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MOBILE SYSTEMS

Empirical Studies on Usability of mHealth Apps: A Systematic Literature Review

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Abstract The release of smartphones and tablets, which offer more advanced communication and computing capabilities, has led to the strong emergence of mHealth on the market. mHealth systems are being used to improve patients' lives and their health, in addition to facilitating communication between doctors and patients. Researchers are now proposing mHealth applications for many health conditions such as dementia, autism, dysarthria, Parkinson's disease, and so on. Usability becomes a key factor in the adoption of these applications, which are often used by people who have problems when using mobile devices and who have a limited experience of technology. The aim of this paper is to investigate the empirical usability evaluation processes described in a total of 22 selected studies related to mHealth applications by means of a Systematic Literature Review. Our results show that the empirical evaluation methods employed as regards usability could be improved by the adoption of automated mechanisms. The evaluation processes should also be revised to combine more than one method. This paper will help researchers and developers to create more usable applications. Our study demonstrates the importance of adapting health applications to users' need.

Keywords Usability · Empirical · Mobile · Applications · mHealth · Systematic literature review

This article is part of the Topical Collection on *Mobile Systems*

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Introduction

Mobile devices have become everyday items and are very popular among consumers [1]. Recent estimates indicate that by 2017 the number of mobile devices per capita will be 1.4, as is reported by the Cisco Global Mobile Data Traffic Forecast 2013 Update [2]. Smartphones are now the most popular mobile technology [3–5]. Worldwide data show that one in every five people owns a smartphone [6]. Smartphones are mobile phones with a more advanced computing ability and connectivity than other phones. Their extended input mode is provided by means of a touch sensitive display. Although the first touchscreen smartphone, known as Simon Personal Communicator, was developed by IBM in the year 1992; the first mobile phone marketed as smartphone was the Ericsson R380 released in 2000 [7]. In the year 2007 Apple announced the first smartphone to be principally controlled by its touchscreen: the iPhone [7]. The Android operating system (OS) for touchscreen mobile devices was released in 2008 [7]. The creation of the first iPhone ruled the evolution of what are currently known as smartphones.

The most popular mobile OS for smartphones are Android, iOS, Windows Phone and BlackBerry [8]. These OS are additionally designed to run on touchscreen tablet computers. Tablets have also become popular in the last few years [9]. Around 6 % of the worldwide population owned a tablet at the end of 2013 [6]. The emergence of application stores is one of the most important reasons for the adoption of smartphones [10].

One of the categories in which application stores classify their applications is that of Health. Google Play store has more than 8,000 medical applications and Apple App Store has more than 20,000 [11]. According to the Mobile Health Market Report 2013–2017 [12], around 500 million people will have adopted medical applications by 2015. Many healthcare organizations are incorporating medical mobile applications

[13, 14]. The potential and accessibility of these new technologies have been recognized as regards diagnosing, monitoring and treating diseases and chronic conditions [15, 16]. The term used for medical practice supported by mobile devices is mHealth [17].

Usability becomes an important topic for smartphones, since it is necessary to prevent applications from being difficult to use [18], and this has been identified as one of the factors that may determine their success [19]. Usability expresses the facility with which users can use a technological artefact to achieve a particular goal [18, 20]. According to the ISO/IEC 9126–1 quality model [21], usability involves understandability, learnability, operability and attractiveness. This model describes usability as a set of attributes that have a bearing on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users. This standard has recently been replaced in 2011 by ISO/IEC 25010 [22]. This standard includes a model of software quality in use that describes usability as the extent to which a product can be used to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. According to ISO 9241–11 [20], the key aspects of usability are: efficiency, effectiveness and satisfaction. ISO 9241–11 presents a broader perspective of usability than ISO 9126–1, but the two points of view are complementary [23]. Some authors have proposed their own model by including the learnability characteristic in the model proposed by ISO 9241–11: Dix et al. [24], Nielsen et al. [25] or Abran et al. [23]. Despite the existence of comparative frameworks, a high percentage of studies do not conduct empirical validations [26].

This study reviews a set of selected papers that perform a usability evaluation of mHealth-related mobile applications. Our paper is focused on empirical studies since we wish to discover whether usability is assessed rigorously and considered an important issue as regards the development of an mHealth application. There is a lack of empirical research on user characteristics in mobile applications [18].

The method selected to investigate the state-of-the-art is the Systematic Literature Review (SLR) process proposed by Kitchenham B [27]. An SLR is a research technique that gathers all empirical evidence in a specific field of study [28]. The evidence is then assessed to obtain conclusions regarding the research questions defined [29]. Although some studies review usability evaluations [18, 26], to the best of our knowledge there are no systematic literature reviews focused on usability evaluations of mHealth.

The article is organized as follows: the SLR method process is detailed in the Systematic Literature Review section. The Results section synthesizes the results obtained according to the research questions. Our findings are considered in the Discussion section, along with the limitations of this study. Conclusions and future work are presented in the Conclusions section.

Systematic literature review methodology

An SLR is “a means of evaluating and interpreting all available research relevant to a particular research question or topic area or phenomenon of interest” [27].

Research questions and search strategy

Nine research questions were defined in order to accomplish the goal of this SLR. These research questions and their motivation are shown in Table 1.

The search strategy involves the selection of the search resources and the identification of the search terms. A set of automated search engines from the most relevant sources in software engineering and health were selected to perform the search for the papers: Science Direct, ACM Digital Library,

Table 1 Research questions

No.	Research question	Motivation
RQ1	What publication channels are the main targets for usability in mobile health applications?	To examine the different sources in which the selected articles have been published.
RQ2	How easy is it to find recognized papers?	To analyse the quality and relevance of the articles found.
RQ3	How has the frequency of studies regarding mobile usability changed over time?	To explore the evolution of the publications over time.
RQ4	Which individual characteristics of usability are dealt with most often?	To provide information about how the different characteristics of usability are handled in the selected articles according to the usability standards (ISO/IEC 9126–1).
RQ5	Which empirical methods are used to evaluate usability?	To examine the types of empirical validation performed to evaluate usability.
RQ6	In what diseases or health conditions are usability evaluations being applied?	To identify the specific diseases that are studied in the selected articles.
RQ7	Do real users evaluate the usability of the applications?	To analyse whether the evaluation processes are completed by real users of the application (patients, doctors, nurses, etc.) or by experts.
RQ8	What are the results obtained by the usability evaluation of the applications?	To extract the results obtained from the usability evaluation.
RQ9	What types of devices and OS have been used to evaluate usability?	To provide information about the mobile devices (smartphones or tablets) and software (iOS or Android OS) that have been manipulated to evaluate usability.

Table 2 Search string

Scope	String
Mobile context	(smartphone OR smart phone OR touchscreen OR mobile phone OR mobile device OR tablet OR phablet) AND
Software	(application OR app OR service OR operating system OR OS OR android OR ios OR blackberry OR windows) AND
Health	(health* OR medic* OR clinic* OR care OR patient) AND
Usability topic	(usab* OR understandab* OR learnab* OR operab* OR attractiv* OR user experience) AND
Research type	(empiric* OR eval* OR assessm* OR test* OR experiment* OR method* OR approach* prediction OR case study OR measure OR estimation OR metric OR validat* OR framework OR prototype OR survey)

IEEE-Xplore, PubMed and Wiley InterScience. The search string was determined by using the PICO criteria [30]: population, intervention, comparison and outcome. The search string should provide the maximum coverage but be of a manageable size. The terms used, which are based on the research questions, have been selected by using five different scopes as a starting point: 1) smartphones as the target devices, including tablets and phablets; 2) the software scope of which the applications consists and the most popular mobile OS: Android, iOS, Windows Phone and BlackBerry [8]; 3) health as the specific field of the applications studied; 4) usability as the topic under study along with the individual characteristics of usability; and 5) the research type that is related to empirical studies. The Boolean OR is used to join alternate terms and the Boolean AND is used to join two major parts. The search string is shown in Table 2.

Screening of papers for inclusion and exclusion

Each study recruited from the initial search process was evaluated to decide whether or not it should be admitted as one of the selected studies. The papers that conformed to all of the following criteria were included:

IC1. The paper is focused on smartphones or tablet devices.
IC2. The paper provides information about usability.
IC3. The paper presents empirical results.
IC4. The paper evaluates an application for final users.
IC5. The paper must be a full or short paper (not an abstract).

The papers that conformed to at least one of the following criteria were excluded:

EC1. The paper is not written in English.
EC2. The paper was published before 2000. The first touchscreen phone marketed as smartphone was released by Ericsson in the year 2000 [7].
EC3. The paper was published after March 2014.
EC4. The paper is focused on a PDA or a feature phone.
EC5. The paper evaluates an internal feature of the smartphone but not any applications that are intended for final users like patients or doctors.

Quality assessment

The purpose of this quality assessment is to weight the importance of each of the papers selected when the results are discussed and to guide the interpretation of findings [27]. The quality assessment checklist is shown in Table 3. The way in which this questionnaire was written was inspired by a previous mapping study [31].

QA1 scores partially when the technology is not detailed in the text of the article but can be deduced from the screenshots of the mobile application. QA6 is rated by analysing the CORE Conference Ranking Exercise 2013 [32] and the Journal Citation Reports (JCR) 2012 [33]. Journals and conferences score differently in QA6 because the average paper in

Table 3 Quality assessment checklist

No.	Quality assessment question	Answer
QA1	Is the technology used detailed in the article?	(+1) Yes/ (+0) No/ (+0.5) Partially
QA2	Is the usability evaluation method specified in the article?	(+1) Yes/ (+0) No
QA3	Are empirical results of the usability evaluation shown?	(+1) Yes/ (+0) No
QA4	Does the article discuss any findings of the usability evaluation?	(+1) Yes/ (+0) No
QA5	Are the negative findings presented?	(+1) Yes/ (+0) No
QA6	Has the study been published in a recognized and stable publication source?	For conferences, workshops, and symposia: (+1.5) if it is ranked CORE A* or A, (+1) if it is ranked CORE B, (+0.5) if it is ranked CORE C, (+0) if it is not in a CORE ranking. For Journals: (+2) if it is ranked Q1, (+1.5) if it is ranked Q2, (+1) if it is ranked Q3 or Q4 (+0) if it has no JCR ranking. For others: (+0)

a top journal is more polished than the average paper in a top conference [34]. Although their acceptance rates should not be compared, publishing in a top journal may be more difficult than in other publication channels [34]. The maximum score a study could obtain by complying with the criteria in the six quality questions is 7 points.

Data collection process

The data collection process is based on the research questions, and the relevant information presented in Table 4 is therefore extracted in order to answer them. The process was carried out by completing a data extraction form.

Results

This section describes the results obtained in order to answer the research questions in Table 1. All the extracted information is detailed in Appendix 1.

Study selection

The study selection process took place in April 2014. A total of 717 papers were obtained in the search phase, as shown in Fig. 1. Of the 717 papers, 66 were identified as duplicates, and

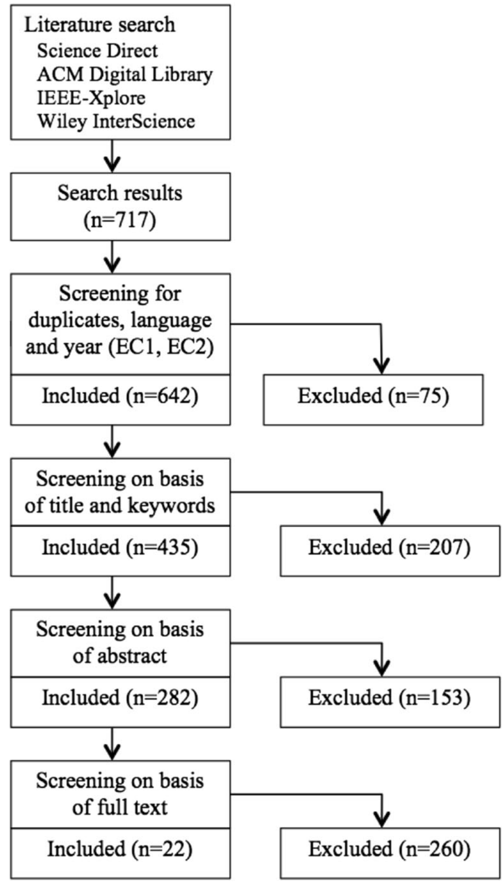


Fig. 1 PRISMA flow diagram

after applying EC1, two papers were discarded because they were not written in English while seven were discarded after applying EC2 because they had been published before the year 2000. The remaining 642 articles were evaluated by considering their titles and keywords. Two hundred seven articles were excluded in this phase. In the next phase, 153 articles were excluded after an examination of their abstracts. The full texts of the remaining 282 articles were investigated, 260 papers were discarded and 22 were finally selected after applying EC4 and EC5. Table 5 presents a list of the papers eventually selected, along with their QA results.

Table 4 Data extraction

No.	Extracted data
RQ1	Publication source should be extracted to answer this question
RQ2	The ranking of the publication sources should be obtained (QA6) to analyse the relevance of papers.
RQ3	Publication year should be considered to obtain the publication evolution
RQ4	ISO/IEC 25010 [22] replaced in 2011 the ISO/IEC 9126–1 [21] standard, but since our search strategy includes papers that were published between 2000 and 2014, the usability model applied in this study is ISO/IEC 9126–1. Based on this model, the usability model involves: understandability, learnability, operability and attractiveness.
RQ5	Information about the process should be extracted to investigate how the usability evaluations are carried out: method, duration and number of people involved.
RQ6	The health topic of the studies should be extracted to identify the diseases or health conditions.
RQ7	Usability evaluations can be performed by experts or real users of the application such as patients or doctors.
RQ8	The main findings of the usability evaluations should be analysed to discover whether problems and lessons learned have been identified.
RQ9	Hardware and software characteristics should be identified to draw the technology map. Hardware refers to the device model and software refers to the OS or platform.

RQ1. What publication channels are the main targets for usability in mobile health applications?

The publication channels are very varied since there are 21 different publication sources in 22 papers. The only repeated source is the Healthcom conference (IEEE International Conference on e-Health Networking Applications and Services), although the two articles were published in different years: 2010 [54] and 2013 [43]. The 21 publication sources are distributed in 16 conferences and five journals.

Only two sources, both journals, are not specifically related to computing technologies but only to health: Pain Medicine

Table 5 Papers selected and quality assessment results. The abbreviation "Pub." stands for publication

Paper	Pub. year	Pub. channel	Pub. name abbreviation	Quality assessment						
				1	2	3	4	5	6	Score
[35]	2014	J	PainMed	1	1	1	1	1	2	7
[36]	2012	J	Int J MedInf	1	1	1	1	1	2	7
[37]	2013	C	CHI	1	1	1	1	1	1.5	6.5
[38]	2011	J	J BiomedInform	1	1	1	0	1	2	6
[39]	2014	J	J Am CollSurg	1	1	0	1	1	2	6
[40]	2012	C	ICCHP	1	1	1	1	1	0.5	5.5
[41]	2014	J	ProcediaComputSci	1	1	1	1	1	0	5
[42]	2013	C	ICHI	1	1	1	1	1	0	5
[43]	2013	C	Heatlhcom	1	1	1	1	1	0	5
[44]	2013	C	HCI	1	1	1	1	1	0	5
[45]	2013	C	ICOSST	1	1	1	1	1	0	5
[46]	2011	C	PETRA	0.5	1	1	1	1	0	4.5
[16]	2013	C	MUM	0.5	1	1	1	1	0	4.5
[47]	2012	C	PervasiveHealth	1	1	0	1	1	0	4
[48]	2013	C	ICOT	1	1	0	1	1	0	4
[49]	2011	C	SIGDOC	0	1	1	1	1	0	4
[50]	2013	C	EMBC	1	1	0	0	1	0.5	3.5
[51]	2013	C	LISAT	1	0	0	1	1	0	3
[52]	2011	C	USAB	0	1	1	0	1	0	3
[53]	2013	C	iCAST-UMEDIA	1	1	0	0	0	0	2
[54]	2010	C	Heatlhcom	1	1	0	0	0	0	2
[13]	2013	C	CinC	1	0	0	0	0	0	1

[35] and the Journal of the American College of Surgeons [39]. The theme of 11 publication sources is that of computing technologies for health and the theme of the remaining eight sources is computing technologies but not particularly for health.

RQ2. How easy is it to find recognized papers?

The papers' reputation can be measured by the ranking of their publication sources. Even though there are only five journals, four of them are ranked as Q1 in the JCR ranking if the best rank for the journal is considered. With regard to conferences, only three out of 16 are ranked in the CORE conference ranking. One of them is ranked in the top level, A*: SIGCHI Conference on Human Factors in Computing Systems [37].

RQ3. How has the frequency of studies regarding mobile usability changed over time?

The papers selected were published between 2010 and 2014. Figure 2 shows the number of papers published per year: 1 paper in 2010, 4 in 2011, 3 in 2012, 10 in 2013 and 3 in 2014 (the first 3 months only).

RQ4. Which individual characteristics of usability are dealt with most often?

Following the usability characteristics of ISO/IEC 9126–1 [21], 32 % of papers evaluate all of them: understandability, learnability, operability and attractiveness. The most frequently evaluated characteristic is that of operability (20 out of 22 papers) while that which is least frequently evaluated is attractiveness (10 out of 22 papers).

Three of the 22 papers evaluate usability by applying the Systems Usability Scale (SUS) developed by Brooke in 1986 [55]. This scale measures usability based on ISO 9241–11 [20]: efficiency, effectiveness and satisfaction. There are two

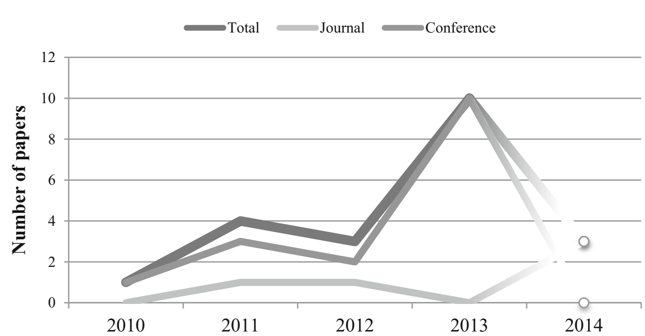


Fig. 2 Number of papers per year

more papers that do not handle the SUS, but also support the usability evaluation that appears in ISO 9241–11. Although not all the papers deal with the ISO 9241–11 model, 41 % of them evaluate the three usability aspects from this model. The most frequently evaluated characteristic is effectiveness (19 out of 22), while that least studied is efficiency (50 %, 11 out of 22). The results of both models are shown in Fig. 3.

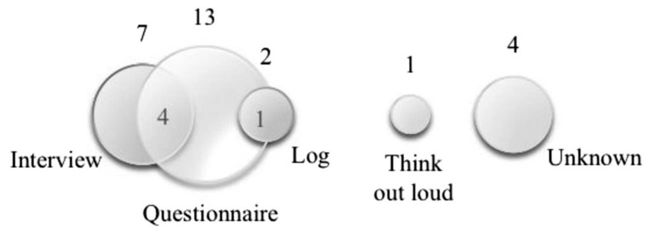


Fig. 4 Number of papers per empirical method

RQ5. Which empirical methods are used to evaluate usability?

Four different empirical usability evaluations methods were investigated in the selected papers: questionnaires, interviews, logs and the "think out loud" method. Figure 4 shows the number of papers that investigate each type of usability evaluation method.

The method most frequently used to evaluate the usability of an application is that of questionnaires (13 papers). Questionnaires consist of a set of questions that users answer after having tested the application being studied. Details about the questions that users were asked were provided in 46 % (6 out of 13) of the papers. Four of the evaluations that work with questionnaires were also supported by interviews. Interviews are the second most frequently adopted method, appearing in seven papers. One paper evaluates usability by not only applying a questionnaire but also implementing a log [54]. The log registers the activity in both the application and the server connections. The other study that examines a log does not provide any details about how the log is implemented or what information was registered in it [50].

Some papers also report how users handle the applications. Twelve papers work with evaluation methods that are based on task completion. Investigators propose a number of tasks to be completed by users with the target application. Ten of those 12 papers explain the evaluation tasks that were performed. The average duration of these task completions is 40 min. The task information in the 12 papers that are based on task completion is shown in Table 11 (Appendix 2).

Five studies performed long-term evaluations. In these evaluations, users test the applications over a long period of time: days, weeks or months. The longest evaluation found in the papers selected lasted 6 months [54]. Figure 5 displays the duration (in hours) of the evaluation processes registered in the papers providing this information.

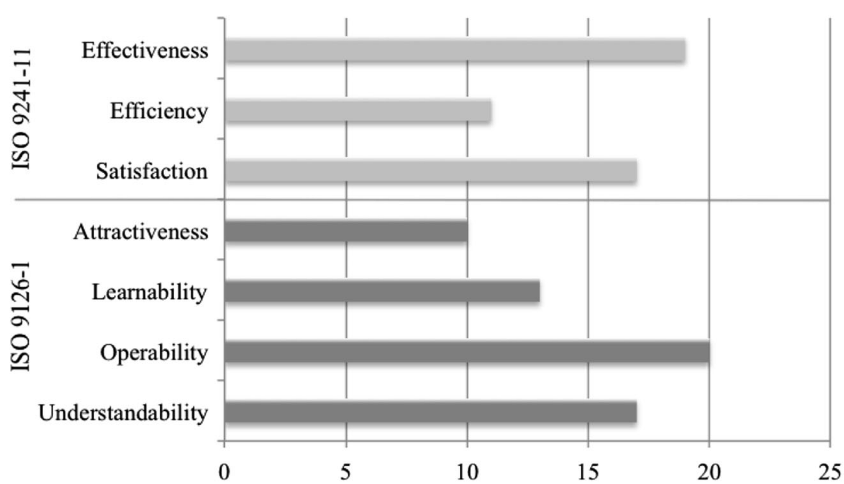
RQ6. In what diseases or health conditions are usability evaluations being applied?

Four papers out of 22 propose remote patient monitoring and one of them focuses on the elderly [42]. For example, Barendse et al. introduce a portable patient monitoring application that shows the vital signs, curves and trend parameters that a monitor would display [13]. Kascak et al. eliminate the need for expensive remote patient monitoring devices by creating a mobile application for patients with chronic diseases that can be used on existing smartphones and tablets [42]. Another application is intended for the elderly with the purpose of promoting exercise and preventing falls amongst older adults [41].

The most frequently studied diseases or health conditions are dementia (three papers) and autism (two papers). There are two papers about nutrition, such as an application with which to manage users' nutritional information [43] that is able to recommend food and drinks based on the user profile if, for example, the user suffers from hypertension or obesity.

The other diseases or health conditions on which the selected studies are focused are: blindness [49], deafness [44],

Fig. 3 Evaluated usability characteristics



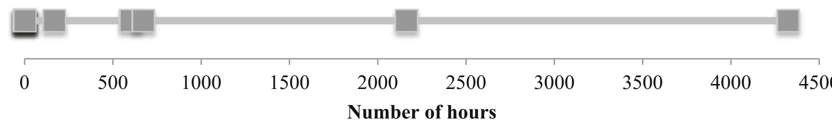


Fig. 5 Duration of task completion

cardiac problems [54], dysarthria [40], Parkinson's disease [16], skin cancer [38], trauma care [39] and pain management [35]. There is also a paper that focuses on recording sleep [37]. Sleep disorders, such as insomnia, can lead to debilitating health conditions.

RQ7. Do real users evaluate the usability of the applications?

Almost 82 % (18/22) of the applications have been evaluated by real users: patients, doctors, nurses or caregivers. For example, in the case of the evaluation of an application intended for the elderly, the users who tested it were aged 65 or over [41]. The application proposed by Hwang et al. that is intended for people with Dysarthria was tested by patients from the Seoul Rehabilitation Centre for the Cerebral Palsied (SRCCP) [40].

The 4 remaining applications were not evaluated by the real users of the application. For example the application for the deaf and people with language dysfunctions [44] was analysed by people without hearing difficulties. Two of the other applications proposed were validated by students and experts [35, 53]. One article does not mention anything about the users that examined the application [13], not even how many of them were involved. The number of users who validated the application is reported in 20 out of 22 articles (91 %). This number varies between four and 194 users, as is shown in Fig. 6.

Some articles distribute the number of users among multiple usability tests. Five out of the 22 articles perform a 2-round evaluation, i.e. after the first usability evaluation, the application is improved and is then tested again in an iterative process. One article performs a 3-round evaluation [41] and another article a 4-round evaluation when developing the iCAN application, version 4.0 [48]. Fifteen of the 22 articles evaluate the usability of the application being studied once.

RQ8. What are the results obtained by the usability evaluation of the applications?

Fourteen of the 22 articles present descriptive statistics and 16 articles discuss their findings. Descriptive results include the time taken by users to finish the tasks, the SUS rating or the users' numerical evaluations of certain characteristics. Some of the findings discussed in the articles are specific to the application being studied, and applying them to another application makes no sense. For example the application for the measurement of sleep [37] reports problems with the level of screen brightness in dark bedrooms. This fact is of no interest in our research on usability in mHealth applications, although some other findings are of interest to us since they can be applied to future applications in order to improve their usability. These findings are presented in Table 6.

RQ9. What types of devices and OS have been used to evaluate usability?

Only five of the 22 papers evaluate the usability of the applications proposed on more than one software platform, which are in all cases Android and iOS. Most of the papers (seven out of 22) test their applications using only the Android platform. Windows and iOS are the only software platforms used in three and two studies, respectively. In addition to the native applications, there are also three applications that are web-based. Two articles out of 22 do not mention the software platform of the applications evaluated. The distribution of the software employed is shown in Fig. 7.

With regard to the types of devices, 14 of the 22 papers present the specific device that was used to evaluate the applications. The most frequently used device is Apple iPad, which is mentioned in 8 papers: 7 of them are iOS applications and one of them is a web-based application. Only one of the 8 papers specifies the exact model: iPad 3. The Samsung Galaxy Tab, Samsung Galaxy Tab 10.1 and Samsung Galaxy Tab 2 10.1 tablets are used in two papers each.

With regard to smartphones, Apple iPhone is used in three papers, but only one paper mentions the model: iPhone 4. Another popular manufacturer is HTC: HTC Titan, HTC Radar, HTC Wildfire S, and HTC Desire S devices are the mobile tools managed in three papers. There is also a paper that employs a Google Nexus 4 device and another that works with a Motorola Droid device.

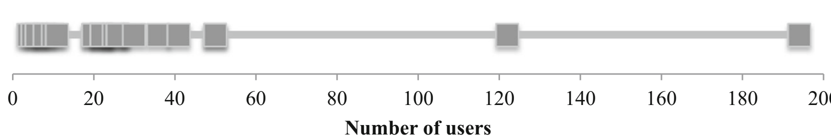


Fig. 6 Number of users evaluating the applications' usability

Table 6 Usability: main results

Usability results		References
Attractiveness		
A1	The colour black is often found to be repulsive	[45]
A2	The colour of components should contrast with the background	[42, 51]
A3	Adults are not interested in gaming applications, unlike teens	[47]
Learnability		
L1	Training is important to reduce the time needed by users to learn how to use the app	[39, 40]
L2	A monotonous user interface causes poor learnability	[45]
L3	A tutorial at the start of the app is desired by users to guide them	[45]
L4	Users learn how to use a touchscreen after a few tries	[49, 42]
Operability		
O1	It takes a young adult a ¼ of the time required by an older adult to complete a task	[46]
O2	Free text inputs should be avoided	[39, 41]
O3	Dropdown menus with prewritten options improve efficiency	[39]
O4	Difficulty in scrolling despite the existence of visual hints	[16]
O5	Difficulty in performing swipe gestures	[16, 41]
O6	Difficulty in holding the tablet and interacting at the same time	[51]
O7	There is no interaction between time and self-rated smartphone confidence	[35]
Understandability		
U1	Texts should be easily understood to avoid confusing terms or actions	[16, 43, 45]
U2	Need for bigger font sizes, even on the keyboard	[40–42, 46]
U3	Buttons need to look like real buttons	[42]
U4	Too much information or commands on a single screen should be avoided	[40, 45]
U5	Tendency to press icons but not the text associated with it	[41]
U6	Difficulty in managing navigation levels, relying on the back button as a safe option	[41]

Discussion

RQ1. What publication channels are the main targets for usability in mobile health applications?

The variety of publication sources (21 different sources in 22 articles) demonstrates that there is no specialized source as regards the general topic of this study: mHealth, and particularly usability in mHealth. Research is still expanding in this area [56, 57]. Furthermore, mobile technologies have a high adaptability that allows them to be practiced in many different fields [58, 59]. This characteristic contributes to the diversity of the publication sources. For example, there is one source focused on people with special needs (ICCHP conference) and another source focused on cardiology (CinC conference).

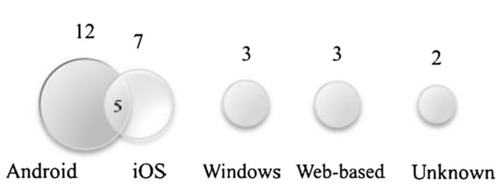


Fig. 7 Classification of papers by software

The difference in the number of conferences and journals may be owing to the fact that conferences are more timely than journals [60]. It can take years for a paper to be published in a journal, but only a few months for it to be published in a conference [60]. Another reason is that in some fields like medicine, conference papers are more effective in propagating the results of new techniques [61]. Journal publications are preferred for established areas and conferences for expanding areas [61]. In computer science, conferences are used as the main publication sources [60].

RQ2. How easy is it to find recognized papers?

Finding recognized journals has been easier than finding recognized conferences. Of the five journals, four of them are related to medicine and one is a computer science journal. The four journals ranked as JCR are medicine journals. Only three out of 16 conferences are ranked in the CORE conference ranking. In computer science, since conferences are used as the main publication sources, the number of low level conferences have undergone a tremendous growth [60]. With the variety of publication sources, the percentage of papers published in recognized sources is low, namely around

32 %. These results confirm that research is still expanding in this area [56, 57]. More recognized conferences concerning the topic of mHealth will have to emerge.

The QA performed demonstrates that the selected papers are appropriate to our research. Upon examining the results of the QA it was discovered that 17 out of 22 papers obtain more than the half of the total score and that two papers obtain the maximum score [35, 36].

RQ3. How has the frequency of studies regarding mobile usability changed over time?

The articles studied were published in recent years, from 2010 to the present. This was expected, considering the restrictions as regards touchscreen smartphone devices. Nevertheless, although the Apple iPhone was announced in 2007 and Android was published in 2008, we cannot find papers that evaluate the usability of smartphone mHealth applications until the year 2010. The development of mobile applications and the preparation of experiments is a long process. The average time needed to create the first version of a mobile application is 18 weeks [62]. Publishing the research findings also takes time since delays occur between the completion of the paper and its final publication [63]. The average publication time for biomedicine journals is 9.47 months, while it is 9.30 months for engineering journals [64]. Whereas smartphone ownership experienced a significant growth of 10 % between 2012 and 2013 [3], our results show that the use of mHealth applications began to expand in 2013. More than 36 % of mHealth application publishers have entered the market in the last 2 years: 2013 and 2014 [65].

Mobile devices have been used for a long time but mHealth is still considered to be a new area of development [56, 57]. The upsurge in mHealth research started in 2008 (the year in which Android was launched) when the articles about this topic were double those of the previous year [58]. The emergence of smartphones, which offer sophisticated communication capabilities and rich applications, has meant the real enhancement of this technology to improve health [57]. However, the adoption of mobile devices in healthcare has not been sufficiently explored [58]. In particular, and in view of the results, usability studies on mHealth apps are expected to undergo an important increase in the coming years.

RQ4. Which individual characteristics of usability are dealt with most often?

If the ISO 9126–1 usability model is adopted, attractiveness is the least frequently evaluated characteristic. Attractiveness should not be ignored, bearing in mind its positive impact on usability, which has a strong influence before the user tests the application and remains strong after it [66, 67]. Attractiveness affects the decision to start using an application [68]. The fact that the evaluation of usability has traditionally been focused on the operational ease of use of the user interface [69] may be one of the reasons for this low results. Furthermore, the operational ease of use as the main target of usability probably explains why operability is, according to our results, the most frequently studied characteristic.

Understandability has also been studied in a high percentage of papers, namely more than 77 %. The readability and understandability of mobile phones is over 50 % lower than in the case of desktop screens [70]. The small screens on mobile devices prevent users from seeing an entire page, signifying that they have to scroll through and navigate page hierarchies [71]. The understandability problems are increased if the main users of an application are elderly or are people who are not familiar with this type of devices [72]. A major group of primary care users have this characteristic [73] and understandability is consequently a key factor to be evaluated.

Learnability can also be influenced by the target users of health applications. For example, older adults have difficulties in learning to use mobile devices and applications [74]. Of the 22 papers, 13 evaluate learnability, and four of these articles and two others (six in total) conduct training sessions before the usability evaluation to teach users how to manage the applications. Little research has focused on improving the learnability of mobile devices but there is more research on developing better resources and training programs [74].

RQ5. Which empirical methods are used to evaluate usability?

Several taxonomies are used to classify usability evaluation methods. The most common classification divides them into (1) empirical user testing and (2) usability inspection [75–77]. User testing covers empirical methods that involve real end-users [75]. Usability inspection covers methods that involve experts or designers [75]. No inspection methods were found in our selected papers since our study is focused on empirical methods. With regard to user testing, some authors consider user testing and usability testing as synonyms, while others differentiate between two terms: usability testing and usability inquiry [78, 79]. Usability testing evaluates how the interface supports users when carrying out a set of typical tasks in a system or a prototype. This category includes methods such as performance testing, question-asking protocols, or thinking aloud protocols [78]. Usability inquiry consists of talking to users to understand how they feel when using the system in order to discover their needs. Usability inquiry includes methods like surveys, logging, focus groups, or interviews [78]. All the empirical usability evaluation methods extracted from the selected papers are included in these categories: 1 of them is a usability testing method (think aloud protocol) and 17 papers work with one or two usability inquiry methods (interviews, surveys and logging).

The think aloud protocol is a direct method by which to evaluate the usability of an application [80]. Both the verbal data obtained and the user interactions have to be transcribed for their analysis because this protocol generates a report of unstructured responses [80], and it is for this reason that the think aloud protocol has been criticized as regards its reliability and validity [81]. A supplementary user questionnaire after the session and at least two evaluators can help with the interpretation of the subjective information provided by users [80].

Surveys and interviews are similar methods since both consist of a set of questions [25]. Surveys and interviews rely on users' subjective memories and rating scales in questionnaires are therefore frequently used to help with the interpretation of results [25, 82]. One example of this is the SUS, which includes ten statements, five positive and five negative, which have a five point scale [55, 83]. The SUS is adopted in three of the selected papers. None of the articles mention any instrument used to validate the accuracy of the questions included in the interviews or surveys. Coefficient alpha should be applied to check the reliability of a set of items by measuring their degree of interrelatedness, length or redundancy [84]. Coefficient alpha is one of the most important statistics used in research to estimate reliability [85]. A further limitation as regards their validity is that when answering surveys and interviews, users tend to give the replies that they think they should give or that are more socially accepted [25, 86]. This situation is known as response bias and is more evident in the case of interviews [25, 86].

A taxonomy that reflects the automated aspects of the evaluation methods can also be adopted. Usability evaluation methods can be classified by their automation type into: (1) none, no level of automation; (2) automatic capture, usability data is automatically recorded; (3) automatic analysis, usability problems are automatically detected; and (4) automatic critique, improvements are automatically suggested [87]. Of the selected papers that indicate the use of the evaluation method, there are 2 papers that employ an automatic capture method (logging). Automated usability evaluation (AUE) methods are a promising area of usability research [88, 89]. AUE methods should be adopted to evaluate the usability of mobile applications, and particularly mHealth applications. AUE methods such as remote testing [89–92] or eye tracking [93, 94] are being used in other fields.

The recommended approach is the adoption of more than one evaluation method because their advantages and disadvantages supplement each other [25]. Only five papers employed more than one evaluation method and worse still, interviews and questionnaires were the chosen methods in four of them.

With regard to the time spent by users evaluating the applications, long-term studies were performed in only 5 papers. Research into how some usability aspects may change over time could provide experts with relevant information. A better understanding of how the measures of effectiveness, satisfaction or learnability develop over time is needed [95].

RQ6. In what diseases or health conditions are usability evaluations being applied?

Dementia is one the most frequently studied diseases in the selected papers. Dementia is a syndrome caused by brain illnesses that affects memory, thinking, orientation, comprehension, language, calculation, learning and judgement [96]. Technology and mobile technologies can improve patients' quality of life by increasing their safety and autonomy [46, 51, 97]. In addition, computer brain games have helped patients to stimulate the brain and reduce the symptoms of the disease [51]. The difficulties that older adults experience when using technologies, and particularly smartphones, are a barrier to their adoption [41]. Health systems should be developed by bearing in mind the needs of the elderly and their adoption of technology [98]. There are guidelines regarding designing the Web for older adults [99–102] but there is a need for recommendations for smartphone user interfaces [41, 97]. The proposed applications for elderly or people with dementia include a remote monitor [53], an application to promote exercise [41], and an assistant with an agenda and reminders [46]. Each of these applications has a single objective, but none of the applications manage multiple diseases simultaneously. These kinds of applications should be explored [103].

Similar to older people, children also require appropriate usable applications. Of the papers selected, two contain articles about autism. The expansion of smartphones has encouraged researchers to develop new tools to help autism [45]. Children with autism are more enthusiastic about computer use than about toys, and their attention and response rate is better when computers are involved [104]. None of the articles about autism deal with usability evaluation methods that have been adapted to children's capacities. Children's applications should be tested by children [105]. Research into usability evaluation methods for children exists [105–107] and the techniques and recommendations for conducting a usability test with children should therefore be applied.

Apart from the articles related to older people and children, there are some papers about nutrition, sleep and two other health conditions. This shows that mobile technologies serve a broad diversity of purposes [58], and usability should be studied in each specific domain.

RQ7. Do real users evaluate the usability of the applications?

Empirical evaluation, also known as user testing, involves real end-users [75]. Knowing the users who test an application is very important because differences between users may affect the usability evaluation [25]. Users' experiences with mobile devices and the task domain are some aspects that should be considered by researchers. Of the 22 papers selected, 18 of them present usability evaluations conducted by real users. These real users include patients, doctors, nurses or caregivers.

Upon examining users' experience with mobile devices, seven papers state that the users who perform the evaluation have some experience with mobile devices or even own a personal smartphone. The rest of the papers do not provide any information about the users' experience with mobile devices or computers. Users' experience with mobile technologies should be reported in the research methodology in order to improve the completeness of the results and the quality of the discussion. There should be representative users and there should be sufficient users to obtain valid results [76].

Most of the applications in our study were evaluated by less than 40 users during the usability testing process. According to Nielsen [53, 108, 109], five testing users are sufficient to find around 80 % of usability problems. Although usability problem detection reaches 100 % when there are more than 15 users, a smaller number of them is recommended [108, 109]. With a smaller number of users per test, multiple tests can be completed, and even more if users are hard to find. A cyclical process of design, evaluation and redesign should be repeated for as long as necessary [110]. Iterative processes produce better applications because some of the changes that attempt to solve one issue may fail to solve another [25]. This strategy is followed in seven articles.

RQ8. What are the results obtained by the usability evaluation of the applications?

Some of the results obtained by the usability evaluations of mHealth applications, which are presented in Table 6, can serve as a guide to researchers and developers when new applications are developed. The categories for which there are the most findings are operability and understandability, while those for which there are the fewest findings are attractiveness and learnability. These results confirm those of RQ4.

The findings in Table 6 also agree with the results of RQ6, which shows important research into older adults. However, developers should create more usable applications, not only for older people but also for novice users.

Smartphones and tablets are perfect tools for novice users. The result identified as L4 in Table 6 specifies that users learn how to use a touchscreen after a few tries. A touch panel and gestural interaction are easier, more accessible and more enjoyable for novice users than a traditional mouse and keyboard setup [111]. The main initial problems with touchscreens are some of the gestures. As results O4 and O5 show, drag and flicking gestures are more difficult to understand than tap gestures, since drag gestures require an uninterrupted pressure for the whole movement and there is a lack of clues regarding whether an element can be dragged [111]. The usability of mobile technologies, and principally their learnability, may be improved with the incorporation of tutorials, as is suggested by result L3. When patients do not have prior experience with touchscreens, animated tutorials have a positive effect [112]. Result L1 also describes that finishing the proposed tasks takes more time if there is no training session for the users to learn how to use the app [39, 40]. Six papers start their usability evaluations with a training session.

In addition to tutorials or training, applications with less information on screen improve their usability for novice users, as is stated in result U4. Simpler applications avoid the need to depend on scrolling or swipe gestures. Finding U6 indicates that complex navigation levels are difficult to manage. Simpler applications also mitigate this problem. A good application structure that accomplishes these recommendations is a lateral navigation drawer. A drawer is a panel that displays the application's navigation options and is often suggested as a top-level navigation system [113–115]. Other patterns such as fixed tabs or springboards offer a worse user experience [116, 117].

Two usability recommendations are found in many articles: the need for more comprehensible texts (U1) and the need for bigger font sizes (U2). Both are related to the texts of the applications. The vocabulary used in an application should correspond to the target users' vocabulary [41]. The texts should not be the same when the application is intended for children as it is when intended for adults or older adults. The size of the texts should also be reviewed since small texts and small buttons are common problems for older adults [118, 119].

RQ9. What types of devices and OS have been used to evaluate usability?

The most popular software platform among the papers selected is Android: 12 of the 22 papers evaluate applications for Android. This mobile OS is also the most popular if worldwide smartphone sales are considered: 78.4 % of the market share in 2013 [8]. The second software platform in the 2013 market share ranking was iOS with16.6 % [8], which is also the second most frequently adopted system in our selected papers: seven out of 22. Unlike iOS or Windows, Android is distinguished by the fact that it is open source, which allows the Android community to port the system to different devices and to connect it to different peripheral hardware [120]. Another advantage is that Android allows applications to be installed, tested and distributed in any device, which facilitates the development of prototypes and their delivery to a small group of users. These Android characteristics contribute to their adoption in research.

Furthermore, unlike other systems such as iOS and Windows, Android allows a large degree of customisation by, for example, the use of different launchers. These launchers provide an easier interface for older people by presenting only the basic functions and displaying big buttons and texts [121–123]. Keyboards can also be customized to show bigger buttons adapted to older people [124].

Many papers work with tablets to evaluate the applications' usability. The most frequently used tablet in our selected papers is the Apple iPad, since eight papers mention its usage. The iPad captured 36 % of the worldwide tablet market share in 2013, followed by Samsung tablets with 19.1 % [125]. Tablets are effective communication and education tools for patients and providers [126]. Tablets' characteristics, such as their large displays or the wireless network connectivity, have contributed to their fast adoption by physicians [127]. Patients find the screen size of smartphones too small to be easy to interact with. Large screen sizes are preferred by patients [128].

Limitations of the study

This study may have some threats to validity, despite the fact that the process was planned with the aim of attaining the utmost achievable accuracy and objectivity:

- Conclusion validity. Relevant research questions may have been overlooked, thus threatening the conclusion validity. To alleviate this threat, the questions were conceived by two independent authors.
- Construct validity. The search process was manual and the search string used may have excluded some relevant papers that would otherwise have been selected. To mitigate this threat, the PICO criteria were applied, thus resulting in an effective search string that contains a rich collection of terms. Bias in the selection process may also affect the construct validity. The final decision depended on two authors and if a disagreement appeared between them, it was discussed to reach agreement.
- Internal validity. Internal validity deals with data extraction and evaluation. One author carried out the data extraction, while the other two authors reviewed the final results.
- External validity. The validity of the conclusions drawn in this paper concerns only this study. This threat is not therefore present in this context.

Implications for research and practice

This paper provides several contributions regarding mHealth applications. mHealth is still in expansion, signifying that researchers have the opportunity to collaborate in the maturity of this field. Our study has contributed by extracting the usability findings listed in Table 6. Several areas that need to be explored have also been identified in this study:

- Creation of specialized sources related to mHealth.
- Adoption of usability models in the design of the evaluation processes.
- Evaluation of the attractiveness and learnability of mHealth applications.
- Combination of two or more different types of usability evaluation methods.
- Automation of usability evaluation methods.
- Validation of the reliability of the evaluation methods employed.
- Long-term usability evaluation methods.
- Recommendations for smartphone user interfaces for older adults.
- Support for recommendations as regards conducting usability tests with children.
- Identification of the users' experience with mobile technologies.
- Adoption of iterative usability evaluation processes.

Conclusions

The growing adoption of smartphones and tablets has encouraged their usage in health systems, thus leading to the emergence of the term mHealth. mHealth solutions have been used in recent years to help both doctors and caregivers, in addition to patients suffering from a wide variety of diseases such as dementia or autism. Usability is one of the main barriers to the adoption of mHealth systems, principally in the case of users with special needs, like older adults or children. Researchers and developers often evaluate the usability of their mHealth proposals by working with empirical methods that involve real users.

This paper has analysed 22 studies that perform usability evaluations of mHealth applications. Our findings show that mHealth applications started their expansion in the year 2013, and research is therefore still growing. We have identified the need to use automated evaluation tools, because almost 73 % of the papers selected use only interviews or questionnaires to evaluate the applications. The lack of design-evaluation iterative processes was also identified. This paper additionally contributes with a summary of the main usability findings, which may be of use to future developers.

As future work, we plan to create a reusable requirements catalogue based on the empirical evidence obtained from the studies examined [129]. A requirements catalogue is a useful source of reusable information that can be adapted to and refined for software development or audit activities. A privacy and security catalogue has already been suggested in eHealth [130] and eLearning areas [131].

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Appendixes

Appendix 1

Table 7 Data extracted for RQ1, RQ2 and RQ3

Paper	RQ1			RQ2	RQ3	
	Pub. channel	Pub. name abbreviation	Pub. type	2012 ranking	Pub. year	Conferences pub. dates
[35]	J	PainMed	Medical	Q1	2014	
[36]	J	Int J Med Inf	Medical informatics	Q1/Q2/Q2	2012	
[37]	C	CHI	Computer science	A*	2013	May
[38]	J	J Biomed Inform	Medical informatics	Q1/Q2	2011	
[39]	J	J Am Coll Surg	Medical	Q1	2014	
[40]	C	ICCHP	Medical informatics	C	2012	July
[41]	J	ProcediaComputSci	Computer science		2014	
[42]	C	ICHI	Medical informatics		2013	September
[43]	C	Heatlhcom	Medical informatics		2013	October
[44]	C	HCI	Medical informatics		2013	June
[45]	C	ICOSST	Computer science		2013	December
[46]	C	PETRA	Computer science		2011	May
[16]	C	MUM	Computer science		2013	December
[47]	C	PervasiveHealth	Medical informatics		2012	May
[48]	C	ICOT	Medical informatics		2013	September
[49]	C	SIGDOC	Computer science		2011	September
[50]	C	EMBC	Medical informatics	C	2013	August
[51]	C	LISAT	Computer science		2013	May
[52]	C	USAB	Medical informatics		2011	November
[53]	C	iCAST-UMEDIA	Computer science		2013	November
[54]	C	Heatlhcom	Medical informatics		2010	October
[13]	C	CinC	Medical informatics		2013	September

Table 8 Data extracted for RQ4

Paper	RQ4							
	ISO 9126-1			ISO 9241-11				Training session
	Understandability	Learnability	Attractiveness	Operability	Efficiency	Satisfaction	Effectiveness	
[35]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[36]	Yes	Yes	No	Yes	Yes	Yes	Yes	No
[37]	Yes	Yes	Yes	Yes	No	Yes	Yes	No
[38]	Yes	Yes	No	Yes	Yes	Yes	Yes	No
[39]	Yes	Yes	No	Yes	Yes	Yes	Yes	No
[40]	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
[41]	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
[42]	Yes	Yes	Yes	Yes	No	Yes	Yes	No
[43]	Yes	No	No	Yes	Yes	Yes	Yes	No
[44]	No	No	No	Yes	Yes	No	No	No
[45]	Yes	Yes	Yes	Yes	No	Yes	Yes	No
[46]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[16]	Yes	No	Yes	Yes	Yes	No	Yes	No
[47]	Yes	No	Yes	Yes	No	Yes	Yes	No
[48]	No	No	No	Yes	No	No	Yes	No
[49]	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
[50]	No	No	No	Yes	No	Yes	No	No
[51]	Yes	Yes	No	Yes	No	No	Yes	No
[52]	Yes	Yes	No	Yes	Yes	Yes	Yes	No
[53]	Yes	Yes	No	No	Yes	Yes	Yes	No
[54]	No	No	No	Yes	No	Yes	Yes	Yes
[13]	No	No	No	No	No	No	No	No

Table 9 Data extracted for RQ5 and RQ6

Paper	RQ5					RQ6
	Evaluation method	Duration	Tasks	# Tasks	# Users	Health condition
[35]	Questionnaire	30 min	Yes	1	41	Pain management
[36]	Questionnaire Interview	3 months	No	–	122	EHR
[37]	Questionnaire	7 days	Yes	8	26	Sleeping
[38]	Questionnaire	–	No	–	194	Skin cancer
[39]	Thinkoutloud	–	No	–	22	Trauma care
[40]	Questionnaire Interview	–	Yes	1, 1	33, 17	Dysarthria
[41]	Questionnaire	20 min	Yes	6, 6, 6	9, 9, 7	Elderly
[42]	Interview	1 h	Yes	–	6, 5	Remote monitoring, elderly
[43]	–	–	Yes	6	8	Nutrition
[44]	–	–	Yes	5	4	Deafness
[45]	Questionnaire	20 min	No	–	50	Autism
[46]	Questionnaire	–	Yes	6, 4	19, 11	Dementia
[16]		–	Yes	25, 21	9, 11	Parkinson's disease
[47]	Questionnaire Interview	90 min	Yes	4	26	Nutrition

Table 9 (continued)

Paper	RQ5					RQ6
	Evaluation method	Duration	Tasks	# Tasks	# Users	Health condition
[48]	Interview	4 weeks	No	–	22	Autism
[49]	Questionnaire	30 min	Yes	–	9, 11	Blindness
[50]	Log	25 days	No	–	5	Remote monitoring
[51]	Interview	–	No	–	–	Dementia
[52]	Questionnaire	–	Yes	6	6	Remote monitoring
[53]	Questionnaire Interview	–	No	–	10	Dementia
[54]	Questionnaire Log	6 months	No	–	36	Cardiac
[13]	–	–	No	–	–	Remote monitoring

Information not provided is marked as "–"

Table 10 Data extraction for RQ7, RQ8 and RQ9

Paper	RQ7		RQ8	RQ9		
	Real users	# phases	# Result from Table 6	OS	Device type	Device model
[35]	No	1	O7	Android	–	–
[36]	Yes	1		iOS	Tablet	iPad
[37]	Yes	1		Android	Phone	HTC Wildfire S, HTC Desire S
[38]	Yes	1		Windows	–	–
[39]	Yes	1	L1, O2, O3	Web-based	Tablet	iPad
[40]	Yes	2	L1, U2, U4	Android iOS	Tablet Phone	iPhone 4, iPad, Galaxy Tab 10.1, Galaxy Tab, Galaxy S2
[41]	Yes	3	O2, O5, U2, U5, U6	Windows	Phone	HTC Titan, HTC Radar
[42]	Yes	2	A2, L4, U2, U3	iOS	Tablet Phone	iPhone, iPad
[43]	Yes	1	U1	Android	Phone	Google Nexus 4
[44]	No	1		Android iOS	Tablet	iPad
[45]	Yes	1	A1, L2, L3, U1, U4	Android iOS	Phone	iPhone
[46]	Yes	2	O1, U2	Android	–	–
[16]	Yes	2	O4, O5, U1	Android	–	–
[47]	Yes	1	A3	Android	Phone	Motorola Droid
[48]	Yes	4		Android iOS	Tablet	iPad
[49]	Yes	2	L4	–	–	–
[50]	Yes	1		Windows	–	–
[51]	Yes	1	A2, O6	Android iOS	Tablet	iPad
[52]	Yes	1		–	–	–
[53]	No	1		Android	–	–
[54]	Yes	1		Web-based	Phone	HTC
[13]	–	1		Web-based	Tablet Phone	iPad 3, Samsung Tab 2 10.1

Information not provided is marked as "–"

Appendix 2

Table 11 Task session information

Ref	Iteration	# tasks	Tasks	Duration	# users
[35]	1	1	Record a pain episode	30 min	41
[37]	1	8	Open the app, log in, set a wake time, start/stop sleep recording, respond to a sleep tone, toggle in/out of bed status, adjust tone settings	–	26
[40]	1	1	Spell a word	–	33
[40]	2	1	Completion of a sentence	–	17
[41]	1	6	–	20 min	9
[41]	2	6	Find results page, find results for a specific day, return to homepage, find screen to insert personal data, return to homepage, find the complete option	20 min	9
[41]	3	6	Find results page, find results for a specific day, return to homepage, find screen to insert personal data, return to homepage, find the complete option	20 min	7
[42]	1	–	–	1 h	6
[42]	2	–	–	1 h	5
[43]	1	6	Import and configure the profile "light products" from the server, create a new shopping list, add a specific product that fits the profile, add a product through barcode scanning, add a product that does not fit the profile, register non-available products	–	8
[44]	1	5	Fire report with UCS (Urgent Communication System), fire report by email, ambulance request by email, ambulance request by UCS, fill out the pre-entry personal data	–	4
[46]	1	6	Name the past activities in the agenda, name the next activities in the agenda, add a new event, add a predefined event, change the time of an event, create a reminder note	–	19
[46]	2	4	Name the last activity, name the next activity, indicate the time that appears for "Take medication", create a reminder note	–	11
[16]	1	25	Identify medicaments, navigate between days, change intake hour, scroll down, find marked days on calendar, select the correct day, use the reminder option, set the repetition option, and so on	–	9
[16]	2	21	Check the correct medication, navigate between days, identify the intake hour, read the coach mark, find missed intake hour, and so on	–	11
[47]	1	4	Set up the app, enter multiple snacks, view individual history, view family history	90 min	26
[49]	1	8	–	30 min	9
[49]	2	8	–	30 min	11
[52]	1	6	Find the patient, select a patient name, add a diagnosis, search a diagnosis, find a medicament, review the record created	–	6

Information not provided is marked as "–"

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