Are the Mobile Applications of Portuguese Higher Education Institutions Accessible?

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Abstract. The number of smartphone users has increased significantly, and the development of mobile applications has brought convenience to daily life. However, large numbers of users who have various barriers, such as visual or hearing impairments, and physical disorders, are not able to fully access and use the referred applications, which is unfair to them, especially when considering its use by students in a university campus where all users should be able to enjoy equal opportunities and experiences. The main goal of this study is to assess accessibility in mobile applications of the education sector. Thus, an evaluation model is also proposed to assess the accessibility of the applications from two perspectives, which are the inherent properties of the applications and the user experience of different disability categories. 46 official mobile applications were tested which related to 23 universities and institutes of Portugal, using automatic and manual testing methods. Several frequently occurring accessibility issues in the apps were identified and summarized, such as color contrast, touch target, missing focus. The results of the accessibility testing showed that the status of web accessibility of mobile applications in the higher education sector in Portugal is unsatisfactory. Most apps have multiple accessibility issues, and they are extremely unfriendly to the users with visual impairments. In addition, the study also proposed a series of accessibility recommendations for mobile application designers and developers, with the purpose of improving the accessibility of apps and providing an equitable user experience for all users.

Keywords: Accessibility · Web accessibility guidelines · Mobile applications · Education

1 Introduction

In the last decade, with the popularity of smart phones, people accessing Web services through a mobile terminal and applications has been an increasingly prevalent

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phenomenon [1]. The growth in the use of mobile devices has been very significant and nowadays this type of system has become one of the most used means by people to access services and information online [2]. The education sector has also benefited greatly from this. People in universities, polytechnic institutes, and other organizations in the higher education sector, including students and professors, are enjoying the convenience provided by mobile application development, such as consulting the daily schedule of a course, the academic calendar, the events to be held, and they can also register online to their favorite subjects via mobile phones.

However, for the user groups with a disability, the Internet has brought new opportunities to them, but it also presents unprecedented challenges [3]. According to the World Health Organization (2020), it is estimated that about one billion people in the world (approximately 15% of the world population) have a disability, being this either visual, auditory, motor, or mental [4]. Therefore, improving the Web accessibility of mobile applications is one of the main factors that motivated this article.

Meanwhile, another important factor is the lack in the literature and of research on accessibility in mobile applications for the education sector. In order to improve web accessibility and make it better for the disabled population, some guidelines and standards were established in the industry, but most guidelines and standards aimed to improve the web accessibility on fixed terminals, such as computers, and not for mobile devices, being rarer for mobile applications [5].

With the elaboration of this paper, we propose to analyze the official mobile applications of Portuguese higher education sectors, regarding their level of compliance with accessibility, finding the common accessibility issue in apps. In the final section, the results of the analysis were discussed, and a set of guidelines and recommendations based on the study was developed, which are provided to application designers and developers with the aim of improving applications' accessibility.

2 Conceptual Framework

2.1 An Overview on the Web Accessibility Paradigm

Web accessibility indicates that all people (whether a healthy person or a disabled person, young or old) should have the ability to access and use the Web resource and information equally and conveniently under different types of circumstances [6, 7]. Accessible Web content needs to be able to support differentiated people using alternatives or tools to complete the input and output of information, as well as accessibility services that require accessibility tools and language features [6, 8].

The overall accessibility concept involves the inclusive design area, thus offering a wide range of products and services that cover the needs of different populations, the adaptation of artifacts and the implementation of alternative means of information, communication, and mobility [9–11].

The societal awareness of accessibility in laws has also been increasing in recent years and many governments around the world have also actively carried out Web accessibility construction and formulated relevant laws and regulations to guarantee equal access to information [5]. In Portugal, for example, the Decree-Law No. 83/2018 emerged, which has determined a series of accessibility demands for websites and mobile applications in the sector of public organizations [12]. It means that improving Web accessibility is not only a public service, but also a requirement according to the laws and regulations.

With the continuous improvement of data processing and storage technologies of mobile terminals, the interaction between people and mobile terminals has also changed from a single physical button to touch screen operation and voice-assisted operation [13, 14]. Various mobile application requirements have been gradually stimulated, from entertainment, to basic services such as communication and information inquiry that have been extended to auxiliary office services such as business office and network finance, and then to public services such as education, medical care, and transportation [15]. Mobile application accessibility is the basic requirement to ensure an equal experience for all users, especially those with disabilities.

2.2 Standards and Guidelines

In 1997, the organization World Wide Web Consortium (W3C) announced the launch of the Web Accessibility Initiative (WAI) to promote and achieve Web functionality for people with disabilities [16]. Since then, W3C has proposed a series of accessibility guidelines and standards. WCAG is the Web Content Accessibility Guidelines which was developed by W3C, which provided suggestions for easier access to Web content [6]. The first version WCAG 1.0 was launched in May 1999, and WCAG 2.1 is the latest version of the standard at present [16]. The document of WCAG indicated the method to make Web content more accessible to people with disabilities. Web content generally means the information in the Web page or application, including natural information such as text, images, sounds and code or markup that defines structure and presentation [10]. The WCAG 2.1 guidelines and Success Criteria are organized around the following four principles:

- Perceivable: Information and user interface components must be presentable to users in ways they can perceive.
- Operable: User interface components and navigation must be operable.
- Understandable: Information and the operation of user interface must be understandable.
- Robust: Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies.

Moreover, according to WCAG 2.1, the specific guidelines under each principle also include different eligibility criteria, which are generally divided into the following three levels, A, AA, AAA, which means the basic level, enhanced levels, and optional level eligibility criteria [8]. This criterion is also applied to the assessment of accessibility.

Google and Apple also provided their own guidelines for mobile application accessibility besides W3C. Google has created guidelines for mobile accessibility to make it easier for developers to develop apps, which aimed at improving the app accessibility to enhance the usability for all users, including those people with visual impairments, hearing impairments, cognitive impairments, motor impairments or situational disabilities. The guidelines of Google have several aspects, which are Assistive Technologies, Hierarchy, Color and Contrast, Layout and Typography, Writing, Imagery, Sound and Motion, and finally Implementing Accessibility [17]. Apple has also established a set of mobile accessibility guidelines for making applications more accessible. The guidelines of Apple have several aspects including Inclusive Design, User Interaction, Navigation, Text Size and Styles, Color and Contrast, Appearance Effects and Motion, and Content [18].

2.3 The Design of Mobile Web Interfaces

The mobile user interface (mobile UI) is the graphical and usually touch-sensitive display on a mobile device, such as a smartphone or tablet, that allows the user to interact with the device's apps, features, content, and functions [19, 20]. Mobile applications usually consist of several parts: Start page, Guide page, Dialog, Home page and menu bar interface, Login and personalized settings interface, as well as the List page. The control in a graphical user interface is an element of interaction, such as the Textview, EditText, Radio Button, and Checkbox [21].

In mobile applications, the focus is the location of the current event being processed, which is crucial to screen reader [21]. Screen reader is the tool to deliver the visual information to users by sound. It will not recognize the content on the position of the screen where users touched or clicked if there is no focus.

In general, users mainly interact through the UI to achieve access to the content or services of the application, which means that the elements and the design of the UI will affect accessibility, and these are the main targets in accessibility testing.

3 Methodological Approach

3.1 Global Overview

This study researched the official mobile applications of higher education sectors in Portugal, including 134 universities and institutes [22]. In order to assess the current state of accessibility of the educational mobile applications, an accessibility testing model was proposed in this study, which was derived by analyzing and summarizing the rules applicable to the mobile application part of numerous standards and guidelines including WCAG 2.1, best practices published by Google and Apple, and additions made by the researchers of the present study during the tests.

Moreover, the analysis of user type was conducted based on the common types of disabilities and the best solution for each type of disabled user was proposed. After the accessibility testing was implemented, the most common accessibility issues in the tests were summarized, and the accessibility of each App was evaluated, as well as the assessment of suitability for different kinds of disabled users according to the best solutions. Finally, this study also proposed specific recommendations for App designers and developers, aiming to improve the accessibility of mobile applications and increase accessibility awareness among the general public.

3.2 Methodological Approach

i. User Type Vs. Best Solution Analysis

In daily life with smartphones, there are certain barriers for users with disabilities to use a mobile application [23]. It is important to note that a disability is not only a permanent physical impairment, such as being blind and deaf, but a barrier that everyone may encounter, including temporary and situational disabilities. A temporary disability means an injury to the body that occurs over a period of time which is reversible, such as impaired vision due to cataracts, impaired mobility due to an injured arm, or impaired hearing due to an ear infection [24]. Situational disability means that the impairment is due to environmental factors, such as the inability to stare at the mobile phone while driving, that hearing is affected in a noisy environment, or cognitive decline in stressful situations [24].

Considering those situations, the types of users with disabilities were divided into four categories including Visual impairment, Hearing impairment, Physical disorders, and Mental disorders (Table 1). For the four types of disabled users above, the following best solutions were proposed (Table 1).

Table 1. Best solution for disability

<table>
<tr><th>User types</th><th>Best solutions</th></tr>
<tr><td colspan="2">Visual Impairment</td></tr>
<tr><td>Color-blindness</td><td>Color inversion</td></tr>
<tr><td>Low vision</td><td>Zoom in & out</td></tr>
<tr><td>Blind</td><td>Screen reader
Speech Recognition</td></tr>
<tr><td colspan="2">Hearing Impairment</td></tr>
<tr><td rowspan="4">Deaf
Weak hearing</td><td>Vibration or visual reminder</td></tr>
<tr><td>Subtitle</td></tr>
<tr><td>Mono audio</td></tr>
<tr><td>Adjustable volume</td></tr>
<tr><td colspan="2">Physical Disorders</td></tr>
<tr><td rowspan="4">Finger-related mobility problems
Users suffering from arthritis</td><td>External devices</td></tr>
<tr><td>EasyTouch (Android)</td></tr>
<tr><td>Assistive Touch (iOS)</td></tr>
<tr><td>Speech Recognition</td></tr>
<tr><td colspan="2">Mental Disorders</td></tr>
<tr><td colspan="2">Input prompt
Unlimited time for operation</td></tr>
</table>

ii. Accessibility Testing

In the accessibility testing, two different mobile phones were selected as the testing platforms, which have different systems with remarkably similar features (Table 2). Both have a screen size of approximately 6 inches, multi-touch, and fingerprint and

16M colors. Although the iPhone 10 has a higher screen resolution than the XiaoMi 8 and both phones have different screen types, these differences are not significant for the tests performed. All tests were performed in the same environment and conditions.

Table 2. Platform of testing

Features	XiaoMi 8	iPhone 10
Operating System	Android 10.0	iOS 13.3
Release Date	2018, May	2017, November
Display (Type)	Super AMOLED, Capacitive touchscreen, 16M colors	Super Retina OLED, Capacitive touchscreen, 16M colors
Display (Size)	6.21 in., 97.1 cm^2	5.8 in., 84.4 cm^2
Display (Resolution)	1080 × 2248 pixels, 16:9 ratio (402 ppi density)	1125 × 2436 pixels, 19.5:9 ratio (458 ppi density)
Sensor	Fingerprint (front-mounted)	Fingerprint (front-mounted)
Screen reader	TalkBack	VoiceOver

Screen reader is an important accessibility tool, helping users perceive information through sound. Every iOS device comes with a screen reader which is VoiceOver, and most Android devices come with a screen reader called TalkBack. Both iOS and Android feature a similar base set of gestures when it comes to navigation; finding and activating a control on the screen [18, 25].

In this study, there are 46 Apps of the Portuguese higher education sector that were searched from Google Play and the Apple Store, related to 23 universities and institutes (Table 3). In the target group, 25 mobile apps have both android and iOS versions, one App "Exames Nacionais" is only available for iOS, and others are only for android.

Table 3. University & Institute and related Apps

University/Institute	Related applications
Universidade de Aveiro	UAmobile, actUA
Universidade do Algarve	MILAGE Learn+
Universidade Autónoma de Lisboa	my Autónoma
Universidade Beira Interior	UBI
Universidade de Coimbra	UCoimbra
Universidade Católica Portuguesa	MyCatólica
Universidade de Évora	My.UE
Universidade Europeia	UE|IADE|IPAM, Univ. Europea

(*continued*)

Table 3. (*continued*)

University/Institute	Related applications
Universidade Lusófona	Ensino Lusófona, Lusófona Docentes, Lusófona Acesso
Universidade Lusíada	eLusiada, eLusiada Mobile
Universidade de Lisboa	Técnico Lisboa, myFenix, ISEG, ISCTE-IUL, ENE3@LISBOA
Universidade da Madeira	Académica
Universidade do Minho	App UMinho, DEI - Universidade do Minho,where@UM
Universidade Nova de Lisboa	SAS Nova, netPApp, @NOVA IMS, myISG
Universidade de Trás-os-Montes e Alto Douro	alunosUTAD, estudarUTAD, InnGage - UTAD, alumniUTAD, juniorUTAD, Active Gym/UTAD, UTAD Innovation
Universidade do Porto	Acontece na U.Porto, uni - A FEUP no teu bolso, FEUP for Students, UPorto
Instituto Politécnico de Leiria	MyInfo@IPLeiria, Exames Nacionais
Instituto Politécnico de Tomar	IPT Mobile
Instituto Politécnico de Bragança Instituto Politécnico de Cávado e do Ave Instituto Politécnico de Viana de Castelo	SAS MOBILE, SASocial
Instituto Politécnico de Viseu	PVStudent
Instituto Politécnico de Beja	MyIPBeja
Instituto Politécnico de Coimbra	MyIPCoimbra

In the sector of mobile applications, no tools were found which could fully and thoroughly assess accessibility at the present time [5]. However, there are certain valuable tools that were uncovered in this study. The Accessibility Scanner is the tool for suggesting accessibility improvements for Android apps without requiring technical skills [26]. The AXE for Android Accessibility Service is an automated accessibility analysis toolkit available for analyzing the accessibility of android applications [27].

WCAG 2.0 guidelines are categorized into three levels of conformance in order to meet the needs of different groups and different situations: A (lowest), AA (mid-range), and AAA (highest) [8]. Therefore, in this study, a qualitative assessment was performed using four levels, where level A, B, and C, correspond to the high, medium, and low degrees, and level D is indicative of being non-accessible. It was implemented to assess the degree to which the application complied with the rules of the accessibility guidelines.

iii. Preliminary Assessment of Apps

In the preliminary assessment of these 46 Apps, 11 Apps were inaccessible which cannot be running normally, including "UBI", "ISCTE-IUL", "UPorto", "MyIPBeja", "MyIPCoimbra", "DEI-Universidade do Minho", "Active Gym/UTAD", "myFenix", "InnGage-UTAD", "MyInfo@IPLeiria", "SAS Nova".

On the other hand, since the mobile applications of the education sector only serve the students, professors, and administrators who are the members of their university or institute, there are 20 Apps with a certain degree of privacy which led to researchers only getting limited access and we hence could only access the login pages and the public areas.

Table 4. Issue of home page in 20 Apps ("VA" Version Android, "VI" Version IOS, "-" skip)

20 apps-with limited access	VA	VI	Issues
where@UM	A	-	
my Autónoma	A	A	
UCoimbra	B	A	Unlabeled button, small focus
MyCatólica	B	A	Unlabeled button, small focus
My.UE	B	A	Unlabeled button, small focus
UE|IADE|IPAM	B	A	Unlabeled button, small focus
Univ. Europea	A	A	
eLusiada	B	B	Unlabeled button, Image no description
eLusiada Mobile	B	-	Low text contrast
App UMinho	B	B	Small focus, Buttons unpronounceable
uni - A FEUP no teu bolso	A	-	
FEUP for Students	A	-	
SASocial	C	-	No access in screen reader
SAS MOBILE	B	-	Unlabeled button, small focus
PVStudent	B	B	Low text contrast
Ensino Lusófona	B	B	Login button no label
Lusófona Docentes	A	A	
netPApp	B	B	Low text contrast
@NOVA IMS	A	B	Low text contrast
myISG	A	B	Low text contrast

The accessibility testing was conducted in normal mode and screen reader mode respectively. As the results of the evaluation of these apps with limited access make evident, as shown in Table 4, there are 6 apps which have good accessibility, 5 Apps which have issues of text color contrast, and others which have low accessibility in screen reader mode, particularly "SASocial" did not work in this mode.

Finally, the rest of the Apps which can be fully accessed, were tested in the main process of accessibility testing, including 16 Apps. There are 8 Apps with both android and iOS version, 7 Apps with only android version, and "Exames Nacionais" has only an iOS version.

4 Testing Mobile Applications Accessibility

4.1 Accessibility Testing

Although both Google and Apple offer fully automated accessibility evaluation tools, such as Espresso and Robolectric for android and Accessibility inspector for iOS [28, 29], all these tools require the source code of the Apps for testing as well as the developer mode, which are not suitable in this study.

The accessibility scanner and AXE for Android were utilized in the automated testing, which analyzed the App and summarized the result automatically, providing suggestions of accessibility, focusing on four properties: content labels, clickable items, contrast, and touch area size. However, they are not available in iOS, so that the automated test was skipped in iOS applications. In addition, due to the complexity and the number of pages in different Apps, the repeatability of accessibility issues will also be affected, so the App with more suggestions given by Accessibility Scanner does not mean its accessibility is lower than an App with fewer suggestions.

The manual testing was also an essential part in the testing. Manual accessibility testing of mobile apps largely involves exploring and inspecting the apps and checking each encountered UI component. It was implemented by two methods, comprising accessibility testing by visual review and under screen reader mode. In the testing by visual review, global settings and user interfaces of Apps were tested, and also evaluated for users with different barriers, using and testing the mobile accessibility under real situations, for example, a near-sighted user needs to resize the text of the App. In the testing under screen reader mode, the composition of Apps was tested, such as the button, edit box, image, and dialog.

4.2 Test of Accessibility Issues

Firstly, the most common issues found by accessibility scanner include that the text/image contrast ratio is lower than the guideline recommended, that the item label is missing, that multiple items have the same description on one page, that a multiple long clickable item should not share its location on the screen, as well as unsupported item types and small touch targets.

Secondly, the most common issues found by visual review, include that the content is unable to resize or generates errors when resized, unchangeable screen orientation, UI dependent on color, and a lack of multi-language supporting. To test the influence of color of user interface, the tool Coblis - color blindness simulator [30] was used in the test, which works by uploading screenshots of the UI to the platform, simulating the UI under the vision of color-blind users, to determine whether the viewing of the UI depends on color.

Thirdly, we registered frequent occurring issues under screen reader mode, which is also the part of the testing where the most problems were found. The issues about focus include one focus covers multiple elements, the focus sequence is not logical, the controls have no focus, the focus is so small that it is hard to click on, error focus, and transparent transmission of focus between two pages. The issues about Dialog box, when the screen reader is running and after the dialog box pops up, are linked to the fact that there is no way provided to close the dialog box. The issues about controls include control with no access, prompt text, status notification of control, and control type cannot be read properly.

4.3 Performed Results

In Fig. 1, we show a stacked bar chart graph, with every column indicating the number of suggestions provided by accessibility scanner, including 7 colors which means 7 accessibility issues in applications. All applications tested have issues of accessibility and the problems with the high frequency issue which happened are text contrast, touch target and item label.

The Apps "MILAGE Learn+", "estudarUTAD" and "juniorUTAD" have the best performance in analysis by accessibility scanner, but they still have some issues of item label. The Apps "IPT Mobile", "alunosUTAD", "ISEG" and "Lusófona Acesso" have the most suggestions provided by accessibility scanner, especially in touch target and text contrast. It is necessary to mention that "Acontece na U.porto" was scanned with a lot of meaningless focus in this test, making it impossible to be evaluated, which was also confirmed later in the test in screen reader mode.

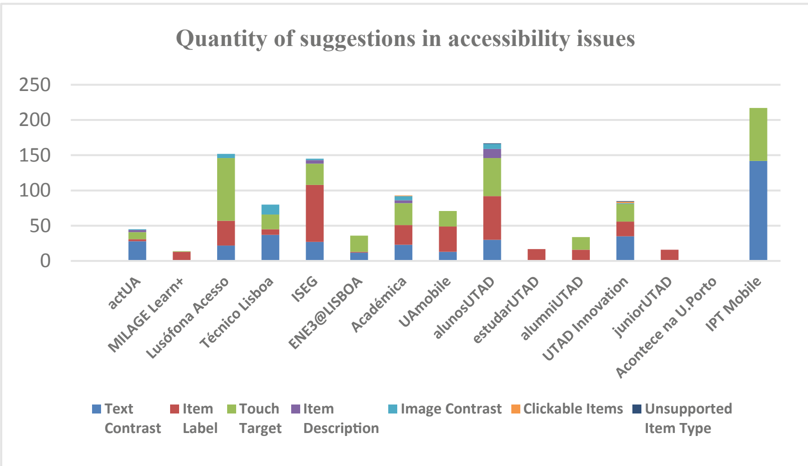

Fig. 1. Quantity of suggestions in accessibility issues

In the test by visual review, the results are shown in Table 5, with REQ 1–4 representing Resize text, Screen orientation, UI not dependent on color, and Multi language support.

Table 5. Issues of control in Apps ("VA" Android, "VI" IOS, "N" Not applicable, "-" skip)

Apps	REQ 1		REQ 2		REQ 3		REQ 4	
	VA	VI	VA	VI	VA	VI	VA	VI
actUA	B	-	D	-	B	-	D	-
MILAGE Learn+	D	D	C	C	B	B	A	A
Lusófona Acesso	B	B	D	D	B	B	D	D
Técnico Lisboa	C	C	B	B	B	B	C	C
ISEG	D	-	D	-	B	-	C	-
ENE3@LISBOA	B	-	D	-	B	-	D	-
Académica	B	-	D	-	B	-	D	-
UAmobile	D	D	D	D	B	B	D	D
alunosUTAD	B	-	D	-	B	-	D	-
estudarUTAD	B	-	B	-	B	-	D	-
alumniUTAD	B	-	B	-	B	-	D	-
UTAD Innovation	B	D	D	D	B	B	C	C
juniorUTAD	B	-	B	-	B	-	D	-
Acontece na UP	D	D	D	D	B	B	C	C
IPT Mobile	B	B	D	D	C	C	B	B
Exames Nacionais	-	B	-	D	-	A	-	D

Most apps have good user interfaces not dependent on color, which means different types of color-blind users have no barriers to accessing those apps. At the same time, the resize text testing had good performance in android, which is better than in iOS. Only three iOS apps could change the text size when the setting of the system changed, but in android, there are 11 apps resizing the text. On the other hand, most apps have no changeable screen orientation, only 5 android apps and 2 iOS apps could change the screen orientation. Those 15 apps have no multiple language supports and will not change the language when the device global setting has changed, but 6 android apps and 5 iOS apps can change language inside of apps.

Tables 6 and 7 show the result of accessibility testing under screen reader mode, the issues of focus, with FCS 1–6 representing Multiple elements, Sequence not logical, No focus, Small focus, Error focus, Transparent transmission; the issues of control, with CTL 1–4 representing No access, Prompt Text, Status notification, and Control type.

Table 6. Issues of Focus in Apps ("VA" Android, "VI" IOS, "N" Not applicable, "-" skip)

Apps	FCS 1		FCS 2		FCS 3		FCS 4		FCS 5		FCS 6	
	VA	VI	VA	VI	VA	VI	VA	VI	VA	VI	VA	VI
actUA	A	-	A	-	B	-	D	-	A	-	A	-
MILAGE Learn+	N	N	N	N	N	N	N	N	N	N	N	N
Lusófona Acesso	B	B	A	A	B	A	B	B	A	A	A	A
Técnico Lisboa	A	A	A	A	A	A	B	B	A	A	A	A
ISEG	A	-	A	-	D	-	C	-	B	-	D	-
ENE3@LISBOA	A	-	A	-	C	-	A	-	A	-	A	-
Académica	A	-	B	-	B	-	A	-	A	-	A	-
UAmobile	A	A	A	A	C	A	B	B	A	A	A	A
alunosUTAD	A	-	A	-	C	-	B	-	A	-	A	-
estudarUTAD	N	-	N	-	N	-	N	-	N	-	N	-
alumniUTAD	N	-	N	-	N	-	N	-	N	-	N	-
UTAD Innovation	A	A	A	A	B	C	B	B	B	A	A	C
juniorUTAD	N	-	N	-	N	-	N	-	N	-	N	-
Acontece na UP	A	C	A	A	B	B	C	C	D	A	A	D
IPT Mobile	A	B	A	A	B	C	B	B	A	A	A	C
EBamesNacionais	-	-	-	A	-	A	-	B	-	A	-	A

"MILAGE Learn+", "estudarUTAD", "alumniUTAD", "juniorUTAD" cannot work with screen reader, and users cannot access the apps when screen reader is running. The most common issues are lacking focus and small focus, only "Técnico Lisboa", "lusófona Acesso" and "UAmobile" of the iOS version have no issues in missing focus, and "ENE3@LISBOA" and "Académica" have no problem regarding small focus.

As concerns the issues of control illustrated in Table 7, the iOS applications have no issue of control with no access, but the android applications have worse performance, and "ENE3@LISBOA" got the lowest level due to many controls with no access. The most frequently occurring issue in both android and iOS applications is the CTL 2 -Prompt text, no Apps got A level and 6 Apps got C - low level. The controls get the focus, but screen reader does not read any information, due to lack of description, operating method, which led to users not knowing what the control is, what it does, and how it operates, which is the biggest barrier for blind users. Most Apps have good performance regarding status notification, control type, except for "Lusófona Acesso" and "Acontece na UP".

Table 7. Issues of control, "N" Not applicable, "-" Skip

Apps	CTL 1		CTL 2		CTL 3		CTL 4	
	VA	VI	VA	VI	VA	VI	VA	VI
actUA	A	-	B	-	A	-	A	-
MILAGE Learn+	N	N	N	N	N	N	N	N
Lusófona Acesso	A	A	C	D	B	B	B	B
Técnico Lisboa	A	A	B	B	A	A	A	A
ISEG	B	-	D	-	A	-	A	-
ENE3@LISBOA	C	-	C	-	A	-	A	-
Académica	A	-	B	-	A	-	A	-
UAmobile	A	A	C	C	A	A	A	A
alunosUTAD	A	-	C	-	A	-	A	-
estudarUTAD	N	-	N	-	N	-	N	-
alumniUTAD	N	-	N	-	N	-	N	-
UTAD Innovation	A	A	C	C	A	A	A	A
juniorUTAD	N	-	N	-	N	-	N	-
Acontece na UP	A	A	C	C	B	A	B	A
IPT Mobile	A	A	B	B	A	A	A	A
EBames Nacionais	-	A	-	B	-	A	-	A

Furthermore, "actUA", "Académica", and "IPT Mobile" have issues concerning dialog boxes. While the screen reader is running, there is no way provided to close the dialog box after it has popped up, and there is no response after clicking the blank space in the screen.

5 Recommendations to Training Courses for Mobile App Developers

5.1 Incorporating the Mobile Accessibility Topic

Through the accessibility testing and analysis above, it can be seen that there are too many accessibility issues of mobile Apps in the education sector, which bring great inconvenience to disabled users and it is unfair to them. The reason for this is the lack of awareness of accessibility construction and the lack of appropriate training for the designers and developers of mobile applications. Therefore, mobile accessibility topics should be incorporated in relevant training courses to establish a human-centered accessibility awareness for every designer and developer from the very beginning.

5.2 Mobile App Accessibility - Functional and Technical Requirements

Based on the WCAG 2.1 guidelines and the best practices published in the market, this study proposed recommendations for mobile apps after mobile application accessibility testing, including the requirements of property of application, the UI design of applications, and advanced requirements. This proposal aims to increase accessibility awareness among designers and developers and can also be adapted to improve the accessibility of mobile applications already released (Table 8).

Table 8. Functional & Technical Requirements

Content	Requirements
Guidelines - Global Settings (Basic Requirements)	
Resize text	Legible and without loss of content at 200 percent zoom;
Small screen size	App user interface is adaptive to mobile phones with different sizes of screens;
Color inversion	Supports color inversion tool of mobile phone;
Screen orientation	Supports orientations (portrait or landscape);
Magnification/Zoom in&out	Supports magnification tool of mobile phone;
Multiple language support	App adaptive language following mobile phone system language setting;
Guidelines - User Interface Design	
UI not depend on color	Color palette of application is appropriate for all users;
Multiple language setting inside app	Provide language switching function inside App;
Consistent Layout	Ensuring that repeated components occur in the same order on each page;
Text alternatives for non-text content	Subtitles for content audio or video with audio; Provide sign language for audio-only content;
Text/image size adjustable inside app	The internal text or image could zoom in&out in Apps
Contrast of text/image	Contrast ratio of at least 4.5:1 for small text, Contrast ratio of at least 3.0:1 for large text;
Touch Target Size and Spacing	Target size bigger than 48 × 48dp, or 32 × 32dp for Views within input method windows or against the display edge; Space length between elements at least 2 mm;
Touchscreen Gestures	All functionalities should be used by simple gestures;

(*continued*)

Table 8. (*continued*)

Content	Requirements
Easy button in proper position	Placing buttons where they are easy to access;
Accessibility label (for screen reader)	Ensure all text, image, controls are usable from VoiceOver/TalkBack;
Provide clear indication that elements are actionable	Avoid users ignoring elements that can be interacted with;
All functionality has unlimited time to be actionable	Provide user enough time for operation
Contextual help	Contextual help is available when a label lacks of explaining of the fill of an area;
Notification for error	Input error automatically detected should have suggestions for correction;
Instructions for gestures	Provide instructions for custom touchscreen and device manipulation gestures
Guidelines - Advanced Requirements	
Positioning important page elements before the page scroll	
Grouping operable elements that perform the same action	
Set the virtual keyboard to the type of data entry required	
Provide easy methods for data entry	
Support the characteristic properties of the platform Provide tips and contact details to collect feedback of accessibility issues encountered by users	

5.3 Mobile App Developers' Ethical Requirements

Privacy and confidentiality are primary concerns when developing mobile applications, especially in the current situation where the technologies of fingerprint and face ID have become popular.

It is also significant to recognize that there are no specific laws which require that mobile applications must become more accessible to all users, even for users with different types of disabilities, which means that the most important factor is the overall smooth operation rather than accessibility in application development [2].

6 Conclusions

Theoretical and Practical Implications

With this study, we can conclude that, in general, most mobile applications tested in the higher education sector in Portugal have an unsatisfactory level of accessibility and have various accessibility issues. The most common issues include text/image contrast, resize text, touch target, accessibility label, controls, and dialog, etc., generated barriers for the users, especially the user with visual impairments.

The App "Exames Nacionais" in iOS, "IPT mobile" in both Android and iOS have better accessibility for users with visual impairments. Since only two Apps provided video content and they have subtitles, all hearing impaired users can access these apps without barriers. All Apps have unlimited time for operating, which is friendly to the users with cognitive disabilities, but the input prompt part only achieved medium level which means certain barriers for those users.

The main reason for this state-of-affairs is that most developers do not pay much attention to accessibility development and testing during the development, and there is no accessibility standard for this process. This study summarized the common accessibility issues and proposed the accessibility recommendations that can help designers and developers to improve the accessibility of apps.

Limitations and Future Work

In this study, there are still several limitations regarding the assessment of mobile application accessibility. The lack of literature and guidelines is the first limitation encountered. Only two studies were found, which focused on the public administration and the tourism sector in Portugal [3, 5]. Another limitation encountered in this study is that the accessibility analysis tools are limited. The automated testing tools Espresso, Robolectric and Accessibility Inspector can only work in the developer mode and require the source code. Furthermore, manual testing requires to test all buttons and pages of a mobile application, which means a lot of work and spending much time, especially under the screen reader mode. Thus, this method is not suitable for a particularly complex application accessibility evaluation.

Concerning future work, the user testing will be supplemented, cooperating with the actual users who have impairments or disorders. This is because they are the related beneficiaries, and their user experience constitutes real feedback, and as a result more issues may be exposed regarding real use. In addition, a battery of tests will be created for applying and validating public service mobile applications, such as the applications for ordering delivery&food, to assess their current accessibility status and promote the recommendations for improvement that will meet all the needs of disabled users, so that they do not feel more excluded from society in this aspect.

Final Considerations

In this study, forty-six mobile applications relative to the Portuguese higher education sector were analyzed, and this analysis revealed that most mobile applications have low accessibility and a significant number of accessibility issues in this area exists. The main reason for this status quo is that most developers have not paid more attention to accessibility development and testing regarding the process of development and have not formed a standard. The mobile application designers and developers should have a greater awareness of accessibility before designing and developing applications, so as to understand the standards, understand the user needs, design rationally, and implement them properly. Hence, users with a disability may also enjoy the convenience provided by modern technology.

In the end, despite the limitations encountered in this study, all the initially identified goals have been achieved, and we hope that this study could lead to a better comprehension of the current status of accessibility for mobile applications in the education sector, thus serving as a case for future research on this topic.

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