Chapter

A Systematic Review of Usability and Accessibility in Tele-Rehabilitation Systems

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Abstract

The appropriate development of tele-rehabilitation platforms requires the involvement and iterative assessments of potential users and experts in usability. Usability consists of measuring the degree to which an interactive system can be used by specified final users to achieve quantified objectives with effectiveness, efficiency, and satisfaction in a quantified context of use. Usability studies need to be complemented by an accessibility assessment. Accessibility indicates how easy it is for a person to access any content, regardless of their physical, educational, social, psychological, or cultural conditions. This chapter intends to conduct a systematic review of the literature on usability and accessibility in tele-rehabilitation platforms carried out through the PRISMA method. To do so, we searched in ACM, IEEE Xplore, Google Scholar, and Scopus databases for the most relevant papers of the last decade. The main result of the usability shows that the user experience predominates over the heuristic studies, and the usability questionnaire most used in user experience is the SUS. The main result of the accessibility reveals that the topic is only marginally studied. In addition, it is observed that Web applications do not apply the physical and cognitive accessibility standards defined by the WCAG 2.1.

Keywords: usability, accessibility, telemedicine, tele-rehabilitation, systematic review

1. Introduction

Innovation and technological advances involve the offering of valuable products and services to improve the quality of life of citizens. In recent decades, the domain of telemedicine has reported advances in the control, monitoring and evaluation of various clinical conditions [1]. In the field of rehabilitation, numerous studies and state-of-the-arts from informatics perspective [2] and different areas of application [3, 4], show the effectiveness and advantages of the use of remote rehabilitation (or tele-rehabilitation) [5, 6]. Tele-rehabilitation aims to reduce the time and costs of offering rehabilitation services. The main objective is to improve the quality of life of patients [7]. Tele-rehabilitation cannot replace traditional neurological rehabilitation [8]. It is considered as a partial replacement of face-to-face physical rehabilitation [9]. Tele-rehabilitation uses mainly two groups of technologies: (1) wearable devices and (2) vision-based systems based on depth cameras and intelligent algorithms [10]. In [5], the authors describe and analyze some characteristics and typical requirements tele-rehabilitation systems.

Design and conception of tele-rehabilitations platforms that do not consider guidelines, metrics, patterns, principles, or practice success factors can affect the access to the service, the effectiveness, quality, and usefulness. It can cause problems of confusion, error, stress, and abandonment of the rehabilitation plan. Therefore, guaranteeing the correct use of these applications implies to incorporate different studies of usability in the life cycle of the interactive system. For this reason, aspects of human factors engineering in tele-rehabilitation systems have been studied with the aim of providing accessible, efficient, usable and understandable systems [11, 12].

User-centered agile development (UCD) approaches allows developers to specify and design the set of interfaces of any interactive system in a flexible and effective way [13, 14]. The agile development life cycle centered on user experience (UX-ADLC) allows iteratively evaluating system interfaces based on the results of the previous iteration. The evaluation also includes the errors and usability problems encountered [15]. Thus, usability studies are an essential aspect of technology development [16]. This is the reason why designers need to meet usability and user experience objectives while adhering to agile principles of software development. Formative and summative usability tests are methods of evaluating software products widely adopted in user-centered design (UCD) [15] and agile UX development lifecycle. Both approaches are frequently used in the development of software applications. Rapid formative usability should be carried out so as to fulfill UX goals while satisfying end users' needs. Formative usability is used as an iterative test-and-refine method performed in the early steps of a design process, in order to detect and fix usability problems [15]. Summative usability allows for assuring, in later phases of the design, the quality of the user experience (UX) for a software product in development. The focus is on short work periods (or iterations) where usability tests (formative and summative) must be contemplated. This means that quick formative usability tests should be carried out to fulfill UX goals [17].

The ISO 9241-11 standard [18] is a framework for understanding and applying the concept of usability to situations in which people use interactive systems and other types of systems (including built environments), products (including industrial and consumer products) and services (including technical and personal services). Likewise, the usability standard ISO 9241-11 facilitates the measurement of the use of a product with the aim of achieving specific objectives with effectiveness, efficiency and satisfaction in a context of specific use [18].

Usability can be studied through software evaluation methods widely accepted in user centered design (UCD) [15]. It can be formative or summative [8]. Formative usability consists of a set of iterative tests carried out in the early stages of the design process. The aim of the tests is to refine and improve the software product, as well as to detect and solve potential usability problems. As a complement, the summative usability allows to obtain an evaluation of the user experience (UX) for a software product in development. Formative usability facilitates decision making during the design and development of the product, while summative usability is useful when studying user experience (UX).

Tullis and Stetson [19] evaluated the effectiveness of the most used questionnaires to measure the summative usability. The authors found that the System Usability Scale (SUS) [20] and the IBM Computer System Usability Questionnaire (CSUQ) [21] are the most effective. SUS provides a quick way for measuring the usability through user experience. It consists of a 10-item questionnaire with 5-likert scale range from "Strong Agree" to "Strongly Disagree." The CSUQ focuses on three main aspects: (1) the utility, which refers to the opinion of users regarding the ease of use, the ease of learning, the speed to perform the operations, the efficiency in completing tasks and subjective feeling; (2) the quality of the information which studies the subjectivity of the user regarding the management of system errors, the clarity of the information and the intelligibility; and finally, (3) the quality of the interface which measures the affective component of the user's attitude in the use of the system.

Large part of the tasks in the tele-rehabilitation systems are carried out by patients who require to treat a temporary disability. Considering the special needs of these users, usability evaluations alone cannot guarantee an appropriate design of the system. On the contrary, accessibility studies can provide the mechanisms to offer the same means of use to all users of any interactive system. A study combining usability and accessibility was presented in [22]. The study analyzes how remote and/or video monitoring technologies affect the accessibility, effectiveness, quality and usefulness of the services offered by tele-rehabilitation systems. To do this, the authors provide an overview of the fundamentals necessary for the analysis of usability, in addition to analyzing the strengths and limitations of various tele-rehabilitation technologies, considering how technologies interact with the clinical needs of end users such as accessibility, effectiveness, quality and utility of the service [22].

For many people, the Web is a fundamental part of everyday life. Therefore, a fundamental aspect to ensure the inclusivity of a Website is its accessibility. For example, people who cannot use their arms to write on their computer can use a mouth pencil [23]. Or someone who cannot listen well can use subtitles to understand a video. Also, a person who has a low vision can use a screen reader to listen what is written on the screen [24]. Therefore, Web accessibility means that people with disabilities can use the Web without any type of barriers [24]. There are several standards related to accessibility that provide guidelines and recommendations [25]. Some of the most important, according to the International Organization for Standardization (ISO), are the following ones:

- ISO 9241: covers ergonomics of human-computer interaction.
- ISO 14915 (software ergonomics for multimedia user interfaces): multimedia controls and navigation structure.
- ISO CD 9241-151 (software ergonomics for World Wide Web user interfaces): designs of Web user interfaces.
- ISO TS 16071 (guidance on accessibility for human-computer interface): recommendations for the design of systems and software applications that allows a greater accessibility to computer systems for users with disabilities.
- ISO CD 9241-20: accessibility guideline for information communication, equipment and services.

The Web Accessibility Initiative (WAI) [26] from the World Wide Web Consortium (W3C) [27] develops Web Content Accessibility Guidelines (WCAG) [28] 2.0 (at present 2.1) that covers a wide range of recommendations for making Web contents more accessible. These guidelines were considered a standard in

2012, the ISO/IEC 40500. Complementary to these guidelines are the W3C User Agent Accessibility guidelines [29] (UAAG) and Authoring tool Accessibility guidelines [30] (ATAG), which addresses the current technological capabilities to modify the presentation based on the device capabilities and the preferences of the user.

The World Wide Web Consortium (W3C) provides international standards to make the Web as accessible as possible. It comprises the Web 2.0 Content Accessibility Guidelines (WCAG 2.0) [31], also known as the ISO 40500 [32], which are adapted to the European Standard called EN 301549 [33].

The current version of the accessibility guidelines is "Web Content Accessibility Guidelines 2.1" (WCAG 2.1) [23]. WCAG 2.1 consists of 4 principles, 13 guidelines and 76 compliance criteria. The four principles refer to [34].

Principle 1—perceptibility: refers to the good practices regarding the presentation of information and user interface components. It consists of 4 guidelines and 29 compliance criteria.

Principle 2—operability: the components of the user interface and navigation must be operable. It includes 5 guidelines and 29 compliance criteria.

Principle 3—comprehensibility: the information and user interface management must be understandable. It has 3 guidelines and 17 compliance criteria.

Principle 4—robustness: the content must be robust enough to rely on the interpretation of a wide variety of user agents, including assistive technologies. It includes a guideline and three compliance criteria.

Usability and accessibility can be combined to achieve the development of more accessible, efficient, equitable and universal tele-rehabilitation systems. This chapter presents a systematic literature review of summative and formative usability studies as well as accessibility studies in the context of tele-rehabilitation systems. The remaining of the manuscript is composed of four sections. Section 2 presents the method used to proceed with the systematic review. Section 3 is a description of the most relevant papers in usability applied to tele-rehabilitation. Section 4 describes the results regarding the accessibility. And Section 5 draws conclusions on the main findings of this literature review.

2. Materials and methods

Systematic reviews and meta-analyzes are increasingly crucial in the area of health care. In order to optimize meta-analysis reports, an international group developed in 1996 a guide called the QUOROM Statement (Quality Of Reporting Of Meta-analyses), which focused on information from Meta-analysis of a randomized controlled trial [35]. One reason for changing the name from QUOROM to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was the desire to encompass both systematic reviews and meta analyses.

To improve the literature revision processes Quorum evolved until arriving at the PRISMA[1] declaration that consists of a checklist of 27 elements and a diagram of four-phase flow that is applied in this study.[2] The PRISMA statement helps authors improving the reports of systematic reviews and meta-analyzes. It is used as a basis to inform systematic reviews of other types of research.

[1] http://www.prisma-statement.org/

[2] http://prisma-statement.org/prismastatement/flowdiagram.aspx

In order to study the current state of Web platforms for tele-rehabilitation of patients with motor disability, we undertook a systematic review of the literature following the procedures specified in PRISMA. Based on that study, we formulate the following research questions:

1. Which studies currently exist on usability in the development of Web platforms for patients who need to perform a tele-rehabilitation?

2. Which studies currently exist related to Web accessibility in the development of inclusive platforms for patients who require a tele-rehabilitation?

The bibliographic search of usability and accessibility in the context of tele-rehabilitation systems was conducted using the ACM, Google Scholar, IEEE Xplore, and Scopus databases. **Table 1** shows the search chains used for each digital library, in order to obtain as many relevant studies as possible. Concerning the usability and accessibility, we limited our research to publications from 1990 to 2019.

There are many studies related to Web accessibility. Therefore, to ensure that the search is manageable and focused on tele-rehabilitation, we defined some inclusion and exclusion criteria when selecting the articles, such as:

- If the studies had been published in more than one journal or in the proceedings of a conference, we chose the complete version, only.

- We excluded non-scientific conferences and journals and papers that are out of the scope of the review.

Digital Library	Usability search	Accessibility search
ACM	acmdlTitle:(usability heuristic evaluation) AND recordAbstract:(tele-rehabilitation) AND keywords.author.keyword:(usability heuristic evaluation)	acmdlTitle:(web accessibility) AND recordAbstract:(telerehabilitation) AND keywords.author.keyword:(web accessibility)
IEEE Xplore	(("Document Title":usability OR "Document Title":"heuristic evaluation" OR "Document Title":"user experience") OR ("Publication Title":usability OR "Publication Title":"heuristic evaluation" OR "Publication Title":"user experience")) AND ("Abstract":tele-rehabilitation) AND ("Author Keywords":usability OR "Author Keywords":"heuristic evaluation" OR "Author Keywords":"user experience")	(("Document Title": accessibility OR "Document Title":"web" OR Document Title":"web accessibility") OR ("Publication Title": web accessibility OR "Publication Title":telerehabilitation)) AND ("Abstract": tele-rehabilitation) AND ("Author Keywords":web accessibility OR "Author Keywords":telerehabilitation)
Google Scholar	intitle:usability OR "heuristic evaluation" OR "User experience" "tele rehabilitation"	intitle: accessibility OR "web" OR "tele rehabilitation"
Scopus	(SRCTITLE (usability OR "heuristic evaluation" OR "user experience") OR TITLE (usability OR "heuristic evaluation" OR "user experience")) AND ABS (tele-rehabilitation*) AND KEY (usability OR "heuristic evaluation" OR "user experience") AND (PUBYEAR > 1989)	(SRCTITLE (accessibility OR "web") OR TITLE (accessibility OR "web") AND ABS (tele-rehabilitation*) AND KEY (accessibility OR "web") AND (PUBYEAR > 1989)

Table 1.
Search strings used for the literature review.

Digital Library	Usability studies	Accessibility studies
IEEE Xplore	1	26
Google Scholar	229	29
Scopus	1	7
ACM	12	14
Total	**243**	**76**

Table 2.
The number of research studies identified.

After the search was completed, 243 results were obtained for usability, and 76 results were obtained for accessibility (**Table 2**). Then, the title and the abstract of these articles were analyzed to identify their relevance to the topic of usability and accessibility in tele-rehabilitation systems.

We use the Start LaPes[3] 2.3.4.2 tool to analyze the databases that meet the search criteria and Mendeley Desktop[4] 1.19.3 to manage all the bibliography, details and appointments. This tool helps in the selection process of the scientific articles in such a way that it allows us to eliminate the duplicate articles, to register/filter the accepted and rejected articles in order to obtain reports that are adequate during the meta-analysis process.

Then, in order to study the current state of usability and accessibility related to tele-rehabilitation systems, we conducted a systematic review of the literature based on the PRISMA procedure [36].

When carrying out the literature review, studies that did not meet the established search criteria or referred to another type of usability/accessibility context were discarded. The phases of the selection process according to the PRISMA-based literature review for both themes, usability and accessibility, are detailed in the next two sections.

3. Usability review

The phases of the selection process for the literature review of papers on usability applied to tele-rehabilitation systems are detailed in **Figure 1**.

The 26 papers that were selected for further analysis are listed in **Table 3**.

Usability studies have a significant impact on the quality of the development of e-health systems. The potential for e-health to improve healthcare is partially dependent on its ease of use [45]. A systematic review presented in 2016 indicates that from 40 telemedicine studies, only 7.5% are focused on evaluating the user experience of the patients [46]. Academics, technical studies and scientific communities or special groups [60] have been conducted to evaluate the usability in e-health systems. [49] propose a methodological framework to perform user experience analysis of e-health technologies for patients' engagements. It considers a set of self-report measurements such as mental workload [61], system usability [20] and negative emotional responses [62], in order to provide descriptive data about the user experience of patients. [45] present a systematic review to identify psychometrically tested questionnaires that measure the usability of e-health tools, and to appraise their generalizability, attribute coverage, and quality. The main usability attributes found during the revisions were: learnability, efficiency, and satisfaction.

[3] http://lapes.dc.ufscar.br/tools/start_tool
[4] https://www.mendeley.com/download-desktop/

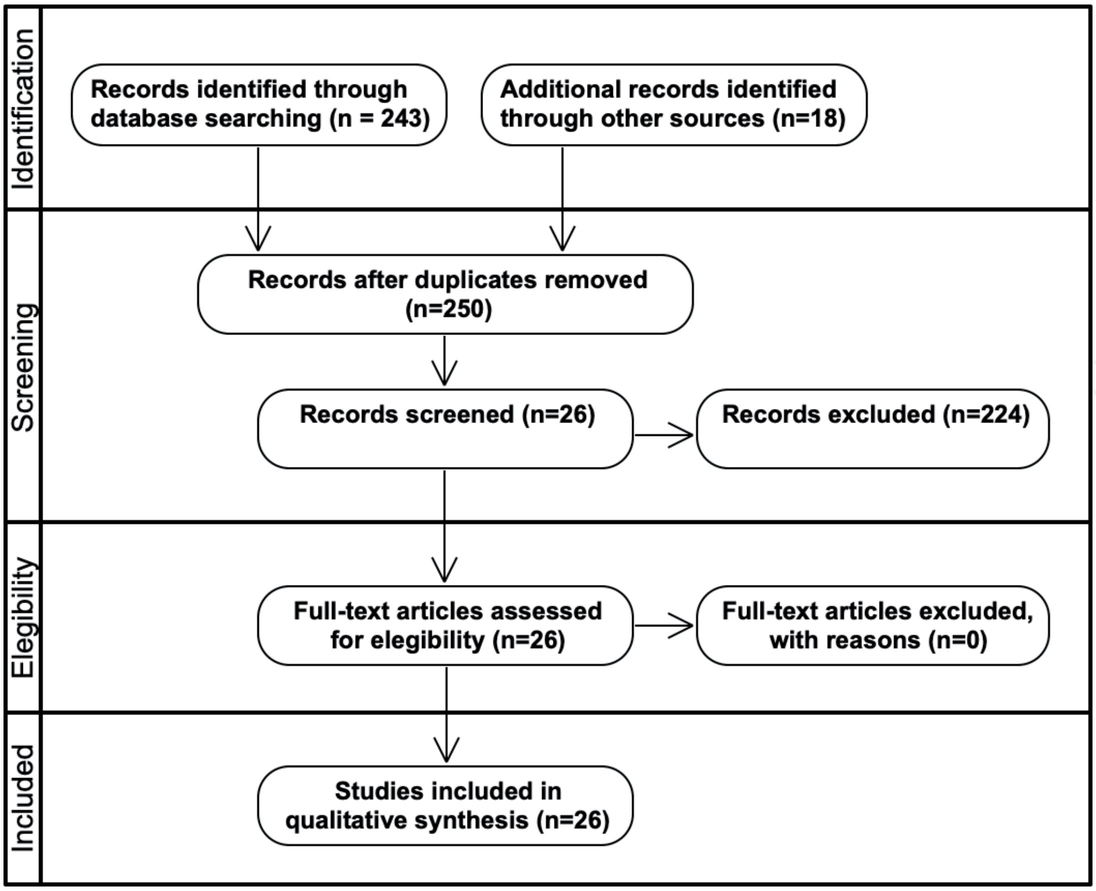

Figure 1.
PRISMA 2009 flow diagram chart that shows the selection process of the papers included in the literature review for usability.

Likewise, quality appraisal showed that face/content and construct validity were the most frequent types of validity assessed.

High levels of usability guarantee the substantial quality-of-life. This leads to the acceptance of tele-rehabilitation systems [58]. Likewise, a usability study, to evaluate patients' rehabilitation-evolution, is presented in [51] conclude that the usability is one of the advantages of the tele-rehabilitation system for both patients and professionals.

In [56], authors study the usability of a rehabilitation system designed to demonstrate, instruct and monitor a therapeutic exercise program. The evaluation of usability was carried out in two stages. The first stage consisted of a formative evaluation to identify initial usability problems, defects or omissions in the system. Secondly, user evaluation was conducted by using VRUSE, a computerized usability questionnaire explicitly designed for the evaluation of virtual reality applications [59].

Weiss et al. [55] present the development life cycle, including usability testing, of a low-cost remote rehabilitation system based on virtual reality technology. The solution was designed to provide remote rehabilitation of the upper extremities in patients who have had a stroke. The usability study was conducted with a population of eight patients. Usability was measured by the 5-point Short Feedback Questionnaire (SFQ) [57]. This instrument documents the enjoyment of participants and their perception of success and control while using the system. The perception was evaluated by using the Borg scale [63]. The subjective ratings were complemented by game performance scores.

In [54], a methodology for a home-based tele-rehabilitation system was presented. This work was done considering patients who require rehabilitation of the arms after having a stroke. The answers were collected via a series of structured

Title	Authors	Year
An Agile Approach to Improve the Usability of a Physical Telerehabilitation Platform	Pilco et al. [37]	2019
Usability study of a Web-Based Platform for Home Motor Rehabilitation	Pérez-Medina et al. [38]	2019
Implementation and Assessment of an Intelligent Motor Tele-Rehabilitation Platform	Rybarczyk, et al. [6]	2019
Analysis and Improvement of the Usability of a Tele-rehabilitation Platform for Hip Surgery Patients	Pilco et al. [39]	2018
A Telerehabilitation System for the Selection, Evaluation and Remote Management of Therapies	Anton et al. [40]	2018
Interaction with a Tele-Rehabilitation Platform Through a Natural User Interface: a Case Study of Hip Arthroplasty Patients	Rybarczyk et al. [41]	2018
Usability Evaluation of a Vibrotactile Feedback System in Stroke Subjects	Held et al. [42]	2017
On the Use of Natural User Interfaces in Physical Rehabilitation: a Web-based Application for Patients with Hip Prosthesis	Rybarczyk et al. [43]	2017
USEQ: A Short Questionnaire for Satisfaction Evaluation of Virtual Rehabilitation Systems	Gil-Gómez et al. [44]	2017
Towards usable E-health. A Systematic Review of Usability Questionnaires	Sousa et al. [45]	2017
A Renewed Framework for the Evaluation of Telemedicine	Jansen-Kosterink et al. [46]	2016
Development of the telehealth usability questionnaire (TUQ)	Parmanto et al. [47]	2016
Validation of a Kinect-based telerehabilitation system with total hip replacement patients	Anton et al. [48]	2016
Evaluating Patient Engagement and User Experience of a Positive Technology Intervention: The H-CIM Case	Triberti et al. [49]	2015
A novel knee rehabilitation system for the home	Ayoade et al. [50]	2014
Telerehabilitation web application for health care	Eguiluz-Perez et al. [51]	2014
SEQ: Suitability Evaluation Questionnaire for Virtual Rehabilitation Systems. Application in a Virtual Rehabilitation System for Balance Rehabilitation	Gil-Gómez et al. [52]	2013
Kires: a Kinect-based telerehabilitation system	Anton et al. [53]	2013
Assessment and training in home-based telerehabilitation of arm mobility impairment	Perry et al. [54]	2013
Development and validation of tele-health system for stroke rehabilitation	Weiss et al. [55]	2012
Usability evaluation of e-motion: a virtual rehabilitation system designed to demonstrate, instruct and monitor a therapeutic exercise program	Fitzgerald et al. [56]	2008
Short feedback questionnaire (SFQ) to enhance client-centered participation in virtual environments	Kizony et al. [57]	2006
Formative evaluation of a virtual reality telerehabilitation system for the lower extremity	Whitworth et al. [16]	2003
Dimensions of diversity in design of telerehabilitation systems for universal usability	Lathan et al. [58]	2000
VRUSE—a computerized diagnostic tool: for usability evaluation of virtual/synthetic environment systems	Kalawsky et al. [59]	1999
Evaluation—Methodology for Telematic Application Systems: Quality for Users and Context	Arnold et al. [60]	1997

Table 3.
List of the usability papers selected in this review.

interviews and seven point Likert-based evaluation questions measuring the level of agreement. Ayoade and Baillie [50] present the results of a randomized controlled study in which the authors investigated the usability and feasibility of a rehabilitation visualization system. This work has employed the principles of user-centered design throughout the development phases of the system. The study was performed with the SUS questionnaire [20]. Additionally, metrics significant for both patients and health professionals such as quality of life and the improved knee were studied.

Anton et al. [40] present a successful study of usability of a tele-rehabilitation system called KiReS [53]. The evaluation was made in a real scenario. The patients involved in the study underwent a total hip replacement surgery (THR). The study of the subjective perceptions of the patients when participating in the rehabilitation sessions was conducted through an empirical 5-point Likert scale questionnaire based on 13 statements and described in [48]. The instrument is structured in three sections: (1) the system, (2) the user experience, and (3) the user interface. The questionnaire also explores the prior knowledge that patients have regarding tele-rehabilitation systems. In general, the criticisms obtained by the patients were on the interfaces of the system [48].

In [16], the formative usability of the Rutgers Ankle Rehabilitation System (RARS) was studied involving three simultaneous users and a remote monitoring. The authors describe a usability evaluation process where engineers and physicians collaborated collaboratively. The usability study uses both traditional and empirical methods to assess the viability of the design of the interface.

A SUS questionnaire was used in order to study the usability and user acceptance of a sensor system called "Arm Usage Coach" (AUC) that provides VibroTactile (VT) feedback if the patient does not move the affected arm above a certain threshold level [42]. The study involved 10 patients who suffered a cardiovascular accident and had a mild to moderate arm impairment. The experiment made use of an AUC device on each wrist. VT feedback was given by the device on the affected arm. The usability was measured by using a semi-structured interview and also the SUS questionnaire. The results of the SUS questionnaire indicate that nine participants responded above 70% and one participant responded below 50%. It means that VT feedback is feasible and the AUC can be used as a tele-rehabilitation device to train and maintain upper extremity used in daily life tasks.

In [64], a web-based portal supporting several clinical activities and the Versatile Integrated System for Tele-rehabilitation video-conferencing system called VISYTER were evaluated through the IBM After-Scenario Questionnaire (ASQ) [65], the Post-Study System Usability Questionnaire (PSSUQ) [66], the Telehealth Usability Questionnaire (TUQ) [47], and two demographic surveys. The use of all these instruments allowed capturing subjective and objective information, resulting in an effective method to evaluate the usability in tele-rehabilitation systems.

The ePHoRt platform, which is a tele-rehabilitation system to support people recovering from a hip replacement surgery, has also been the subject of previous usability studies. The first reported usability study was conducted through the SUS. The overall score was 81 out of 100, which suggests a good usability of the Web application [43]. Next, in [39], the authors assert that the lack of usability may lead to problems of confusion, error, and delay, or even abandonment of the physical therapy. This study was a preliminary analysis based on an empirical heuristic evaluation. Unfortunately, the study was not significant enough since most of the interfaces evaluated do not represent the central aspects of the tele-rehabilitation system. Likewise, the study does not consider the efficiency, effectiveness, and satisfaction of patients. However, the authors suggest making successive evaluations of usability. So, a successive usability study was conducted and presented in [41]. The user experience was measured through two aspects: (1) the tasks completion time, and (2) the SUS questionnaire [20]. The results were correlated to an empirical sociodemographic questionnaire. The overall value of the SUS questionnaire was 76.1 out of 100, which can be considered an acceptable evaluation of the usability of the platform.

A more recent work conducted on an updated version of ePHoRt synthesizes the results obtained from a study of effectiveness, efficiency, and subjective user satisfaction [38]. Thirty nine participants tested the platform and were asked to evaluate its usability by using the IBM CSUQ. The empirical results based on subjective perception and self-reported feedback show that the application is useful, effective, efficient, easy to use, and its interfaces are acceptable. In addition, the evaluation of the user experience enables us to identify usability aspects that should be implemented, in order to improve the visual interface. The experiment indicates that user guidance is a critical aspect to ensure good usability of the tele-rehabilitation platform. Likewise, the error messages received by users should be as detailed as possible. Finally, in [6] the authors suggest to carry out usability tests with real patients and during the whole completion period of the rehabilitation program, as indicated in [36]. For this purpose, there are usability instruments specifically designed to measure the user experience with e-Health platforms, such as SEQ [52], USEQ [44] and TUQ [47].

Pilco et al. [37] is a very recent usability study that makes use of an agile user centered design process [13, 14] to assess the ePHoRt platform. The evaluation process stated with a heuristic evaluation by using the Nielsen's 10 heuristics principles [67]. In addition, a cognitive workload assessment was performed to complete the usability evaluation. Likewise, users were involved through all the stages of the iterative refinement process. Usability issues were progressively reduced by applying improvements suggested from the iterative assessments. For instance, usability issues originally cataloged as catastrophic were reduced to zero, major usability problems were diminished to 10 (2.75%), and minor usability problems were decreased to 141 (38.74%).

4. Accessibility review

The goal of most studies in the area of Web accessibility is to develop inclusive applications. However, this is a great challenge, because most applications do not follow the WCAG 2.1 standards suggested by the World Wide Web Consortium. Web accessibility studies have a high impact and significant benefits in the development of tele-rehabilitation applications. The World Health Organization (WHO) [68] estimates that more than 1 billion people live with some form of disability. This corresponds to approximately 15% of the world's population. Between 110 (2.2) and 190 million (3.8%) people aged 15 years and over have significant operational difficulties.

In addition, disability rates are growing because of the population aging and the chronic diseases associated with the increasing life expectation. Disability is now considered a human rights issue. People are disabled by society, not just by their bodies. Therefore, the universal access to technology must be considered in building an egalitarian society. After applying the search strings defined in **Table 1** and using the PRISMA method, a total of 76 publications were recorded for Web accessibility. In the screening phase, 14 duplicate articles were excluded, 11 articles meeting the inclusion parameters were included, and 51 were rejected as being out of the inclusion criteria. In the eligibility phase, a total of 11 articles were assessed as fully meeting the inclusion criteria (**Table 4**). The phases of the selection process according to the PRISMA literature review method are detailed in **Figure 2**.

Table 4 presents the references of the 11 articles selected in the literature review.

Calle-Jiménez et al. [69] explain some of the challenges that exist to develop accessible Web platforms in tele-rehabilitation applications for patients after a partial or total hip replacement, known as arthroplasty. The authors propose an iterative method to improve the level of accessibility through automatic evaluation tools. Three online WAVE, AChecker, and TAW tools were applied in the study. The

Title	Authors	Year
Analysis and improvement of the web accessibility of a tele-rehabilitation platform for hip arthroplasty patients	Calle-Jimenez et al. [69]	2019
Educational resources accessible on the tele-rehabilitation platform	Acosta-Vargas et al. [70]	2019
An mHealth App for Users with Dexterity Impairments: Accessibility Study	Yu et al. [71]	2019
Towards Web Accessibility in Tele-rehabilitation Platforms	Acosta-Vargas et al. [72]	2018
Personalized technology-enhanced training for people with cognitive impairment	Buzzi et al. [73]	2018
Design and Development of One-Switch Video Games for Children with Severe Motor Disabilities	López et al. [74]	2017
Internet Use By People Living With Neurological Conditions: a Scoping Study	Siegert et al. [75]	2015
Computer-based cognitive training in adults with Down's syndrome	Bargagna et al. [76]	2014
Visual Complexity, Player Experience, Performance and Physical Exertion in Motion-based Games for Older Adults	Smeddinck et al. [77]	2013
Tele-rehabilitation interface strategies for enhancing access to health services for persons with diverse abilities and preferences	Winters [78]	2013
Accessibility of e-health services for people with disabilities	Bąkała et al. [79]	2010

Table 4.
Summary of the accessibility papers selected in this review.

results of the analysis indicate that the studied platform does not comply with all WCAG 2.0 accessibility standards.

Acosta-Vargas et al. [70] propose to apply the Accessibility Guidelines for educational content, in accordance with the Web Accessibility Initiative, to a tele-rehabilitation platform. The accessibility of the Web resources is assessed by using the Photosensitive Epilepsy Analysis Tool (PEAT). This open access software application applies several WCAG 2.0 standards and is combined with a manual evaluation method. The results of the study show that the multimedia resources evaluated do not reach an acceptable level of accessibility, as well.

Yu et al. [71] present a mobile health system (m-Health) to assist people with chronic diseases and disabilities in their self-management regimens. The authors studied the accessibility by using the WCAG 1.0 and 2.0 guidelines. The evaluation process was performed manually. The results indicate that on the importance of customization of interfaces to improve accessibility.

Acosta-Vargas et al. [72] present an accessibility study performed on a Web platform to promote a physical rehabilitation of patients with an arthroplasty. Web Content Accessibility Guidelines (WCAG) 2.0 and Website Accessibility Conformance Evaluation Methodology (WCAG-EM) 1.0 were applied. The authors used tools through plugins installed in the Web browser. WAVE,[5] Siteimprove,[6] Open WAX,[7] and Tenon[8] were used. The results indicate that the tele-rehabilitation platform requires improvements to reach an appropriate level of Web accessibility.

[5] https://wave.webaim.org/
[6] https://siteimprove.com/
[7] https://github.com/goonoo/OpenWAX
[8] http://tenon.io/

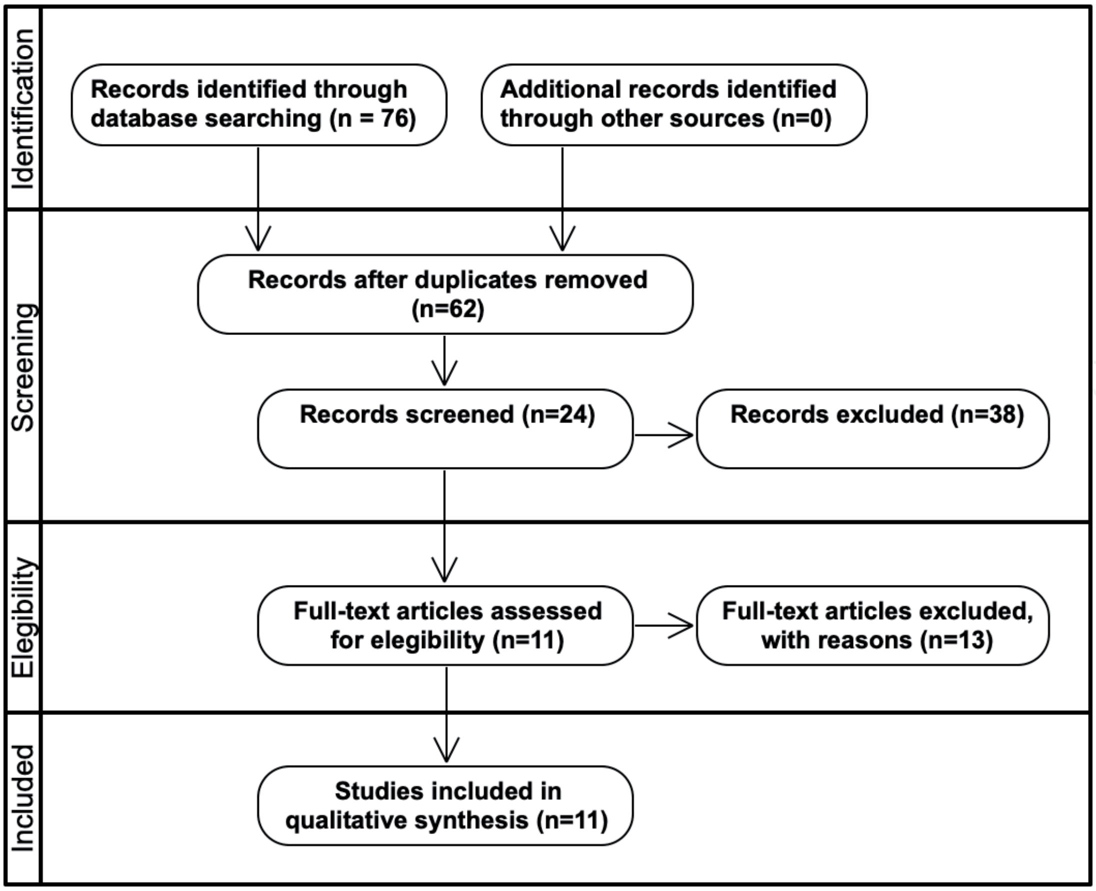

Figure 2.
PRISMA 2009 flow diagram chart showing the selection process.

Buzzi et al. [73] propose a Web platform to offer accessible games to individuals with cognitive disabilities, such as people with Down Syndrome (DS). Some WCAG 2.0 guidelines are applied manually, but no tools are applied in accessibility evaluation. The results of this study highlight the importance of motivation and flexibility to personalize the content according to the limitations of each user. Based on this experience, some basic guidelines for refining protocols for accessibility testing with people with DS have been proposed to maximize engagement, increase usability, and gather feedback to improve the accessibility of game design.

López et al. [74] argue that video games are not played just for fun, but are a useful tool for children's cognitive, emotional and social development. The article contributes to reducing accessibility barriers. The development game, called "Gaming NOMON" or (GNomon) is based on a guide of accessibility for videogames. It application has been evaluated for children with severe motor disabilities, so the study can serve as lessons learned for future research and design of accessible video games.

Richard Siegert et al. [75] indicate that little is known about Internet use among people with disabilities. This study explores how people with neurological conditions, such as multiple sclerosis, traumatic brain injury, or stroke use the new technologies. Some WCAG standards were applied in the research. The authors are not concerned with evaluating the accessibility per se. but the potential benefits of Internet for health and the well-being of people with disabilities.

Also, Bargagna et al. [76] describe a set of computerized exercises designed for cognitive training of adults with Down Syndrome. The objective of the study is to develop a tele-rehabilitation platform by following WCAG 2.0 guidelines for Web application. For future studies, the researchers propose to develop more training games to investigate the long-term effects of software use and assess its relevance in preserving cognitive capacity and individual autonomy in everyday activities.

Smeddinck et al. [77] point out that motion-based video games may have a variety of benefits for players and are increasingly applied in physiotherapy, rehabilitation, and prevention of older adults. The authors suggest that aspects of accessibility and immersion should be considered if the potential benefits of motion-based video games are to be harnessed for target groups with a broad spectrum of visual impairments. The application does not use WCAG-related guidelines, and does not apply specific tools to assess Web accessibility. The results show that visual complexity affects the perception of the games. The findings of this study can help to improve the design of motion-based games for therapy and rehabilitation in older adults.

Winters [78] proposes a preliminary classification scheme for tele-rehabilitation processes in order to apply it to human factors and to the analysis of the accessibility of electronic systems. The study proposes a novel framework in the development of interfaces that lead to a universal access to tele-rehabilitation for people with disabilities. This study makes use of some guidelines related to WCAG and Section 508. The results suggest that during the development of Web applications, accessibility guidelines should be considered in order to have more inclusive Websites.

Finally, Bąkała et al. [79] explain the concept of online health services in Poland, which tends to include people with disabilities. The researchers present a comparative analysis of e-health solutions in Poland and in other European countries. They conclude that there are possibilities to adapt existing services, in order to include people with disabilities. The study analyses the WCAG guidelines, but it does not apply tools to evaluate tele-rehabilitation platforms.

5. Conclusions

The main result of the usability review for tele-rehabilitation systems shows that the user experience predominates over the heuristic studies, and the most used questionnaire to assess user experience is the SUS. Even though it would be relevant to carry out user experiences with real patients and in real conditions, there are still few usability questionnaires proposed in tele-rehabilitation. Likewise, studies do not measure the performance of the patients in terms of completion time of the tasks and percentage of errors during the rehabilitation exercises.

Regarding the question of Web accessibility in tele-rehabilitation platforms, the review shows that this topic is still marginally studied. Many applications do not care about developing accessible and inclusive platforms. Some studies refer to Section 508 and WCAG 1.0 and 2.0 guidelines, but they are not applied in their entirety in addition, no work applies the WCAG 2.1, which is the most recent Web accessibility guideline. It is also to mention the fact that the analyzed studies lack the application of combined methods to ensure an adequate level of Web accessibility. Thus, our review suggests that the development of future e-Health applications should apply the guidelines of WCAG 2.1 that will allow access to all types of users regardless of their physical and cognitive abilities. This conclusion is particularly relevant in the case of the development of tele-rehabilitation platforms, which should include both usability and accessibility iterative tests.

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