Are End-Users Participating in the Life Cycle of Healthcare Application Development? An Analysis of the Opportunities and Challenges of the Use of HCI Techniques in the Healthcare Sector

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Keywords: End-Users, Healthcare Application Development, HCI Techniques.

Abstract: Health information systems (HIS) play a fundamental role in society, providing a solid technological basis for collecting, storing, processing, and making decisions in the healthcare sector. Due to the significant increase in software solutions and the limitations arising from the difficulties associated with mastering healthcare, it is appropriate to consider including end-users in the application development life cycle. This paper presents a systematic review of the literature to identify the presence of the end-user throughout the software life cycle and assess whether the techniques used in requirements elicitation and application evaluation are aligned with usability standards or best practices. The study resulted in the analysis of twenty-seven studies, indicating that many works do not incorporate end-users at all stages of development. Although many studies involve users in software evaluation, the methods used need more support in usability standards or guidelines. In addition, little evidence of the involvement of healthcare professionals in the development life cycle of healthcare applications was identified in the studies, which indicates that the knowledge of the domain specialist needs to be taken into account. Thus, it will be possible to investigate whether understanding the domain expert specified in openEHR archetypes can improve the life cycle of healthcare applications.

1 INTRODUCTION

The global market for software products has grown significantly in recent years, with an annual growth rate of 12.5% between 2022 and 2023 (Company, 2023). The market's growth forecast indicates that it will continue to grow significantly in the coming years, specifically between 2023 and 2030 (Reports, 2023). In addition, the global healthcare software market is expected to grow at an annual rate of 19.8% between 2022 and 2027 (Markets and Market, 2023), and this growth is driven by the increasing and constant adoption of electronic health record (EHR) software, telemedicine, mHealth, and other digital technologies. Given this environment, technological advances have significantly transformed the healthcare software landscape, incorporating more and more information systems to optimize management, monitoring, and service delivery processes (Pinochet et al., 2014).

Health Information Systems (HIS) play a fundamental role in this context, providing a solid technological basis for collecting, storing, processing, and analyzing data related to this domain (de Freitas et al., 2021). However, many software resources used in hospital environments, such as electronic patient records, telemedicine systems, and health management systems, have significant limitations in terms of usability, among other factors that include potential risks to software quality (de Freitas et al., 2021), (Pitkänen and Pitkäranta, 2016), (Bitkina et al., 2020), (Meehan, 2020). On the other hand, the use of HIS is more comprehensive than data manipulation in clinical and administrative environments. An example is the chatbots aimed at the health area, which have emerged in the literature due to their generative capacity for services; however, domain experts have pointed out deficiencies in the medical information generated from the knowledge domain (Kowatsch et al., 2017).

Due to the significant increase in software solutions and the limitations arising from the difficulties associated with mastering healthcare software, it

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DOI: 10.5220/0012572800003657

In *Proceedings of the 17th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2024) - Volume 2*, pages 789-796
ISBN: 978-989-758-688-0; ISSN: 2184-4305

is appropriate to consider including end-users in the application development life cycle. The inclusion of end-users requires an approach with an emphasis on Non-Functional Requirements (NFR), specifically those related to the usability of systems, requiring specific techniques and the application of a Human-Computer Interaction (HCI) approach, an area concerned with human aspects in interactive computer systems in the development of software (Barbosa et al., 2021), (Riasat et al., 2023), (Rosson and Carroll, 2009).

HCI emphasizes the active participation of the end-user throughout their activities and decision-making stages, presenting a more agile learning process as a solution, which positively impacts both the quality of the solution and the identification and correction of possible problems (Rogers et al., 2013). On the other hand, when considering processes that do not adhere to HCI design approaches, the system's quality is compromised regarding usability when analyzing the user experience during their interactions (Couto et al., 2020).

An alternative way of approaching end-user involvement in the software lifecycle is to adopt a methodology that listens to the user's needs, from requirements elicitation to the final phase of the application, considering the understanding of the problem domain, and increasing the acceptance, use, and fidelity of the system to the natural environment of use (Stafford et al., 2003), (Govella, 2019). Requirements elicitation seeks to understand end-user needs, considering the search, discovery, acquisition, and elaboration of requirements for computer systems, to correctly identify the facts that make up the functionalities so that there is correctness and completeness of understanding of what is required (Pressman, 2011).

This article searches the literature for evidence of end-user involvement in the development life cycle of healthcare applications. Specifically, it investigates whether the end user's knowledge of the problem domain has been considered when eliciting requirements and building graphical user interfaces. It also examines which HCI techniques have been used in the usability evaluation of healthcare applications and which categories of end-users in the healthcare sector are present in the studies. At the end of the study, we aim to answer the following questions. Is there evidence of end-user participation in the development life cycle of healthcare applications? Are the challenges found in the state of the art related to the use (or not) of HCI techniques in developing healthcare applications?

The other sections of this article are organized as follows. Section 2 presents the basic concepts adopted to support the development of this research. Section 3 details the state-of-the-art analysis, subsequently exposing the methodology used to collect the articles covered in the study. Section 4 provides an overview of the state-of-the-art research and discusses the main results, leading to a more in-depth study analysis and discussion. Finally, Section 5 describes the final considerations, followed by suggestions for future research.

2 BACKGROUND

The growing insertion of software systems in health services, from operations and processes to the new dynamics of business models in this domain (Chandran et al., 2020), has required development processes centered on the user's needs and perspective, integrated with their context and tasks (Barbosa et al., 2021). In this scenario, HCI provides an essential foundation based on the interaction between different users and the most diverse technologies in a quest to design interactive systems that are more effective, efficient, and pleasant to use. This approach is based on the understanding that the individual's social context influences how the user sees and behaves towards a software system, so it is essential to consider it in development activities (Peres and Morais, 2021).

In this context, user-centered design (UCD), as an HCI method, considers in the development cycle the broad participation of the end-user and other interested parties in iterative activities that believe their expectations as a knowledge base for decision-making in a largely collaborative process (Govella, 2019). About the health domain, this is a method that considers end-users, who are mostly doctors and patients, as key players in providing a fundamental basis for developing software that adheres to the reality and context of use (Ghazali et al., 2014) (Bitkina et al., 2020). Therefore, the implementation of UCD methods for the design and development of healthcare applications will bring benefits to those who use the various systems since it makes it likely to increase usability and, consequently, well-being, reduce stress levels, improve accessibility, and reduce the threat of harm (Maramba et al., 2019).

The lack of an approach that considers the end-user when developing software applications leads to a disconnection with user needs, high error rates, late corrections of problems, user dissatisfaction, wasted time and resources, and high maintenance and support costs, among others. In healthcare, there is an even more significant concern, as this is a highly complex application domain linked to human lives, and a us-

ability error can directly affect the doctor's work and put the patient's life at risk (Meehan, 2020).

In short, a user-centered approach advocates that by integrating the end-user into development processes from an HCI perspective, in contrast to traditional software engineering approaches, they are no longer only consulted during validation. Instead, they are considered from the initial design phases, development, and maintenance, including activities that promote continuous feedback identifying problems and opportunities for improvement throughout the process. This constant feedback cycle makes it possible to make adjustments and refinements to more effectively meet user needs, keeping the technology up to date and in line with constantly evolving expectations (Govella, 2019).

3 LITERATURE REVIEW PROCESS

This section analyzes the end user's participation in the development of health applications and is organized as follows. Section 3.1 presents the research methodology used, while Section 3.2 discusses the systematic literature review, in which the selected works will be presented according to the acceptance criteria adopted.

3.1 Methodology

This study used a methodological approach based on the structured, systematic literature review process, which adopts methods for identifying, selecting, and critically evaluating state-of-the-art studies. A search strategy was defined as the first activity to achieve this goal, where relevant terms combined with Boolean operators were considered. Thus, the search strategy shown in Figure 1 was formulated.

(HCI OR "HUMAN-COMPUTER INTERACTION") AND (USABILITY OR REQUIREMENT) AND HEALTHCARE AND "INFORMATION SYSTEMS" AND ("HEALTHCARE APPLICATION" OR "HEALTH INFORMATION SYSTEMS")

Figure 1: Search Strategy.

Following the definition of the search strategy, the repositories were chosen, and the four primary computing-related databases were identified as ACM Digital Library, Springer, IEEE Xplore, and Science Direct. Furthermore, the decision was made to incorporate the PUBMED database because of the boundary between computing and health, leading to publication in both domains.

Three hundred-seven studies were identified after applying the search strategy to the repositories. However, the studies underwent an inclusion analysis, which only considered studies describing the process of developing software in the health sector and published between 2018 and 2023. The time interval of the last five years was adopted due to the dynamicity of research involving the health sector and the representativeness of recent studies in the area investigated. Duplicate papers and papers of another nature unrelated to the research were also excluded. This process was essential for identifying studies in line with the scope of this work.

Only thirty-eight articles were chosen to move on to the second analysis stage, following a preliminary analysis that involved reviewing the abstracts and findings of the three-hundred-seven papers. At this stage, each of these studies was subjected to a full reading, resulting in the final selection of twenty-seven relevant studies for inclusion in the systematic review. Figure 2 represents the outline of identifying these studies, which carefully examined and described the main contributions and the execution of individual development in each study.

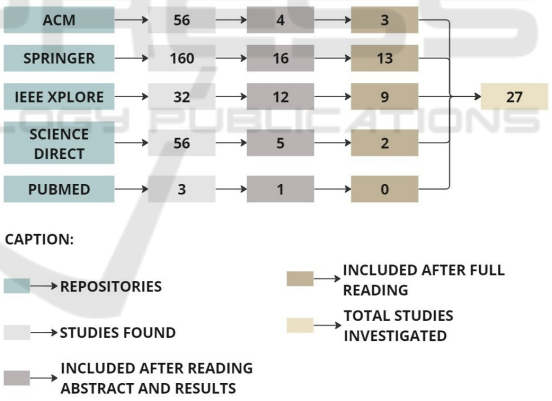

Figure 2: Research Method Used.

3.2 State of the Art Analysis

The constant creation of computer solutions with different purposes and scope evidences the diversity of software applications in the healthcare sector. Our investigation identified twenty-seven studies, which could be categorized into four different types of software: healthcare software, software redesign, health information and communication, and health management systems. This categorization was done to group studies with similar objectives, establishing connections within each identified group. In addition, the

analysis consisted of four primary phases in the software life cycle process: requirements elicitation, prototyping, application development, and evaluation.

The studies analyzed in this section were categorized to answer the research questions described in Section 1. Thus, considering software aimed at health care, fourteen studies were identified, where (Giachelle et al., 2021) specifies a biomedical annotation tool, and (Maeda et al., 2019) develops memory care software that uses virtual agents. The end-user is not involved in the software development process in either work. In addition to these, other healthcare projects involved end-user participation only in the software evaluation phase, including (Bacungan et al., 2021), (Islam et al., 2023), (Rezaei-Hachesu et al., 2018), and (Marinho et al., 2019), the latter of which developed a system to support the management of biobanks and biorepositories.

Continuing the analysis of the works, in (Nimmolrat et al., 2021), a pharmaceutical application is presented to meet the needs of visually impaired users in managing their medicines, and the end-user is only involved in the requirements elicitation phase. In other studies, the end-user only actively elicited requirements and evaluated the computer solutions developed (Ladwa et al., 2018), (Quinde et al., 2019). In other studies, the end-user was actively involved in all stages of the software cycle, a practice observed in the development of mobile applications used by health professionals and patients (Koumpouros, 2021), (Faizzati and Arifiansyah, 2022), (Lehmann et al., 2022), (Veale et al., 2019). In (Dahella et al., 2020), the end-user only participates in a tool's requirements elicitation, prototyping, and development phase, preventing unscheduled admissions to the intensive care unit.

Only two of the twenty-seven papers investigated were classified in the software redesign category. In (Puspitasari et al., 2018), the end-user only participated in the evaluation phase of the computer solution. In contrast, (Martini et al., 2022) proposed the redesign of software that focuses on improving the medication process, and in this research, the end-user participated in all stages of the software's life cycle. In addition, three papers were identified in the health management software category, where (Ishak et al., 2021) analyzes the feasibility of cloud technologies in a prototype, and end-user participation is only in evaluating the tool. On the other hand, (Rahutomo et al., 2022) only involves the end-user in the requirements elicitation phase. Finally, a clinical decision support system for treating diabetes is presented in (Fico et al., 2019), and in this work, the end-user is involved in all phases of the software's life cycle.

In the health information and communication category, (Jacobs et al., 2018) develops a software application to provide patients with access to cancer diagnosis information, (Falcão et al., 2019) specifies a solution aimed at preventing diseases transmitted by the Aedes aegypti mosquito, while (El Hefny et al., 2021) and (Roque et al., 2021) design chatbot applications to inform and guide the population on the coronavirus pandemic. As a common point between the works mentioned, the end-user was only involved in the evaluation phase of the computer solutions developed. A step ahead of the other works in this category, (Alabdulhafith et al., 2018) includes the end-user in the requirements elicitation and evaluation phases and (Chatterjee et al., 2022) developing a healthy lifestyle application. In both cases, end-users are involved in requirements elicitation, prototyping, and coding. Finally, (Zotov et al., 2020) and (Francese et al., 2021) propose computational solutions involving the end-user throughout the software development life cycle.

Research	End-User Participation in the Software Life Cycle				Insertion of All End-User in the Requirements Elicitation Phase			
	P1	P2	P3	P4	TE	PE	PH	PHE
(ALABDULHAFITH et al., 2018).	✓			✓	3		✓	✓
(JACOBS et al., 2018).				✓	1	✓		
(KOUMPOUROS, 2021).	✓	✓	✓	✓	2	✓	✓	✓
(PUSPITASARI et al., 2018)	✓	✓	✓	✓	3	✓	✓	✓
(ISHAK et al., 2021).				✓	3			✓
(BACUNGAN et al., 2021).				✓	3		✓	✓
(FAIZZATI; ARIFIANSYAH, 2022).	✓	✓	✓	✓	1	✓		
(FALCÃO et al., 2019).				✓	1	✓		
(HEFNY et al., 2021).				✓	1	✓		
(ROQUE et al., 2021).				✓	1	✓		
(LEHMANN et al., 2022).	✓	✓	✓	✓	3	✓	✓	✓
(RAHUTOMO et al., 2022).	✓				1	✓		
(ZOTOV et al., 2020).	✓	✓	✓	✓	1	✓		
(REZAEI-HACHESU et al., 2018).				✓	1	✓	✓	✓
(MARTINI et al., 2022).				✓	2			✓
(FICO et al., 2019).	✓	✓	✓	✓	3	✓	✓	✓
(NIMMOLRAT et al., 2021) .	✓				1	✓		
(CHATTERJEE et al., 2022).	✓	✓	✓		1	✓	✓	
(VEALE et al., 2019).	✓	✓	✓	✓	1	✓	✓	
(FRANCESE et al., 2021).	✓	✓	✓	✓	1	✓	✓	
(QUINDE et al., 2019).	✓			✓	1	✓		
(ISLAM et al., 2023).				✓	1	✓		
(LADWA et al., 2018).	✓			✓	1	✓		
(MARINHO et al., 2019).				✓	1			✓
(DAHELLA et al., 2020).	✓	✓	✓		3	✓	✓	✓
(MAEDA et al., 2019).					1			
(GIACHELLE et al., 2021).					1			✓

P1 - Usability Requirements Analysis || **P2 -** Prototyping || **P3 -** Application development || **P4 -** Validation

TE - Types of End-User || **PE -** Participation of All End-Users || **PH -** Participation of Health Professionals || **PHE -** Health Professionals and End-User

Figure 3: End-User Participation in the Life Cycle of Healthcare Applications.

To make it easier to understand the research car-

ried out in this study, Figure 3 shows the mapping of the works considering the authors, year of publication, and end-user involvement in the software life cycle. In this context, column P1 corresponds to requirements elicitation; P2 is equivalent to software application prototyping; P3 covers the coding phase; and finally, the evaluation of the computational solution is represented by column P4. Also, in Figure 3, the column (TE) identifies the number of types of end-users present in the studies, while the column (PE) shows whether all kinds of end-users participated in the phases of the software life cycle in which their presence was found. Next, the column (PH) considers the category of software in the health area, and the column (PHE) checks whether the health professionals who took part in the studies were also considered to be end-users of the application.

4 RESULTS AND DISCUSSION

Beginning our understanding of the investigated studies, we identified six categories of end-users: patients, students and health professionals, health managers, and administrators. The patient category is present in eighteen studies, and other health professionals are present as end-users in twelve articles.

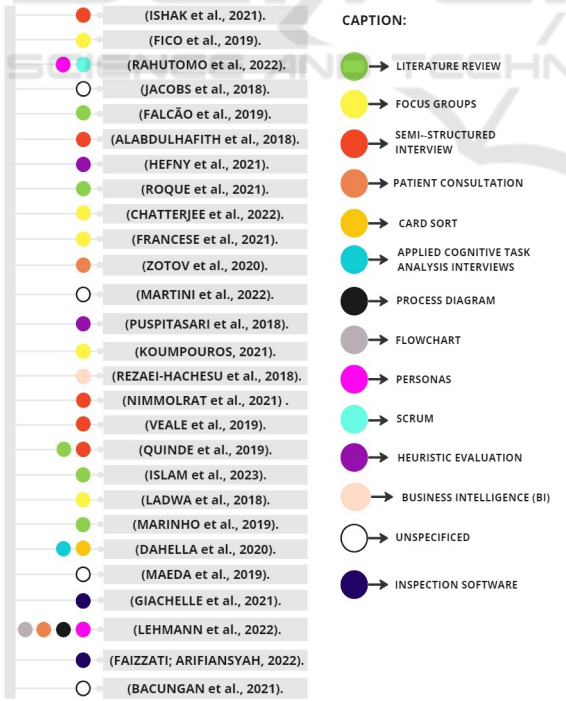

Figure 4: Requirements Elicitation Techniques Found in Studies.

Looking at the requirements elicitation techniques found, we mapped fourteen types of techniques, with some studies using more than one for different purposes. Furthermore, some methods did not involve direct contact with the end-user. Thus, five studies included a literature review, one study used business intelligence indicators, two studies employed tool inspection, and four studies did not specify the use of any requirements elicitation technique, as shown in Figure 4.

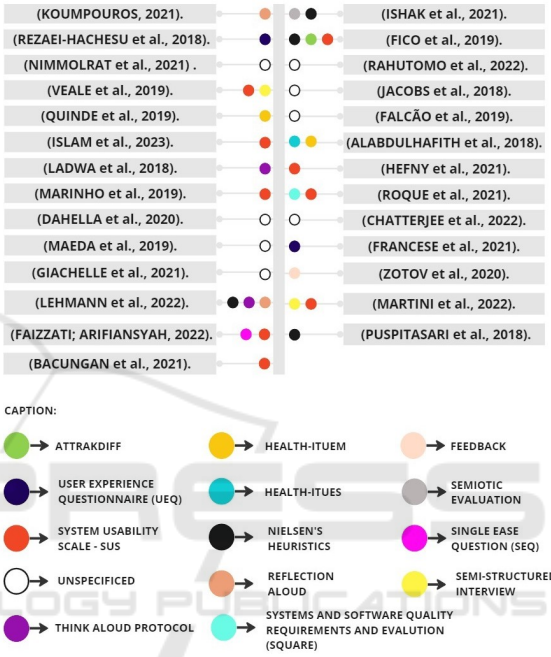

Figure 5: Usability Methods and Standards to Support Software Evaluation.

In addition to requirements elicitation techniques, we also looked at the standards and good practices used to evaluate the software studied. Twelve evaluation methods and two standards were identified. Figure 5 shows this categorization and highlights some data, such as the predominance of the system Usability Scale (SUS) method in nine software evaluation papers and the use of Nielsen's heuristics in four papers. In addition, eight papers do not specify usability evaluation methods.

Another relevant piece of information is that only five studies use one evaluation method with at least one usability best practice standard. However, only two studies use a software evaluation method explicitly developed for application in the health care software. Based on the state-of-the-art analysis, the results present critical reflections on the software development life cycle in the health sector, and some challenges will be addressed below.

An initial observation reveals the need for more evidence of including end-users from the health sector throughout the software life cycle, except in the evaluation phase. Some studies have involved healthcare professionals in the development process, but they have not considered them as end-users for unspecified reasons. This gap can result in technological solutions that do not meet the desired needs, compromising the quality of health services.

Although most studies have included the end-user in the evaluation phase, not all categories have been included in some studies. This may result in inadequate attention to the user's needs, given that not all perspectives have been analyzed. In addition, there is a gap when we note that most of these studies, despite using methods to evaluate the tools, need to specify whether these measurements are based on guidelines or technical standards for good usability practices. In this context, although there are methods and standards focused on developing software for the health sector, only two studies mention and use these support resources.

5 CONCLUSION

This article investigated end-user participation throughout the software development lifecycle in the healthcare sector. In our study, we sought to identify whether the challenges encountered in the involvement of these users are linked to the use or not of HCI techniques during the development of healthcare applications. Based on a careful analysis that corroborated the selection of twenty-seven articles aligned with the defined theme, it was possible to identify some gaps and challenges in adopting user-centered processes, considering the issues addressed in this research. However, there are some differences in the end user's involvement in the various phases of the software life cycle.

In the requirements elicitation phase, many papers did not directly incorporate the end-user at this stage. There is also a need for more evidence that the techniques used are based on good usability practice standards. In the coding stage, some studies have used end-users to carry out incremental and validation tests, but the evidence still needs to be found more participation by health domain experts.

In the evaluation stage, it was also noted that although many studies involve end-users, only two use specific methods aimed at good usability practices in the health area. The results point to the incidence of studies that do not involve health professionals significantly in the processes, which reflects an even more significant challenge since there is no validation of the knowledge domain applied by these professionals. In general terms, the studies recognize the need for end-user participation in the life cycle of health applications. Still, more should be said explicitly about the reason for the low level of user participation in the studies. The lack of end-user involvement can lead to high maintenance levels, poor usability, and the development of software applications that do not meet the needs of the problem domain.

To indicate future work, we intend to conduct a study with healthcare professionals using the openEHR Archetype standard in the requirements elicitation phase. The study investigates whether the domain expert knowledge specified in a healthcare standard can improve the software development life cycle in the healthcare sector.

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