XmNYF3
GL23	Acessibilidade — experiências acessíveis em vários dispositivos.	https://goo.gl/z8JdbK
GL24	Acessibilidade — muito além do design.	https://goo.gl/56gnFi
GL25	Acessibilidade — o impacto das cores.	https://goo.gl/x4JtvT
GL26	Algumas dicas de Acessibilidade.	https://goo.gl/sFsKnD
GL27	Always use a label.	https://goo.gl/2fejoW
GL28	Basic Patterns for Mobile Navigation.	https://goo.gl/DGozio
GL29	Basic Patterns for Mobile Navigation.	https://goo.gl/KpPBmz
GL30	Basic Patterns for Mobile Navigation 2.	https://goo.gl/yQmsFV
GL31	Basic Patterns for Mobile Navigation — A Primer.	https://goo.gl/qZmsCh
GL32	Best table pagination pattern for a mobile browser experience.	https://goo.gl/HS3Lbo
GL33	Building accessible flash messages.	https://goo.gl/ceZteP
GL34	Cards for layout in mobile apps.	https://goo.gl/C18b4h
GL35	Considerations for mobile accessibility.	https://goo.gl/wLEFft
GL36	Danger! Testing Accessibility with real people.	https://goo.gl/Lmev72
GL37	Design Patterns — UX.	https://goo.gl/ggX5W7
GL38	Designers, let's talk about accessibility.	https://goo.gl/FVHKxm
GL39	Designing A Dementia-Friendly Website.	https://goo.gl/a4bhqZ
GL40	Designing Accessible Mobile User Experiences.	https://goo.gl/4TXzy6
GL41	Designing for Accessibility — The Ultimate in UX.	https://goo.gl/HdCS7G
GL42	Designing for Everyone.	https://goo.gl/czSqnd
GL43	Designing For The Elderly — Ways Older People Use Digital Technology Differently.	https://goo.gl/b1WLpv
GL44	Designing inclusively.	https://goo.gl/jLRWRm
GL45	Designing Perfect Text Field — Clarity, Accessibility and User Effort.	https://goo.gl/pVk3dx
GL46	Developing for Android vs. iOS — Navigation Patterns.	https://goo.gl/sgBNsd
GL47	Disabilities first design.	https://goo.gl/XzkQaV
GL48	Diseñando productos digitales accesibles para móvil.	https://goo.gl/z1DNxj
GL49	Do mobile devices/computer tablets have a future in video games in a way that offers immersion and accessibility.	https://goo.gl/UAo5ET
GL50	Ensure High Contrast for Text Over Images.	https://goo.gl/Qju2x5
GL51	Everything About Color Contrast And Why You Should Rethink It.	https://goo.gl/1uEDk7
GL52	Float Label Pattern.	https://goo.gl/Ta4z7B
GL53	Hamburger menu alternatives for mobile navigation.	https://goo.gl/qE3dbM
GL54	Hamburger menus and Hidden Navigation Hurt UX Metrics.	https://goo.gl/zNAJya
GL55	How accessible are dropdown lists on mobile devices.	https://goo.gl/J9t3Gw
GL56	How can graphic design be more accessible for people with disabilities.	https://goo.gl/c5hhk5
GL57	How To Design Error States For Mobile Apps.	https://goo.gl/UyrFEv
GL58	How to Design for Color Blindness.	https://goo.gl/W2gSBQ
GL59	How To Design For Different Age Groups.	https://goo.gl/3RdTtg
GL60	How to Design for Dyslexia.	https://goo.gl/FQTkE7
GL61	How to make a menu discoverable with the right icon on e-commerce mobile.	https://goo.gl/FY2zpN
GL62	How to Make Navigation (Even a Hamburger) Discoverable on Mobile.	https://goo.gl/pYTqeZ
GL63	How To Plan for Visually Disabled Users on Computers and Mobile Devices — Color Blindness, Low Vision, and Blindness.	https://goo.gl/9Xoxk4
GL64	In Plain Sight — Text, Contrast, and Accessibility.	https://goo.gl/FdxEcy
GL65	Infinite Scrolling — Let's Get To The Bottom Of This.	https://goo.gl/kPd5AG
GL66	Infinite Scrolling, Pagination Or "Load More" ButtonsUsability Findings In eCommerce.	https://goo.gl/Gxg9yu
GL67	Is top navigation an accepted pattern for mobile devices.	https://goo.gl/1P6nnE
GL68	It sounds stupid but how important are design patterns.	https://goo.gl/zTTJpZ
GL69	La accesibilidad en entornos digitales.	https://goo.gl/j9BRj9
GL70	Las personas con discapacidad y el acceso a la Web.	https://goo.gl/TfnhL6
GL71	Lessons from building mobile-friendly, accessible data tables.	https://goo.gl/W5eXoD
GL72	List Thumbnails on Mobile — When to Use Them and Where to Place Them.	https://goo.gl/e1gskw
GL73	Looking for a Mobile device for an uncle with epilepsy.	https://goo.gl/bxkLjD
GL74	Low-Contrast Text Is Not the Answer.	https://goo.gl/ZN5pv7
GL75	Misused mobile UX patterns.	https://goo.gl/YLfH5o

(*continued on next page*)

Table B.12 (*continued*).

Id	Title	Available at
GL76	Mobile And Accessibility — Why You Should Care And What You Can Do About It.	https://goo.gl/Nx5GbR
GL77	Mobile Design Pattern — Inventory-Based Discrete Slider.	https://goo.gl/91SpCG
GL78	Mobile First Is NOT Mobile Only.	https://goo.gl/jZWMs6
GL79	mobile input feedback design pattern.	https://goo.gl/cQEngf
GL80	Mobile Navigation For Smashing Magazine — A Case Study.	https://goo.gl/h7HrmA
GL81	Mobile Navigation — Image Grids or Text Lists.	https://goo.gl/66gq8V
GL82	Mobile Phones and the Importance of Accessibility.	https://goo.gl/6PGGvt
GL83	Mobile platform design guidelines vs consistency in user experience across platforms.	https://goo.gl/THnYdA
GL84	Mobile UI Design Patterns — Sign In.	https://goo.gl/Bse534
GL85	Navigating the Mobile Application — 5 UX Design Patterns.	https://goo.gl/4X8iBT
GL86	Notes On Client-Rendered Accessibility.	https://goo.gl/DziGiQ
GL87	O impacto do menu hamburger nas métricas do seu produto.	https://goo.gl/SuLWbx
GL88	Opciones de accesibilidad para dispositivos móviles.	https://goo.gl/P5Xuqp
GL89	Placeholders in Form Fields Are Harmful.	https://goo.gl/czso2T
GL90	Prototyping accessibility in web and mobile UI design.	https://goo.gl/fnDbik
GL91	Responsive Navigation Patterns.	https://goo.gl/6mfZWT
GL92	Rethinking Mobile Tutorials — Which Patterns Really Work.	https://goo.gl/nbm4KY
GL93	Screen Readers on Touchscreen Devices.	https://goo.gl/KezSUw
GL94	Seeking design patterns for indicating more content below the fold.	https://goo.gl/FjQEYM
GL95	Smartphone UI Patterns.	https://goo.gl/gh1hyz
GL96	Successful Mobile Applications — Using UI Design Patterns.	https://goo.gl/uJi7n6
GL97	Supporting Mobile Navigation in Spite of a Hamburger menu.	https://goo.gl/sjV4o9
GL98	Taking Pattern Libraries To The Next Level.	https://goo.gl/jhF1oY
GL99	The 4 Types of Creative Website Scrolling Patterns.	https://goo.gl/EKSTsD
GL100	The Beginner's Guide to Accessible Mobile UI Design.	https://goo.gl/psVxXE
GL101	The Burger Menu.	https://goo.gl/SQt9zi
GL102	The cost of accessibility.	https://goo.gl/j6dQYT
GL103	The Golden Rules Of Bottom Navigation Design.	https://goo.gl/VrwJKJ
GL104	The Hamburger menu doesn't work.	https://goo.gl/zjb2ZU
GL105	The Hamburger menu Doesn't Work it's a beautiful, elegant solution that gets it all wrong, and it's time to move on.	https://goo.gl/JaNiVP
GL106	The Most Creative Mobile Navigation Patterns.	https://goo.gl/gc4JQW
GL107	The Most Creative Mobile Navigation Patterns 2.	https://goo.gl/65KbXz
GL108	The Quest For Mobile Accessible Apps.	https://goo.gl/HEB1Vs
GL109	The Thumb Zone — Designing For Mobile Users.	https://goo.gl/uy1TQi
GL110	The Underestimated Power Of Color In Mobile App Design.	https://goo.gl/ADzbdf
GL111	The UX of Password fields.	https://goo.gl/qm6u4A
GL112	UIUX design and accessibility.	https://goo.gl/MBrLRS
GL113	We need to talk about Accessibility on Chatbots.	https://goo.gl/5B1cBo
GL114	Web Layout Best Practices — 12 Timeless UI Patterns Analyzed.	https://goo.gl/MGFVSp
GL115	What features do blind/visually-impaired look for in audio voice memo recorders on mobile.	https://goo.gl/LhNCtt
GL116	What is the best UX pattern for large dropdowns in case of mobile web pages.	https://goo.gl/tBfow6
GL117	What's holding back accessibility in 2016.	https://goo.gl/CxiWME
GL118	What's so wrong about Hamburger menus.	https://goo.gl/aCDK1X
GL119	What's the best navigation UI pattern for nested resources on mobile.	https://goo.gl/gopnbB
GL120	When to Choose the Dark Side in Mobile Design.	https://goo.gl/bkz4r3
GL121	When to ignore 'Mobile-First'.	https://goo.gl/p9xdqB
GL122	Why accessibility impacts UX web design.	https://goo.gl/Ysvrs3
GL123	Why and How to Avoid Hamburger menus.	https://goo.gl/anH76n
GL124	Why mobile design means accessible design.	https://goo.gl/rEHZFX
GL125	Why you should never pair Green and Red on the Web.	https://goo.gl/NbDaNC
GL126	Why Your Links Should Never Say "Click Here".	https://goo.gl/NfeiGy
GL127	Writing for all people — how to use alternative text well.	https://goo.gl/9pfX3

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