Investigating accessibility issues of UI mobile design patterns in online communities: a virtual ethnographic study

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ABSTRACT
With the dissemination of mobile devices and the migration of activities that were once executed only on desktop computers to smartphones and tablets, the concerns related to accessibility in this environments have increased. However, the accessibility impact of mobile interface design patterns in the life of disabled people has not been widely addressed in academic works. At the same time, the community of mobile designers and developers has made significant advances in identifying accessibility issues with design patterns on mobile interfaces, reporting these findings in virtual spaces of discussions as forums, blogs, etc. Aiming at exploring the experiences and knowledge of professionals, this paper presents an ethnography study in 18 virtual communities of mobile design and development with the goal of identifying issues on the accessibility of Android mobile UI design patterns. As a result, we analyzed 127 documents in order to propose recommendations to improve the accessibility of mobile interfaces.

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation: User Interfaces—*Graphical user interfaces (GUI), Interaction styles*

Author Keywords
Mobile UI Design Patterns, Mobile Accessibility, Virtual Ethnography

INTRODUCTION
Accessibility is defined as the quality or characteristic of something that is possible to approach, enter or use; it refers to the design of products were people who experience disabilities are able to access, therefore, accessibility is a requirement for everyone [?]. The interest of studying the accessibility subject has been increased recently, motivating practicals and researchers to the uncovering of issues and new challenges about the theme [?].

The latest report (2011) on world disability by the World Health Organization (WHO) estimates that more than one billion people currently live with a disability. In other words, approximately 15% of the entire world population has a disability [?]. In Brazil the scenario is not different, according to a census of 2010 by the Brazilian Institute of Geography and Statistics (IBGE) 23,9% of the Brazilian population declares to have some kind of visual, auditory, cognitive or motor disability [?].

Furthermore, in the last 50 years the life expectancy in Brazil has increased in 25 years [?]. And as the population ages, it's more likely that the number of people with disabilities will grow as elder users experience a decline in several abilities and thus age is related to the appearance of disabilities [?]. On most cases, people that have visual, cognitive, motor or auditory deficiencies require assistive devices (screen readers or special braille keyboards, for example). However, the use of assistive devices is not sufficient to provide access to any content on mobile devices as it's necessary mobile applications and websites that also delivers accessible content [?].

For the disabled population, mobile devices are also an important ally as they concentrate several functionalities in a single device (phone, internet browser, camera and media player). Many of these features can be used to improve the access to information of these users [?], for instance, to recognize money bills by visual impairment users, or to video face call to use sign language by hearing impaired users. Although the design of user interface is essential for promoting the accessibility to any content, in some cases problems with the interface may lead to accessibility barriers [?], which are conditions that make it difficult for people to achieve a goal when using the web on mobile or desktop devices.

In the sense of dealing with accessibility aspects, the UI design patterns might support the building of mobile user interfaces [?]. UI design pattern is an interface element, that is a widely used concept on Software Development [?]. In specific situations, however, these patterns are not given much importance in terms of user interaction with the pattern and the usability and accessibility aspects that comes along [?].

Searching for guidelines, the World Wide Web Consortium (W3C) provides documentations with several guidelines and

recommendation for making accessible pages (as the WCAG -Web Content Accessibility Guidelines- for content accessibility) that are part of the Web Accessibility Initiative (WAI). Although there are recommendations for building accessible content for the general web, mobile guidelines on accessibility are still being made and the documentation is currently a draft [**?**].

Considering the technological evolution of mobile devices, the online spaces have been recognized as spaces of sharing practical experiences, creating repositories about the theme. The exploration of online spaces, where professionals discuss problems and solutions of different topics, can reveal important practical knowledge which trigger trends and issues to be worked by the academic community [**?**].

This paper presents an investigation on accessibility of UI elements (design patterns) of mobile applications. The study consists of a virtual ethnography [**?**] of 18 information sources that resulted in the analysis of 127 documents from both forum discussions and blog posts and comments in the subject of mobile accessibility. The goal of the study was to identify accessibility issues and recommendations to better understand the problems faced by disabled users when using the UI mobile design patterns. For the analysis of the virtual ethnography results, the qualitative research method Grounded Theory [**?**] was used in order to identify key information that may help to build mobile applications that comply with the needs of disabled users.

The main contributions of this paper are the communication of an study on UI design patterns accessibility with the use of virtual ethnography as means to find evidences of practical problems and solutions on the accessibility of mobile interfaces throughout design patterns. Also, we present recommendations, to some of the interface design patterns, for overcoming accessibility issues that UI design patterns may cause when used.

The next sections of this paper are structured as follows: Section 2 introduce important concepts, while Section 3 present related works to this research and Section 4 explain the planning, execution and analysis performed in the study. Section 5 presents the findings of the study and, finally, Section 6 concludes this paper.

FUNDAMENTALS

This section introduces important concepts of accessibity and UI mobile design patterns and virtual ethnography.

Accessibility and Design Patterns

The Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) [**?**] presents guidelines, strategies and resources related to accessibility in various contexts. However, some guidelines defined by W3C are not applicable or adapted to the mobile world and, as the web become more mobile and ubiquitous, the need for accessibility in any context and device is urgent [**?**].

Alongside the impairments and accessibility barriers that users encounter while using a website, their mood is directly related to the overall experience. The accessibility of a website or app is beneficial for everyone as it improves the usability for every user [**?**] [**?**]. Universal Accessibility or Universal Design is the process of developing a system or product that can be used by any person with any disability (or without disabilities), in any situation or environment [**?**]. In Human Computer Interaction (HCI), it is mainly related to the development of computer systems for any person with any limitation [**?**]. For disabled people, accessibility is essential in order to actually have access to information, while for people with situational accessibility, this concern is mere convenience [**?**].

The concept of Design Pattern was developed with the goal of being components of language that could be used as dialog about organizations and development process. Design Patterns can be understood as best practices or some sort of heuristics of well knows design problems [**?**, **?**].

There are various pattern libraries that can be consulted during the design process of web and mobile interfaces. One that can be highlighted is based on a comparative analysis of different patterns which results in 21 mobile web design patterns [**?**, **?**].

Virtual Ethnography

Ethnography may help in situations where the goal is to understand a community by analyzing it's behavior and social interactions as it is a qualitative research method that can combine techniques of observation, participation, interview and document analysis as tools to aid in this discovery [**?**]. While classical ethnography research focuses on the study of social interactions of communities that take place in physical spaces, virtual ethnography transfers the research site to socials spaces in the Internet [**?**]. With the emergence of new forms of interaction on the Internet as online multiplayer games and social networks as Myspace, Orkut and later Facebook, different settings for ethnographic studies appeared with new challenges of data collection from chat logs and different types of media as pictures, video and audio files. This new reality demands to the development of strategies to interact with the online communities [**?**].

Virtual ethnography shifts the location of observation to online spaces adapting the classical ethnography directions [**?**]. Sharp et al [**?**] suggest five dimension which aid the researcher in the planning of an ethnography: (a) participant and non-participant observation (levels of participation between only observation and total participation [**?**]); (b) duration of the field study; (c) space and location; (d) use of theoretical underpinnings to support the conduction and the analysis of results; and (e) the ethnographers' intent in undertaking the study. In virtual ethnography, the first puzzle that the researcher must face is choosing a participation role in the research. While some researchers in the literature may agree that some degree of participation is necessary, the nature of the community may force the researcher to adopt an observer or hybrid position in the study [**?**].

Different qualitative techniques can be used with the purpose of carrying out of results analysis. One of them is Grounded Theory (GT), a method that uses a systematic set of procedures in order to develop and to derive inductively a theory grounded about a phenomenon based solely on the data col-

lected [**?**]. Based on the collection of qualitative data, the researcher reviews the data and analyze concepts and ideas that are classified in the form of codes. Coding is a process where data is segmented on small fractions that can be conceptualized and integrated in order to form a theory. This way, codes are aggregated in concepts. Later, these concepts are organized in categories, that are the base to build the theory. The analysis and coding process reaches its end when theoretical saturation is reached, that is, when nothing new emerges from the process of analysis and categorization of the data [**?**].

As a result of the Grounded Theory method, many artifacts can be created an one of the most important artifacts is the Memo. Memos are notes about the data, codes, relationships between codes or even conclusions that the researcher finds useful to better mold the theory [**?**]. The creation of memos is extremely important as these annotations are the first attempt to communicate in textual format the results of a Grounded Theory.

RELATED WORKS

Many efforts have been made in the challenge of improving accessibility on mobile devices for users with different disabilities. [**?**] present a valuable set of guidelines to achieve accessibility in mobile interfaces for elderly users as a result of a literature review study of academic works, standards and best practices of mobile web design. Also as people with disabilities are often excluded from the society by not having access to information through technology (and older people are included in this group), the guidelines were compared with a survey of three mobile Android apps, that were advertised as accessible, where all applications showed accessibility problems.

Some efforts have been developed aiming to solve accessibility gaps to visually impaired users. A literature review was carried out resulting in the mapping of 65 existing accessibility problems in the interaction with mobile devices [**?**]. The accessibility issues were classified in seven groups of problems which contributed to the establishment of a set of recommendations to improve accessibility. Concentrating on visually impaired issues, Color Vision Deficiency (CVD), which means the difficulty or inability recognize a certain color or to perceive color differences, can be seen as another important disability that affects many people in the world. A solution that adapts colors preserving properties of the original colors was proposed by [**?**].

An accessibility evaluation of the Moodle Mobile application is presented in the context of Universal Accessibility. Moodle was used by 21 participants without disabilities in order to assess their emotional response to seven interaction design patterns. Also, key points of difficulties and problems in the interaction of the users with the mobile application were analysed. The results identified accessibility barriers related to the design patterns and the work discussed the implications of these barriers in the students' learning process [**?**].

An experimental study with maps and location information was performed in order to identify the user's preference in using one or another search interface design pattern in order to complete two tasks. The authors presents a comparison of five location search UI design patterns on mobile, but do not directly addresses accessibility concerns [**?**].

Concerning on accessibility issues for elderly, a usability testing of three mobile applications exploring navigation and interaction of older users was conducted. The evaluation outcomes led the authors to propose recommendations regarding the design of mobile applications for older adults[**?**]. Similarly, [**?**] investigates the optimal target and spacing size between elements in mobile applications intended for older adults. In the study, the gestures of tap and swipe were used by 40 older users in two tasks on a mobile application. From the data collected in the experimentation, the authors recommended appropriate implementations of large tap and large swipe targets for the use of mobile applications by the elderly.

Lastly, one important work on virtual ethnography analyzed online message boards conversations in the online community with focus and detail on three specific aspects of the research method: space and time, identity and authenticity, and ethics [**?**].

The related works presented in this paper addresses various aspects of accessibility in mobile devices in the context of older adults, the visually impaired, Color Vision Deficiency and even universal accessibility. Although some studies use interface design patterns, these studies are either focused on only one interface element or on a specific deficiency. However, the solutions and recommendations proposed do not address a wide variety of UI design patterns and do not account for what the active community of designers and developers has studied and developed outside the academic environment to address accessibility issues related to mobile interface design patterns.

INVESTIGATING ACCESSIBILITY ISSUES

In this section we present the phases and steps of a virtual ethnography study to investigate the problems and solutions involving the use of UI design patterns in the mobile context by analyzing public information available in forums and blogs that are not present on academic articles. Besides the existence of few articles in the literature on accessibility of mobile UI design patterns, the choice of using Virtual Ethnography was also made due to the importance of knowing the practical experience of designers and developers who have faced accessibility problems in the context of mobile interfaces and proposed improvements to surpass these barriers.

In this study we have considered only information related to Android UI design patterns. Thus, we discarded iOS and other mobile operating systems due to the fact that Android has 81.7% of the smartphone market share in the world [**?**] and 93.2% of the smartphones in Brazil are Android [**?**].

The virtual ethnography follows the same phases of the classical one (planning, execution and analysis). Due to the fact that the virtual ethnography success is directly linked with the online locations where the study is carried out, we conducted a pre-planning phase in order to collect relevant references to be investigated.

Pre-planning

The identification and choice of sources of information with trustworthy and relevant data is a crucial requirement for the success of any virtual ethnography study. Because of this, we decided to question active designers and developers in the community about which places they used to gather information about mobile accessibility and design patterns.

In order to achieve this, a quick survey was created in Portuguese and English with questions about experience working with mobile technologies and accessibility (so that we could better understand the participants of the survey) and a last question where any source found relevant to the topics should be informed.

The survey was shared (in mailing lists of universities, partners and on social network groups dedicated to design) during three weeks in November 2016 and reached a total of 44 participants (designer and developers) from 14 countries (Brazil, Colombia, Chile, Germany, USA, Ireland, Japan, Spain, Portugal, France, England, Mexico, Peru and Italy). Although the participants of the survey were anonymous, some professional questions were asked and we could find that 56% of the 44 participants were developers (which means that the survey reached a similar amount of designers and developers). Also, 32% of the developers and 58% of the designers have between 5 to 10 years of experience working in their profession and 63% of all participants "knew" or "knew a lot" about Mobile UI Design Patterns and Accessibility.

The survey resulted in 72 websites, forums and blogs informed by the participants. However a preliminary analysis was done and all sources were accessed and searched in a process that resulted in 54 sources being eliminated due to several reasons: some addresses or names were not found, other sources were documentations or had focus on iOS development or nothing on mobile accessibility and design patterns was found. Which resulted in the selection of 18 information sources that were used in the study and will be reported in analysis section.

After gathering sources where the information would be collected, we proceeded with the planning step.

Planning

In the literature, [?] presents a set of dilemmas and practices of online ethnography that includes several characteristics of ethnographic studies in virtual communities as the participation role of the researcher and the duration of the ethnography.

While [?] compiles five general dimensions of ethnographic studies in Software Engineering containing key topics to help the researcher in the planning and execution of the ethnography. These definitions together are used to advise the researcher about key points of an ethnographic study. However, in our study we have identified the urge of two new dimensions that are specific for ethnographic studies in virtual communities which are described below.

Before starting to search the web for information regarding mobile accessibility and interface design patterns accessibility, we defined several aspects of our virtual ethnographic study in order to give the directions of the investigation. In the sections below, we present 7 dimensions that compose the ethnography protocol.

The first aspect is **participation role** which addresses the role of presence in the ethnographic study. Due to the nature of our research goal (we wished to examine public information available in the Internet), we decided to adopt the role of observer. Also, as the role of observer does not directly interacts with the studied subjects, the researcher's identity was not informed to the community. Another important aspect of ethnography is the ethical position of the researcher regarding the anonymity of the participants and the informed consent and age. Forum and blog users, even of public content, often assume that anonymity is secured on the Internet and that information and opinions posted online will not be traced back to their real identities [?]. Although all information collected was public and shared in the Internet without restrictions of reproduction and use, it was decided to maintain the subject's identity intact by not sharing citations linked to a username. Also the use of informed consent and age was discarded as each online platform (blogs, forums and sites) already require its users to agree with terms of use and disclosure of information.

Following the aspects defined in the literature, the **duration** of the study cannot be foreseen by the researcher, however, the researcher can trace a plan of work that determines the time spent in the field site and doing data analysis. For this research we defined to take an approach where the analysis of data would be done after each source had been completely scanned. The **location** where study will be conducted is another aspect. As a result of the initial analysis of the academic literature it was decided to search blogs, forums and other virtual references collected from researchers, developers and designers. The **theoretical underpinning** adopted in this study came from our previous work on accessibility of mobile design patterns [?] and from a technical report that assessed a set of design patterns in terms of usability and accessibility barriers for the web [?]. The **ethnographers intent** is important to set up the study goal. The intent of this research was to identify the practice of developers and designers regarding mobile UI design patterns and understand issues faced in the development of mobile application and solutions that are proposed.

We added two new dimensions to support the planing and execution a virtual ethnography. First, the **historical period** was identified during the planning phase where we understood that we had to define a period in which the information would be accepted in the research. As we often deal directly with technology on HCI, it's important to have in mind the relevance, popularity and usage curve of the technology in order to select a space of time where information about this technology will be relevant. Because of the rapid changes on mobile design and mobile platform in the last years, we decided to consider articles or conversations that were published after 2012.

As a second contribution to virtual ethnography, we introduced the **storage of volatile data** aspect. Online information is volatile [?] and as ethnography in virtual communities often deals with historical data, it's important to store and catalog such information in order to preserve its integrity: a blog post that was accessed and analyzed two weeks ago may not be

available anymore or may have been edited since then. In this study we decided to adopt the strategy of redundancy when storing articles and forum conversations by generating a *.png* image of the entire page with the help of a plugin for Chrome browser in order to maintain the original state of the page and 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 generates ready for print *.pdf* files) alongside with a *.txt* file containing the URL of the page.

Execution

Having our virtual ethnography planned with a well defined protocol and the 18 information sources selected (Subsection 4.1), the next steps were (i) the exploration of the information sources searching for relevant data, (ii) data selection and (iii) data storage. This process is composed by these three steps in a cyclic iteration over each one of the sources of information. This process consisted of 18 cycles (one for each information sources) where the first cycle started on December 2016 and the last cycle was completed only 14 weeks later.

The first step (i) consisted of accessing a source and searching for content that was valuable to the study. In order to do this, we had to create search queries that would express the topics we wished to find. As many web pages, all 18 sources had content and title based search engines with no sophisticated search controls, which means that we had to create a set of expressions in plain text and search for each expression. The definition of these search strings is not random, the researcher shall have previous knowledge of the topic studied and know which expressions are often used to refer to each specific topic. In our study, as we reached professionals from several countries in the survey and obtained sources in three different languages: Portuguese, English and Spanish, we had to adapt. The list of search strings used in this research consisted of 10 expressions and small variations of these expressions: Mobile Design Patterns, Mobile Accessibility, Design Patterns, Inclusive Mobile, Inclusive Design Patterns, Android Accessibility, Android Design Patterns, Mobile UI, Mobile UI Accessibility, UI Design Patterns.

The data selection step (ii) consisted of accessing each information source and exploring that source by using the search engine with the search strings. Each source was then explored by accessing every blog post or forum discussion returned by the search query and analyzing its content in order to evaluate its relation and relevance with the topic and also the importance and value of the raw content, links to other sources and comments. As defined in our protocol on the planning phase, we selected only information that had been published after 2012 and that were relevant to the research.

As we had defined on Section 4.2, any documents found relevant in the Data Selection step (iii) would be saved in *.png* and *.pdf* formats in order to preserve the original content from the date it was visited and collected. However it is also necessary to establish a set of criteria to catalog and organize all documents. Usually in a classical ethnographic study where interview transcripts are analyzed, the researcher organizes the transcripts by subject and date. In our study we decided to

adopt a similar approach adapted to the nature of Internet information: we decided to create a structure of files containing domain folder, sub-domain folder (if present) and publication title. With this approach we were able to organize all documents and identify its origin, also, we chose to not catalog the publications by date because all of them were published in the last 5 years and because this information was not considered relevant to the study.

After analyzing all 18 information sources, we had selected 127 publications. The distribution of publication by domain was not uniform. Some sources presented a greater concentration of documents extracted as *medium.com* with 46 and *smashingmagazine.com* with 21 publications. Following on *nngroup.com* with 12, *stackexchange.com* with 10, *reddit.com* with 9, *creativeblog.com* with 7, *uxpin.com* with 6, *torresburriel.com*, *grihotools.udl.cat*, *uxmovement.com*, *usabilitygeek.com* and *bradfrost.com* with 2, *androiduipatterns.com*, *visualhierarchy.co*, *lmjabreu.com*, *mobile-ui-design.ionicthemes.com*, *linkedin.com* and *jamessarcher.me* with 1 document.

Analysis

By the end of the second phase of the virtual ethnography, 127 blog articles and forum discussions had been collected and stored as described in Section 4.3. The data analysis method chosen for this research was the qualitative research method Grounded Theory (GT) [**?**].

There are different methodologies with small differences of how to conduct Grounded Theory research as the classical definition [**?**] and more recent and practical approaches [**?**]. In this study, we decided to follow a more practical form of Grounded Theory introduced by [**?**] that present a structured guide for doing research.

For the Grounded Theory approach that we have chosen for this study, there are three main steps that are the open coding, axial coding and selective coding. On the first step, all data from the 127 documents was analyzed in order to assign codes to particular chunks of text that were pertinent to the research.

There is more than just one method for coding. One popular coding technique is called word-by-word coding. In this technique each word (or small groups or words) receives a code in the open coding step and it's usually used on extremely dense documents. Another technique analyzes and assign a code to each line or each sentence, called line-by-line [**?**]. The coding technique that we adopted in this GT study 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 on documents that have low density, 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.

The second step, called Axial Coding, reorganizes the data and established initial connections or relationships between the codes. This means that new codes can be created and also that existing codes can be deleted or merged into new ones. While on the first coding step (open coding) 243 codes were created, by the end of the second step 189 codes were left.

In the third coding step, Selective Coding, the codes created on the two previous steps were refined and analyzed in order to identify main subjects in which the codes would be categorized. In this step, the 189 codes were organized in 27 categories.

Lastly, but of utmost importance, several memos were created based on the discoveries that were made from the coding process and relationships that were found between the codes. This resulted in 21 memos that detail several accessibility problems cited on the documents identified in the virtual ethnography. These memos also contain important thought and conclusions about possible solutions that might improve the accessibility of content and design patterns on mobile devices.

Symbol	Relationship	Name
$\longrightarrow$	A *one-way* relationship can be used to demonstrate a relationship between items which has a definite direction..	Leads to
——	An *associative* relationship can be used to demonstrate that items are in some way affiliated.	Associated with
$\longleftrightarrow$	A *symmetrical* relationship demonstrates a two-way activity between the items	Is related to

Table 1: Relationship connectors on Nvivo 11

In this research, the qualitative research software Nvivo 11 [**?**] was used. Also, in this study all three coding steps from the GT method were used. Once each category is defined and all codes are refined, it's possible to determine relationships between categories and between codes. These relationships are defined with the use on connectors that are provided by Nvivo 11. These relationship types are presented on Table 1.

After analyzing the data through the Grounded Theory research method with the creation of all needed codes and memos, it was possible to better understand the problems faced by developers and designers in the field of mobile accessibility of design patterns and also learn from the creative solutions proposed to some of the accessibility issues. The findings of our study are detailed in next section.

FINDINGS AND DISCUSSION

From the GT in the data analysis phase a total of 189 codes were created and organized in 27 categories with 21 Memos. Table 2 presents a summary of the three most coded design pattern categories ordered by number of codes. In this table, the first column (*Category*) presents the name of the category of codes, while the second column contains the number of sources of information where this category was coded. The third column contains the number of times that a code from the category was coded. The column *Description of Category* provides a brief description of the category containing key information to better understand how the subject affects the accessibility of mobile applications. The last column contains

text snippets of codes and relevant accessibility issues reported and identified in the virtual ethnography study.

Although the GT analysis resulted in 27 general categories (with 12 categories being UI design patterns), there is not enough space to detail each of those categories in this paper due to the limited number of pages. Thus, the complete list with all categories is available at `https://ux-leris.github.io/vitor_casadei/ihc2017/`. In this paper, we spotlight three categories, which represent UI mobile design patterns, that were most coded.

In the end, the categories that resulted from the GT method consisted of UI Design Patterns and also other aspects related to accessibility. For example, the most coded category is *Navigation* with 130 codes where this category contains citations related to navigation mobile UI elements such as *hamburger menu* and *tab navigation*.

Other categories that are not UI design patterns were also identified in the study but will not be explored in this paper. An example of category is *Color*. Although color is not a design pattern, it affects the accessibility of any UI element. Thus, these other categories are also important and relevant for mobile accessibility.

In the following sections we will present the findings from the three most frequently coded patterns that can be seen in Table 2. Figures 1, 2 and 3 are extracted from NVivo.

Navigation
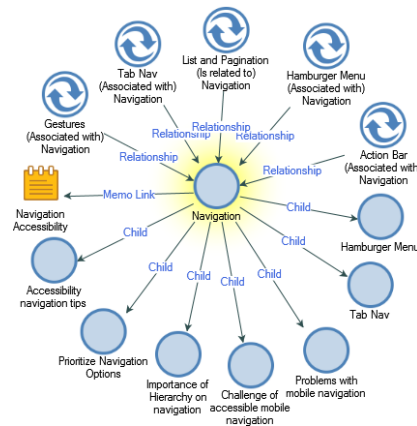

Figure 1: Relationships of category *Navigation*

Based on the information of the pattern (see Table 2), the Navigation category was present on 28 documents with a total of 130 coded sentences. Thus, navigation is the most frequent subject found in our research.

From the analysis of the codes identified for "Navigation", it was uncovered that only two mobile navigation design patterns were discussed in the 28 documents where the theme was found: the *navigation drawer* (or *hamburger menu*) and the *tab navigation*.

In Figure 1 we can see that the Navigation category has relationships with other five categories that are *Hamburger Menu*, *Tab Nav*, *Action Bar*, *Gestures* and *List and Pagination*. These

Category	Sources	Codes	Description of Category	Accessibility Issues
Navigation	28	130	On mobile design there are basically two UI design patterns that are most used for mobile navigation: The Drawer Menu (often called hamburger menu) and the Tab Navigation.	While the drawer menu offers the possibility of several navigation options that don't occupy screen space (only when the navigation button is triggered) it hurts the discoverability of content. Users who access applications drawer menus use less the menu options because they either forget that the menu exists or do not recognize that there is a hidden menu under an icon. The tab navigation on the other hand provides navigation options that are always available to the user, thus improving the discoverability. However, the navigation is limited to a maximum of 5 items, which may not be enough for some applications.
Input	14	69	Input is any kind of UI element that is used to insert information from the user to the application. Usually, inputs fields are used in forms.	As there are several types of input fields, there are many issues regarding the accessibility of this pattern. One serious concern of almost any kind of input is the use on placeholders to display information. Many implementations use only placeholders to inform the user about the field's purpose in order to save screen space. The problem is that placeholders are, in most scenarios, not recognized by screen readers for example.
List and Pagination	6	44	This category aggregates concerns with appropriate patterns for pagination on mobile devices. Also, it contains concerns about the accessibility of displaying information in form of lists.	On mobile devices, one pattern that is widely used is the infinite list. This patterns replaces the pagination with a (seeming) infinite list of items where new items are loaded when the user reaches the end of a set of items. Although this approach may seem interesting because the users do not need to click on any button to load new items, it has serious problems with engagement and location as users do not have any notion of progress while using this pattern.

Table 2: Summary of the most frequent code categories of UI design patterns

relationships are important as they evidence that navigation accessibility problems are affected or affect the interaction with mobile devices through gestures for example.

Also, the navigation category has 7 child nodes represented by circles filled in blue, these are some of the codes that compose this category. Although the software used to in the GT method (NVIVO 11) doesn't allow to show, the child nodes *Hamburger Menu* and *Tab Nav* are also subcategories of navigation and contain 5 and 7 child codes respectively. Similarly, navigation contains a memo containing key information about accessibility issues on mobile applications and the subcategories *Hamburger Menu* and *Tab Nav* also contain memos reporting specific concerns about each design pattern that are not shown on Figure 1 due to limitations on the qualitative data analysis software.

From the analysis of the codes in the category Navigation and its relationships, it's clear that the concern with accessibility in this category is focused on general navigation interaction with mobile interfaces. It's then possible to conceive recommendations to improve or implement accessibility for general navigation in mobile applications.

When dealing with complex processes on mobile application, many times there is a big number of steps that the user must follow in order to complete a task or achieve a goal. Although

it may seem more organized and appropriate to split actions in multiple steps, on multiple screens, this segmentation of information requires the memorization of previous actions. The problem is that people with cognitive deficiencies may struggle to remember previous actions or information as they often suffer from short memory loss. Also, elderly users also have problems locating themselves and remembering something they did only moments ago. Even users that do not suffer from any disability may have difficulty following actions that are split in multiple screens when using the mobile device on busy environments where the user must be aware of its surroundings (in a bus for example).

One simple but effective solution for improving the general navigation experience of users and provide accessible feedback to any user is to use breadcrumbs or hints of some sort that inform the current location. Although breadcrumbs are a common practice on web development, it's rarely used on mobile. With the information of the current location, older users that often get lost on mobile applications and are insecure about how to undo some action for example, will be able to understand better where they are. However, the developer or designer must understand that, by providing more information, more space is occupied and less space is available for the content. Thus it's important to find the appropriate place to

display such information, as for example an action bar or a simple field above the page title.

There are also other concerns with mobile navigation accessibility that are specific to implementations of mobile navigation. The sections below provide more detailed conclusions about the subcategories *Hamburger Menu* and *Tab Navigation*.

Hamburger Menu

Hamburger menu is a kind of navigation UI design pattern mostly used on mobile applications that consists of presenting navigation options that are initially hidden and that can be triggered by the click of a button.

The problem with this approach is that the navigation is hidden from the user that needs to have previous knowledge to understand that the menu can be accessed by clicking a button. The menu icon has low information scent, and, even with a label called "Menu", users may still not use the navigation as they do not know which options are available and don't even click the button.

In the documents analyzed several use cases were presented about big companies that initially adopted the hamburger menu, but soon changed to Tab navigation. Some companies as Facebook and BBC used the drawer navigation, but due to the low discoverability that this type of menu provides, they identified that users had problems locating sections and menu options.

Tab Navigation

The main advantage of the tab bar is that it doesn't hide the navigation options, they 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 important contribution of tab navigation is that the tabs communicate the user about the current location by visually featuring the current position in the related navigation option. This simple feature makes the user capable of visually understanding the current location and also gives more control to visually impaired user who use screen readers and also to users with cognitive deficiencies who struggle with short term memory.

Although tab navigation may seen the perfect navigation element for mobile devices, it can hold only up to 5 navigation options in order to be able to fit in the screen with appropriate font size. In these situations, there are two approaches to still use a navigation tab bar: the first approach is to add a last option called "more" or other appropriate label that will open a navigation drawer.

The second approach applies the use of a horizontally scrollable navigation tab bar. In this approach, the navigation bar can hold more options while keeping the optimal touch-target size. The downside of both approaches is that they still have discoverability issues.

Input

Inputs were probably one of the first interface interactions that were designed in the early days of graphical computing and they have not changed much ever since.

In Figure 2 we can see all relationships and codes related to the Input category. One of the accessibility concerns that were most present in this category is the correct use of placeholder and labels on input fields.

The use of placeholders alone saves the designer space for more elements. However, when an input field does not have a label, the hit area of that element is reduced. This is harmful for older users or users with motor disabilities that may limit they movement, for instance.
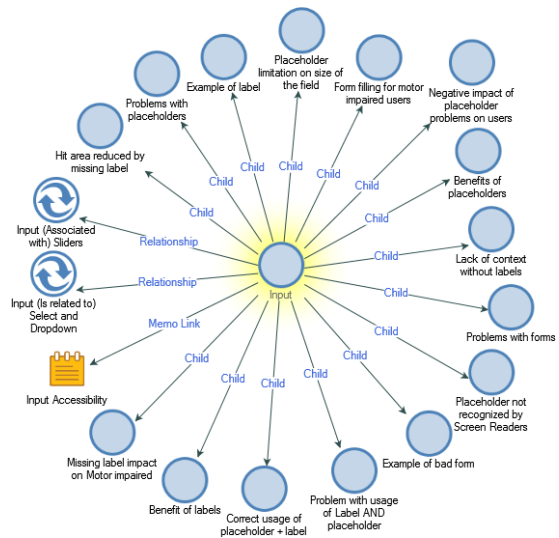

Figure 2: Relationships of category *Input*

In addition, a placeholder disappears when the user starts typing, which instantly removes all the context of the input field. This problem is also harmful for people with cognitive deficiencies as they may struggle to work with short term memory. Placeholders are presented with low contrast to the background, which may spoil the experience of users with visual impairments or users with situational disabilities caused by screen reflection in the screen. There is no solution for this problem because if the contrast is higher, the user may confuse the placeholder with actual content of the input, for example.

A solution for most of these problems is the appropriate use of label and placeholder together. Labels are not help texts and thus should be succinct, short and descriptive so that users can quickly identify what information is required. Also, labels must present the necessary information for the user, for example: on a login form where the user can use a username or an email to access the account, the label must contain "username or email".

Placeholders that are used with labels must be meaningful and contain information about the format expected in the input field or other necessary information. Both on placeholders

and on labels, the text should never be in all caps, as it's more difficult to read and harder to quick scan.

List and Pagination

From Figure 3 we can see that the category "List and Pagination" is related to the "Navigation" category which is explained by the fact that the user navigates through the items in a list.
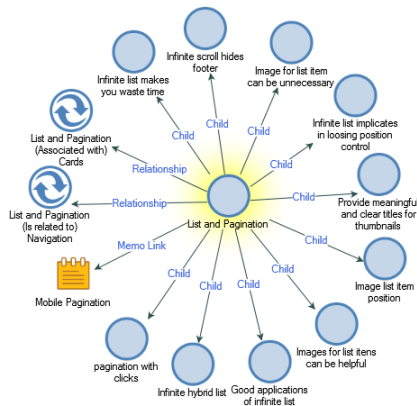

Figure 3: Relationships of category *List and Pagination*

On web desktop list navigation is usually implemented with pagination controls at the bottom or top of the page. With these controls, the user has variety of actions to choose as skipping pages, jumping to the end or returning to the first page.

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

Although the infinite list may seem like a good alternative of minimalist and practical design, it raises serious accessibility concerns. On situations of low bandwidth, that are common when using mobile devices outside a Wi-Fi network, infinite list may present long waiting times while loading for new items to be displayed. This long wait may cause the user to think that the application is not responding or think that the list has reached its end. Also, visually impaired users may not understand what is happening because the screen reader may not be able to correctly inform the user that the application is loading new information.

One of the major problems with infinite scrolling is that it does not provide any information regarding the position on the list. The same way that the lack of information about location in the navigation of mobile applications (Section 5.1) can cause serious problems for people with different disabilities (and even people without disabilities). It also may cause confusion and uncertainty for many users that are not sure of their current position, to how they got there and how to share or save the position of an item in the list for example.

Also, on some implementations, the infinite list is sorted by date or alphabetically. This situation causes a new problem

where it's extremely difficult and tiresome to find an item at the end of the list as it's not possible to jump to the end of the list. Many times, list implementations do not provide any kind of filtering options, which contributes to these issues.

With these issues, it was found that, in terms of accessibility, the better list navigation pattern is still pagination, even on mobile devices (of course that with fewer controls due to the small viewport). Also, it's important to provide filtering and ordering options in order to lower the number of items in the list.

Although in theory pagination requires more clicks and actions from the user, it provides more control. Also, as pagination is controlled by buttons, screen readers are able to correctly parse the elements in the page.

CONCLUSIONS AND FUTURE WORKS

In this paper we presented an investigation of issues on the accessibility in mobile UI design patterns. Guided by a vitual ethnographic study conducted in 18 virtual communities of mobile design accessibility, we found out 127 occurrences of accessibility issues organized in 27 categories.

The qualitative analysis based on Ground Theory supported the findings of many accessibility concerns with special attention to the use of UI design patterns. As the available space was not enough, in this paper, we concentrated the analysis on those that mostly come up in the qualitative data analysis. The main contribution of this work was to bring up the issues of using popular UI mobile design patterns which can introduce accessibility concerns. The results can aid the developers' community on concentrating efforts in the improvement of these patterns as well as in being more careful in their use in order to avoid accessibility problems.

As future work, the authors intend to extend the knowledge on accessibility problems of mobile UI design patterns and propose recommendation for a better design for these patterns in order to improve their accessibility.

ACKNOWLEDGMENTS