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Accessibility in the mobile development industry in Brazil: Awareness, knowledge, adoption, motivations and barriers☆

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ABSTRACT

Accessibility is a quality sub-characteristic intended to make software products accessible to a broad range of users, regardless of their physical, motor, intellectual or cognitive skills. Mobile accessibility has been on the spotlight recently due to the increasing shift towards mobile platforms. Thus, many advances have been made in this field when it comes to the development of assistive technologies, conception of well-documented accessibility guidelines and supporting tools. However, a general lack of accessibility in mobile applications has been observed in several studies. Researchers have conducted investigations to understand the same phenomenon in web development from the perspective of those involved in the development process, but studies concerning accessibility in the context of mobile applications are still scarce. This paper presents a survey conducted with 872 people involved in mobile application development in the Brazilian industry to gather information on their awareness, adoption, motivations and barriers to ensure digital accessibility. Results show that most participants have moderate accessibility awareness, but low levels of knowledge or adoption in practice. In addition, accessibility is usually not considered in their projects due to lack of requirements, time, training and focus on users with disabilities.

1. Introduction

People with disabilities may encounter several challenges in everyday activities, including the access to digital products or services that are badly designed. Considering that an estimated 15% of the world population has some type of disability (Organization and World Bank, 2011), accessibility plays an important role since it intends to promote user autonomy by removing barriers that may prevent people with disabilities to fully perceive, understand and operate digital products and services (W3C, 2018b,a; ISO, 2011, 2018).

In the software development context, accessibility is a non-functional requirement and a sub-characteristic of usability according to the product quality model defined by the ISO/IEC 25010:2011 (ISO, 2011). Accessibility is defined as the capacity of a software product or service to be used by a wide range of users with different characteristics and regardless of their physical, mental, motor or cognitive skills (W3C, 2018a; ISO, 2011, 2018). Although accessibility is mostly intended to address requirements related to users with disabilities, it should be considered a key quality attribute that contributes with the overall usability and quality of any software product or service (Gay et al., 2018).

Many advances have been made over the years to promote accessibility both in the software operation and production contexts, namely assistive technologies (e.g. screen readers, voice navigation and screen magnifiers) that can enhance user capabilities; the conception of accessibility standards and guidelines (e.g. W3C's Web Content Accessibility Guidelines) to drive the implementation of accessible software systems; tool support for developing and evaluating the accessibility of software products (Silva et al., 2018); and specific legislation devised by many countries to enforce accessibility-related policies to make sure people with disabilities are not excluded (Lazar, 2019).

Web accessibility is perhaps the most notable case of digital accessibility since the WWW (World Wide Web) has been the most popular platform on which public or private companies share information and offer many of their services. However, mobile accessibility has also been on the spotlight recently, specially due to the increasing shift towards mobile platforms and the challenging nature of mobile devices when it comes to user interaction: small screens, large amount of possible hardware and

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software configurations, complex user interaction (e.g. gestures) and so forth.

Many studies have been conducted to investigate whether mobile applications developed and used in different contexts take accessibility requirements into account to be accessible to people with disabilities. Unfortunately, most studies have found a general lack of accessibility in mobile applications of different categories, sizes, complexities and popularity (Serra et al., 2015a; Eler et al., 2018; Yan and Ramachandran, 2019; Vendome et al., 2019; Alshayban et al., 2020; Acosta-Vargas et al., 2020). One question that arises in this context is "why do designers and developers not implement accessible products given that accessibility is an important quality attribute and many accessibility-related resources are available (e.g. assistive technology, guidelines, legislation and tools)?".

This same phenomenon has also been noticed with web applications and some studies have been conducted to understand the accessibility awareness of people involved in web development and possible reasons for the general lack of accessibility (Lazar et al., 2004; Freire et al., 2008; Oliveira and Eler, 2017; Inal et al., 2019; Barzilai-Nahon et al., 2008; Putnam et al., 2012). Most studies reported the lack of awareness of people involved in the development process and several reasons why accessibility is not generally adopted in web application development, such as tight deadlines, lack of proper training, lack of proper tools, and so forth. Even though such type of investigation with respect to Web accessibility has been already explored, studies with people involved in mobile application development are still scarce.

Therefore, we set up a study to understand whether accessibility is addressed in mobile development projects. Specifically, we want to characterize the mobile application development industry with respect to the awareness and knowledge on digital accessibility of the people involved in the development process; to which extent accessibility practices and tools are adopted; the motivations that drive the development of accessible products; and the barriers that usually prevent accessibility to be properly addressed. As the mobile development industry worldwide is vast, we focused on a particular group, the Brazilian mobile development industry, to be able to collect data from a representative sample of the population. Brazil is the fifth most populous country and the 9th largest economy in the world. Furthermore, according to a study conducted by the Brazilian Association of Software Companies (ABES, 2018), Brazil is the 9th largest software market worldwide.

This paper presents and discusses the results of our study that was conducted based on the survey research method. For this investigation, we designed a Web-based questionnaire comprising 19 questions to collect data from people involved in mobile application development in Brazil. Participants were selected by a non-probabilistic sampling method and we were able to collect valid answers from 872 participants from all macro-regions of the country. Our results show that few participants have deep knowledge of accessibility standards and guidelines. Thus, accessibility is not fully addressed in most mobile development projects. In addition, participants seem to be motivated more by social conscience and personal reasons than organization and project demands. This is related to the most popular barriers mentioned by participants: lack of accessibility requirements, lack of time, lack of training and the lack of awareness that people with disabilities are numerous and also potential users of any digital product.

In addition, a cross analysis showed that the participants with higher levels of accessibility awareness, knowledge, adoption and evaluation, but still in low levels, usually work for larger organizations, have more experience in the software development process, work for private or public companies, or develop mobile applications for the iOS platform. For organizations of all sizes, the most frequent barrier to accessibility adoption is that it is not a requirement. Particularly, for micro and small companies, high cost and lack of training are the most prevalent barriers. For public organization, private companies and freelancers, the most mentioned barriers were that accessibility is not a requirement, lack of time and training.

This paper is structured as follows. Section 2 presents concepts related to digital accessibility. Section 3 gives an overview of previous studies conducted to characterize the context of mobile and web development with respect to accessibility. Section 4 describes the research method we selected to reach our results and conclusions. Section 5 presents the analysis of the data collected by our survey. Section 6 discusses the results of our study and compares our findings with related work. Section 7 presents the concluding remarks.

2. Background

Usability can be defined as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 2018). The concept of usability is crucial to Human-Centered Design (HCD) methods that are mainly concerned with ways in which interactive systems can enhance human–system interaction by delivering software products and services with good usability (ISO, 2019).

In a World where an estimated 15% of the population presents some type of disability (Organization and World Bank, 2011), accessibility also plays an important role in HCD methods because it is a sub-characteristic of usability according to the product quality model defined by the ISO/IEC 25010:2011 (ISO, 2011). Accessibility is defined as the capacity of a software product or service to be used by a wide range of users with different characteristics and regardless of their physical, mental, motor or cognitive skills (W3C, 2018a; ISO, 2011, 2018). Although accessibility is mostly intended to address the requirements related to users with disabilities, it should be considered a key quality attribute that contributes with the overall usability and quality of any software product or service (Gay et al., 2018).

One common strategy to promote accessibility is by means of assistive technologies, which have been broadly used to enhance the capabilities of people with disabilities and to support the usage of electronic services or products. For instance, users with visual impairment can use screen readers to navigate through and to operate both web content and mobile applications, or use magnifying features to increase a focused area on the screen. However, assistive technologies are effective only when digital products and services are built to be accessible.

Many accessibility standards and guidelines have been devised to guide people involved in content and software development on delivering accessible products. WCAG (Web Content Accessibility Guidelines) (W3C, 2018b) is perhaps the most popular guideline since it is maintained by the W3C (The World Wide Web Consortium) and has been widely used as an accessibility reference in many countries, including on specific legislation regarding digital accessibility. This guideline was firstly intended to address accessibility recommendations for web development, but most recently it also covers accessibility aspects concerning mobile applications.

There are accessibility guidelines devised specifically for mobile applications, as the BBC's mobile accessibility guideline (BBC, 2020), for example. BBC's accessibility guidelines cover most criteria defined by the WCAG and it splits their recommendations into different sections: audio and video; design; editorial; focus; forms; images; links; notifications; scripts and dynamic content;

structure and text equivalence. Mobile development platforms have also created their own set of accessibility recommendations. Google's Material Design and Apple's UIKit synthesizes general principles of good design for designers and developers. Both guidelines have specific sections to explain general concepts and recommendations for designing and implementing more accessible mobile applications.

Accessibility evaluation is an important activity to identify whether accessibility requirements and recommendations were properly implemented. Such activity can be conducted using three different strategies: (i) specialists can inspect the user interface looking for accessibility violations; (ii) users with disabilities can test the application by trying to perform specific tasks to report barriers they may have found; and (iii) automated evaluation tools may automatically detect a set problems. A combination of such strategies can be adopted to achieve better results.

Automated tools can help the accessibility evaluation process, even though many accessibility barriers can only be detected based on human judgment (Vigo et al., 2013; Mateus et al., 2020). There are many automated tools for accessibility evaluation available for both Android and iOS platforms (Silva et al., 2018; Siebra et al., 2018), which can perform static or dynamic analysis. Some tools were specifically designed to support accessibility evaluation, such as MATE (Eler et al., 2018), Accessibility Scanner (Google, 2016), Mobile Web Accessibility Checker (MWAC, 2018), Accessibility Inspector, IBM AbilityLab Mobile Accessibility Checker (IBM, 2018), AXE (Deque, 2020), but some of them are testing tools or frameworks that can enable accessibility testing. For instance, Espresso (Google, 2018a) and Robolectric (Google, 2018b) are testing frameworks that allow testers to simulate user interactions with the application under test and reveal failures, but they also allow testers to enable accessibility checkers that will automatically check for specific accessibility properties in all user interfaces visited in the test session.

3. Related work

Many studies have been conducted to understand the accessibility perception and awareness of people involved in software development. Table 1 provides an overview of related work, concerning the studies' methods, sample size (N), characteristics of the participants (e.g. location and role of participants in software development), and the platforms within the study scope. Note that our study is described in the last row, thus allowing a general comparison with the remaining studies.

Most studies are surveys like ours, with a few qualitative studies based on data collected from interviews (Farrelly, 2011; Patel et al., 2020). There is also an experience report about a workshop on designing for accessibility (Crabb et al., 2019). Among the surveys, our study stands out for its number of participants (N=872), which is significantly higher than the other studies.

Considering location, our study targeted the population of Brazilian developers, similarly to Tangarife and Mont'alvao (2006), Ferreira et al. (2007), Freire et al. (2008), Antonelli et al. (2018) and Pichiliani and Pizzolato (2019). In particular, our questionnaire design is based on the study of Freire et al. (2008), similarly to the study of Antonelli et al. (2018). Hence, we provide a comparative analysis for these two studies (Section 6). We did not compare our results with other Brazilian surveys such as Tangarife and Mont'alvao (2006) and Ferreira et al. (2007) because they surveyed few participants. Besides, the latter only addressed public organizations. As to the study of Pichiliani and Pizzolato (2019), they specifically addressed cognitive accessibility, so we chose studies that addressed accessibility in a more comprehensive manner.

As presented by Column "Platform" of Table 1, most studies are related to Web accessibility awareness and, as far as we know, only one study is concerned with mobile accessibility (Abdulaziz Alshayban and Malek, 2020). There are some studies that do not focus on a specific platform, but rather discuss accessibility for software systems in general, which are identified as "several" in the table (Lopes et al., 2010; Crabb et al., 2019; Patel et al., 2020).

Finally, the last column lists participants' roles in software development for each study. It is important to pinpoint from where the perceptions on accessibility are coming from, since responsibility shifting may occur, i.e. the belief that accessibility should be handled by others (Nahon et al., 2012). Note that our study covers a varied range of roles, including developers, testers, designers and managers.

In general, participants in these studies were asked about the factors that lead them to adopt or not accessibility in their projects. A summary of such results is given in Table 2. Although using different terms, it is possible to observe that some factors are repeated through the studies. Frequent barriers include lack of awareness, lack of education/training, requirements conflict, limited resources (cost and time), lack of tools, focus on different target public, lack of management support and outside responsibility. Motivations, in turn, include legislation, awareness, management/client requirement, training, software tools, personal motivation, guidelines and product quality. Some factors appear both on barriers and motivations. For example, awareness is a motivation and lack of awareness is a barrier.

Note that some studies do not present accessibility factors, such as Lopes et al. (2010) and Yesilada et al. (2015). It may be the case that authors investigated accessibility from another viewpoint. In particular, Yesilada et al. (2015) investigated how participants perceive the relationship on the concepts of usability and accessibility.

Still, some studies attempt to form a theoretical framework using these factors, such as Yesilada et al. (2015), Vollenwyder et al. (2019). Both studies use the Theory of Planned Behavior (TPB) aiming to model such factors in terms of intentions, attitudes and behavior, i.e. the behavior to create accessible products.

In a related perspective, it is also possible to observe in the studies the extent to which practitioners are familiar with accessibility guidelines. Considering the most prominent standard, WCAG, some studies report low numbers, such as Tangarife and Mont'alvao (2006), Putnam et al. (2012), Antonelli et al. (2018), for which at most 20% of participants are familiar with WCAG. On the other hand, some studies present higher numbers, such as Lazar et al. (2004), Freire et al. (2008), in which the percentages of participants familiar with WCAG are around 64% and 60%, respectively.

Nonetheless, for both situations, being familiar or not with guidelines does not seem to translate into adoption of accessibility in practice. For example, in the study of Lazar et al. (2004), which had optimistic numbers for familiarity with WCAG (64%), only the websites of 24.6% of respondents complied at the time with accessibility laws. In the study of Antonelli et al. (2018), around 20% of participants were familiar with some option of standard, and 64.4% did not address accessibility issues in their regular projects at the time.

Moreover, despite the substantial advancement in the understanding of the awareness of developers and practitioners regarding Web accessibility, there is still scant evidence of the awareness of developers regarding the accessibility in the development of mobile applications. Even practitioners who are aware of Web accessibility guidelines and practices need to become acquainted with the specificities of how disabled people interact with mobile technologies and how to address those issues in mobile software development.

Table 1
Studies on accessibility perception and awareness by developers.

Study	Method	N	Location	Platform	Role/Occupation
Lazar et al. (2004)	Survey	175	USA, other countries	Web	Webmaster
Tangarife and Mont'alvao (2006)	Survey	68	Brazil	Web	System designer, programmer, web designer
Ferreira et al. (2007)	Survey	87	Brazil	Web	Web developers
Freire et al. (2008)	Survey	613	Brazil	Web	Researcher/lecturer, analyst, manager, and other roles
Lopes et al. (2010)	Survey	408	–	Several	Developers, service providers, public servants and officials, accessibility assessors, elderly and people with disabilities
Farrelly (2011)	Qualitative	23	Canada	Web	Web practitioners
Putnam et al. (2012)	Survey	199	USA, UK, Brazil, Germany, China	Web	UX and HCI professionals
Nahon et al. (2012)	Survey	417	Canada, USA	Web	Non-professional developers of online content
Yesilada et al. (2015)	Survey	300	USA, Canada, Europe, Australia, other countries	Web	Web accessibility experts, HCI specialists, software engineers, designers, others
Antonelli et al. (2018)	Survey	404	Brazil	Web	Web designer, programmer, systems analyst/engineer, webmaster and others
Inal et al. (2019)	Survey	113	Turkey	Web	UX professionals
Crabb et al. (2019)	Experience report	197	UK	Several	Students, developers and designers
Pichiliani and Pizzolato (2019)	Survey	105	Brazil	Web	Web developer, web designer, platform developer, software engineer, team leader, professor, test/QA analyst, project manager, teacher of technical high school and others
Vollenwyder et al. (2019)	Literature review, survey	342	Switzerland, Europe, other countries	Web	Web practitioners (testing, management, project management, development, product owner, visual design)
Abdulaziz Alshayban and Malek (2020)	Survey	61	Brazil, USA, other countries	Mobile	App developers
Patel et al. (2020)	Survey, qualitative	71, 10	USA	Several	Software developers, UX/UI designers, project managers, accessibility experts
This study	Survey	872	Brazil	Mobile	Developer, system analyst, management role, designer, tester, researcher, software architect, others

In this sense, our study collected data to investigate these factors, the awareness and the adoption on the mobile development scenario as well, focusing on the population of Brazilian software practitioners. Additionally, we performed the comparison of our results with the scenario that has been further investigated of web development.

4. Research method

The goal of our study is to characterize people involved in the development of mobile applications in Brazil with respect to their awareness, knowledge, adoption, motivations and barriers related to mobile accessibility. To reach such a goal, we resorted to a survey method (Robert M. Groves et al., 2009; Molléri et al., 2016; Linåker et al., 2015) to systematically gather information from people involved in mobile application development and thus construct quantitative descriptors concerning those aspects of interest. Following, we describe our research procedures in detail.

4.1. Questionnaire design

The questionnaire we designed was largely inspired by previous work (Freire et al., 2008), which intended to investigate the accessibility awareness of people involved in Web development projects in Brazil. The new questionnaire was adapted to the mobile development context and based on interviews conducted with four mobile application developers based in the city of São Paulo-Brazil. Three of them were Android developers and one was a test analyst. They had six years of experience in average and none of them had any knowledge or experience with basic concepts related to accessibility.

The questionnaire we devised is composed of 19 questions divided into two sections. The first section collects demographic data, such as age, work location (Brazilian macro-region), education level, organization type (e.g. private, public) and size (e.g. small, large), job position (e.g. developer, designer, tester), years of experience, and development platform. The second section gathers information related to the specific aspects of interest of this investigation: accessibility awareness and knowledge (whether and how visually impaired users use mobile applications, assistive technologies, accessibility standards and guidelines, source of information), adoption (in which extent and which standards and guidelines are adopted, evaluation method, tools), motivations and barriers. All questions are of multiple choice type, but participants could include other answers if applicable. In many questions, participants could select more than one answer. Participants could remain anonymous, but they also had the option to inform their contact information voluntarily to receive a copy of the results of this research and/or to engage in further activities related to digital accessibility. In any case, participants were assured that, on agreeing to provide their answers to be used in our research, all data would be handled with confidentiality and anonymity.

4.2. Pilot study

We conducted a pilot study to evaluate the questionnaire. The questionnaire was answered by 10 developers from start-ups based in the city of São Paulo. We asked participants to provide

Table 2
Results of related work on factors to adopt accessibility.

Study	Barriers	Motivations
Lazar et al. (2004)	Education of webmasters, conflict with design requirements, cost, other stakeholders' perception on accessibility	Legislation, awareness, management/clients requirements, training, accessibility software tools
Tangarife and Mont'alvao (2006)	Budget limitations, lack of experts, time, lack of accessibility awareness by managers	–
Ferreira et al. (2007)	Low priority of accessibility in their organizations, big amount of information, lack of experts, too many standards to be observed	–
Freire et al. (2008)	Lack of training, not an organization requirement , not a client requirement, time, cost, focus on other public, lack of skills, and others	Personal motivation, addressing more customers, web standards, target public, legal factors, good reputation, customer requirement, and others
Lopes et al. (2010)	–	–
Farrelly (2011)	Social and individual values, inadequate guidelines and support, monetary demands, lack of education and training	Personal responsibility
Putnam et al. (2012)	External factors or limited resources (time, budget, clients)	Research/inquiry, laws and guidelines, personal initiative/advocacy, organizational support
Nahon et al. (2012)	Cost, extrinsic motivation	Community context, attitude, self-efficacy
Yesilada et al. (2015)	–	–
Antonelli et al. (2018)	Lack of training, not a customer requirement, time, not an organization requirement, focus on other public, lack of skills, work overload, cost, law does not apply, lack of material in Portuguese, high costs of tools and others	–
Inal et al. (2019)	Lack of awareness, accessibility is not required by target group/customer, lack of training/knowledge, outside participants' job descriptions, time restrictions, lack of support from the management, not being responsible for accessibility, not an organization requirement, lack of human resources, budget restrictions, insufficiency of legal arrangements, lack of guidelines to help them in the process	Being inclusive, developing better products, customer requirements, being ethical, increasing income, finding research opportunities, search engine optimization, designing
Crabb et al. (2019)		
Pichiliani and Pizzolato (2019)	Lack of knowledge, focus on other audience, lack of materials on the subject, others	Guidelines on cognitive accessibility, knowledge on these disabilities, how to apply existing guidelines to this audience, courses or conferences on the subject, translated content, others
Vollenwyder et al. (2019)	Requirements conflict, personal effort	User advocacy, self-perception as specialist, product quality
Abdulaziz Alshayban and Malek (2020)	Lack of awareness about accessibility and its importance, additional cost of ensuring accessibility, lack of support from management, lack of tools, lack of standards and guidelines, not sure which standards to follow	–
Patel et al. (2020)	Limited knowledge and skills about accessibility, company management, lack of accessibility resources, tight development cycles	–

us with feedback to adjust the questionnaire accordingly, aiming at making it straightforward and easy to answer, but participants said the questionnaire was easy to understand and the number and the content of the questions were appropriate.

4.3. Population and sampling method

We aim at characterizing how accessibility is addressed in the mobile application development industry in Brazil. Therefore, the target population of our survey is Brazilian professionals involved in mobile application development. Accordingly, we adopted a non-probabilistic sampling method once we could not determine the size of our target population nor could we select participants according to the requirements of a probabilistic sampling method — we cannot guarantee that the whole population has been invited to participate in our survey.

We adopted two main strategies to reach potential participants of our study. In the first strategy, we published invitations in mobile development groups in a social network: Facebook. However, we noticed that the large amount of daily publications in such types of groups prevented many people from visualizing our invitation. After a few attempts to invite participants using this method, we concluded that broadcast invitations using social networks might not be very effective.

Following, we adopted a more effective strategy to reach potential participants for our study. This time we decided to send individual invitations to users of a different social network: Linkedin. We used the search engine provided by this social network to find users that are involved in the mobile development process using keywords such as "mobile", "ios" and "android". The invitations were sent by three authors of this study and a plan was devised to avoid duplicate invitations.

4.4. Survey execution

We resorted to a Web-based questionnaire to collect information from the participants of our survey and it was publicly available at the Google Forms during 4 months. In the first month, we adopted the strategy to publish invitations on Facebook groups, but from the second month on we resorted only to direct invitations sent to Linkedin users.

By sending invitations to Linkedin users in the sequence they appeared in our search results, we noticed that the search algorithm is biased towards showing first the users that we have up to a third degree connection[1] and are somehow related to our profile (e.g. city or region). Thus, we decided to establish connections with participants we invited to increase the potential users we could interact with. In addition, aiming at reaching participants from all Brazilian regions, we performed several searches narrowing results based on different regions (e.g. Brazilian states). Unfortunately, we have not tracked how many users from each region have been invited.

In total, we received valid responses from 872 participants from all regions of Brazil. We cannot calculate the exact response rate of our survey since we cannot know for sure how many users visualized our broadcast invitations published on social media and how many participants forwarded invitations to their colleagues as we suggested in both strategies. However, we can estimate the response rate based on the individual invitations sent to Linkedin users. We estimate that only 40 participants answered our questionnaire during the time we published invitations on Facebook groups. Therefore, about 830 responses to our questionnaire came from around 5200 invitations sent to Linkedin users, which results in a response rate of 16%.

4.5. Limitations

The sampling method we used necessarily imposes some limitations to the conclusions of this study. We cannot determine and have access to the whole population we are interested in, which makes it impractical to survey a random sample of participants. In that case, we adopted a non-probabilistic sampling method. Consequently, we resorted to a convenience sampling since we targeted participants that have a specific social network profile (Facebook or Linkedin) or were members of a particular group on Facebook (e.g. mobile developers). Even though a convenience sampling method was adopted, there is a large number of professionals of the software development industry on Linkedin, which might represent our target population.

5. Results

This section describes the results of our investigation. In total, 874 participants answered our questionnaire. However, we removed data provided by two respondents that declared to be under age[2] since we have not provided respondents with any parental authorization form. Therefore, our investigation is based on 872 valid responses. Our results are presented in four parts: demographics; accessibility awareness and knowledge; accessibility adoption in practice; accessibility evaluation; and motivations and barriers.

5.1. Demographics

Fig. 1 shows the distribution of participants with respect to their age. The majority of participants (almost 90%) are between the age of 18 and 35 years. Only around 8% of the participants are between the age of 36 to 45 and 1% between 46 to 60 years.

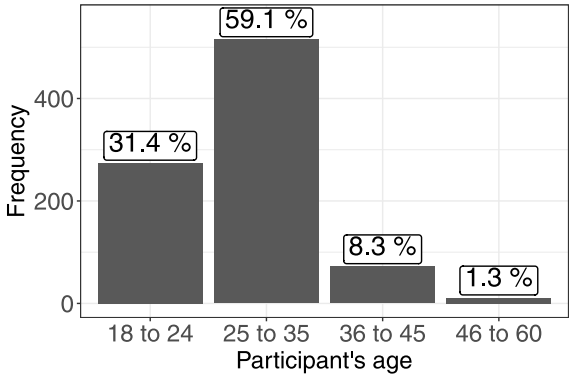

Fig. 1. Distribution of participants according to their age.

Fig. 2 depicts the distribution of participants regarding the Brazilian macro-region where they are based. Although seemingly uneven, this distribution roughly reflects the population density in Brazil. For instance, the highest number of respondents live in the Southeast, which is also the most populous macro-region.

Fig. 3 presents the distribution of participants concerning their educational background. Note that most participants completed higher education (80,8%), which includes those with Bachelor (57.7%), Specialization/MBA (16.6%), Master (5.8%) and PhD (0.7%) degrees. Few participants had only finished high school (7.2%), received a technical degree (6%) or were undergraduate students (6%) by the time this survey was run.

Fig. 4 shows the distribution of participants according to their organization type. The majority of the participants are mainly involved in the development of mobile applications in private companies (around 80%); nearly 8% in personal projects; about 7% in freelance jobs; around 5% in public companies; and the remaining 1% in research, education, or open source software.

Fig. 5 shows the distribution of participants according to the size of their company. Most respondents work for big companies (54%), followed by small (17.7%), micro (10.7%) and medium (8.1%) size companies. The remaining 9.5% of the participants do not work for any organization. Even though freelancers are self-employed, they indicated the size of the organization for which they develop software, thus defining their development context.

Fig. 6 shows the distribution of respondents according to their role in the software development process. The vast majority of respondents are developers (85.4%), followed by systems analysts (4.8%), managers (3.3%) designers (3.3%), testers (2.3%) and other positions (0,8%).

Fig. 7 shows the distribution of participants according to their experience (in years) in mobile application development. Many participants (42.3%) have between two to five years of experience; 23.7% have more than five years of experience; 21.6% have between one to two years of experience; and 12.4% have less than 12.4% of experience.

Fig. 8 shows the distribution of participants according to the platform for which they develop mobile applications. Android is the predominant platform (64.4%), followed by iOS (50.6%) and the hybrid approach (38.5%), which combines native and web components. Only a small percentage of participants said to develop applications using multiplatform frameworks (0.8%).

[1] A connection between two users on Linkedin means they can see and interact with each others publications and send direct messages freely.

[2] The majority age in Brazil is 18 years-old.

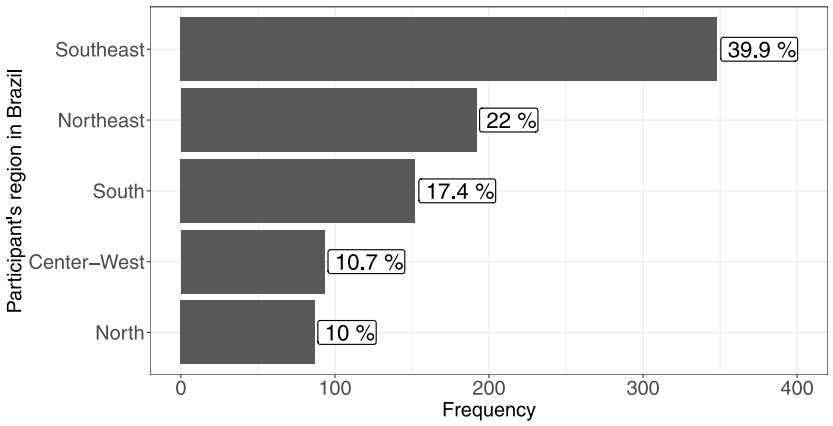

Fig. 2. The distribution of participants according to the Brazilian macro-regions they are located.

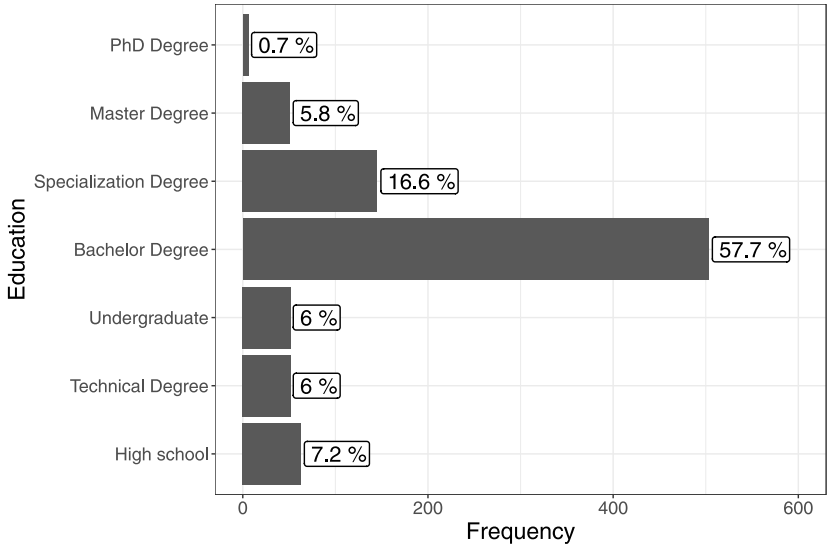

Fig. 3. Distribution of participants according to their educational background.

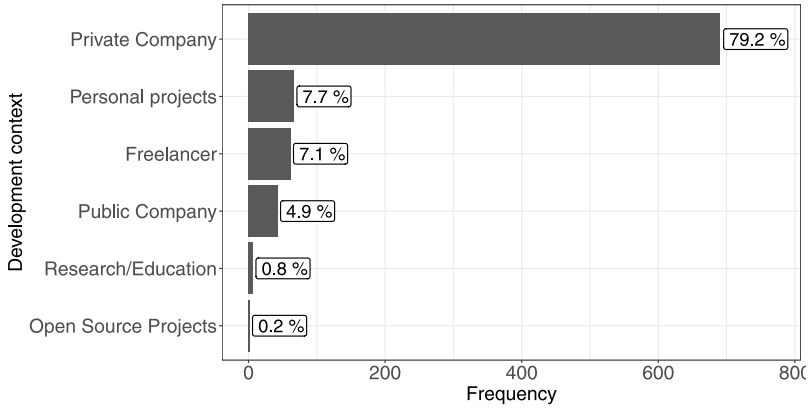

Fig. 4. Distribution of participants according to the organization type. Participants were instructed to choose only the most relevant answer in the case they are involved in mobile software development in more than one organization.

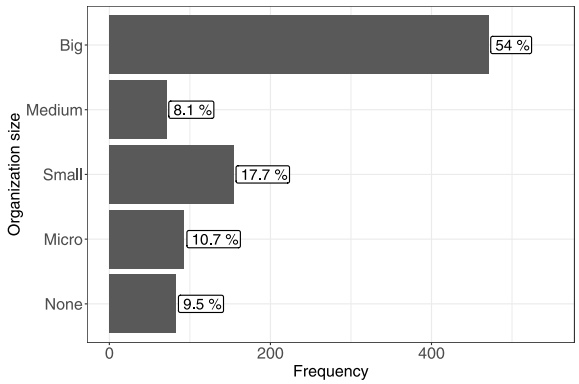

Fig. 5. Distribution of participants according to the size of their organization. The following scale was adopted for company size, considering the number of employees: micro (less than 9), small (10 to 49), medium (50 to 99), and big (more than 100).

Summary: The participants of our investigation come from all Brazilian macro-regions and most of them can be characterized as young (18 to 35 years old) professionals that hold at least a college degree and work mainly as mobile application developers with more than two years of experience in large-sized private companies.

5.2. Awareness and knowledge

Fig. 9 presents an overview of participants' perceptions on the use of mobile applications by visually impaired users since it is the most frequent disability worldwide. Note that almost all respondents know that a visually impaired user can use mobile applications (99%) and how they do so (85.9%). Nonetheless, a much smaller percentage of respondents know how to create accessible mobile apps (57.3%).

Fig. 10 shows the distribution of participants according to the assistive technologies they know. Note that the most popular assistive technology is the voice navigator (71.4%), followed by screen amplifier (66.4%), increased contrast (54.5%), screen reader (36.1%) and special keyboard (27.6%). Other assistive technologies such as tactile feedback, color adjustment, switch access and font adjustment were mentioned only by a small part of the participants, representing less than 1% of the participants each. Few participants (3.7%) had no knowledge of any assistive technology.

Being able to recognize assistive technologies, however, does not imply that participants understand that the mobile application needs to implement specific features so the assistive technology can work properly. One possible evidence of this conclusion is the fact that 57.3% of the participants do not know how to create accessible apps, which might also imply they are not aware of how assistive technologies work internally, while only 3.7% of the participants do not know any assistive technology.

Fig. 11 depicts the distribution of participants according to the accessibility guidelines they are aware of. WCAG is the most popular set of guidelines (33.8%), followed by Apple's UIKIT (29.7%) and Google's Material Design (27.1%). Only 5.5% of the respondents (48) know the Brazilian Accessibility Model (e-MAG) and 3.3% know the BBC guidelines. Few participants used specific guidelines, such as custom (0.5%) and GuAMA (Correia et al., 2019). 38.4% of participants do not know any set of guidelines.

Fig. 12 shows the distribution of participants according to their knowledge level on any accessibility standard or set of guidelines. The results show that a quarter of the participants had no knowledge on any guideline (25.1%). Most participants have only a very superficial knowledge on accessibility guidelines, as 29.7% of them have only read about it, while 22.7% have only heard about it, which represents about half of the participants. Only few participants said to hold a good theoretical (6.8%) or also practical knowledge (15.7%).

Fig. 13 shows the distribution of participants according to the source from which they gathered any information on digital accessibility. Many participants learned about accessibility in lectures (34.4%), followed by accessibility courses (17%), online material[3] (14.1%), and undergraduate course (11.5%). Participants also acquired knowledge on accessibility from coworkers (4.6%), design courses (4.2%), platform documentation (3.7%), and graduate course (2.6%). Only a small number of participants learned accessibility by their contact with people with disabilities (1.6%), in software development courses (1.3%) and other sources that represent less than 1% of the participants. A significant set of our sample (28.2%) has not acquired knowledge from any source of information.

We further analyzed our results with respect to the awareness and knowledge on digital accessibility by crossing data regarding the following dimensions of our questionnaire: job role, experience, organization size, organization type, and implementation platform. In the following paragraphs, Chi-Square tests report the statistic χ^2 (chi-square statistic), df (degrees of freedom) and p-value. Figures with significant differences in statistical tests were marked with an asterisk (*) in tables.

Table 3 shows a summary of the accessibility awareness and knowledge of the participants according to their job role. The distribution of participants by job roles is unbalanced because developers represent around 85% of the participants. Besides, the roles "Researcher" and "Software Architect" were not included in this analysis because there were fewer than five participants in each of these categories. When it comes to awareness, Column 3 shows whether participants knew how blind people use mobile applications and Column 4 shows whether participants knew how to create accessible applications. Regarding accessibility knowledge, Column 6 (Superficial) is the sum of "I've read about it" and "I've heard about it" answers (cf. Fig. 12). Column 7 refers to good theoretical knowledge and Column 8 to both good theoretical and good practical knowledge. The results show that there was no significant difference with respect to accessibility awareness across job roles, both concerning awareness of how blind people use mobile apps ($\chi^2 = 1.96$, df=4, p-value=0.74) and technical knowledge about technical aspects regarding how to create mobile apps ($\chi^2 = 0.68$, df=4, p-value=0.95). When it comes to levels of knowledge about technical guidelines, no significant difference was found in the proportions of answers when comparing job roles ($\chi^2 = 12.519$, df=9, p-value=0.18). However, there was a slight tendency in the group of designers to have more knowledge about guidelines. Most designers stated to have at least a superficial knowledge, and they are also the group with more practical knowledge on this subject, followed by testers.

Table 4 shows an analysis of the accessibility awareness and guidelines knowledge according to the participants' professional experience. There was a significant difference between the proportions of participants who were aware of how blind people use mobile apps ($\chi^2 = 21.196$, df=3, p-value < 0.001), with a significantly lower percentage of awareness by participants who had less than one year of experience, compared to others. A significant

[3] In this particular question, Online content refers to diversified sources of information mentioned by the participants, such as Blogs, specific web portals, online videos, a post on social media, and so forth. In a way, platform documentation could be considered Online content, but we decided to keep it as separate source since it is a set of structured and official documents, different from blog posts or social media content.

Table 3
Accessibility awareness and guidelines knowledge according to participants role in the development process.

Job role	N	Awareness		Guidelines knowledge			
		Users	Technical	None	Superficial	Theoretical	Practical
Designer	29	89.66%	37.93%	3.45%	62.07%	6.90%	27.59%
Developer	745	85.50%	43.22%	25.91%	52.61%	6.71%	14.77%
Management role	29	93.10%	37.93%	31.03%	41.38%	6.90%	20.69%
System analyst	42	85.71%	42.86%	23.81%	52.38%	7.14%	16.67%
Tester	20	90.00%	40.00%	20.00%	45.00%	10.00%	25.00%

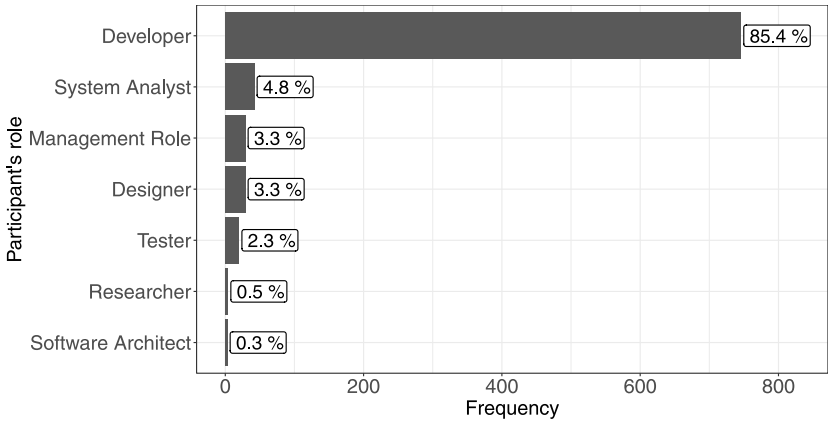

Fig. 6. Distribution of respondents according to their role in the software development process.

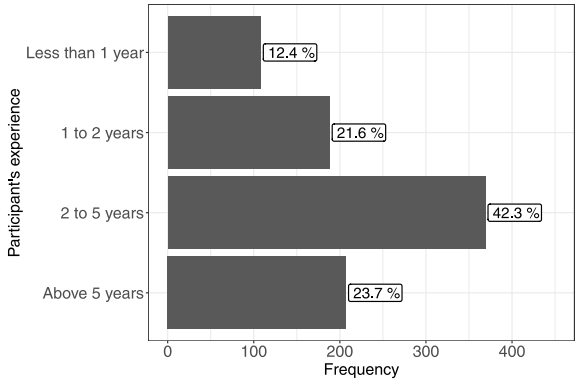

Fig. 7. Distribution of participants according to their experience (in years) of mobile application development.

difference was also found when comparing the level of awareness about technical aspects of creating accessible apps ($\chi^2 = 90.027$, df=3, p-value < 0.001). The percentage of participants who were aware of how to create accessible apps increased with years of experience with software development. A significant difference was also found when comparing the levels of knowledge about technical accessibility guidelines when comparing the years of experience participants had ($\chi^2 = 242.217$, df=9, p-value < 0.001).

Table 5 presents an analysis of the accessibility awareness and guidelines knowledge according to the organization size. A significant difference was found in the awareness about how blind people use mobile apps ($\chi^2 = 18.249$, df=4, p-value < 0.01). A significant difference was also found on the awareness about how to make accessible apps ($\chi^2 = 65.088$, df=4, p-value < 0.001) when comparing participants from different organization sizes. Significant differences were also found when comparing the levels of knowledge of accessibility guidelines between participants from companies from different sizes ($\chi^2 = 48.371$, df=12, p-value < 0.001). The results suggest that participants who work for larger companies tend to have more awareness and more practical knowledge about accessibility guidelines.

Table 6 shows an analysis of the accessibility awareness and guidelines knowledge according to the organization type. Research/Education and Open Source are not presented in this table because few participants fit into these categories. A significant difference was found between the awareness of how blind users use mobile apps ($\chi^2 = 9.589$, df=3, p-value < 0.05), and the awareness about technical guidelines for accessibility ($\chi^2 = 20.015$, df=3, p-value < 0.001). However, no significant difference was found in the proportion of participants in different levels of knowledge about guidelines according to the organization type ($\chi^2 = 13.064$, df=9, p-value $= 0.16$). It seems participants who worked for private companies had more awareness about users and technical aspects, while participants who worked for public companies had slightly more theoretical and practical knowledge. Participants that are freelancers or develop applications in personal projects seem to have less awareness and knowledge in general. Notice that the distribution of participants across this dimension is unbalanced, since 80% of the participants worked for private companies. Therefore a more significant comparison would require more participants in each category.

Table 7 shows the accessibility awareness and guidelines knowledge according to the implementation platform. A significant difference was found in the comparison between developers of Android and iOS platforms between the awareness of how blind users use mobile apps ($\chi^2 = 16.523$, df=2, p-value < 0.001), and the awareness about technical guidelines for accessibility ($\chi^2 = 61.687$, df=2, p-value < 0.001). There was also a significant difference in the levels of knowledge of accessibility guidelines between the participants who develop for Android and iOS ($\chi^2 = 26.035$, df $= 6$, p-value < 0.001). It seems that iOS developers have more awareness and knowledge than Android developers or developers that build applications for both platforms.

Tables 8 to 12 show the accessibility guidelines known or recognized by participants according to their role in the development process, professional experience, organization size,

Table 4
Accessibility awareness and guidelines knowledge according to the participants experience.

Experience	N	Awareness		Guidelines knowledge			
		Users	Technical	None	Superficial	Theoretical	Practical
Less than 1 year	108	72.22% *	25.00% *	34.26% *	49.07% *	3.70% *	12.96% *
1 to 2 years	188	84.57% *	28.72 * %	28.72% *	55.32% *	4.79% *	11.17% *
2 to 5 years	369	88.89% *	48.24% *	24.39% *	51.22% *	7.86% *	16.53% *
Above 5 years	207	88.89% *	54.59% *	18.36% *	53.62% *	8.21% *	19.81% *

Table 5
Accessibility awareness and guidelines knowledge according to the organization size.

Org. size	N	Awareness		Guidelines knowledge			
		Users	Technical	None	Superficial	Theoretical	Practical
None	83	77.11%	20.48%	34.94%	55.42%	4.82%	4.82%
Micro	93	78.49%	27.96%	31.18%	53.76%	4.30%	10.75%
Small	154	83.12%	29.87%	28.57%	57.79%	8.44%	5.19%
Medium	71	83.10%	35.21%	26.76%	57.75%	4.23%	11.27%
Large	471	90.23%	54.78%	20.81%	49.04%	7.43%	22.72%

Table 6
Accessibility awareness and guidelines knowledge according to the organization type.

Org. type	N	Awareness		Guidelines knowledge			
		Users	Technical	None	Superficial	Theoretical	Practical
Freelancer	62	74.19% *	20.97% *	32.26%	56.45%	3.23%	8.06%
Personal projects	67	82.09% *	34.33% *	31.34%	56.72%	1.49%	10.45%
Private Company	691	87.55% *	46.16% *	24.46%	51.66%	7.24%	16.64%
Public Company	43	83.72% *	30.23% *	16.28%	55.81%	9.30%	18.60%

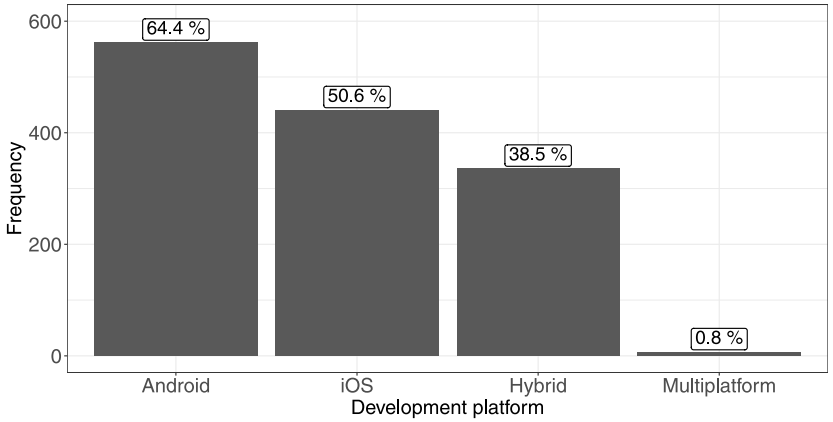

Fig. 8. Distribution of participants according to the mobile platforms. Participants were allowed to choose more than one answer.

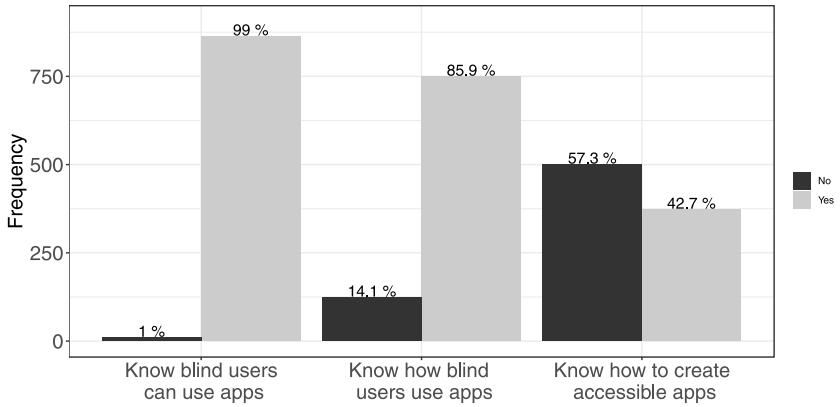

Fig. 9. Participants' awareness with respect to mobile applications usage by and development for blind users.

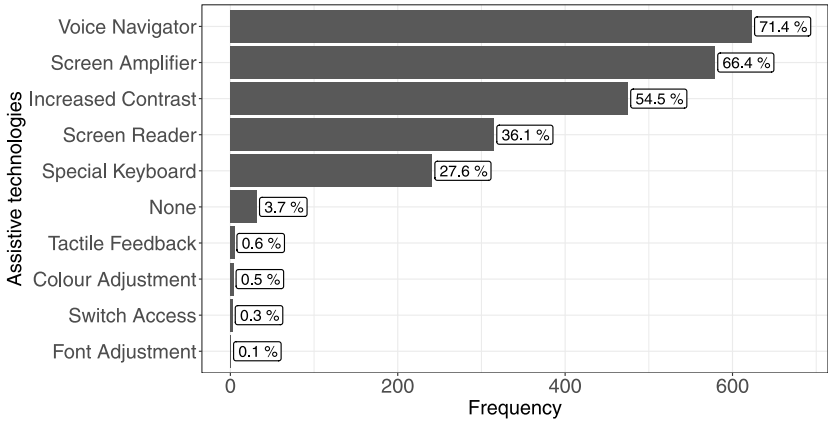

Fig. 10. Distribution of participants according to the assistive technologies they know.

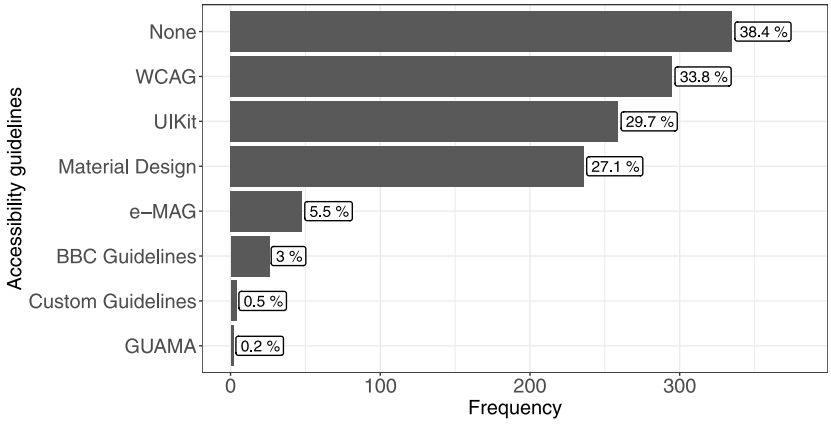

Fig. 11. Distribution of participants according to the accessibility guidelines, models or standards they are aware of.

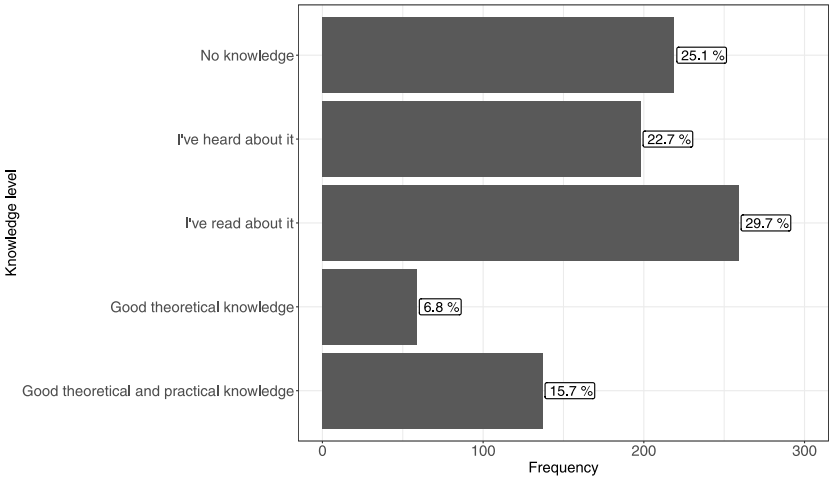

Fig. 12. Distribution of participants according to their knowledge level on accessibility guidelines.

Table 7
Accessibility awareness and guidelines knowledge according to the implementation platform.

Platform	N	Awareness		Guidelines knowledge			
		Users	Technical	None	Superficial	Theoretical	Practical
Android	332	83.43% *	37.35% *	28.61% *	53.01% *	5.12% *	13.25% *
iOS	212	94.34% *	65.09% *	17.45% *	48.58% *	8.96% *	25.00% *
Both	328	82.93% *	33.54% *	26.52% *	54.27% *	7.01% *	12.20% *

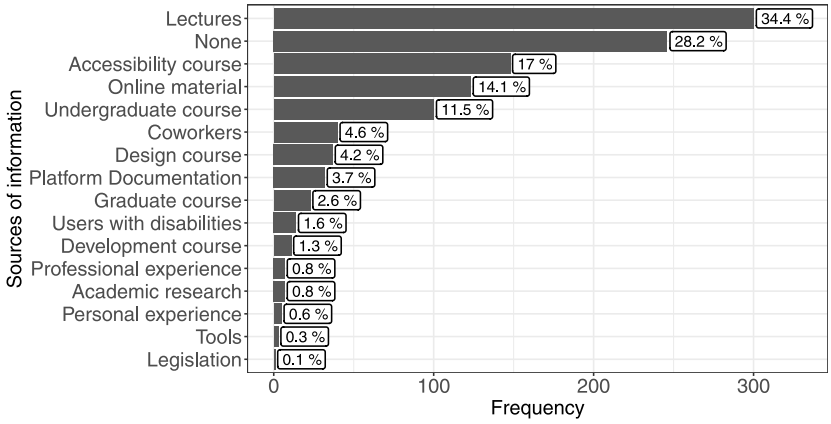

Fig. 13. Distribution of participants according to their source of information on digital accessibility.

Table 8
Known or recognized accessibility guidelines according to the participants role in the development process.

Job role	N	None	WCAG	Platform	BBC	E-MAG
Designer	29	13.8% *	72.4% *	65.5% *	13.8% *	17.2% *
Developer	745	40.4% *	31.0% *	57.3% *	2.3% *	4.0% *
Manager	29	34.5% *	44.8% *	48.3% *	6.9% *	3.4% *
Analyst	42	33.3% *	38.1% *	59.5% *	2.4% *	4.8% *
Tester	20	15.0% *	55.0% *	35.0% *	10.0% *	45.0% *

Table 9
Known or recognized accessibility guidelines according to the participants experience.

	N	None	WCAG	Platform	BBC	E-MAG
Less than 1 year	108	50.0% *	25.9% *	38.0%	2.8%	6.5%
1 to 2 years	188	43.1% *	27.7% *	51.1%	2.7%	3.7%
2 to 5 years	369	37.4% *	34.7% *	58.3%	3.0%	6.0%
Above 5 years	207	30.0% *	42.0% *	69.1%	3.4%	5.8%

Table 10
Known or recognized accessibility guidelines according to the organization size.

Org. size	N	None	WCAG	Platform	BBC	E-MAG
None	83	51.8% *	22.9% *	44.6%	3.16%	1.2%
Micro	93	52.7% *	28.0% *	41.9%	1.1%	4.3%
Small	154	43.5% *	22.7% *	53.2%	1.9%	7.8%
Medium	71	40.8% *	39.4% *	45.1%	7.0%	8.5%
Large	471	31.2% *	39.7% *	64.18%	3.0%	5.3%

Table 11
Known or recognized accessibility guidelines according to the organization type.

Org. type	N	None	WCAG	Platform	BBC	E-MAG
Freelancer	62	41.9% *	32.3%	61.3%	1.6%	3.2% *
Personal projects	67	53.7% *	22.4%	41.8%	1.5%	4.5% *
Private company	691	37.5% *	34.9%	57.3%	3.0%	4.9% *
Public company	43	27.9% *	39.5%	60.5%	4.7%	20.9% *

organization type and implementation platform. There were significant differences across different job roles in the knowledge about WCAG ($\chi^2 = 40.006$, df=4, p-value < 0.001), about the platform's guidelines ($\chi^2 = 11.483$, df=4, p-value < 0.05), about eMAG ($\chi^2 = 16.494$, df=4, p-value < 0.01) and the BBC's guidelines ($\chi^2 = 17.832$, df=4, p-value < 0.05). Designers seem to be more aware of the WCAG than other professionals, while Testers seem to be more aware of the Brazilian Accessibility Model (e-MAG) than other participants. Few participants were aware of the BBC's guidelines and most participants were aware of platform guidelines (UIKIT from iOS and Material Design from Android), with a lower level of knowledge from testers.

Table 9 suggests that guidelines awareness increases along with professional experience, except when it comes to e-MAG and the BBC's guidelines. There were significant differences among participants with different experience in the knowledge about WCAG ($\chi^2 = 8.743$, df=3, p-value < 0.05) and about the Android and iOS guidelines ($\chi^2 = 22.965$, df=3, p-value < 0.001). However, no significant differences were found in the knowledge about the BBC's guidelines ($\chi^2 = 0.769$, df=3, p-value $= 0.85$) and about e-MAG ($\chi^2 = 3.921$, df=3, p-value $= 0.27$). Similarly, participants who work for bigger companies seem to be more aware of accessibility guidelines.

Table 10 shows the distribution of the percentages of participants according to the size of the organizations they are linked to. Significant differences were found between the participants from organizations of different sizes in the knowledge about WCAG ($\chi^2 = 33.504$, df=4, p-value < 0.001) and the platforms' guidelines ($\chi^2 = 15.624$, df=4, p-value < 0.01). However, no significant differences were found in the proportion of participants regarding the knowledge about the BBC's guidelines ($\chi^2 = 1.357$, df=4, p-value=0.85) and e-MAG ($\chi^2 = 0.601$, df=4, p-value=0.96).

Table 11 shows the distribution of responses about knowledge about different sets of guidelines according to the type of the participants' organization. Significant differences were found across the types of organizations for knowledge about WCAG ($\chi^2 = 9.003$, df=3, p-value < 0.05) and e-MAG ($\chi^2 = 38.97$, df=3, p-value < 0.001). Participants involved in personal projects had a higher level of knowledge about WCAG, and participants from public organizations had a higher level of knowledge about e-MAG. No significant differences were found across participants from different types of organizations in the level of knowledge about the platforms' guidelines ($\chi^2 = 2.213$, df=3, p-value=0.53) and the BBC's guidelines ($\chi^2 = 1.207$, df=3, p-value=0.75).

Table 12 shows that participants that develop mobile applications only for iOS are more aware of accessibility guidelines than participants that develop only for Android or for both platforms. No significant differences were found among developers of different platforms in the knowledge of general-use accessibility guidelines, such as WCAG ($\chi^2 = 2.446$, df=2, p-value $= 0.29$), e-MAG ($\chi^2 = 0.504$, df=2, p-value $= 0.77$) and the BBC's guidelines ($\chi^2 = 2.734$, df=2, p-value $= 0.25$). Significant differences across participants who develop for different platforms were found for the knowledge about Apple's UIKit ($\chi^2 = 432.422$, df=2, p-value < 0.001) and Google's Material Design ($\chi^2 = 29.076$, df=2, p-value < 0.001). However, iOS developers were much more aware of the design recommendations of the iOS platform (UIKit) than Android developers of their platform recommendations (Material Design).

Table 12
Known or recognized accessibility guidelines according to the implementation platform.

Platform	N	None	WCAG	UIKit	Mat.Design	BBC	E-MAG
Android	332	47.6%	31.0%	6.3% *	31.9% *	4.2%	3.92%
iOS	212	20.3%	31.6%	72.6% *	11.3% *	1.9%	6.13%
Both	328	40.9%	38.1%	25.6% *	32.3% *	2.4%	6.71%

Table 13
Accessibility guidelines adoption according to accessibility knowledge.

Knowledge	N	Nothing	A little	Partially	Totally
None	219	56%	34%	7%	3%
Superficial	457	25%	43%	25%	7%
Theoretical	59	8%	51%	29%	12%
Theoretical/Practical	137	1.5%	6.5%	34%	57.6%

Summary: Most participants are aware that people with disabilities are mobile platform users, but most of them do not know how to create accessible applications. Only a small percentage of participants had a deep theoretical and practical knowledge on specific accessibility standards and guidelines required to build accessible products. Most participants learned about accessibility in specific lectures, courses or online material. Cross data analysis suggest that awareness and knowledge increases if the professional has more experience and works for larger organizations. App developers for the iOS platform have more knowledge about the platform's design guidelines than Android developers.

5.3. Accessibility adoption

Fig. 14 shows the distribution of participants according to how much they employ accessibility recommendations in their projects. Note that accessibility is scarcely adopted since 35.6% of the participants answered "A little" and 27.9% answered "nothing" to the question "how much of accessibility guidelines is adopted in your development process?". Only 22.2% of the participants partially adopt accessibility during development, while just 14.3% fully adopt guidelines in the development process.

Fig. 15 shows the distribution of participants according to the guidelines they adopt during mobile application development. Note that 54% of participants do not use any particular guideline. Some of them do not use any particular guideline because they do not take accessibility into account (cf. Fig. 14), but some participants implement some accessibility requirements that are commonly known (e.g. use labels for non-textual elements). Considering participants that do adopt some specific standard or guideline, 22.9% apply UIKit (Apple), 19.3% use the WCAG and 16.7% employ Material Design principles. Some participants use the e-MAG (2.3%), the BBC guideline (1.3%) and GuAMA (0.1%).

Even though lack of knowledge was mentioned by 3% of the participants, we crossed the data concerning accessibility knowledge with accessibility adoption to understand the possible influence in this scenario. Table 13 shows the results of this analysis.

Participants that have both good theoretical and practical knowledge on accessibility guidelines adopt guidelines partially (34%) or totally (57.2%). When it comes to participants that only have superficial knowledge, the partial adoption of accessibility principles is 19% and the full adoption is 6%.

We analyzed the accessibility adoption levels and the adopted guidelines in software development projects by job roles, participants experience, organization size, organization type, implementation platform and knowledge level. In such analysis, we did not include standards and guidelines mentioned by less than five participants. Platform recommendations such as Material Design (Android) and UIKit (iOS) are combined for the sake of our analysis, except when it comes to the influence of the implementation platform on the accessibility guidelines usage.

Table 14 shows that there are no significant differences with respect to the levels of adoption of accessibility practices during the development process across different roles ($\chi^2 = 17.989$, df = 12, p-value = 0.116). There was a slight tendency that designers would likely adopt accessibility guidelines more than participants in other job roles. Significant differences were found across the different job roles on the adoption of WCAG ($\chi^2 = 13.423$, df = 4, p-value < 0.01), the platforms' guidelines ($\chi^2 = 11.483$, df = 4, p-value < 0.05), the BBC's guidelines ($\chi^2 = 17.832$, df = 4, p-value < 0.01) and e-MAG ($\chi^2 = 16.494$, df = 4, p-value < 0.01). Designers are also the top adopters of accessibility recommendations, especially the WCAG.

Table 15 indicates that, even though awareness and knowledge increase with experience (cf. Table 4), it does not significantly influence the partial or total adoption of accessibility guidelines. No significant difference was found in the level of adoption of accessibility guidelines across the different levels of experience ($\chi^2 = 16.081$, df = 9, p-value = 0.06). On the other hand, adoption of recommendations of specific guidelines seems to increase along with the participant's experience. Significant differences were found across the different levels of experience on the adoption of WCAG ($\chi^2 = 8.743$, df = 3, p-value < 0.05) and the platforms' guidelines ($\chi^2 = 22.965$, df = 3, p-value < 0.001). No significant differences were found on the adoption of the BBC's guidelines ($\chi^2 = 0.769$, df = 3, p-value = 0.856) and e-MAG ($\chi^2 = 3.921$, df = 3, p-value = 0.27).

Table 16 shows the breakdown of adoption of accessibility guidelines by participants according to the size of their organizations. No significant difference was found across participants from organizations of different sizes regarding the levels of adoption of guidelines ($\chi^2 = 9.24$, df = 9, p-value = 0.415). Significant differences were found across participants affiliated to organizations of different sizes in the adoption of WCAG ($\chi^2 = 33.504$, df = 4, p-value < 0.001) and the platforms' guidelines ($\chi^2 = 15.624$, df = 4, p-value < 0.01). No significant differences were found for the adoption of the BBC's guidelines ($\chi^2 = 1.357$, df = 4, p-value = 0.85) and e-MAG ($\chi^2 = 0.601$, df = 4, p-value = 0.96). The results showed that larger organizations tend to have higher levels of accessibility adoption and to follow specific guidelines. This is particularly clear when it comes to a specific platform (e.g. iOS, Android) recommendations for designing usable and accessible products.

According to the results presented in Table 17, no significant differences were found in the level of accessibility adoption across organization types ($\chi^2 = 12.857$, df = 9, p-value = 0.169). With regards to specific guidelines, no significant differences were found across participants affiliated to different organization types in the adoption of WCAG ($\chi^2 = 4.689$, df = 3, p-value = 0.196), the platforms' guidelines ($\chi^2 = 2.213$, df = 3, p-value = 0.529), the BBC's guidelines ($\chi^2 = 1.746$, df = 3, p-value = 0.626). A significant difference was found in the adoption of e-MAG ($\chi^2 = 38.97$, df = 3, p-value < 0.001). Despite still low, participants from public organizations had a significantly higher adoption level of e-MAG.

Table 18 shows that, in addition to having more awareness and knowledge on digital accessibility, iOS developers have higher adoption levels of accessibility in practice. A significant difference was found across the different platforms participants developed for in the level of adoption of accessibility guidelines ($\chi^2 = 49.551$, df = 6, p-value < 0.001). Significant differences were found across the types of platforms on the adoption of UIKit ($\chi^2 = 268.655$, df = 2, p-value < 0.001) and Material Design ($\chi^2 = 29.076$, df = 2, p-value < 0.001)

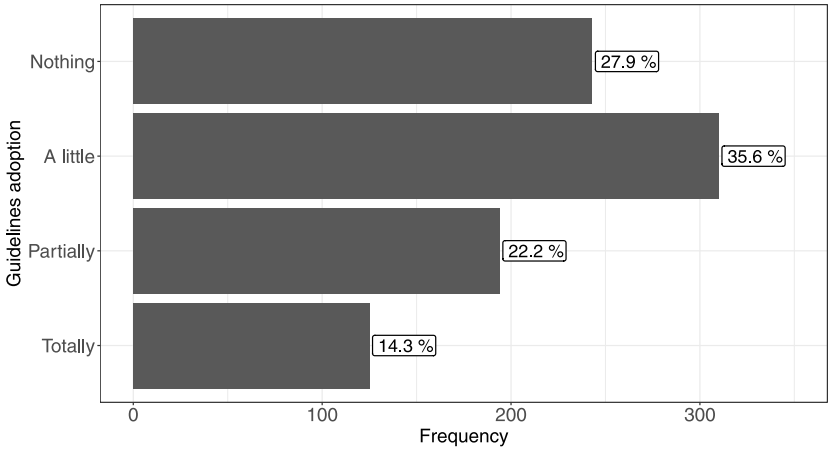

Fig. 14. Distribution of participants according to how much they employ accessibility recommendations in their projects. Participants had to pick an option in an increasing adoption level: nothing, a little, partially and totally.

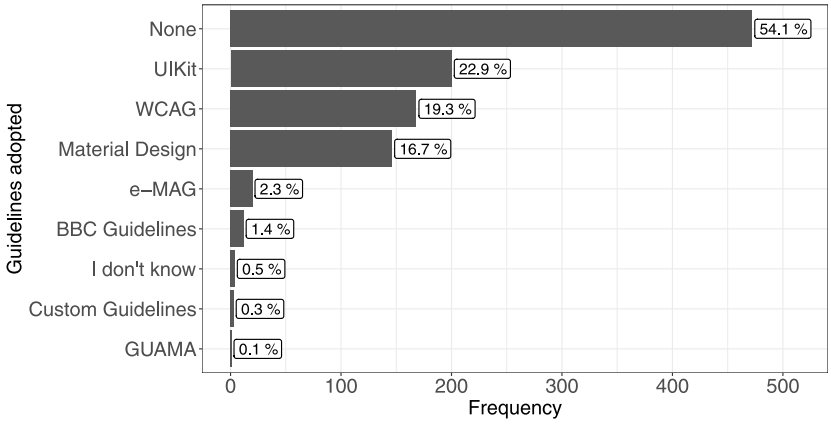

Fig. 15. Accessibility guidelines adopted by participants.

Table 14
Accessibility guidelines adoption according to the role of the participant in the development process.

Job role	N	Adoption level				Adopted standard/Guideline				
		Nothing	A little	Partially	Totally	None	WCAG	Platform	BBC	eMAG
Designer	29	6.9%	34.5%	41.4%	17.2%	27.6%	58.6% *	48.3% *	6.9% *	10.3% *
Developer	745	28.3%	36%	21.7%	14%	55.3%	16.5% *	40% *	1.1% *	1.7% *
Manager	29	41.4%	24.1%	27.6%	6.9%	55.2%	27.6% *	34.5% *	3.4% *	3.4% *
Analyst	42	33.3%	31%	16.7%	19%	54.8%	23.8% *	42.9% *	2.4% *	0% *
Tester	20	20%	45.0%	15%	20%	60%	40% *	5% *	0% *	10% *

Table 15
Accessibility guidelines adoption according to the participants experience.

Experience	N	Adoption level				Adopted standard/Guideline				
		Nothing	A little	Partially	Totally	None	WCAG	Platform	BBC	eMAG
Less than 1y	108	35.2%	25%	20.4%	19.4%	63%	16.7% *	24.1% *	0.9%	2.8%
1 to 2y	188	33%	31.9%	23.9%	11.2%	59.6%	14.4% *	33% *	1.1%	1.1%
2 to 5y	369	25.2%	37.9%	23%	13.8%	52.6%	19% *	42.5% *	1.4%	1.9%
Above 5y	207	24.2%	40.1%	20.3%	15.5%	47.3%	25.6% *	48.8% *	1.9%	3.9%

No significant differences were found on the adoption of WCAG ($\chi^2 = 2.446$, df $= 2$, p-value $= 0.29$), the BBC's guidelines ($\chi^2 = 2.734$, df $= 2$, p-value $= 0.254$) and e-MAG ($\chi^2 = 0.504$, df $= 2$, p-value $= 0.777$). The adoption level of design principles and recommendations of their own development platform is higher for iOS developers (UIKit) than for Android developers (M.D. - Material Design).

Table 16
Accessibility guidelines adoption according to the organization size.

Org. size	N	Adoption level				Adopted standard/Guideline				
		Nothing	A little	Partially	Totally	None	WCAG	Platform	BBC	eMAG
None	83	32.5%	32.5%	26.5%	8.4%	65.1%	10.8% *	28.9% *	2.4%	1.2%
Micro	93	35.5%	36.6%	19.4%	8.6%	60.2%	15.1% *	31.2% *	1.1%	2.2%
Small	154	39%	39%	18.8%	3.2%	64.9%	6.5% *	36.4% *	0.6%	2.6%
Medium	71	39.4%	40.8%	12.7%	7%	63.4%	19.7% *	32.4% *	1.4%	2.8%
Large	471	20.2%	34%	24.6%	21.2%	46.1%	25.7% *	45.4% *	1.5%	2.3%

Table 17
Accessibility guidelines adoption according to the organization types.

Org. type	N	Adoption level				Adopted standard/Guideline				
		Nothing	A little	Partially	Totally	None	WCAG	Platform	BBC	eMAG
Freelancer	62	40.3%	30.6%	14.5%	14.5%	59.7%	17.7%	35.5%	0%	1.6% *
Pers.Prj.	67	25.4%	32.8%	29.9%	11.9%	61.2%	10.4%	32.8%	1.5%	1.5% *
Priv. Org.	691	27.6%	36.8%	21%	14%	53.5%	19.8%	40.2%	1.3%	1.6% *
Pub. Org.	43	20.9%	30.2%	34.9%	14.0%	51.2%	25.6%	44.2%	2.3%	16.3% *

Table 18
Accessibility guidelines adoption according to the implementation platform.

Platform	N	Adoption level				Adopted standard/Guideline					
		Nothing	A little	Partially	Totally	None	WCAG	UIKit	M.D.	BBC	eMAG
Android	332	31.6% *	32.5% *	22.3% *	13.6% *	63.9%	17.8% *	2.4% *	20.8%	2.1%	2.1%
iOS	212	15.6% *	32.5% *	26.4% *	25.5% *	31.6%	17.5% *	62.3% *	4.7%	1.4%	1.9%
Both	328	32.0% *	40.5% *	19.5% *	7.9% *	58.8%	22.0% *	18.3% *	20.4%	0.6%	2.7%

Summary: Accessibility standards and guidelines are fully implemented in the mobile development process by only a few participants. Cross data analysis shows that only participants with both theoretical and practical knowledge tend to partially or fully adopt accessibility guidelines in their projects. Results also show that specific accessibility standards and guidelines tend to be more adopted by designers, by professionals in larger organizations, and by participants that build applications for the iOS platform.

5.4. Accessibility evaluation

Fig. 16 shows the distribution of participants according to the accessibility evaluation methods adopted. Most participants (56%) do not use any accessibility evaluation method. Hence, those who use some method add up to 44%, subdivided in: user testing (people with disability – 25.6% – and elderly users – 6.1%), using automated testing tools (15.8%), manual evaluation using the guidelines (17.1%), evaluation with assistive technologies (14.1%), third party evaluation (7%) and considering user reviews from the app store (0.1%).

We cross analyzed accessibility evaluation according to participants job role, experience, organization size, organization type, and platform. Table 19 shows the percentages of responses regarding types of evaluation methods used by respondents in different job roles. Significant differences were found across the roles in the use of automated tools ($\chi^2 = 24.838$, df = 4, p-value < 0.001), manual inspections ($\chi^2 = 25.262$, df = 4, p-value < 0.001) and user evaluations ($\chi^2 = 29.669$, df = 4, p-value < 0.001). No significant differences were found in the use of third-party evaluations ($\chi^2 = 4.646$, df = 4, p-value = 0.32). Testers had the highest rates of usage of automated tools, manual evaluations and user evaluations. Designers also had a relatively higher percentage of use of manual inspections and user evaluations than other job roles.

Table 20 presents the percentage of participants who employed different evaluation methods according to their experience level. Significant differences were found across the experience levels concerning the use of manual evaluations ($\chi^2 = 7.818$, df = 3, p-value < 0.05) and user evaluations ($\chi^2 = 9.445$, df = 3, p-value < 0.05). However, no significant differences were found on the use of automated evaluation methods ($\chi^2 = 7.557$, df = 3, p-value=0.056) and third-party evaluations ($\chi^2 = 5.335$, df = 3, p-value = 0.114). These results show that manual inspections and user evaluations had a higher prevalence among participants with more experience.

Table 19
Accessibility evaluation according to the participants role in the development process.

Job role	N	None	Aut. tools	Manual	Users	Third party
Designer	29	34.5% *	24.1% *	44.8% *	48.3% *	10.3%
Developer	745	57.3% *	15.2% *	29.1% *	21.6% *	7.1%
Manager	29	51.7% *	20.7% *	41.4% *	24.1% *	0.0%
Analyst	42	61.9% *	7.1% *	21.4% *	11.9% *	9.5%
Tester	20	40.0% *	25.0% *	75.0% *	60.0% *	0.0%

Table 21 shows the percentages of participants who used different evaluation methods according to the size of the organization they work for. Significant differences were found across the sizes of organizations regarding the use of automated evaluation ($\chi^2 = 18.108$, df = 4, p-value < 0.01), manual inspections ($\chi^2 = 46.918$, df = 4, p-value < 0.001), user evaluations ($\chi^2 = 72.08$, df = 4, p-value < 0.001) and third-party evaluations ($\chi^2 = 15.98$, df = 4, p-value < 0.01). This suggests that larger companies tend to employ more accessibility evaluation methods than smaller organizations.

Table 22 shows the percentage of participants who employ accessibility evaluation methods according to the type of organization they are affiliated to. No significant differences were found across the organization types regarding the use of methods of automated evaluations ($\chi^2 = 2.639$, df = 3, p-value = 0.45), manual inspections ($\chi^2 = 4.975$, df = 3, p-value = 0.17) and third-party evaluations ($\chi^2 = 1.037$, df = 3, p-value = 0.79). A significant difference was found in the use of user evaluation methods ($\chi^2 = 9.42$, df = 3, p-value < 0.05). Participants deemed as "freelancers" had a significantly lower level of adoption of user evaluation methods than participants in other organization types.

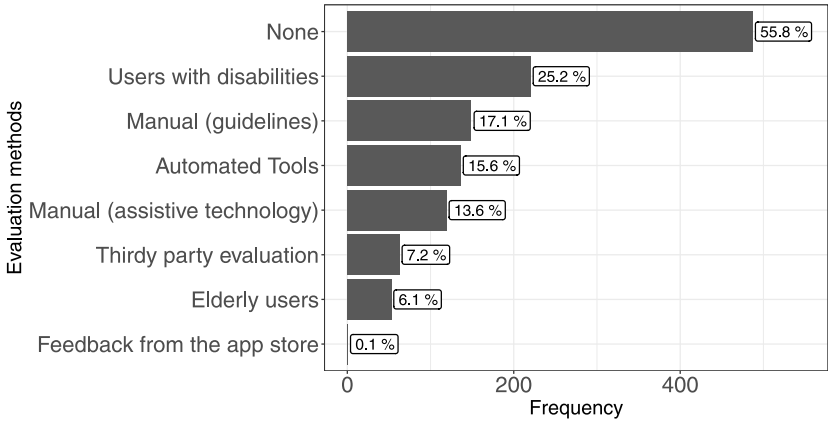

Fig. 16. Accessibility evaluation methods used by the participants.

Table 20
Accessibility evaluation according to the participants experience.

Experience	N	None	Aut. tools	Manual	Users	Third party
Less than 1 year	108	64.8%	9.3%	24.1% *	25.0% *	5.6%
1 to 2 years	188	60.6%	13.3%	25.0% *	27.1% *	7.4%
2 to 5 years	369	56.1%	16.0%	33.6% *	30.9% *	5.7%
Above 5 years	207	46.4%	20.3%	34.3% *	39.1% *	10.6%

Table 21
Accessibility evaluation according to the organization size.

Org. size	N	None	Aut. tools	Manual	Users	Third party
None	83	71.1%	8.4% *	16.9% *	10.8% *	4.8% *
Micro	93	63.4%	18.3% *	16.1% *	29.0% *	4.3% *
Small	154	74.7%	7.1% *	19.5% *	14.3% *	2.6% *
Medium	71	67.6%	12.7% *	26.8% *	18.3% *	2.8% *
Large	471	43.7%	19.5% *	40.3% *	42.9% *	10.4% *

Table 23 shows the percentages of participants who stated they use different types of evaluation methods according to the platforms they develop for. Significant differences were found across participants who develop for different platforms in the adoption of manual evaluations ($\chi^2 = 22.727$, df $= 2$, p-value < 0.001) and user evaluation ($\chi^2 = 30.912$, df $= 2$, p-value < 0.001). No significant differences were found for automated evaluations ($\chi^2 = 3.535$, df $= 2$, p-value $= 0.17$) and for third-party evaluations ($\chi^2 = 5.184$, df $= 2$, p-value $= 0.07$). The results indicate that the level of accessibility evaluation with manual and user evaluation is higher in the development of mobile apps for the iOS platform than those involved in Android or multi platform projects.

Fig. 17 shows the distribution of participants according to the testing tools or frameworks they use in mobile application development. It is important to emphasize that responses include testing tools for mobile apps in general, which may or may not include accessibility testing. The results show that nearly 50% of the participants do not use any tool. Espresso is the most popular (25.2%), followed by Apium (16.6%), Accessibility Inspector (10%), UiAutomator (9.5%), KIF (6.5%), Robotium (4.8%), Monkey (4.6%), Mobile Accessibility Checker (2.5%), XCUITest (1%), EarlGrey (0.8%) and XCTest (0.7%).

A cross analysis of tool adoption by participants experience, organization size, level of knowledge and level of adoption can provide us with some insight in this subject. Considering the tools mentioned by more than 10 participants, significant differences were encountered in the level of adoption of at least one mobile accessibility automated evaluation tool, when analyzing groups by level of experience ($\chi^2 = 71.531$, df $= 3$, p-value < 0.001), organization size ($\chi^2 = 68.836$, df $= 4$, p-value < 0.001), level of knowledge about accessibility standards and guidelines ($\chi^2 = 63.462$, df $= 3$, p-value < 0.001) and level of adoption of accessibility guidelines ($\chi^2 = 62.906$, df $= 3$, p-value < 0.001). It seems that the level of adoption concerning at least one tool generally increases with experience (cf. Table 24), organization size (cf. Table 25), knowledge level (cf. Table 26) and degree of accessibility adoption (cf. Table 27). Specifically, it is noticeable how the usage of the Accessibility Inspector tool, a tool designed for supporting accessibility evaluation, increases along with those dimensions. Other tools, such as Espresso, are more widely used by more experienced developers than by those with fewer years of experience.

Summary: Accessibility evaluation is fully conducted in the mobile development process of only a few participants. In addition, tools that support accessibility evaluation are scarcely used. Cross analysis shows that the adoption of any method of accessibility evaluation is higher for most experienced professionals, larger companies and iOS developers. The employment of general or accessibility-specific automated tools increases with professional experience, organization size, level of accessibility knowledge and adoption.

5.5. Motivations and barriers

Fig. 18 presents the distribution of participants according to their reasons to consider developing accessible applications. The main reasons are to foster digital inclusion (55.6%) and due to personal motivations (33.1%). Many respondents are also motivated by the fact that accessibility is in project requirements (28.2%) and that accessible projects increase the range of target users (27.1%). Some participants are motivated because accessibility is an organizational requirement (18.2%) or because it is required by the law (17.9%). Some other reasons were mentioned by a small number of participants, such as simply to follow guidelines (0.2%), to make user interface testing easier (0.1%) and to increase the app reputation (0.1%).

Table 28 shows the main motivations presented by more than 10 participants according to the organization size. Significant

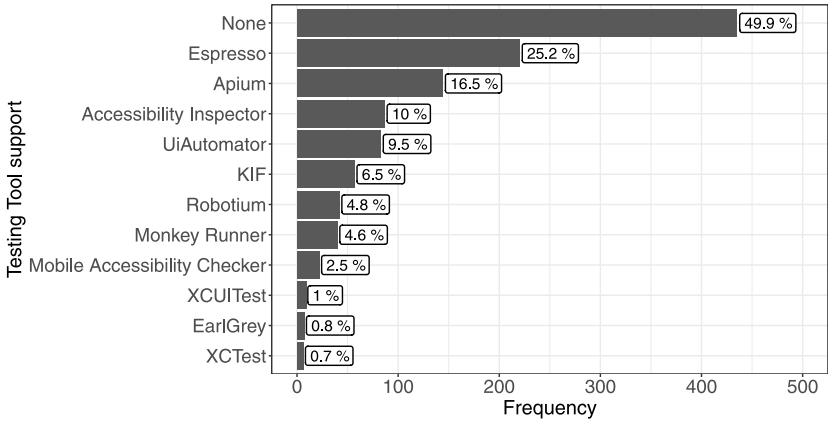

Fig. 17. Testing tools/frameworks used by participants. We only show tools that has been selected by at least 5 participants since many tools have been mentioned by only one individual (e.g. SES, AZE, Calabash, Cavy, Cucumber, Detox, Flutter Driver, Inspecto, Katlan, Lighthouse, Lint, Mockito, Robolectric, Selenium, TestFlight, UITests, Voice Over, Xamarin.UITest).

Table 22
Accessibility evaluation according to the organization type.

Org. type	N	None	Aut. tools	Manual	Users	Third party
Freelancer	62	64.5%	16.1%	22.6%	14.5% *	4.8%
Personal projects	67	65.7%	9.0%	26.9%	31.3% *	6.0%
Private company	691	54.6%	16.4%	32.1%	33.1% *	7.5%
Public company	43	51.2%	14.0%	20.9%	27.9% *	9.3%

Table 23
Accessibility evaluation according to the implementation platform.

Platform	Participants	None	Aut. tools	Manual	Users	Third party
Android	332	58.4%	12.7%	26.2% *	26.8% *	12.4%
iOS	212	42.9%	17.5%	43.9% *	46.7% *	24.2%
Both	328	61.6%	17.4%	26.8% *	25.9% *	8.4%

Table 24
Testing tools and frameworks used according to participants experience.

Experience	N	None	Espresso	Appium	Acc. Insp.	UIAut.	KIF	Robotium	Monkey runner	MobAcc checker
<1 year	108	73.1% *	6.5%	5.6%	6.5%	2.8%	2.8%	0.9%	1.9%	0.9%
1–2 years	188	65.4% *	17.6%	8.5%	5.3%	5.3%	1.1%	2.7%	4.3%	2.7%
2–5 years	369	45.3% *	28.7%	17.6%	14.1%	7.9%	8.1%	5.1%	3.5%	2.2%
>5 years	207	31.9% *	35.7%	27.5%	8.7%	19.8%	10.6%	8.2%	8.2%	3.9%

Table 25
Testing tools and frameworks used according to the organization size.

Org. size	N	None	Espresso	Appium	Acc. Insp.	UIAut.	KIF	Robotium	Monkey runner	MobAcc checker
None	83	75.9% *	6.0%	7.2%	3.6%	4.8%	0.0%	2.4%	3.6%	1.2%
Micro	93	72.0% *	9.7%	3.2%	8.6%	6.5%	2.2%	4.3%	4.3%	3.2%
Small	154	58.4% *	26.6%	11.0%	5.2%	9.1%	0.6%	7.1%	4.5%	1.3%
Medium	71	45.1% *	31.0%	14.1%	5.6%	9.9%	4.2%	5.6%	5.6%	4.2%
Large	471	38.9% *	30.4%	22.9%	13.6%	11.0%	10.8%	4.5%	4.7%	2.8%

Table 26
Testing tools and frameworks used according to the level of knowledge regarding accessibility standards and guidelines.

Knowledge	N	None	Espresso	Appium	Acc. Insp.	UIAut.	KIF	Robotium	Monkey runner	MobAcc checker
None	219	66.2% *	33.3%	12.8%	10.5%	10.5%	8.7%	13.3%	5.5%	2.7%
Superficial	457	51.0% *	9.8%	15.8%	7.2%	8.3%	5.9%	4.6%	4.8%	1.3%
Theoretical	59	42.4% *	23.7%	20.3%	16.9%	15.3%	6.8%	12.0%	6.8%	1.7%
Practical	137	23.4% *	29.2%	23.4%	30.7%	19.0%	16.8%	34.4%	5.1%	10.9%

differences were found across the responses from participants affiliated to organizations of different sizes in the motivations to adopt accessibility due to legal reasons ($\chi^2 = 11.69$, df $= 4$, p-value < 0.05), the possibility of increasing the user range ($\chi^2 = 205.593$, df $= 4$, p-value < 0.001), organizational requirements ($\chi^2 = 41.549$, df $= 4$, p-value < 0.001), to promote digital inclusion ($\chi^2 = 20.282$, df $= 4$, p-value < 0.001), project requirements ($\chi^2 = 21.86$, df $= 4$, p-value < 0.001) and for personal reasons

Table 27
Testing tools and frameworks used according to accessibility adoption.

Adoption	N	None	Espresso	Appium	Acc. Insp.	UIAut.	KIF	Robotium	Monkey runner	MobAcc checker
Nothing	243	62.6% *	24.3%	13.6%	1.2%	7.0%	1.2%	4.5%	4.5%	0.4%
A little	310	54.8% *	21.6%	18.1%	7.1%	9.7%	6.1%	3.5%	4.2%	1.0%
Partially	194	44.8% *	28.4%	11.3%	13.9%	9.8%	6.7%	6.2%	5.7%	5.2%
Totally	125	20.8% *	31.2%	26.4%	28.0%	13.6%	17.6%	6.4%	4.0%	6.4%

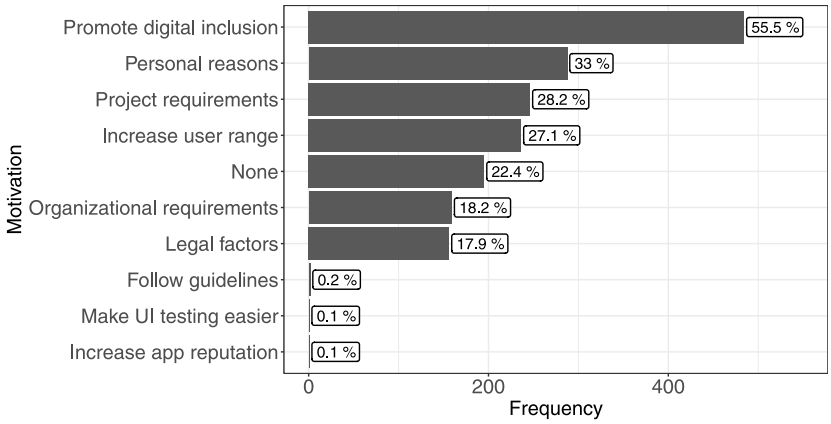

Fig. 18. Participants motivations to consider accessibility in their projects.

($\chi^2 = 9.501$, df = 4, p-value < 0.05). Participants who work for larger organizations seemed to have more reasons to implement accessible projects in general. Particularly, they are more motivated by following the legislation, reaching a wider range of users, implementing project or organizational requirements, and promoting digital inclusion than other participants.

Table 29 shows the main motivations presented by more than 10 participants according to the organization type. Significant differences were found across participants affiliated to different organization types in the motivations to adopt accessibility due to legal factors ($\chi^2 = 10.484$, df = 3, p-value < 0.05), organizational requirements ($\chi^2 = 15.979$, df = 3, p-value < 0.01) and personal motivation ($\chi^2 = 19.32$, df = 3, p-value < 0.001). No significant differences were found in motivations due to increasing user range ($\chi^2 = 0.233$, df = 3, p-value = 0.97), promoting digital inclusion ($\chi^2 = 2.667$, df = 3, p-value = 0.445) and project requirements ($\chi^2 = 7.074$, df = 3, p-value = 0.069).

It seems that participants who work for public companies are more motivated by the law and with the intent to promote digital inclusion than by project or organizational requirements. Participants carrying on personal projects are less motivated by organizational requirements, which was expected, as well as the legislation.

Fig. 19 presents an overview of barriers or limitations that hinder accessibility adoption in mobile development projects according to the participants of our survey. The main reason is that there are no accessibility requirements in their projects (36%), followed by lack of time (32.6%), lack of training (28.9%), lack of organizational requirement (23.3%), and focus on other public (23.1%). Participants also mentioned other reasons to not consider accessibility in their development process: it is not mandatory (19.3%), impacts few users (15.1%), it may conflict with layout design (9.7%), increases cost (9.3%), lack of knowledge (3.4%), it is not a priority for the company (0.9%), and lack of patterns (e.g. design, templates).

A cross analysis of the barriers mentioned by more than 10 participants according to participants' organization sizes and type of organization. Table 30 shows that some barriers are just as frequent as the others and some barriers are more popular prevalent on participants from particular organization sizes.

Significant differences were found across the organization sizes in the barriers to adopting accessibility due to accessibility not being a project requirement ($\chi^2 = 15.747$, df = 4, p-value < 0.01) and lack of training ($\chi^2 = 163.137$, df = 4, p-value < 0.001). No significant differences were found in barriers due to lack of time ($\chi^2 = 1.11$, df = 4, p-value = 0.892), lack of knowledge ($\chi^2 = 4.268$, df = 4, p-value = 0.37), accessibility impacts few users ($\chi^2 = 8.972$, df = 4, p-value = 0.06), accessibility is not mandatory ($\chi^2 = 8.025$, df = 4, p-value = 0.09), conflict with layout ($\chi^2 = 1.504$, df = 4, p-value = 0.825), high cost ($\chi^2 = 5.802$, df = 4, p-value = 0.214) and people with disabilities not being the organization's target public ($\chi^2 = 4.395$, df = 4, p-value = 0.355).

For all organizations, accessibility not being a requirement is a frequent barrier. For micro and small organizations, high cost was the most frequently mentioned barrier. Lack of training and knowledge is slightly more frequent in micro or small organizations. most barriers are less frequently mentioned by participants who work for no company (none).

Table 31 presents the barriers mentioned by more than 10 participants according to the organization type. A significant difference was found across the participants' organization types in barriers due to accessibility not being a project requirement ($\chi^2 = 9.472$, df = 3, p-value < 0.05). No significant differences were found in barriers due to lack of time ($\chi^2 = 3.428$, df = 3, p-value = 0.33), lack of knowledge ($\chi^2 = 2.507$, df = 3, p-value = 0.474), accessibility impacts few users ($\chi^2 = 4.708$, df = 3, p-value = 0.194), lack of training ($\chi^2 = 2.08$, df = 3, p-value = 0.555), accessibility is not mandatory ($\chi^2 = 6.64$, df = 3, p-value = 0.084), conflict with layout ($\chi^2 = 4.44$, df = 3, p-value = 0.217), high cost ($\chi^2 = 1.839$, df = 3, p-value = 0.606) and people with disabilities not being part of the organization's target public ($\chi^2 = 5.193$, df = 3, p-value = 0.158). It seems that the mentioned barriers are not much different across the elements of this dimension.

The most prevalent barriers for public organizations were that accessibility is not a requirement, lack of time, training and knowledge. For private organizations and freelancers, the most prevalent barriers were the fact that accessibility is not

Table 28
Motivations to develop accessible applications according to the organization size.

Org. size	N	None	Law	User range	Org.Req.	Inclusion	Proj.Req	Personal
None	83	27.7% *	9.6% *	31.3% *	6% *	56.6% *	24.1% *	36.1% *
Micro	93	20.4% *	14.0% *	21.5% *	9.7% *	49.5% *	26.9% *	31.2% *
Small	154	38.3% *	6.5% *	20.8% *	9.1% *	45.5% *	19.5% *	24.0% *
Medium	71	35.2% *	7% *	21.1% *	12.7% *	42.3% *	14.1% *	28.2% *
Large	471	14.6% *	25.5% *	30.4% *	25.9% *	61.8% *	34.2% *	36.5% *

Table 29
Motivations to develop accessible applications according to the organization type.

Org. type	N	None	Law	User range	Org.Req.	Inclusion	Proj.Req	Personal
Freelancer	62	25.8%	14.5% *	29.0%	11.3% *	50%	29%	30.6% *
Personal projects	67	26.9%	4.5% *	28.4%	3% *	58.2%	23.9%	38.8% *
Private company	691	22.4%	19.4% *	26.9%	20.8% *	54.8%	29.5%	32.9% *
Public company	43	11.6%	23.3% *	25.6%	14% *	65.1%	11.6%	30.2% *

Table 30
Barriers to developing accessible applications according to organization size.

Org. size	N	None	Lack of time	Not a req.	Few users	Lack of training	Not man datory	Layout conflict	High cost	Other public	Lack of knowledge
None	83	25.3%	28.9%	31.3% *	7.2%	39.8% *	9.6%	7.2%	14.3%	25.3%	23.8%
Micro	93	16,1%	35.5%	63.4% *	14.0%	35.5% *	25.8%	11.8%	80%	29%	20%
Small	154	16,2%	32.5%	71.4% *	21.4%	31.8% *	18.8%	11%	72%	26%	20%
Medium	71	19,7%	35.2%	69% *	14.1%	23.9% *	16.9%	8.5%	42.9%	19.7%	0%
Large	471	30.4%	32.3%	58.0% *	14.9%	25.5% *	20.2%	9.6%	29.4%	21%	11.9%

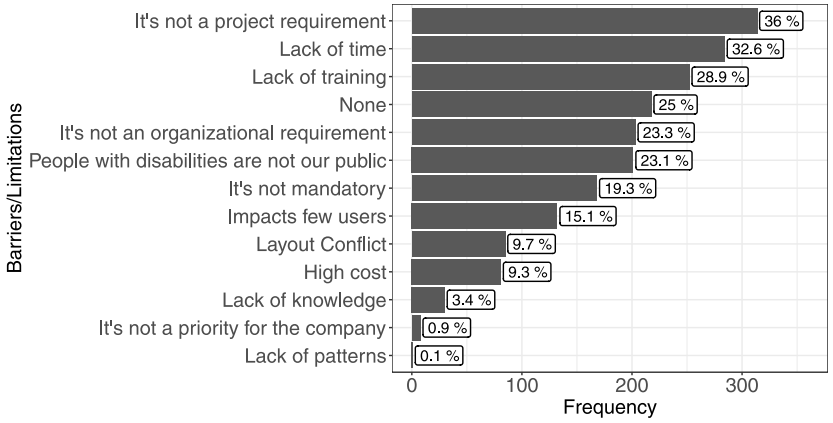

Fig. 19. Participants limitations to consider accessibility in their projects.

a requirement in their projects in addition to the lack of time and training. It seems that most barriers are not very prevalent among participants conducting personal projects, with reasons due to lack of requirements being less frequent than for other organization types.

Summary: Social conscience to promote digital inclusion and personal reasons are the most frequent reasons why participants consider accessibility in their projects, followed by project requirements related to accessibility and the designer to make the app accessible to a wider range of users. On the other hand, the lack of project and/or organizational requirements, lack of time, lack of training and lack of awareness on the needs of the population and the law concerning accessibility seem to be the main reasons why accessibility is not addressed in many mobile development projects. Accessibility not being a requirement was a frequent barrier even for participants affiliated to public organizations in Brazil, which is a legal requirement.

6. Discussion

This section discusses the results of our investigation following the aspects of interest of our survey: sample characterization, accessibility awareness and knowledge, accessibility adoption, motivations and barriers. We also discuss insightful results we obtained by crossing the response from different dimensions of our questionnaire.

6.1. Sample characterization

The 872 participants of our survey are well distributed in the Brazilian macro-regions according to the distribution of the country population. Most participants have at least a college degree and work for big private companies, which shows that the majority of them have proper training and are involved in professional and competitive environments. It is important to understand in which context the participants are involved in mobile application development since it could influence how digital accessibility is addressed in their projects. For instance, developers that create mobile applications to be used by real users, either within an organization or as a personal project, might take accessibility

Table 31
Barriers to develop accessible applications according to organization type.

Org. type	Part.	None	Lack of time	Not a req.	Few users	Lack of training	Not man datory	Layout conflict	High cost	Other public	Lack of knowledge
Freelancer	62	19.4%	27.4%	58.1% *	12.9%	25.8%	16.1%	11.3%	33.3%	30.6%	25%
Pers.Proj.	67	32.8%	26.9%	25.4% *	7.5%	35.8%	10.4%	7.5%	182%	22.4%	13.6%
Priv.Org.	691	25.2%	32.7%	63.5% *	15.9%	28.8%	21%	9.4%	39.7%	23.3%	12.1%
Pub.Org.	43	18.6%	41.9%	55.8% *	20.9%	25.6%	11.6%	18.6%	50%	11.6%	37.5%

more seriously than a student developing an application in the context of a software development course.

The sample of participants in the present study was composed by a majority of respondents who declared themselves as "developers". We acknowledge that there could be differences in the involvement of different developers with accessibility issues, depending on whether their roles are connected to fullstack developers or software engineering operations. However, the present study did not have the identification of such particularities in their roles. The previous studies used in the comparisons analyzed in this paper with the perceptions of accessibility in the Web context (Freire et al., 2008; Antonelli et al., 2018) did not separate between full stack developers or software engineering operations either. The analysis of differences between the particularities of such roles in development on the perception and attitudes towards accessibility in the context of mobile and Web development should be addressed in future studies.

6.2. Awareness and knowledge

Our results show the vast majority of the participants were aware that a blind user can use mobile applications and how to do so. However, only around 42% knows how to create accessible apps. It does not mean they know specific guidelines in detail, but they know at least some requirements that should be implemented to make sure a screen reader can really assist visually impaired users, such as to write descriptions to non-textual components. This is an interesting result because it indicates that the sole awareness of how a person with disabilities uses mobile apps does not necessarily impact the knowledge on how to build an accessible app.

When we compared the differences in awareness between different job roles, no significant differences were found in the proportions of awareness of how blind people use mobile apps, how to create accessible apps, and their level of knowledge about guidelines. However, there was a slight tendency to observe higher levels of knowledge about guidelines by designers, followed by testers. Nevertheless, the number of participants in such roles was not still representative enough. Future studies would be necessary to establish whether there would be a significant difference between those groups.

With regards to differences in the level of experience of the participants, the study found significant differences in the levels of awareness about accessibility and in the level of knowledge about technical accessibility guidelines. Despite showing knowledge levels as "superficial" across all levels of experience, the results showed a higher proportion of participants with higher levels of knowledge about accessibility guidelines for participants with more years of experience taking part in software development processes.

The analysis stratified by the sizes of the companies in which participants worked showed that people in larger companies tended to have higher levels of awareness about how people with disabilities use mobile apps and about technical guidelines. The higher level of awareness could be due to wider training programmes, compliance procedures and multinational companies that follow standard accessibility procedures in different countries. This finding shows the need to further investigate accessibility issues in companies of different sizes. Qualitative studies could shed light into this fact and help to understand the factors that influence on the adoption of accessibility requirements in companies of different sizes in Brazil and further afield.

Regarding the organization type, there were significant differences between the awareness of how blind users use mobile apps and technical aspects. However, no significant difference was found between the levels of knowledge about accessibility guidelines. In principle, participants who work for public companies should be more aware and have more knowledge on digital accessibility since adopting accessibility standards to provide citizens with accessible electronic services and products is mandatory. Yet, this is not surprising once several studies have shown similar results (Oliveira and Eler, 2017; Oliveira et al., 2020a; Serra et al., 2015b; Carvalho et al., 2016; Oliveira et al., 2020b). The study had more than 80% of the participants working for private companies. Further research with a more balanced sample would be necessary to investigate the differences between public and private and other types of organizations in Brazil.

When comparing developers who work on Android and iOS platforms, there was a significant difference in the awareness about how blind users use mobile apps and technical guidelines, as well as on the knowledge levels about guidelines. The higher level of awareness of iOS developers may be due to stricter procedures for the verification of observance of Apple's standards (which include accessibility aspects) when making apps available in their store.

When it comes to the participants awareness on accessibility standards and guidelines, it was not surprising that WCAG was the most known guideline (33.8%) since it was devised by a large worldwide initiative (W3C) and became an international standard (ISO/IEC 40500:2012). Also, it has been revised for many years since its first publication in 1999. On the other hand, precisely because of such relevance, we expected that it would be known by most of participants, even though it was originally devised for web content. Likewise, Apple's UIKIT (29.7%) and Google's Material Design (27.1%) are well known platform documentations that synthesize general principles of a good design. Even though they are not accessibility guidelines, they have specific sections to recommend some accessibility principles.

Yet, it was surprising that only 5.5% of the respondents (48) knew the Brazilian Accessibility Model (e-MAG) devised by the federal government. It is understandable that the developers of the private sector are not aware of the e-MAG because many companies follow international standards such as the WCAG, which was the inspiration to design the Brazilian model. However, it was unexpected that only 8 out of 43 (19%) participants who work for the public sector recognized the e-MAG as an accessibility standard.

What draws more attention is that 38.4% of participants have not selected any accessibility guideline. We believe, however, that many of these participants actually are aware of the existence of some accessibility standards and guidelines, but have not felt comfortable to select any of them because they do not know it in detail. In fact, only 25.1% of the participants said to have no knowledge on any accessibility guideline. Many participants

know that some guidelines exist, but they have just read or heard about it. Only 22.5% of the participants are really familiar with accessibility guidelines.

We understand that accessibility awareness and knowledge are not exclusively related to any knowledge on accessibility standards and guidelines. However, we believe that standards and guidelines present accessibility principles and recommendations in a systematic way and cover a wide range of requirements related to several types of disabilities. In that sense, we believe that people who have deeper knowledge on specific accessibility standards and guidelines are more technically able to develop accessible products than those who know only a set of broad accessibility recommendations.

From the comparisons between job roles concerning knowledge about different sets of guidelines, significant differences were found between the distributions for different guidelines sets. It was surprising to find out that, although testers had a higher level of knowledge about WCAG, for example, they had the lowest level of knowledge about the specific Android and iOS platforms accessibility guidelines. However, the number of testers in the study was comparatively lower than the number of developers. Further studies with more representatives from different job roles would be necessary to analyze the implications of the knowledge of different guidelines sets in design and evaluation procedures. Specific guidelines for mobile accessibility, such as the BBC's, are known to only a small portion of participants in all job roles, but especially among developers. Whilst the platform-specific accessibility guidelines provide important standards to accessibility, guidelines such as those proposed by the BBC to mobile development contain valuable knowledge from experiences with tests involving people with disabilities. Promoting the sharing of knowledge of such documents is very beneficial to promote the accessibility in mobile apps.

Work experience played a role in the knowledge about WCAG and the platforms' knowledge. However, no significant differences were found in the percentages of participants who knew the BBC's guidelines and e-MAG. This may be due to the wider promotion of WCAG and Android's and IOS's guidelines, which may have had more opportunities to reach out to more experienced professionals.

Organization size had a similar behavior, with an influence on knowledge about WCAG and the platforms' guidelines, but no significant difference in the knowledge about the BBC's guidelines and e-MAG. This suggests that larger organizations tend to favor the promotion of internationally-recognized accessibility guidelines.

Regarding organizations of different types, people involved in personal projects had a higher level of knowledge about WCAG than people from other organization types. Participants from public organizations had a higher level of knowledge about the Brazilian e-MAG than other types of organizations. However, only around 20% of participants from public organizations stated they had knowledge about e-MAG. This is very worrisome, considering that the guidelines have been established more than one decade ago by the federal government. This shows that policies should be promoted in the context of the government to disseminate governmental guidance on accessibility more effectively.

In the comparisons between developers for different platforms, significant differences were found in the knowledge about Apple's UIKit and Google's Material Design for Android. iOS developers had higher levels of knowledge about the design guidelines than Android developers. This shows that Apple's policies for stricter verification of their design standards may have an effect on developers observance of their recommendations, which include accessibility guidelines. This fact may suggest that app stores such as Google's Play store could also use stricter procedures to verify the adherence to design standards and accessibility recommendations as a means to promote the use of such practices.

One of the questions of our survey is related to where participants acquired their knowledge on accessibility. The answers we received for this question are important to show that classic formal education (e.g. undergraduate and graduate courses) is not the main source of information in this subject. To learn about accessibility, most participants had to resort to specific lectures or courses, or find good reading material online.

In comparison to previous studies conducted in Brazil (Freire et al., 2008; Antonelli et al., 2018), there was a reduction in the percentage of participants who argue they have a lack of training. This trend may be an indication of an improvement on the perception of developers of training and ability to incorporate accessibility in the development of their apps. This finding is in line with other findings that more participants reported having had some kind of training on accessibility in formal and informal contexts.

Despite the low rate of participants who learnt about accessibility in formal education, the study showed some evidence of a growth of accessibility education in undergraduate degrees. This finding is in line with previous findings from studies that showed that accessibility has been increasingly included in Human–Computer Interaction curricula in Brazil (Gasparini et al., 2015; Boscarioli et al., 2014). This is an evidence that, despite initial efforts, curriculum-based courses should review their classes related to Human–Computer interaction to include accessibility.

The comparison of the results of this survey with previous studies in Brazil (Freire et al., 2008; Antonelli et al., 2018) showed a growth the percentage of participants who were aware of how people with visual disabilities use mobile devices. This growth may indicate that there has been a wider dissemination of knowledge about how disabled people use digital resources and how to develop more accessible digital applications. Despite evidences of lack of accessibility in mobile applications (Serra et al., 2015a; Eler et al., 2018; Yan and Ramachandran, 2019; Vendome et al., 2019; Alshayban et al., 2020; Acosta-Vargas et al., 2020), this improvement may indicate some small, but positive change in developers' awareness.

Despite the growth in developers' awareness, there is still room for improvement, as many participants have low awareness about accessibility in Brazil. Other studies have also shown that lack of awareness about accessibility in digital technology is still an issue in other countries (Inal et al., 2019; Alshayban et al., 2020).

6.3. Accessibility adoption

In general, accessibility recommendations are scarcely adopted in practice and some of the reasons for this outcome were presented in the previous section. Also note that the accessibility adoption of participants that have only good theoretical knowledge is much lower if compared to participants that also hold practical experience. This might be evidence that training is also important to make sure accessibility guidelines are known in theory and in practice.

The study showed that there is also a gap between awareness about accessibility guidelines and practices, and actual adoption of them. For the most widely known set of guidelines, for example, WCAG was known by 33.8%, but was adopted by only 19.3% of participants. Apple's UIKit had a narrower gap between those who stated that they were aware of the guidelines (29.7%) and those who stated they adopted them (22.9%). The stricter

enforcement from Apple Store seems to play an important role not only in making people more aware about the guidelines, but in their actual use.

It was interesting to observe that the adoption of guidelines was higher in the analysis according to the developers' platforms. iOS developers had a higher level of adoption of apple's design guidelines. However, it is worth noting that this difference was not pronounced in the adoption of accessibility-specific guidelines, such as WCAG. Whilst 62.3% of iOS developers affirmed they adopt Apple's UIKit, only 17.5% stated they adopted WCAG. UIKit does include many important accessibility aspects in its recommendation, and this undoubtedly results in better levels of accessibility. However, it is worrying to see that even those developers have limited adoption of guidelines that have more specific recommendations about accessibility that are not fully covered in the platforms' guidelines.

Regarding the adoption of the governmental standard e-MAG, participants from public organizations had a higher adoption level than other groups. However, only 16.3% of participants from public organizations stated they actually adopted WCAG. Unfortunately, the study had limitations in terms of the type of Brazilian governmental bodies they were affiliated to. The guidelines from e-MAG are currently mandatory only to federal bodies from the executive power. Agencies from the legislative and judiciary powers at the federal level and governmental agencies from state and municipal levels are encouraged to adopt e-MAG, but there is no regulation to enforce its adoption. The lack of regulation for other spheres in government seems to play a role in the low adoption of e-MAG. Another possible reason for the low adoption of e-MAG amongst mobile developers is the lack of specific guidelines for the mobile context, since e-MAG is mostly based on the Web platform.

6.4. Accessibility evaluation

Accessibility evaluation is also barely conducted in most development projects. Only a quarter of participants said that their evaluation is conducted with users with disabilities, while the remaining participants relied on automated, manual or third party evaluation. One interesting result of this study is that, despite the fact that user feedback (e.g. comments, ratings) collected from app stores are valuable information to plan for software evaluation (e.g. fix bugs, add new features) (Palomba et al., 2015), only one participant use app reviews to look for accessibility violations reported. This might be evidence that either developers are not concerned with user feedback related to accessibility or that indeed such type of feedback is scarce as suggested by recent studies (Eler et al., 2019; Abdulaziz Alshayban and Malek, 2020).

Evaluation by users with disabilities is fundamental to achieve accessibility, in that it enables those users to effectively perform their tasks in the systems. However, despite the improvement in the past decade when comparing the present study with previous studies in Brazil (Freire et al., 2008; Antonelli et al., 2018), the percentage of developers who stated they employ tests with users with disabilities is still very small. Encouraging developers to involve users with disability in the evaluation of their systems is very important to promote effective accessibility in their applications.

Only around 15% of the participants said that accessibility evaluation is conducted using automated tools in their projects. A proper accessibility evaluation cannot be conducted only by supporting tools (Vigo et al., 2013) because many accessibility violations can only be detected within a context and subject to human judgment. Nevertheless, it can reduce the effort of this laborious task and, in some cases, it might be the only option due to time, budget and human resources limitation. Note that many participants already use general purpose testing frameworks and tools that also support automated accessibility testing. For instance, Espresso, which is used by 25% of the participants, can automatically check accessibility violations in all interfaces executed during a test session.

When crossing the analysis of the types of evaluations conducted according to participants' job roles, testers showed higher levels of use of automated, manual and user evaluations. However, the number of participants identified as testers was still small in comparison to other groups. The result, however, is an indication that further investigation would be important to reveal the role software testers have in evaluating accessibility in mobile software development. Designers also had more responses related to the use of evaluation methods than other job roles. The findings show that it is important to further dive into the understanding between the interplay of software testers, User Experience researchers, designers and other professionals in the evaluation of accessibility.

In the comparison according to participants' experience level, manual inspections and user evaluations had higher prevalence with more experienced participants. Despite not finding a significant difference, there was a slight tendency in a higher level of use of automated tools by participants with less experience than participants with more experience. These results suggest that methods that demand more knowledge and experience in fact are more prevalent with participants with more years of experience, even though they were still low in percentage even in these groups.

Participants who work for larger organizations also seemed to employ more usability evaluation methods than those from smaller organizations, following a similar trend to the higher knowledge about accessibility guidelines detected in these organizations. When the type of organizations participants were affiliated to, there were no significant differences in the use of automated tools, manual inspections and evaluations performed by third-party companies. However, freelancers had a significantly lower level of adoption of user evaluation methods. One possible explanation to this could be the fact that freelancers are normally commissioned to develop specific features of a certain system, or to specific tasks related to the development of apps, and might not be involved with the whole development and evaluation process.

The comparison of this study and previous studies in Brazil (Freire et al., 2008; Antonelli et al., 2018) showed that there has been little change in the prevalence of use of automated tools in accessibility evaluation. Given the more recent availability of automated accessibility evaluation tools for mobile apps in comparison to web accessibility evaluation tools, it is a positive result that no significant difference was found in the use of such tools. This may point that, despite being more recently available, there has been a similar uptake and acceptance of such tools as automated web accessibility evaluation tools. One limitation of the present study, however, is lack of an account of which tools are used by practitioners. The data could not reveal whether developers use general-intended evaluation tools or automated tools to assess guidelines such as the Apple's App Store Review Guidelines.

On the other hand, tools especially designed for accessibility testing are scarcely used (Accessibility Inspector and Mobile Accessibility Checker). That might indicate that, considering the developers perspective, integrating accessibility evaluation into general testing frameworks and tools would make the adoption of automated accessibility evaluation smoother.

6.5. Motivations and barriers

The main reasons why participants adopt or would adopt accessibility in their projects are personal motivations or social conscience, rather than the organization, project or legislation demands. Nevertheless, the results of our survey shows that accessibility is seldom used in practice. Hence, it seems that good motivations alone are not sufficient to guarantee the delivery of accessible products once the limitations imposed by the development settings can be overwhelming.

High demand and short deadlines push companies to focus on delivering running software in small increments based on business value prioritization, which commonly moves or simply ignore non-functional requirements such as security and accessibility (Oliveira and Eler, 2017). In that case, even when developers are personally motivated to design accessible projects, the lack of specific organizational or project requirements is a major issue once there will be no time or budget allocated to proper training, implementation and evaluation.

When analyzing the motivation and barriers to adopting accessibility practices, important findings were identified in the study. The data suggested that larger companies were more aware of legal obligation to adhere to accessibility practices as a motivation to adopt them. Participants who developed personal projects were less aware of legal obligations towards accessibility. Public organizations were also more aware about the legal obligation of accessibility requirements.

Despite having a smaller proportion of participants affiliated to public organizations, it was very surprising to find out that a low percentage of such participants mentioned accessibility being a requirement as motivation to adopt accessibility practices in their projects. In fact, when asked about barriers to adopting accessibility practices, participants from public organizations mentioned that lack of project and organization requirements for accessibility were among the most frequent barriers, despite the legal requirements. The results were in line with previous results from another study performed by some of the authors of the present paper (Oliveira et al., 2020a). That study was based on freedom of information requests to federal governmental agencies in Brazil regarding mobile systems. The results showed that a very small number of the agencies included accessibility as a requirement for mobile systems.

Many participants also mentioned that accessibility is not considered in their projects because people with disabilities do not use their applications, thus it would impact just a few users. Unfortunately, the data seem to suggest that the perception of disable people being potential customers to digital products has not improved in the past decade in Brazil, when comparing the results from the present study and previous studies conducted in Brazil (Freire et al., 2008; Antonelli et al., 2018). This points to a need to better promote the economic aspects of accessibility, as a means to widen the range of potential customers, and the fact that disabled people are also consumers. This is an evidence of the lack of developers awareness that people with disabilities represent a significant percentage of the Brazilian and the world population, which want to use any digital product as any other user. In addition, even though accessibility is enforced by the law, a fifth of the participants mentioned that creating accessible products is not mandatory.

Despite still having a high percentage of respondents, the reduction in the percentage of the participants who pointed to the lack of organizational concern about accessibility in comparison to previous studies may be a good indicator that accessibility has been more broadly discussed at organizational level. It could be an indicator that advances in Brazilian accessibility legislation may have had some effect, at least at an organizational level. However, it is important that organizational awareness be effectively translated into practical action in software companies. Nevertheless, the percentage of participants who pointed to the lack of organizational requirements is still very high, given that the Brazilian Law of Inclusion of People with Disabilities considers accessibility in digital resources mandatory to private and public organizations.

It was noteworthy that there was a growth in the percentage of participants who stated that accessibility is not a legal requirement in their projects from the Brazilian studies in 2008 (Freire et al., 2008) and 2018 (Antonelli et al., 2018), and a decrease in the percentage of participants who pointed legal factors as a motivator to implement accessibility. This phenomenon may be due to several reasons. One possible reason is the larger percentage of participants related to governmental and educational organizations in the 2008 study, which have stricter requirements for the accessibility of their systems.

Furthermore, mobile accessibility still has important gaps in Brazilian accessibility legislation. Another possible reason is the fact that Brazilian legislation is still reticent regarding mobile applications. However, it is worrying that the 2018 study also found a higher percentage of participants who do not recognize accessibility as a legal requirement in their projects in the context of Web applications, even though the legislation at the time regarding Web accessibility in Brazil was already consolidated. The Brazilian Law of Inclusion of People with Disabilities from 2015 still mentions requirements for the accessibility of Web-based systems, but not for mobile apps. This lack of legal requirements may also be a factor that would impact on the perception of developers. This shows the need to promote accessibility legislation and to put in place effective law-enforcement schemes to ensure accessibility legal requirements are considered in digital systems, both on the Web and in mobile apps.

Legislation was pointed as a significant motivator to implement accessibility in a previous study in Brazil in 2008 (Freire et al., 2008) and in a study conducted primarily in the United States in 2004 (Lazar et al., 2004). However, as summarized in Section 3, other recent studies have not found strong emphasis on legislation as in the earlier investigations. This may be an indication that the influence of legislation on the accessibility of digital technologies needs to be investigated into more detail in Brazil and worldwide.

7. Conclusion

The results of the survey we conducted with 872 participants provides evidence that the mobile application development industry in Brazil needs to improve dramatically when it comes to accessibility awareness, knowledge, adoption and evaluation. Even though a further analysis showed that the results may vary across different dimensions (e.g. organization size and type), results still show that the level of accessibility awareness, knowledge, adoption and evaluation is still low for all groups.

Even though most participants of our study are developers that have none or superficial knowledge on digital accessibility, they should not be held as the sole accountables for the fact that accessibility is not properly handled in most software development projects. In fact, delivering accessible products requires the commitment of all people involved in the development process, including upper level managers, technical staff, designers, developers and the users themselves.

Our study shows that organizations play an important role in this context since many barriers reported by participants are related to the companies' perspectives with respect to accessibility. If people with disabilities are not considered potential users and the organization is not familiar with the legislation that enforce

accessibility policies, there will be no explicit requirements to make sure mobile applications are accessible. Naturally, the absence of accessibility requirements imposes more barriers even when developers have their own motivations to design accessible projects for they will not have specific training, tools, time or budget to properly implement and assess the accessibility of the applications they develop.

There are no simple and short term solutions to such a situation. However, we believe some actions might transform this scenario over time. For instance, accessibility should be properly addressed in curriculum-based courses as knowledge and proper training can be decisive on the influence of team members and managers to include accessibility into the development process. Even when developers are not involved in the conception and the design of user interfaces, they should learn how design decisions impact users with disabilities, so they can either recognize accessible user interfaces to make sure it is implemented as it was designed, or to detect and report issues that might impose barriers to any user.

Further research on the benefits of developing accessible products both social and business-wise could help organizations to understand that creating accessible applications is not only a matter of complying with the legislation, but also a business strategy to increase the range of potential customers and provide them with high quality solutions and a good user usability and user experience. We believe that, once organizations include accessibility in their business agenda, barriers associated with lack of time, lack of training, and lack of project or organizational requirement tend to be overcome.

CRediT authorship contribution statement

Manoel Victor Rodrigues Leite: Conceptualization, Methodology, Investigation, Writing Original Draft. **Lilian Passos Scatalon:** Investigation, Writing - Original Draft. **André Pimenta Freire:** Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Marcelo Medeiros Eler:** Conceptualization, Methodology, Investigation, Data curation, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding acquisition.

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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