Accessibility in mobile applications for elderly users: a systematic mapping

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***Abstract*—This Research Full Paper presents a systematic mapping that aims to characterize the current scenario of mobile application development considering accessibility issues for elderly people. Currently, the use of mobile devices has been growing exponentially, giving way to new ways of relating, working, performing daily tasks and learning. In this context, mobile learning has emerged seeking to democratize access to knowledge for different audiences. To achieve this democratization, it is necessary to develop mobile learning applications considering accessibility issues, in order to reduce barriers that might exist. Due to the increase of the life expectancy, such applications must also be accessible for elderly users. In this context, we conducted a systematic mapping that aims to characterize the current scenario of mobile application development considering accessibility issues for older people. The idea is that the results help us to establish a set of accessibility guidelines to assist in the process of developing and evaluating mobile learning applications for senior users. To achieve the main objective, 32 studies were considered to extract the data. The results obtained are relevant to highlight the current panorama of the area, as well as to present discussions about the need for studies related to the development of accessible mobile applications.**

I. Introduction

The number of mobile devices has increased significantly in the last years; cell phones, for instance, which in the past were used only to phone calls, have now gained new features and functionalities giving rise to the smartphones. Besides cell phones, other mobile devices, such as tablets, have gained more and more attention, bringing new possibilities to their users [1]. Collectively, these devices represent the most ubiquitous interactive Information and Communication Technologies (ICT) on the planet [2].

The number of people connected to mobile services surpassed 5 billion globally [1]. In Brazil, the adoption of mobile phones for Internet access among Brazilians, in 2010, was greater than the use of personal computers [3]. In addition, Brazil was recognized as the Latin American country with the largest mobile phone market in 2015 [4].

Currently, ICTs have the potential to improve people's life in different ways and in several contexts, with a special contribution in the educational area. In this context, mobile learning (m-learning) has become popular quickly. Interaction among students, virtual learning environments and mobile technologies have challenged the conventional education of knowledge acquisition in a single place, providing new possibilities for broadening learning, supported by personal media communicators [5].

Mobile learning involves the use of the mobile technology itself, or combined with other ICTs, to enable learning anytime, anywhere [2]. This learning modality has created great expectation in the educational area, specially due to the benefits related to the flexibility of teaching and training. Actually, mobile learning provides flexibility and adaptation to the context of use of the learners, teachers and tutors, being adaptable in terms of space and time [6].

Because of this flexibility and adaptation, mobile learning aims to democratize access to education. It must therefore be appropriate and structured for the elderly. According to the World Health Organization, the world's population over 60 years will exceed the number of 2 billion by 2020, a larger amount than that of children up to 5 years [7]. According to Whitbourne [8] our abilities to learn, remember, solve problems and have knowledge of the world are fundamental to our sense of identity and adaptability. Therefore, such applications should be developed considering accessibility criteria in order to reduce barriers that may be found by the elderly, since such users may have their physical, mental and learning capacity compromised due their age.

Accessibility has been considered in several scenarios, being usually classified as 'quality of access', whether it is related to the social or technological environment. In the latter case, we will adopt the ISO 9241-171 standard definition [9], accessibility is the "usability of a product, service, environment or facility by people with the widest range of capabilities".

In this paper we discuss the main aspects of a systematic mapping, conducted in order to characterize the current scenario of mobile applications development considering accessibility issues for elderly people. The data extraction for this systematic mapping considered 32 selected studies. The results showed that few studies are focused on the development or evaluation of mobile applications for elderly users. However, these users face several accessibility barriers when using mobile applications. Regarding the guidelines identified in the studies, we could verify that the results showed well established guidelines for mobile application, but such guidelines are not focused on the learning domain or any other domain. Thus, there is a need to propose specific guidelines for mobile learning applications.

This paper is organized as follows. Section II presents the systematic mapping, detailing the phases of planning, conducting, study selection and data extraction. In Section III, a summary of the data retrieved is presented, with a

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quantitative analysis. Section IV shows the qualitative data and aims to answer the research questions proposed by the mapping. Finally, Section V summarizes our conclusions and perspectives for future work.

II. Systematic Mapping: an overview

A systematic mapping aims to identify evidence clusters and evidence deserts to direct the focus of future systematic reviews and to identify areas for more primary studies to be conducted [10]. Through a categorization, the mapping provides a visual summary and a more detailed overview [11]

Our systematic mapping was conducted according to the phases presented by Kitchenham and Charters [10], as shown in Figure 1. An overview of each phase conducted in this mapping is provided next.

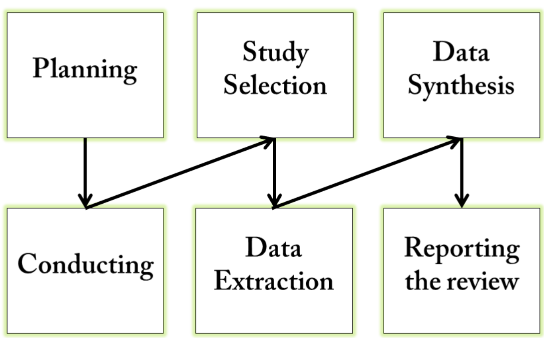

Fig. 1: Guidelines for conducting systematic mapping

A. Planning

The purpose of our systematic mapping is to characterize the current scenario of mobile applications development considering accessibility issues for elderly people. Aiming to achieve this goal, the following research questions were formulated:

RQ1: Are there methods/approaches/frameworks being used for the development and/or evaluation of accessible mobile applications?

RQ2: What accessibility guidelines have been/can be used in mobile applications?

RQ3: What accessibility barriers do elderly users find when interacting with mobile applications?

The studies identified by automated search were conclusively included for further analysis or excluded based on a set of inclusion and exclusion criteria. Such criteria clearly specify whether a study helps to answer the research questions. The inclusion and exclusion criteria used in this systematic mapping are the following:

Inclusion Criteria

IC.1. The study should describe methods / approaches / frameworks that have been used for the development of accessible mobile applications.

IC.2. The study should describe methods / approaches / frameworks that have been used to evaluate accessible mobile applications.

IC.3. The study should describe accessibility guidelines that have been used in mobile applications for elderly users.

IC.4. The study should describe the accessibility barriers found by elderly users.

Exclusion Criteria

EC.1. The study is not written in English.

EC.2. The study was published before 1999[1].

EC.3. The study is an editorial, position paper, abstract, keynote, opinion, panel discussion, or technical report. A paper that is not a peer-reviewed scientific article may not be of acceptable quality or may not provide a reasonable amount of information.

EC.4. In case of duplication, only one paper will be selected.

EC.5. The full text of the study cannot be obtained by the researchers.

B. Conducting

Aiming to guide the search string construction process, the definition criterion proposed by Petticrew and Roberts [12], entitled PICO (population, intervention, comparison, outcome), was used. This criterion assists in the identification of the relevant research topics as well as in the definition of the issues of interest. Through its use, it is possible to identify the topics that should be addressed by the research and what goals are to be achieved. Our definition of PICO was as follows:

Population Accessibility research in mobile applications for the elderly.

Intervention Guidelines, barriers and methods / approaches / frameworks.

Comparison Not applicable.

Outcome Accessibility overview in mobile applications for elderly users.

Our search string was defined by the combination of terms of greater relevance for research, such as “accessibility”, “accessible”, “access difficulty”, “mobile”, “m-learning”, “elderly”, “senescent”, “older people”, “older adult”, “senior”, “elder”, “silver age”. It is worth mentioning that there are other synonyms related to the mobile context, besides “mobile” and “m-learning”, such as “mobile learning”, “mobile assistive technology”, among others. However, these other synonyms contain the substring “mobile” and, therefore, they are already covered by this term.

The terms of the search and their synonyms were defined according to experts’ opinion, with the literature and with the research questions defined for the mapping. The generic search string used in our search is shown in Table I.

The generic search string has been modified to fit the advanced search of each of the selected search sources: ACM[2],

[1]The 1999 date was chosen as a prime date for this study because this was the year of publication of the Web Content Accessibility Guidelines (WCAG 1.0). These guidelines are considered to be of great importance for the process of developing accessible computer systems.

[2]http://portal.acm.org

TABLE I: Search string

("accessibility" OR "accessible" OR "access difficulty")
AND
("mobile" OR "m-learning")
("elderly" OR "senescent" OR "older people" OR "older adult" OR "senior" OR "elder" OR "silver age")

Engineering Village[3], IEEE[4], Science@Direct[5], Scopus[6], Taylor & Francis online [7] and Web of Science[8].

The search was initially conducted on December, 2017 and the files found were downloaded and organized in Parsif.al[9], a tool to support researchers for the development of systematic reviews or mappings.

In total, 637 documents were selected; 274 of them were duplicated, that is, they appeared in two or more databases. Thus, only one document was taken into account by the researchers. At the end (without the duplicate files), the search returned a total of 363 selected files. Table II shows the number of studies selected per research database.

TABLE II: Studies found per research database

Research Database	Total of Studies
ACM	10 (1.56%)
Engineering Village	158 (24.80%)
IEEE	36 (5.65%)
Science@Direct	21 (3.29%)
Scopus	311 (84.74%)
Taylor & Francis online	5 (0.78%)
Web of Science	96 (15.07%)

C. Study Selection

The selection process of the studies was carried out in three steps:

First Step: The studies retrieved in the automated search were stored in a list that included: title, authors, year, abstract, keywords and URL for the full text.

Second Step: Title, keywords and abstract were analyzed by the researchers, who indicated if the paper was relevant or irrelevant to the mapping. If the abstract didn't provide enough information to make an initial judgment, the conclusion section of the study was also considered, as suggested by Brereton *et. al* [13].

Third Step: All studies selected in the second stage were reassessed based on the full text reading of the study by the researchers. In the end, the studies selected in the third step were used for data extraction.

The studies were evaluated by two researchers. The level of agreement among the researchers was measured using the Cohen Kappa statistic. Kappa is a measure whose maximum value is 1, and this value represents total agreement (Table III)[14].

TABLE III: Interpretation of Kappa Values

Kappa Values	Interpretation
< 0	No agreement
0–0.19	Poor agreement
0.20–0.39	Fair agreement
0.40–0.59	Moderate agreement
0.60–0.79	Substantial agreement
0.80–1.00	Almost perfect agreement

To guarantee a consensus between the researchers and reliability to the selection process, 50 studies were arbitrarily selected to obtain the Kappa measure. Table IV shows the data of the analysis of the papers selected by researcher A and B with the decision to include (I) or exclude (E) the work. The overall Kappa value calculated with the results shown in Table IV indicated almost perfect agreement among researchers with a value of 0.836.

TABLE IV: Data used in the calculation of Kappa Value

		JUDGE B		
		Cat. 1 - I	Cat. 2 - E	Total
JUDGE A	Cat. 1 - I	19	1	20
	Cat. 2 - E	3	27	30
Total		22	28	50

From the 637 studies selected, 50 were used in the Kappa method for the calculation of concordance, whereas the others were divided between the researchers for selection. From the remainder 587 primary studies analyzed, 71 were selected for the next step. However, 13 studies were unavailable for downloading and, as a result, 58 studies were completely read by the researchers. At the end of the 58 studies analyzed in the whole, 32 final studies contributed to this systematic mapping, and their data were extracted. Figure 2 shows the workflow followed in the systematic mapping.

D. Data Extraction

At this step, the data of the primary studies were extracted and summarized in order to answer the research questions. The first step of this activity was to extract the data according to the defined Data Extraction Form (Table V), according to Kitchenham [15] guidelines. The form was completed for each of the 58 studies considered relevant by the selection criteria.

The Table V shows the data extraction form organized as follows: Question block 1 is for documentation purposes only and is not related to the data to be extracted. Block 2 is about how the review was conducted. Question blocks 3, 4 and 5 are to answer RQ1, RQ2 and RQ3, respectively. Such extraction was carried out during the full reading of the selected final works.

At first, we had 58 selected studies. However, during the data extraction step, we noticed that some studies did not answer the research questions of the systematic mapping.

[3]https://www.engineeringvillage.com
[4]http://ieeexplore.ieee.org
[5]https://www.sciencedirect.com/
[6]https://www.scopus.com
[7]https://www.tandfonline.com/
[8]https://www.isiknowledge.com/
[9]https://parsif.al/

TABLE V: Data Extraction Form.

ID	Name	Value	Related RQ
1A	Title		
1B	Authors		
1C	Year of Publication		
1D	Source		
1E	Abstract		
1F	Keywords		
2A	How was the research conducted?	Automatic (Database name)	
3A	What are the methods/approaches/frameworks identified for the development of accessible mobile applications?	Text fields	RQ1
3B	What are the methods/approaches/frameworks identified for the evaluation of accessible mobile applications	Text fields	RQ1
4A	What accessibility guidelines are identified in the study?	Text fields	RQ2
4B	Which accessibility guidelines are for mobile applications?	Text fields	RQ2
4C	Of these guidelines, is there any specific for mobile learning applications?	Text fields	RQ2
5A	What accessibility barriers are identified in the study?	Text fields	RQ3
5B	What accessibility barriers refer to mobile applications?	Text fields	RQ3

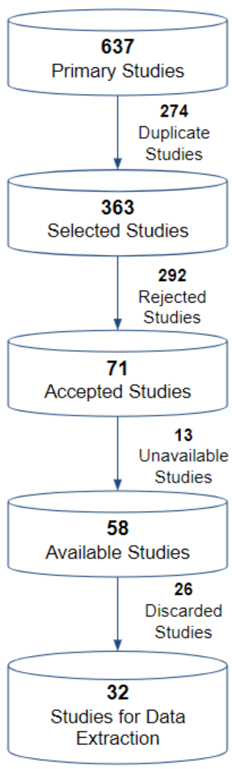

Fig. 2: Stages of Systematic Mapping

Thus, of the 58 articles selected, 32 answered at least one of the three research questions; such studies were considered for data synthesis.

III. Data Synthesis

After the extraction and summarization of the data, the results obtained were analyzed.

Figure 3 shows the number of studies per year of publication. Among the 32 studies retrieved, we can notice an increase in publications in recent years. A subtle trend of greater investigation of the theme can be observed in 2015 and 2016.

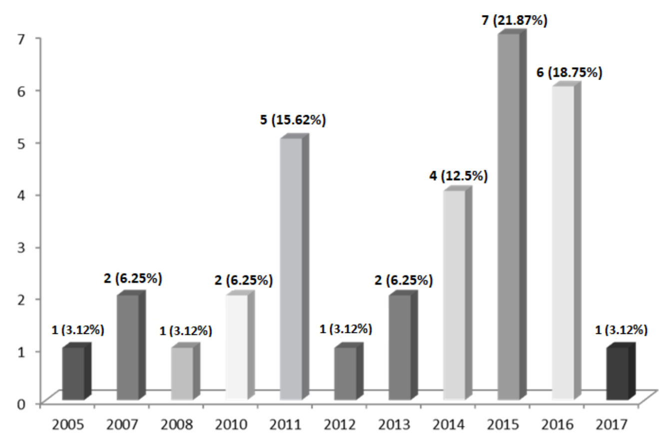

Fig. 3: Number of publications per year.

Regarding publication vehicles (Figure 4), we observed that 24 studies were published in conferences, and eight studies were published in journals, suggesting this is an emerging research area.

The countries with participation in the selected research were: Australia, Austria, Brazil, Canada, China, Czech Republic, England, France, Iran, Italy, Japan, Netherlands, Norway, Portugal, Saudi Arabia, Slovenia, South Africa, Spain, Sweden, United States. The number of papers identified by continent can be seen in Figure 5. Spain (7 studies), Brazil (3 studies) and Austria (3 studies) are the countries with the highest number of studies in the area.

IV. Accessibility in mobile apps for the elderly: reporting the map

The discussions presented herein are based on the results obtained from the analysis of the 32 studies identified (Table VI) and provide answers to the defined research questions.

TABLE VI: Selected studies

ID	Title	Author(s) Name	Year	Reference
S01	A Review of Senescent's Motivation in the Use of Tactile Devices	Fortes et al.	2015	[16]
S02	Accessibility for older users through adaptive interfaces: Opportunities, challenges and achievements	Edlin-White et al.	2011	[17]
S03	Accessibility to mobile interfaces for older people	Diaz-Bossini and Moreno	2014	[18]
S04	Accessible mobile biometrics for elderly	Blanco-Gonzalo et. al	2015	[19]
S05	Accessible way finding on mobile devices for different user groups	Krainz et al.	2016	[20]
S06	An analysis of application usage for notes and reminders by older persons: ElderNote Case study	Melo et al.	2016	[21]
S07	An inclusive mobile texting system	Pustišek and Peternel	2011	[22]
S08	Barriers to the adoption of cell phones for older people with impairments in the USA: Results from an expert review and field study	Pedlow et al.	2010	[23]
S09	Design and development of Medication Assistant: older adults centred design to go beyond simple medication reminders	Teixeira et al.	2017	[24]
S10	Developing mobile application design of virtual pets for caring for the elderly	Hsieh	2015	[25]
S11	Development of universal design mobile interface guidelines (UDMIG) for aging population	Ruzic et al.	2016	[26]
S12	Evaluation of PhonAge: An adapted smartphone interface for elderly people	Arab et al.	2013	[27]
S13	FrontPanel: Tangible user interface for touch-screens dedicated to elderly	Ziat et al.	2016	[28]
S14	How elders evaluate apps: A contribution to the study of smartphones and to the analysis of the usefulness and accessibility of ICTS for older adults	Fondevila et al.	2015	[29]
S15	'I need to know, i cannot, i don't understand': Older users' requirements for a navigation application	Angeletou et al.	2003	[30]
S16	Imhotep: An approach to user and device conscious mobile applications	Almeida et. al	2011	[31]
S17	Improving accessibility of tactile interaction for older users: loweringaccuracy requirements to support drag-and-drop interaction	Motti et al.	2015	[32]
S18	KoalaPhone: touchscreen mobile phone UI for active seniors	Balata et al.	2015	[33]
S19	Mobile Apps Repository for Older People	Conde et al.	2014	[34]
S20	Mobile for older adults: Towards designing multimodal interaction	Ferron et al.	2015	[35]
S21	Mobile touch interfaces for the elderly	Stone	2008	[36]
S22	Older adults' attitudes and barriers toward the use of mobile phones	Navabi et al.	2016	[37]
S23	OldGen: Mobile phone personalization for older adults	Olwal et al.	2011	[38]
S24	Personalizing health-related ICT interface and application: Older adults and elderly caregivers preferences	Santos et al.	2016	[39]
S25	The effect of previous exposure to technology on acceptance and itsimportance in usability and accessibility engineering	Holzinger et al.	2011	[40]
S26	Touch-based mobile phone interface guidelines and design recommendations for elderly people: A survey of the literature	Al-Razgan et al.	2012	[41]
S27	Towards mobile accessibility for older people: A user centered evaluation	Diaz-Bossini et al.	2014	[42]
S28	Universal design activities for mobile phone: Raku Raku PHONE	Irie et al.	2005	[43]
S29	Universal design and mobile devices	Hellman et al.	2007	[44]
S30	Usability evaluation method for mobile applications for the elderly: A methodological proposal	Caliz and Alaman	2014	[45]
S31	Using participatory activities with seniors to critique, build, and evaluate mobile phones	Massimi et al.	2017	[46]
S32	Worth-centred mobile phone design for older users	Renaud and Biljon	2010	[47]

A. Are there methods/approaches/framework being used for the development and evaluation of accessible mobile applications?

During the data extraction, with regard to the first research question, we chose to divide the question into two parts:

- Are there methods/approaches/frameworks being used for the development of accessible mobile applications?
- Are there methods/approaches/frameworks being used for the evaluation of accessible mobile applications?

In relation to the methods/approaches/framework used for the development of more accessible mobile applications, only one work was identified. Almeida *et. al* [48] proposed a study on Imhotep, a framework that helps developers to build more accessible applications. Through Imhotep, a particular application can adapt to different types of elderly users, respecting the characteristics of each person.

Regarding the evaluation of mobile applications, a greater number of papers were identified. In total, 17 studies addressed at least one type of evaluation. The types of evaluation identified are presented in Table VII.

Figure 6 shows the types of evaluation identified in the studies. It is important to note that Heuristic Assessment [43], [45] and Usability Metrics [40] refer to usability assessments. However, as accessibility can be considered an usability subcategory [9], these evaluations were also considered in our

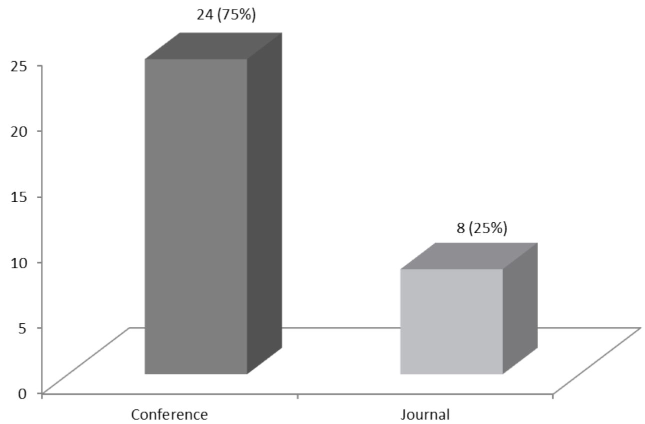

Fig. 4: Publishing vehicles.

TABLE VII: Type of Evaluation identified in the systematic mapping by author

Type of Evaluation	Number of Studies	References
Test with users	11	S01 S05 S06 S07 S09 S10 S17 S23 S24 S30 S31
Heuristic evaluation	2	S28 S30
Checklist	2	S03 S22
Interview with users	1	S12
Questionnaire application	1	S12
Focus group	1	S14
Usability metrics	1	S25

study.

B. What accessibility guidelines have been / can be used in mobile applications?

Regarding the accessibility guidelines, four papers [42], [18], [26], [17] presented guidelines that addressed accessibility issues. It is important to note that one study may have cited more than one guideline. The guidelines identified in the studies are presented in Table VIII.

TABLE VIII: Guidelines identified in the systematic mapping by author

Guidelines	Number of Studies	References
Web Content Accessibility Guidelines (WCAG)	2	S03 S27
Mobile Web Best Practice (MWBP)	1	S27
User Agent Accessibility (UAAG)	1	S27
Authoring Tool Accessibility Guidelines (ATAG)	1	S27
Accessible Rich Internet Applications (WAI-ARIA)	2	S03 S27
Universal Design Mobile Interface Guidelines (UDMIG)	1	S11
Ergonomics Data and Guidelines for the application (ISO/TR 22411:2008)	1	S02

Figure 7 shows the guidelines identified in the studies. As we can observe, the cited guidelines are well established in the computing area and, although the studies are related to mobile applications, only WMBP and UDMIG guidelines are specific to this type of domain. In addition, none of the guidelines specifically dealt with mobile learning applications, showing a research gap in this context.

C. What accessibility barriers do elderly users find when interacting with mobile applications?

In total, 20 studies presented at least one accessibility barrier that can be found by elderly people in the use of mobile applications. In some cases, the same study dealt with more than one barrier of accessibility and, therefore, all identified items were grouped and are presented in Table IX.

TABLE IX: Accessibility barriers identified in the systematic mapping by author

Acessibility barriers	Number of studies	References
Font Size	9	S01 S10 S15 S18 S19 S21 S24 S26 S29
Text and complex languages	2	S26 S29
Lack of help options	1	S29
Small space to click	2	S18 S20
Vertical and horizontal screen orientation	3	S15 S21 S29
Small spacing between contents	2	S21 S24
Automatic screen lock	1	S14
Difficulty with the touch screen	4	S18 S19 S21 S29
Virtual or physical keyboard with small size	2	S13 S19
Error messages without clarity	3	S01 S19 S29
Contrast	4	S01 S04 S18 S24
Difficulty of access to the Menu and submenus	5	S10 S15 S19 S24 S32
Inaccessible data insertion interfaces	3	S04 S15 S19
Difficulty with drag-and-drop features	3	S17 S18 S19
Difficulty identifying the symbols and icons used in the application	3	S10 S12 S19
Lack of perception of audio notifications and reminders	1	S18
Difficult navigation and information flow	1	S29
Lack of an option to resize the text	2	S04
Poor sound quality	1	S19

Figure 8 shows accessibility barriers that can be faced by older people while using mobile applications. Of the 19 barriers mentioned, 16 of them (84.21 %) refers to user interface and can be solved or minimized through the development of mobile applications. Only barriers “Automatic screen lock”, “Virtual and physical keyboard with small size” and “Difficulty of the touch screen” deal with problems related to the operating system or the device itself (hardware). Still, it is possible that the application be developed in such a way that the user interaction can be facilitated independently of the device or operating system used.

Fig. 5: World map with number of studies from each continent.

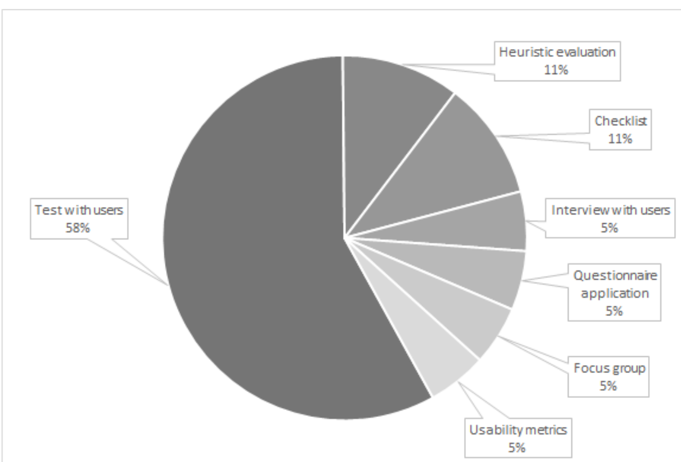

Fig. 6: Type of Evaluation identified in the systematic mapping by percentage

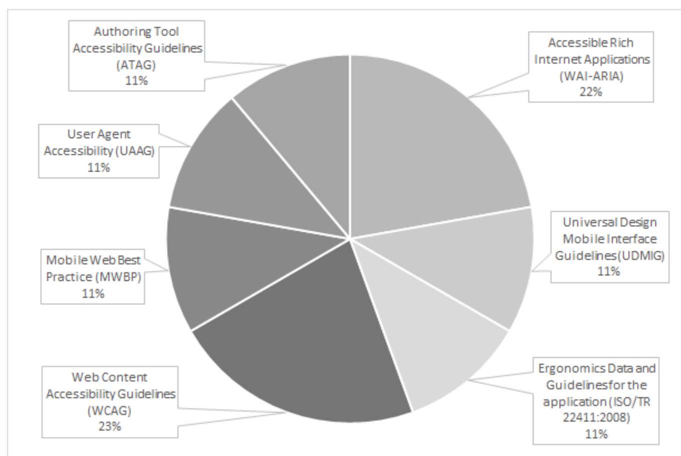

Fig. 7: Guidelines identified in the systematic mapping by percentage

V. Conclusions and Future Work

In this paper we described a systematic mapping conducted in order to characterize the current scenario of mobile applications development considering accessibility issues for elderly people. The obtained results were relevant to provide a current panorama of the area, as well as to point out the need of more studies related to the development of accessible mobile applications, mainly referring to mobile learning applications.

Although our final research interest be in the learning domain, in the systematic mapping presented herein we decide to use a generic search string. Our intent was to verify methods, approaches and frameworks for the development and evaluation of accessible mobile applications, regardless of the domain. We also searched for accessibility guidelines and accessibility barriers found by the elderly considering generic mobile applications, independently of the domain.

In relation to the methods/approaches/framework used for the development of more accessible mobile applications, it

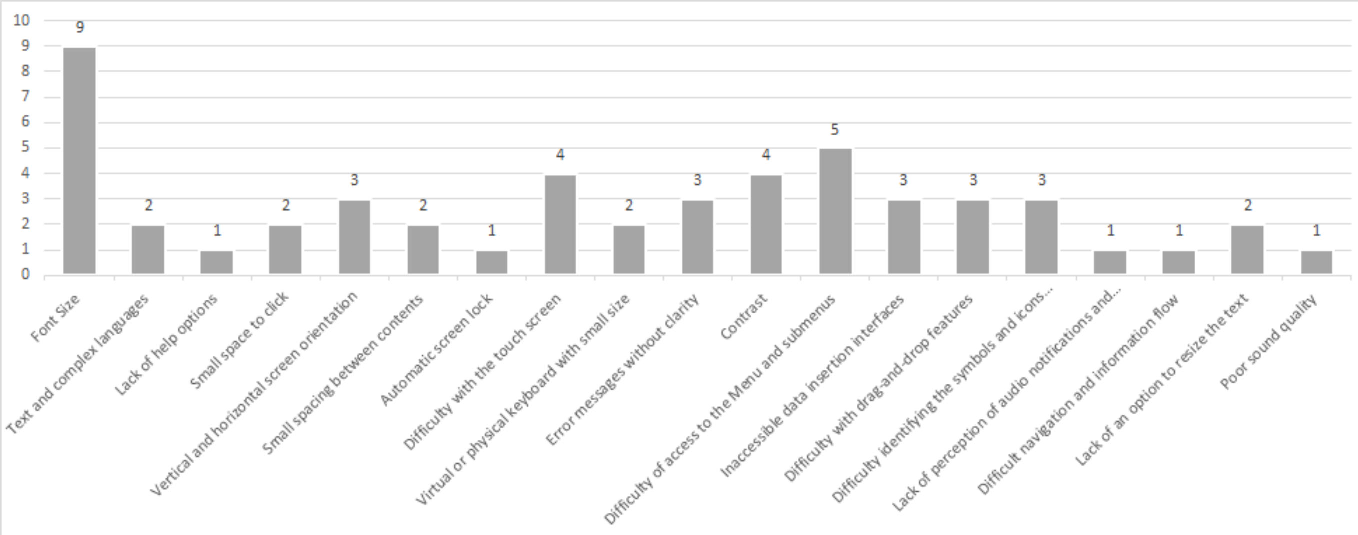

Fig. 8: Accessibility barriers identified in the systematic mapping

was possible to verify that only one work addresses this question. Regarding the evaluation of mobile applications, a greater number (17 studies) of papers were identified, considering methods/approaches/usability and accessibility assessment frameworks. Regarding the accessibility guidelines, four papers presented guidelines that addressed accessibility issues. Among the guidelines identified are: Web Content Accessibility Guidelines (WCAG), Mobile Web Best Practice (MWBP), User Agent Accessibility (UAAG), Accessible Rich Internet Applications (WAI-ARIA) Interface Guidelines (UDMIG) and Ergonomics Data and Guidelines for the Application (ISO/TR 22411:2008). Finally, 20 studies presented at least one accessibility barrier that can be found by elderly people in the use of mobile applications.

From the obtained results, we pointed out that no study specifically addresses mobile learning applications, emphasizing the need of studies focusing in the learning domain. Although the retrieved guidelines aim to reduce accessibility problems in computer systems, there still are few guidelines focusing on native mobile applications. Furthermore, none of such guidelines is focused on the learning context, considering, for instance, pedagogical strategies, and teaching and learning practices.

Aiming to bridge this gap, as future work we intend to investigate and propose a set of accessibility guidelines to help in the process of developing mobile learning applications for the elderly. In this context, the results gathered from this systematic mapping will serve as an important input to our research.

Besides that, we also intend to update our systematic mapping with other types of searches in order to complement the results obtained so far. For instance, manual search and snowballing can bring a greater number of results and contributions to the area.

Acknowledgment

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