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Methodological Approach to Cost-effective Usability Evaluation in the Initial Stage of Development of e-Health Systems: Application to an Electronic Health Record–integrated Platform

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Resumen

La implementación de la tecnología de la información ha tenido un gran impacto en las organizaciones ya que implica un cambio en las prácticas de trabajo de las personas; por lo tanto, es importante gestionar este proceso. Una forma de obtener la aprobación de los involucrados es presentar un producto de calidad, tanto en sus funciones como en su usabilidad (por ejemplo, el producto debe ser fácil de aprender y utilizar, ser útil; el producto tiene que ser intuitivo y sencillo). La medición de la usabilidad en las primeras etapas de desarrollo es necesaria para evitar errores de diseño que se podrían llevar a las siguientes etapas. Resolver estos errores una vez terminada la plataforma es costoso en tiempo y recursos; por lo tanto, es aconsejable realizar evaluaciones desde el principio, incluso cuando solo existe un prototipo. Este estudio propone examinar la viabilidad de la utilización de diversas técnicas de evaluación de la usabilidad en base en un mínimo de recursos y su aplicación a un sistema de salud de Cataluña (en España) en su etapa inicial de desarrollo.

En este estudio se aplicaron tres técnicas de evaluación de la usabilidad de una interfaz de usuario que son bien conocidos en el campo de la Ingeniería de usabilidad. Estas técnicas son examinadas en un entorno médico específico: SISBE (Sistema de Información de Salud de Barcelona-Esquerra), una plataforma de integración de registros médicos electrónicos de diferentes proveedores que operan en una gran área urbana de Barcelona. Las técnicas se aplican en el orden siguiente: La evaluación heurística, las personas y pruebas de usuarios. La evaluación heurística se ha adaptado al sistema a evaluar, y la técnica de las personas se ha elaborado teniendo en cuenta los resultados de la técnica anterior. Del mismo modo, la prueba del usuario también ha sido desarrollada de acuerdo con los errores detectados anteriormente. La razón de utilizar tres técnicas es detectar complementariedades y coincidencias, y determinar los puntos fuertes en la evaluación de los sistemas en las primeras etapas de desarrollo

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La aplicación de las técnicas mencionadas para evaluar el sistema seleccionado dio resultados consistentes en la identificación de errores de usabilidad. La evaluación heurística permitió la detección de errores en la interfaz. La técnica de las personas detecta errores encontrados previamente en la evaluación heurística y también fue sensible al contexto de uso del sistema. Por último, las pruebas de usuario detectan algunos de los errores que ya se han encontrado, pero, puesto que implica a los usuarios reales en entornos reales, reforzó los resultados observados desde el punto de vista de la interacción humano-computadora.

Palabras Clave: *Sistemas de registros médicos, Evaluación de Usabilidad, Evaluación Heurística, Técnicas cognitivas, Pruebas de Usuarios.*

Abstract

The implementation of information technology has had a great impact on organizations because it involves a change in people's work practices; thus, it is important to manage this process. A way to gain the approval of those affected is to present a quality product, in both its functions and its usability (i.e., the product must be easy to learn and use; to be useful; the product needs to be intuitive and simple). The measurement of usability in the early stages of development is necessary to avoid design errors that could be carried over to the next stages. Solving these errors once the platform is finished is costly in time and resources; hence, it is advisable to perform assessments from the start, even when only a prototype exists. This study proposes to examine the feasibility of using various techniques of usability evaluation based on minimal resources and his application to one Catalonian healthcare system (in Spain) in its initial stage of development.

In this study we applied three techniques of usability evaluation of a user interface that are well known in the field of Usability Engineering. These techniques are tested in a specific healthcare setting: SISBE (Health Information System of Barcelona-Esquerra), an integration platform of electronic medical records of different providers operating in a large urban area in Barcelona. The techniques are applied in the following order: Heuristic evaluation, Personas and User Testing. Heuristic evaluation has been adapted to the type of system to be evaluated, and the Personas technique has been developed taking into account the results of the previous technique. Similarly, the User Test has also been developed according to previously detected errors. The reason for using three techniques is to detect complementarities and overlaps, and to determine their relative strengths in the evaluation of systems in the early stages of development.

The application of the mentioned techniques to evaluate the selected system gave consistent results in the identification of usability errors. Heuristic evaluation allowed the detection of errors in the interface. The Personas technique detected errors previously encountered in the Heuristic evaluation and was also sensitive to the context of use of the system. Finally, the User testing detected some of the errors already found but, since it involves real users in real settings, it reinforced the observed results from the human-computer interaction standpoint.

Application of these techniques by evaluators trained in the healthcare environment is advantageous and necessary because a prompt detection of problems in early stages is key to reducing implementation costs and decreasing resistance to use. The methodology presented shows how, even with minimal resources, it is possible for an organization to detect usability problems in the initial stage of system development.

Keywords: *Medical Records Systems, Usability Evaluation, Heuristic Evaluation, Cognitive Walkthrough Techniques, User Testing.*

1. Introduction

The incorporation of information technology (IT) in healthcare organizations is a complex and expensive process because it needs to be planned carefully and comprehensively. The mistakes and errors carried over from the early stages are difficult to solve later, and they can slow the development, compromise the quality of the system and generate resistance to its incorporation. For these reasons, the process of creating IT products must include iterative evaluation from the beginning. This evaluation should be conducted from different perspectives, considering the system's functionality (actions performed) and its usability (easiness of use) for this process. Although evaluation has traditionally focused on reviewing functionality, usability is gaining importance due to the advantages demonstrated by user-centered design (UCD), which integrates the perspectives of users in the life cycle of projects in the initial stages [1]. The incorporation of UCD has the potential to mitigate development costs resulting from poor design and facilitate the adoption by users and organizations [2].

In the healthcare environment, the professional faces a complex and demanding situation that requires clarity, speed and ease of access to information to minimize the possibility of medical errors. Nevertheless, the evaluation of healthcare information systems seems to be more focused on epidemiological findings (such as reducing morbidity), on improving quality of life or on the optimization of business hours [3]. However, in the past five years approaches that consider the incorporation of technologies in healthcare settings as a socio-technical process have been gaining ground. That process affects healthcare professionals, organizations, and patients [4], as well as methodologies that enable more robust research in e-Health [5].

One of the most interesting approaches to the general process of evaluating the incorporation of IT in healthcare is the one proposed by [6]. They point out that ongoing evaluations, both iterative and multifaceted, allow monitoring of the project development and obtaining timely and relevant insight that helps to measure the efficiency and cost-effectiveness of interventions at different stages. The authors describe a methodology that spans the entire system's life cycle and incorporates assessment of usability in the initial phase of system development.

A key part of these methodologies corresponds to the assessment of usability. Usability is defined by standard ISO 9242 (1998) as “the extent to which a product can be used by specified users to achieve

specified goals with effectiveness, efficiency, and satisfaction in a specified context of use."[1] In other words, we can say that usability is a qualitative attribute that indicates the easiness of a user interface. In the healthcare environment, [7] define usability as the ability of a system to allow users to carry out their duties in a safe, effective, efficient and enjoyable manner.

Most of the studies on usability in the health care domain have targeted systems designed for patients rather than those to be used by clinical staff. Among them, various assessment techniques can be found. In [8], Heuristic evaluation is the main technique applied, but it is preceded by conversational qualitative techniques. [9] Use the User testing method - the most common evaluation technique in usability, in order to compare the usability of a system for people of different ages. Also [10] use the User testing, but in this case to evaluate the iconography of an electronic medical record's user interface. [11] Who also analyze with patients the use of a health system; evaluate a personally controlled health record. This is a test that is performed under laboratory conditions in which the participating users execute a series of tasks in the system. It is common that the moderatos ask them for expressing their thoughts out loud (in these cases the technique is named "think aloud protocol"). In User Testing the sessions are recorded and subsequently analyzed by the investigators.

Other papers apply the user testing with clinical staff, as [12, 13], who evaluate the physicians' satisfaction with an electronic medical record system.

In this paper we explore a usability evaluation methodology that involves adapting and implementing consecutively three validated techniques: Heuristic evaluation, Personas and User Testing. To test this approach we have selected a Spanish health information system that is currently in an initial phase of development. This system is called SISBE (an acronym for Health Information System Barcelona-Esquerra in Catalan) and it can be defined as a platform that provides a common view of parts of the electronic medical records of different providers in the catching area of Hospital Clinic of Barcelona (Spain).

So, in our study, the following premises were considered:

- Information and Communication Technologies (ICT) investment in the health field is high and benefits are expected to follow from it.

1 ISO 9242-11:1998. Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 11: Guidance on usability. Archived at: http://www.webcitation.org/5u7eXyHJA

- The quality of a system refers, among others, to its functionality and usability [14]
- A system with functionality and usability matching users' expectations increases its chances of acceptance by the end users [15].
- The poor usability of an EHR often has a negative impact on patient centeredness because the physician is focusing on the system [16].
- Healthcare organizations, although conscious of the importance of evaluating the usability of systems, don't employ usability professionals or allocate resources to this type of evaluation. Today this is a limitation for the design of quality systems.

Based on these five assumptions, this study proposes to examine the feasibility of using various techniques of usability evaluation based on minimal resources (not demanding in terms of cost, professional skills, or time consumption) and applying the techniques to a healthcare system in its initial stage of development. The aim is to make available to the design teams and health IT developers an effective methodology of usability evaluation that requires few resources.

To design and test the effectiveness of our proposed method, we started by selecting the usability evaluation techniques to be used and their order of application. We then worked in the following sequence: i) Heuristic evaluation design and application in SISBE; ii) design of the Personas technique and implementation in SISBE; and iii) design of the User Test and application to SISBE.

The paper is structured as follows: Section 2 presents the selected techniques, their use in healthcare settings, the design of each, their application to the SISBE case study and the main results observed in each case. In Section 3, we present the full results of the study. Finally, Section 4 presents a discussion of the merits of the techniques and the feasibility of applying a methodology for evaluating the usability of healthcare systems with the minimum possible resources.

2. SISBE

Developed with the support of the hospital's IT department this system is a perfect platform to test usability evaluation techniques according to what we propose for two reasons: i) it is in an early stage of development, so decisions are still being made regarding its design and thus some flexibility exists to change in response to observed improvements, and ii) SISBE co-exists with other electronic heath record (EHR) systems that are already in use, which makes it necessary to convince the professionals of the benefits of using this new platform. For clarification, we will explain the context in which these professionals work.

Currently, in the specific setting where we carried out our study, several information systems are used to search for health information: primary care centers have their own EHR solutions, and centers of secondary and tertiary care have access to other platforms (i.e. Laboratory Information Systems, Image system), in addition to the EHR, that contain more information. SISBE is a web platform that allows intercommunication among the various systems that are used in the Barcelona-Esquerra area by public health care providers. SISBE makes it possible to see information stored in other electronic health records available in the area of the study, as well as requesting information from other registries (i.e. Central Registry of Patients, Health Professionals Registry). SISBE also includes a small module that handles indicators on performance and health management, therefore, it will not replace existing information systems but will be an integrative layer facilitating information exchange across levels of care to support the health care processes. This feature is extremely important because if the release of the system presents usability problems, it is more likely that clinicians will have a resistance to its use. If clinicians find it difficult to understand the system and if finding information is not fast and intuitive, they will continue to use older systems that and will not be motivated to learn to use the new system. Because SISBE is in an early stage of development, it is a perfect setting in which to apply the techniques of usability evaluation.

3. Design and Methods

The first step in the methodology of this study was the choice of techniques to perform the usability evaluation. For this, we initially considered the different techniques that were available in the professional literature on usability. From these readings, we selected three techniques that showed greater use and validity in addition to feasibility of application in the context of the research. The techniques we chose were Heuristic evaluation, Personas and User Testing [17].

The selected techniques were adapted in accordance to the results from a focus group conducted in the assessment phase of system requirements in September 2009, as recommended by Rose et al. [18]. These data were used to determine the profile of SISBE users, their expectations and their main concerns about the new IT tool.

Fig. 1 shows the order in which the techniques were applied to our case study. We started by the heuristic analysis because it analyzes the system itself, without considering other factors, allowing us to focus on the interface. From the errors found, we designed the Personas technique and applied it in a second stage. Because putting the focus on

certain tasks can reveal errors related to the context of use, User Testing was left for the end. Since it requires the involvement of real users, User Testing is the most complex technique to set up. With this third technique, the errors that were previously found in testing are detected and new errors may come to light that arise from the expectations of users and their attitude toward the system.

For this research, a team of three people was involved: a usability expert, a professional with vast experience in the use of IT in healthcare settings, and a professional in Social Sciences with experience in R&D projects in the area of e-Health. The entire study was carried out in 3 months, including the stages of design, implementation and analysis.

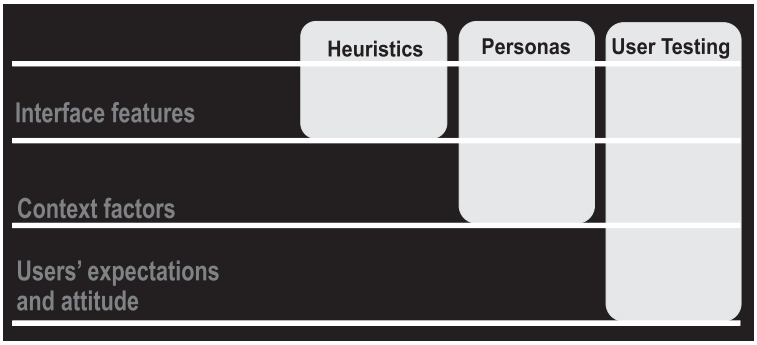

Fig. 1. Order of application of the different usability evaluation techniques and features on which each one is focused

3.1 Heuristic Evaluation

This evaluation technique of usability was introduced in the early 90s based on a proposal made by Jacob Nielsen [19] and has since been validated by multiple investigations. This technique can identify errors of usability testing for the presence or absence of a number of properties that are written in the form of indicators. The indicators are grouped into heuristic rules. In Table I we show an example of the detailed indicators of one of the heuristics. A team of usability experts verified the heuristics responding to each of the indicators with "Yes," "No" or "Sometimes." In the healthcare context, this methodology has been used in various projects [20], in France [21], Canada [22] and the U.S. [23], as well as in different health domains such as dentistry [24] [25], nursing [26], telemedicine, and systems designed for patients.

3.1.1 Design: To generate indicators and to determine the heuristics that were part of our study, we took as our starting point the following published proposals:

a) "Electronic Health Record Usability. Evaluation and Use Case Framework," published in 2009 [27]. Includes a list of heuristics, called the Multiple Heuristics Evaluation Table (MHET).
b) "Ten Usability Heuristics," by Nielsen [28]. A list of the most-used heuristics internationally and the most quoted in the literature on usability.
c) "Guide for Heuristic Evaluation of Websites," by Hassan and Martín [29]. A document in Spanish that is notable for its clarity in explaining how to implement each indicator.
d) "Heuristic Evaluation of Infusion Pumps: Implications for Patient Safety in Intensive Care Units," by Graham et al. [30]. A list of heuristics designed to evaluate three interfaces of infusion pumps.

After reviewing the documents, we tailored a list of heuristics and indicators that were appropriate for the healthcare environment. We decided to take as our initial list the one presented on the MHET, because its heuristics incorporated aspects of the other three documents. Indicators listed on the MHET were discarded if the type of feature explored could not be evaluated at this stage of system development. This first list was tested and modified according to the Nielsen heuristics and those of Hassan and Martín. In this way, we obtained a list of 47 indicators that were mutually inclusive (each statement referred to a single concept) and exclusive (only one criterion needed to evaluate each feature). Finally, we grouped the 47 indicators in the heuristics that were relevant to the healthcare context and to access to information in electronic health records. The result was a set of 12 heuristics:

- Consistency
- Customization
- Efficiency
- Help
- Information architecture
- Information clarity
- Information flow
- Interface clarity
- Learning and cognition
- Legibility
- System status
- User control

As an example, Table 1 shows details of the indicators corresponding to one of the heuristics—specifically to evaluating the information architecture—and the recorded results in each one.

Heuristic	Evaluated criteria in SISBE	Results (yes/sometimes/no)
Information Architecture	The system uses the same system of organization in all parts.	No
	The system uses a clear organizational system.	Sometimes
	The navigation menu has a number of elements that do not produce rote overload.	Yes
	The navigation menu has a number of terms per element that do not produce rote overload.	Yes
	All links lead to some information system (on another level, another section of the system).	Sometimes

Table 1. Details of the indicators for the Information Architecture heuristic (see the full table in the Results section).

3.1.2 Application: Although Nielsen's recommends that several usability experts made this assessment in parallel [31], in this study we intentionally aimed at minimizing the resources required to implement this technique since a less costly procedure could likely favor adoption in healthcare settings.

The results were analyzed by presenting a descriptive account of the heuristics in which the strengths of the system were greatest in identifying potential usability errors. The process of applying the technique lasted seven hours. We then spent a week writing a report of the results.

3.2 Personas

Personas is a technique commonly used in the analysis stage of system requirements. The technique involves the construction of characters (personas) based on user profiles and the definition of "scenarios" of use from the tasks that users typically perform in the system. For each persona, one or more scenarios of use are defined. Based on each persona and his scenario, an expert takes a cognitive walkthrough of the system acting as one of the identified personas. The cognitive walkthrough considers the use of the system for a particular task. By this approach, it is possible to identify usability errors that the system presents and record them for improvement. Beside, were used another techniques with the same proposes in healthcare systems [32].

In the healthcare context, Hägglund and Scandurra [33] used the Personas technique to support the work of an interdisciplinary home healthcare team. They concluded that the technique is a powerful tool for

understanding work routines, information demands and other characteristics at a clinical level, both in the initial system design and throughout the development process. These researchers suggest using the technique before the development of technologies, enabling an effective incorporation of a socio-technical perspective. On the other hand, this technique is also used in the evaluation stages of the system to determine whether it meets the defined requirements of the system and to understand the user's perspective [34]. Hyun's study [26] used the Personas technique for the evaluation of the design of the interface of a computer system for nurses. The authors noted that the results obtained by a test using scenarios were consistent with those of the Heuristic evaluation of the system conducted in the same study.

3.2.1 Design: In our study, the design of the personas assumed that the characters were clinicians with individual characteristics, as shown in Table 2. Six personas were created as a combination of different characteristics.

Characteristics	Categories
Gender	Male/Female
Age	26 to 35 /36 to 45 /46 to 55/56 to 65 years
Seniority	Recently joined/5 to 9 years/10 years or more
Professional linking	Resident Physician/Assistant Physician/ General Practitioner/Specialist Physician
Everyday use of technology	Low/Medium/High
Level of use of the systems	Low/Medium/High
Knowledge of SISBE	Low/Medium/High
Interest in learning new IT systems and in using the current ones	Low/Medium/High

Table 2. Characteristics of *personas* user profiles

To create the scenarios, the profile of each of the personas was taken into account along with the features of the system to be evaluated (mainly searching and retrieving information, because that is what these professionals do most often) as well as usability problems detected in Heuristic evaluation. A scenario for each persona was created. For each pair of persona and scenario, tasks were written for testing the system with the cognitive walkthrough method, including the following:

- Access the care contact report for the patient in PDF format.
- Access the patient's immunization records.
- Access the latest diagnostics of the patient from any medical center in the Barcelona-Esquerra area.
- Access the contact details for other professionals.

3.2.2 Application: With the aim of maintain a minimum investing in resources, a single investigator --the professional in Social Sciences, did the cognitive walkthrough. The researcher carried out tasks in which she personified each of the six defined *personas*. For the performance of the course, the investigator assumed that the *personas* had participated in training sessions with the system. During the process, she took notes on the problems the *personas* had in moving toward completion of the task. The cognitive walkthrough took 14 hours in total and a week was spent preparing a report of the results.

3.3 User Testing

The technique of User Testing allows the identification of usability errors through the observation of users performing certain tasks under lab conditions while expressing their thoughts out aloud [35] [36] [37]. Although there is no consensus on how many users are required to detect all errors of system usability, Nielsen [38] points out that testing with 5 users will detect 85% of the errors, and 15 users are required to detect 100% of the errors. A 2009 study demonstrated statistically that testing with 3 users detects 87% of the errors and that 5 users is enough to find all usability errors if the scope of the evaluation is well defined, if only a subset of functions is being evaluated and if the audience is well represented by selected users [39].

Bojko (2013) [40], based on Sauro and Lewis (2012) [41], explains how to calculate the sample size for usability studies that has as a goal to uncover issues in the tested system. According them, two values are needed to calculate it: problem discoverability (p), that is the average probability of detecting a problem; and problem discovery goal [$P(x \geq 1)$], that is the desired probability of detecting that problem at least once during the study. If these two numbers are plugged into the formula $P(x \geq 1) = 1 – (1 – p)n$ and solve for n, the sample size is obtained. Table 3 shows the sample size for several cases and justify that in this study only one user has participated in the user test:

		Problem Discovery Goal ($P(x \geq 1)$)					
		50%	75%	85%	90%	95%	100%
Problem Discovery (p)	50%	1	2	3	4	5	7
	90%	1	1	1	1	2	2

Table 3. Sample size required in a usability study according with the goals

After the users complete the tasks or when they indicate that it is not possible to perform them, a semi-structured interview is performed to discuss the problems encountered. In the healthcare environment, this technique has been used in various stages of the development of systems [6].

3.3.1 Design: Testing with users is intended to confirm the usability errors detected in the two tests outlined above; therefore, tasks were designed that might repeat the usability errors already detected. Thus, previous experiences recorded in the literature of e-Health and in the field of consulting were considered. Then, we defined the tasks that users would be asked to perform and the aspects that would be addressed in the interview.

3.3.2 Application: Because of the conditions of the study (reduction of expenditures to the bare minimum), we performed the test with only one user. The user profile selected was a family physician in primary care. The test was conducted at the premises of the Information Systems Directorate of the Hospital Clínic of Barcelona, in a room without noise that was equipped with a computer and a webcam to record the session. The user was asked to carry out four tasks. During the course of the session, the researcher took field notes, recording what the user was doing, the comments she made, her exclamations and her facial expressions. When the test was concluded, an interview was conducted that included questions about the main difficulties the user had encountered while performing the tasks. The data analysis was performed descriptively. The user test and the interview lasted one hour. The analysis of information and generation of the document with the results were conducted over the course of a full working week.

3.4 Schedule

The assessment presented was performed in a total of 50 days. Besides, 20 days were spent in preparing the methodology to be used in the study before its commencement. The Gantt chart below shows the order in which the various tasks were performed and the time it took for each (Fig. 2).

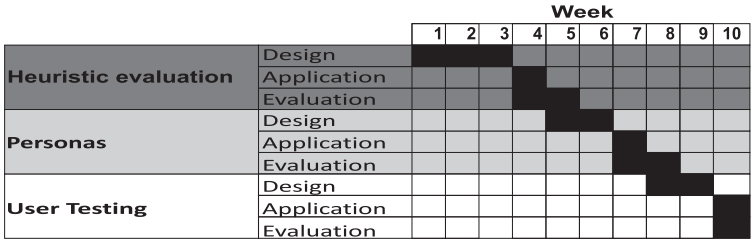

Fig. 2. Gantt chart with the schedule and order of application of the three evaluation techniques of usability.

4. Results

4.1 Heuristic Evaluation

The errors found in the Heuristic evaluation were divided among various heuristics (Table 4).

Fig. 3 shows in larger type those heuristics in which the system had better results and in smaller type those that had lower scores. Of the 47 indicators, the system currently met 20, 12 indicators were met sometimes and 12 were not met.

Fig. 3. Results of the Heuristic evaluation in SISBE. The heuristics represented in larger type sizes are those for which the system showed better results.

The Heuristic evaluation allowed identification of the main problems of usability with the current system interface. In general, we can say that of the 12 heuristics evaluated, the positive features of SISBE were readability, clarity in reporting, efficiency and consistency. On the other hand, the features that had some problems with usability, meaning those that the system met insufficiently, were the clarity of the interface itself, the information architecture (inconsistencies have been detected in the navigation of the site, which is likely to cause confusion when trying to access to patient information), information about system status, ease of learning and cognition, and the fact that the user had control of the system. Finally, a feature where SISBE currently performed poorly was related to the flow of information; and two heuristics that could not be scored in SISBE were the support and customization options, because the system did not offer them; hence, these options received the lowest

Heuristics	Indicators evaluated in SISBE	Result (0-1-2)
System status	1. The system informs the user what is happening at each step	2
	2. The system informs the user what has been completed at each step	0
	3. The system shows all the icons, commands and options that are available to the user	1
Information workflow	4. The system provides information to complete each task	1
	5. The system shows how to fill the different fields in the form	0
	6. The system´s forms show what is the minimum information needed to fill in the spaces	0
Easiness of use for learning and cognition	7. The system is easy to learn	2
	8. The system integrates the "help" functions into the commands	0
	9. The system uses standardized labels	0
	10. The system predicts the answer before the user has clicked in that space	2
	11. The system has visual metaphors: recognizable and comprehensive by any user	0
	12. The system offers shortcuts to expert users (or frequent users)	0
Customization	13. The system allows configuration by preference and user needs	0
	14. The system allows easy changes to the default options	0
Clarity and clearness of the Interface	15. The system don't present excessive amounts of information on the screen (such as too many text boxes at the same time)	2
	16. The system does not have any kind of extraneous visual effects	2
	17. The system has few blank spaces without information	0

Heuristics	Indicators evaluated in SISBE	Result (0-1-2)
Clarity and clearness of the Interface	18. The system visually differentiates the information shown	2
	19. The system uses secondary signals with different text levels to differentiate between levels	0
	20. The system has easily recognizable links	1
Clarity of information	21. The system can easily be searched for needed information	1
	22. The language used in the system is clear and concise.	2
	23. The system speaks the same language as the users	2
	24. The proper use of images adds value to the system	2
	25. The proper use of animations adds value to the system	2
Consistency	26. The system has a coherent design	2
	27. The system doesn't show discrepancies between design elements and the commands	1
	28. The system doesn't show discrepancies between the language used or other navigational aspects	1
Efficiency	29. The system has adequate response times	1
	30. The system offers reasonable processing time for complex actions (max 10 seconds)	2
	31. The system offers reasonable processing time for simple actions (max 3 seconds)	1
User control	32. The system responds correctly to the user commands	2
	33. The system gives exit options to the user	0
	34. The system allows to the user to undo commands	1

Heuristics	Indicators evaluated in SISBE	Result (0-1-2)
Architecture	35. The system is organized consistently throughout its various parts	0
	36. The system uses a clear organizational style	1
	37. The navigation menu has a number of elements that do not require to much memorization	2
	38. The navigation menu has a number of terms by element that do not require to much memorization	2
	39. All the system links work properly	1
Easiness of reading	40. The font and text size are easy to read	1
	41. The font size is easy to read	2
	42. The topographic effects provide easy readability	2
	43. The line width provides easy readability	2
	44. Proper text alignment provides easy readability	2
	45. The system has a high contrast between the font color and the background color	2
Help	46. The system clearly informs the user when an error has occurred	0
	47. The system clearly informs the user how s/he may correct the error	0

Table 4. Results from the Heuristic method: no=0, sometimes=1, yes=2.

4.2 Persona Technique

The report of the results shows the profile of each persona, the scenario designed for each and details of the cognitive walkthrough. Table 5 shows a summary of the major difficulties two *personas* encountered in the application of this technique.

Persona	Stage	Results
Oliver, 39, Family Physician in Primary Care	Oliver arrives at the health center 20 minutes before office hours and has time to check a list of the visits for the day. The second of his patients had been coming to see him for several years. Oliver wants to confirm whether she was discussed in a consultation that he had requested. He needs to know the specialist's response to make a decision regarding the treatment regimen.	**Mission accomplished.** No **Difficulties encountered.** The system displays an error message in the search without having made any inquiry, which disorients the user. The user does not understand how to set up the menus by date in one of the files of the EHR or how to adjust the width of the bars to display the information. The information sought is not in PDF format, which is the format he wanted it in. **Time spent.** 2 minutes
Mariona, 30, Family Physician in Primary Care	Mariona is attending an 82-year-old patient in the health center. This is the first time she has seen him. In the last minutes of the consultation, the patient points out that he needs "the other vaccine," which he was told he needed to receive, but he cannot remember what kind of immunization it was. The doctor needs to check the information about the immunizations the patient has received before he leaves. Mariona has several patients waiting for care and is well over the time allotted for the visit.	**Mission accomplished** . Yes **Difficulties encountered.** The user had difficulty identifying which of the two sheets of the EHR contains the information she sought. She also struggled with the navigation buttons to return to the previous information and did not understand whether to use the browser buttons or the SISBE buttons to return to the previous interface. **Time spent.** 6 minutes
Carlos, 59, Specialist Physician in a Clinic Hospital	A primary care colleague phones Carlos to ask his opinion about a patient who has been referred to him, but he has not been able to look at it until the end of the workday. Now, before leaving, he wants to check whether his colleague will be able to view his report in SISBE.	**Mission accomplished** . No. **Difficulties encountered** . The user had difficulties with finding the path to the file containing the clinical data of the patient. He struggled with the buttons to return to the previous screen. **Time invested** . 3 minutes

Table 5. Results obtained with two of the created Personas.

The use of the Personas technique helped identify common problems in the routine use of SISBE. In general, the personas spent between 2 and 8 minutes to perform the proposed tasks. In only half of the cases they were able to find what they were looking for in the system and finish the task. SISBE presented problems to the six personas that were designed, some of which took place during the process of searching for information in the EHR files.

In the overall navigation of the system, the SISBE interface had consistency problems with its navigation buttons. This is because sometimes a function has its own button and sometimes it does not, making users unsure whether to use the SISBE interface or the browser buttons.

Regarding the information search process, the system showed an error message when the persona had not entered any search criteria. In addition, the return key was not configured to execute the search, which confused the personas, who had assumed it was enabled.

Finally, regarding the two types of EHR files that are accessible from SISBE, several problems were identified. First, it was sometimes possible to access the same information in various ways, which confused the users, who were unsure about where to find the information they were seeking. In addition, there was a lack of consistency in the criteria and graphic options available to present information from the two files. Furthermore, data obtained from each of the two types of EHR were easily confused. Finally, the information was presented with little clarity.

4.3 User Testing

The application of this technique to a single user allowed confirmation of some of the usability problems that were identified using the techniques mentioned above, plus other usability problems. The test confirmed our assumption that minimizing resources in a first stage of the product design can be worth.

The user took 15 minutes to complete the four tasks. The time for each task ranged from 3 to 5 minutes. It was found that some interface elements “were not seen” by the user. Specifically, the user was focused on information related to the clinical aspects that were presented in the center of the screen and tended to ignore the side windows on the screen that offered guides for finding information.

It was found that the user was unclear about the two formats of electronic health records of patients that provided access to similar information. As a result, the user was unsure in which of the two to begin searching for clinical information. This issue was again highlighted during the interview.

One of the usability problems that had been detected in previous tests was inconsistency in the use of the return and navigation buttons of the SISBE system itself. This error of usability was confirmed during the

user test, but it posed no impediment to the completion of tasks. Finally, this test detected that the user repeatedly moved closer to the screen to have a better reading of the characters that were displayed in a small font size, a problem that was also raised during the interview.

5. Conclusions

The three usability evaluation techniques used have been shown to be consistent with each other in identifying errors of usability in this study (inter-technical consistency). Because the techniques were applied cumulatively, each drew on the information obtained in the prior technique, which also helped in making findings consistent. This does not detract from the methodology because, although there were errors that were identified by the three techniques, their combined use permitted a wider range of coverage of the usability aspects.

Heuristic evaluation allowed detection of how the system responded in its current stage of development to the classical rules of usability. Building a list of heuristics contextualized to the healthcare environment led to greater accuracy in identifying usability errors that are critical in the clinical setting.

Moreover, the Personas technique, apart from confirming the usability errors identified in the Heuristic evaluation, also permitted the observation of contextual aspects, for example the limited time that the doctors have to use the system, or the possibility to stop using the system if does not quickly address their needs for information. Finally, the use of this technique detected the most common tasks and thus suggested an outline for the User Testing. This kind of test is easy to design for the healthcare systems professionals because they are familiar with the user profiles and the tasks they traditionally performed.

Finally, through the observations of a real user, User Testing was able to confirm the errors of usability detected in the two previous tests. This technique also allowed us to identify on which areas of the interface the user focused while using the system.

The main finding of this study is that using the three techniques described and applying them consecutively allow the researcher to i) have a progressive approach to evaluating the usability of the system from different perspectives and ii) identify aspects that lead to reduce the problems of use for future users, which is consistent with the literature of IT assessment in healthcare that recommends the use of formative evaluation and iterative models [42] [5] [43].

In summary, the results of this study demonstrate the feasibility of performing actions to assess the usability of systems from the early stages of development with a minimum investment for healthcare organizations and to formulate good guidelines for improving healthcare information systems. These results are relevant to system developers, but they are important in particular because they directly affect end users, who are health professionals, and reduce the resistance generated by the incorporation of information technology in healthcare organizations.

6. Discussion

Although the techniques of usability evaluation cut across different areas, it is necessary to perform a design specific to the field in which they are to be applied [42][16]. This requires the involvement of the interested organizations, a point that does not always occur. This lack of interest in introducing these techniques in health care domain can be exemplified by the poor representation or even absence of professionals with the appropriate skills in the health care centers. This is a clear drawback when planning the introduction of new IT [43].

We argue that, in the healthcare domain, there is a need for a "super-user" that could deal with the introduction of IT projects in support of the professionals' work practices [44]. The needed profile would be an individual who knows the key factors of design, testing and training of the new IT tools. This professional would be able to understand the flow of work and most of the processes that take place in each healthcare organization, and which are key factors in the successful incorporation of these tools [45]. This optimal situation rarely occurs, so the methodology proposed in this paper is an alternative to this "super-user" and could be incorporated as part of the training that is taught in academia and in health organizations. The costs associated with the proposed methodology are low in both human resources and time, at least in the initial stages of system development.

The results of the study allow us to observe that the techniques used, in addition to being effective in identifying usability problems, have particular strengths. On the one hand, Heuristic evaluation is useful to detect design errors without considering the context of use; on the other hand, the Personas technique and the User Testing are sensitive to contextual elements of the use of the system. We also confirm, as was already found in the literature, that the combination of different evaluation methodologies is successful in incorporating IT in the healthcare environment [37].

From our results, it might seem that completion of the test with users is sufficient to detect a large proportion of usability errors in the system.

The reality is that User Testing is effective, but the design of this test has been based on tasks performed in the Personas technique, which, in turn, took into account the errors identified in the Heuristic evaluation.

On the other hand, Heuristic evaluation is shown as the most deficient technique since it does not provide the context (simulated in the Personas technique and real in the User Testing). Instead, it is advisable to do Heuristic evaluation first to detect inconsistencies and errors that can be resolved before proceeding to the other two techniques. Second, Heuristic evaluation allows the evaluator to be familiar with what is considered a usability error. Because healthcare agencies do not have usability professionals and it is likely that other professionals with different profiles will address the assessment, they should use this technique to approach the problems of usability of the system before beginning to design the techniques of Personas and User Testing. Finally, given that the costs involved in Heuristic evaluation are very low thanks to the existing checklists that can be applied with few modifications, the design work is greatly simplified.

Regarding the number of reviewers who must participate in an investigation, in this study we aimed to test the usability evaluation techniques relying on the minimum possible resources. Although a team of three people worked on the project, only one did the assessment tasks while the other two working as consultants. We are in a similar situation as far as the number of users who should participate in User Testing. In this case, we decided to test the system with a single user to maintain the initial premise of the performance evaluation of relying on minimal resources, and we have obtained satisfactory results. However, we assume that testing the user with an only user can be a limitation, but if this user has been well chosen and can represent the target, her feedback will be very useful.

On the other hand, if we are to mention a possible limitation to our results, it is that we have applied the techniques of usability evaluation to a particular case, SISBE. To confirm the appropriateness of applying this methodology in other contexts, it would be necessary to test other cases of EHR and other IT platforms in the healthcare field.

In conclusion, we believe that the results of this research are relevant to teams who develop healthcare systems, ideally both software developers and health services researchers [46], because the use of these assessment techniques in the early stages of development of a system can result in changes that will lead to lower costs to organizations and continuing development and iterative evaluation throughout the project. Thus, the quality of the system is ensured and resistance to adoption of the system in organizations is minimized.

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