Acceptance and Usability of Complex Medical Systems

A Study with Radiology Professionals

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ABSTRACT

The increasing demand for imaging tests has made radiology information systems crucial in medical practice, especially those based on web technology. These systems include Picture Archiving and Communication System (PACS), Radiology Information Systems (RIS), and Hospital Information System (HIS), generate and manipulate images through specialized software. To operate this complex software, require attention to detail and image manipulation techniques for accurate diagnoses. Usability issues in medical image manipulation software, given the process of adapting to new software and complex tasks, can result in inaccurate diagnoses with clinical impact. This is a qualitative study, which is based on the work routines of radiology professionals, focusing on issues of cognitive learning, interaction, and usability with radiology software. Moderate usability tests with radiology technicians were conducted to identify the difficulties and challenges they encounter while using medical image manipulation software. The analysis identified 64 problems grouped into 20 categories and organized under Visual Presentation, Content, Information Architecture, and Interactivity. The paper emphasizes violated heuristics and describes how these problem categories impact users in their medical activities and their influence on the clinical process. The obtained results provide insights to enhance usability practices and recommendations, aiming to support the development systems used in radiology practice.

KEYWORDS

usability issues, radiology systems, qualitative analysis

1 INTRODUCTION

Health information systems are extremely important in medical practice and clinical interventions, and are essential for the activities carried out by health professionals in hospitals and clinics [5, 8, 14, 34, 35]. There are works in the literature that apply computing to medical images to assist healthcare professionals. The work of Vieira et al. [37] used Applied Explainable Artificial Intelligence (XAI) in the classification of retinal images to support Glaucoma diagnoses. Martins et al. [27] presented a web-based platform that provides a intuitive interface suitable for Machine Learning computational pathology research to be easily carried out.

In this study, the focus is on radiology systems, which are essential for carrying out clinical analyses. The tasks involving these analyses require attention to detail through image manipulation techniques to make a medical diagnosis. Are systems that have led to optimizing the quality and productivity of healthcare professionals [1]. Figure 1 shows a simplified workflow of radiology professionals and communication between systems. These professionals operate radiology equipment to generate medical images, which are manipulated in specific software and archived in the Image Archiving and Communication System (PACS). The images can be viewed on workstations, being accessed through the Radiology Information Systems (RIS) and Hospital Information System (HIS). The area painted in yellow between the arrows indicated with numbers 1 and 2 in the figure indicates that the focus of this study covers the processes that integrate the tasks in medical image manipulation software [8, 9].

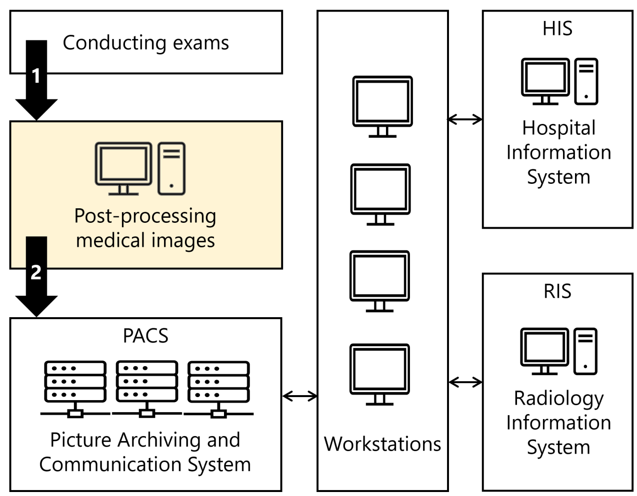

Figure 1: Simplified layout of professional workflow and inter-system communication
Source: Adapted from Silva [8]

It is important to highlight that many healthcare systems were developed based on web technology, especially PACS and DICOM (Digital Imaging and Communications in Medicine) imaging systems [3, 4].

Medical systems used in radiology are multimedia systems with the ability to integrate and present medical images alongside text such as medical reports. The interactivity in viewing images, with zoom, rotation and annotation functionalities, in addition to the ability to present several photos in an integrated and simultaneous way, and the transmission of medical data for remote and collaborative access, demonstrate the multimedia essence of the system.

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Previous studies have carried out several evaluations on PACS and RIS systems and found several usability problems that impact the performance of complex image capture and analysis tasks [9, 11, 15, 16, 38]. However, there is limited knowledge about image manipulation systems, whose aspects influence the procedural aspects and results of clinical examinations in hospitals and clinics, mainly in the Brazilian scenario. Another important aspect that was also revealed in a study with radiology professionals [8], points out that the work routine, the characteristics of the systems and the interaction of radiology professionals with these systems, are conditioned by the hospital or clinic process, where the system is process-centric and not user-centric.

This paper aims to study and qualitatively analyze the post-processing tasks of medical images performed by radiology professionals, observing the aspects of cognitive learning, the software usability problems encountered in these tasks, how these problems impact the process of hospitals and clinics, and how radiology professionals accept these systems.

The study involves usability testing, given the CAAE research protocol nº 49170921.6.0000.5148, to understand in practice the tasks of radiology professionals and identify the difficulties and usability problems that these professionals present when using a medical image manipulation system model.

This study seeks to answer which usability factors influence the use of radiology systems in the Brazilian context and what the impact of these problems would be on the radiology service provided.

The paper is organized as follows. Section 2 presents the main concepts of radiology information systems, DICOM standard and related works. Section 3 presents the main methodological aspects. Section 4 presents the results, Section 5 the discussion and, finally, Section 6 the conclusions and future work.

2 BACKGROUND

This section describes concepts about information systems in radiology and related works.

2.1 Radiology Information Systems and DICOM standard

Hospital radiology departments have been using digital systems on a large scale, which has generated an increasing volume of data. This reinforces that the solutions to manage these data and digital images are adopting a PACS and RIS system [38].

According to Dias et al. [9] and Huang [13], PACS is a short- and long-term image management system which consists of archiving medical images. These images are generated by medical equipment, such as digital radiography, computed radiography, computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound. PACS plays a vital role in health information systems, helping reduce costs, facilitate access to medical images and improve workflow in the radiology department. PACS improves the processing, storage and transmission of medical images for radiologists [38]. RIS and HIS are management systems that distribute data about diagnoses, procedures and patient exams over the network. The difference between them is that RIS is a radiology information system while HIS is a hospital information system. The complexity this systems can lead to different problems, such as procedural errors, delay in diagnosis, possible errors in the diagnosis of results and even discomfort or stress on the part of health professionals who use these systems for a long time. The usability of these systems is essential to avoid errors in collection and diagnosis.

Images generated by radiology systems have a specific file format called DICOM (Digital Imaging and Communications in Medicine), a standard model for storing medical image information [36]. This standard provides a framework that allows the exchange of multiple medical images and related information stored in a single format by the PACS system.

For post-processing tasks of DICOM images, medical image viewing software is used with measurement, zoom, contrast, and other tools to review patient exam images and work with other medical data. This software may be from the same company as the radiology equipment or third-party software. In addition to being essential software during an exam to obtain the medical report, there are web versions for patient access to consult the exams.

2.2 Related Works

Several studies in the literature have reported evaluations and analyzes of usability in radiology systems. In 2017, a systematic literature review conducted by Dias et al. [9] examined and compiled usability issues identified in ten primary studies involving radiology professionals, resulting in 90 problem cases. The qualitative analysis revealed the causes and effects of the identified usability problems, classifying them according to the usability heuristics established by Nielsen and Molich [30], which were later improved and popularized by Nielsen [29]. The study provided implications related to the most common problems, with the top five heuristics with the highest number of reported usability problems being “Flexibility and efficiency of use”, “Consistency and standards”, “Match between system and the real world”, “Recognition rather than recall”, and “Help and documentation” [12, 15–18, 20, 25, 26, 31]. These implications include: attention to sequential steps in accordance with clinical analysis practices; direct access to crucial information for clinical decision-making; facilitate integration with other systems for producing clinical reports; improve efficient access to images that require simultaneous analysis; assisting in efficient basic image manipulations within the system; ensure consistency in patient identification to avoid misinterpretations; align information architecture with clinical terminology; maintain consistency in important features across tasks; system rules that accommodate real-world clinical procedures; accurate recognition capabilities; and easily recognizable feature activation.

A study by Esfahani et al. [11] emphasized the significance of user interaction in selecting PACS. The study employed the Think-Aloud protocol in conjunction with a post-usability questionnaire to compare user interaction issues across various PACS user interfaces. The assessment focused on efficiency, encompassing aspects of usability such as efficiency, learning, error, and satisfaction, revealing user interaction challenges within three tested PACS systems.

A study conducted by Salahuddin et al. [33] delved into the behavior of healthcare professionals regarding the adoption of a Health Information System (HIS) and its impact on patient health. Through a qualitative approach, the study conducted semi-structured interviews with 31 physicians across three hospitals that had implemented the system. Thematic qualitative analysis of the interview results revealed four key themes: (1) carelessness, (2) alternative solutions, (3) non-compliance with the procedure and (4) copying and pasting habits. The study provides practical examples of how these professional behaviors may lead to unintended consequences in the utilization of the HIS.

In a more recent study by da Silva et al. [8], semi-structured interviews were conducted with 10 radiologic technologists to gain insight into the daily work routines of professionals in the radiology field, encompassing processes, workload, responsibilities, and challenges associated with the use of radiology systems. The data from this study underwent thematic analysis, facilitating the organization and description of a dataset that identified issues, comprehended processes, responsibilities, and factors influencing the routines of radiology professionals. Several important findings were presented, revealing that the work routines, system characteristics, and interactions of radiology professionals with the systems are contingent upon the processes of the hospital or clinic, demonstrating how participants had difficulties reporting when asked about system usability. The narratives underscore the need for professionals to adapt to system features, even if it requires memorizing actions and utilizing functionalities in languages they may not fully comprehend.

Despite progress in studies of radiology systems, there is a lack of information about the Brazilian scenario. Previous research has focused mainly on aspects of usability and impact, often failing to explore in depth the implications of these systems in the work processes of healthcare professionals, as well as in hospital and clinical contexts. This study seeks to fill this gap by carrying out usability tests with radiology professionals, providing a comprehensive perspective on the use and challenges faced by these users in medical imaging software, enabling future work to deepen studies on the various aspects presented in this paper.

3 METHODS

This study analyzes DICOM image post-processing tasks, evaluating the usability aspects of radiology systems in use in Brazil. The study included usability tests, which led to significant results regarding users' behaviour and difficulties in using the software.

The method counted on content analysis and thematic analysis to divide problems into categories according to how they affect the interaction. Data analysis was qualitative, where the unstructured data found were transformed into texts and other artifacts in a detailed description of the situation or problem, considering the essential aspects [22].

3.1 Participants

Four male and two female radiology technicians were recruited (Table 1). The recruitment of participants for usability tests was done through contacts on social networks, e-mails, and by indication from the participants themselves. The research protocol was approved and registered by the university's Research Ethics Committee with protocol CAAE 49170921.6.0000.5148 in August 2021.

Table 1: Participant details

#	Academic level	G*	State	W*	Workplace
1	PhD	M	Pará	4	UPA*
2	BSc degree	F	Paraná	6	Hospital
3	Specialization	M	São Paulo	17	Hospital
4	Specialization	M	São Paulo	9	UPA*
5	BSc degree	F	São Paulo	10	Clinic
6	Specialization	M	São Paulo	5	Hospital

* *G - Gender | W - Work in years | UPA - Emergency care unit*

The participants had different characteristics, such as regionally, place of work and professional experience. Regarding academic training, three of the participants had specializations, two had a bachelor's degree and one had a doctorate. Regarding the place of work, three worked in the hospital, two in the UPA Unidade de Pronto Atendimento, which translated means "Emergency Care Unit"), an emergency care unit, and the other worked in a clinic. The average professional experience of these participants is eight years, with the most experienced participant having seventeen years of experience and the least experienced having four years.

Regarding the level of knowledge and experience with using the computer, the majority considered themselves to have an acceptable level, on a scale between low, acceptable and advanced levels. Likewise, most claim to have a good level of experience with radiology systems.

3.2 Usability testing

This study applied a usability assessment in radiology systems with users as a data collection instrument. These tests were carried out remotely from November 2021 to March 2022, using Google Meet, with video recording, participant audio, and a computer screen later used to document all important and valuable information. During the evaluations, the Think-Aloud [10] protocol was used as a specific technique, which suggests the user describe aloud what he is thinking and doing while performing tasks. This technique focuses on user cognition when interacting with the system [11].

Usability testing was moderated and performed remotely and individually. The participant remotely accessed the primary researcher's computer, which contained the software and images used during the test, through the Google Remote Desktop service. Then the participants were given the tasks to perform while moderated by the researcher.

The software used in this study for the tests is the JiveX DICOM Viewer, free software for non-commercial use for viewing images in DICOM format. JiveX DICOM Viewer is software that runs installed on the computer, unlike some software that runs in web browsers. In this software, it is possible to manipulate the image using several tools that are common in software used by radiology professionals. The JiveX DICOM Viewer software was chosen after research and testing on some software with the help of a professor and professional in the field of radiology. As the tests were planned to be run remotely, it was decided to choose free software, without the need to create accounts, that did not consume much memory during image processing and that had a sufficient variety of tools to carry out the tasks. Some sets of example medical images, and the user manual for this software are available for download on the Visus website[1].

The main author provided participants with images publicly available by the TCIA service, which de-identifies and hosts an extensive archive of medical cancer images accessible for public download[2]. The download of medical images is done through specific software called NBIA Data Retriever. Installation guidelines can be accessed from the site[3]. The queries for images can be made at https://public.cancerimagingarchive.net/nbia-search.

The tasks were shared with the participants by Google Meet e which task was read. The tasks performed were: Select layout; Adjust the position (rotation); Adjust the size (zoom); execute windowing (darken, lighten, highlighting); Describe the side or name of the incident; Open four images in 2x2 layout; Export file; and Print. The aspects studied and evaluated are cognitive learning (perception and attention, comprehension, memory, and active learning), interaction and usability problems with information systems and other elements related the radiology systems [21].

It is worth mentioning that none of the participants knew the software used in the test. Each test took about 60 minutes. After completing the tasks, two satisfaction and usability questionnaires were applied to assess the participants' post-task impressions. One of the questionnaires is a demographic survey developed by the author himself, which includes, for example, the participant's education, age, position held, time of experience with the use of the computer, and the system. The other questionnaire is the PSSUQ - Post-Study System Usability Questionnaire [23], an instrument based on a script of post-test questions with 19 items that assess user satisfaction with the usability of a system. In this case, the author used an adapted version of this research in European Portuguese. These questionnaires are available in Portuguese in link https://bit.ly/questionnaires-pssuq. The PSSUQ questionnaire is important to understand participants' acceptance of new software, even if the tools presented are similar to the software they are used to on a daily basis at work.

3.3 Test data analysis

This section outlines the analysis methods employed in conducting the usability tests for this study. The approach is based in content and thematic analysis techniques, categorizing identified issues based on their impact on user interaction. The qualitative data analysis involves transforming unstructured data into detailed textual descriptions and other artifacts that provide an in-depth understanding of the situation or problem, considering essential aspects [22]. The usability issues identified in the content analysis were systematically organized using thematic analysis principles [6].

The problems detected during the recorded tasks were transcribed by principal author, recording the usability problems identified in the recordings. Transcriptions and coding were carried out in the Microsoft Word word processor, then transported and organized in Google Sheets.

[1]https://www.visus.com/en/downloads/jivex-dicom-viewer.html
[2]https://www.cancerimagingarchive.net/about-the-cancer-imaging-archive-tcia
[3]https://wiki.cancerimagingarchive.net/display/NBIA/Downloading+TCIA+Images

Open coding was performed by authors after identifying the problems and generating the initial codes to categorize the problems found. After each round of open coding, the version of the categorization instrument was used to assess inter-coder reliability, being evaluated based on the Cohen coefficient [28]. After reaching an acceptable level of reliability, differences were discussed and resolved between the authors. The next step in thematic analysis involved identifying themes for the categories identified in the categorization round. For categorization and organization into themes, the four major categories (Physical Presentation, Content, Information Architecture, and Interactivity) described in the work of Petrie and Power [32] were adapted. Finally, at the end of the stage, the themes, categories and usability problems identified during the entire process were presented.

This analysis consolidated recommendations for the designs and acceptance of radiology systems, incorporating the usability aspects identified and related to the Brazilian context.

4 RESULTS

This section presents the results obtained in analysing usability tests carried out with six radiology professionals for this research. The software used in the usability test had no integration with a PACS and RIS system. So, we only consider the process of editing the radiology image done by the radiology technician.

4.1 Problem categories

The researchers found 64 problem situations, with an average of 10 problems per user. Problems were separated into 20 problem categories organized into the following themes: Visual Presentation, Content, Information Architecture, and Interactivity. The Table 2 is organized by problem categories, presenting just a few problem situations as examples in each category. In this link (https://bit.ly/tab-categorization) you will have access to another table with all problem situations, that is organized by users/problems found. For better understand the tables it is important to note that two types of codes appear in both tables. In the case of the "U4-P5" code, for example, this identifies that "U4" is user 4 and "P5" is this user's problem 5. While in the case of the "visu1" code, for example, it identifies the theme "Visual Presentation", with the number 1 representing a problem category of this theme.

Visual Presentation details the visual presentation of the software to the user. Findings from four categories indicate that users encountered challenges in navigating the layout due to a lack of clarity and organization in its functionalities. The presentation of certain icons also led to user confusion. Consequently, several times, some users took time to find the interactive elements to perform the tasks.

The **Content** theme has four categories, outlining issues related to the layout. These problems include sections displaying excessive content, often with unclear contexts, occasional duplication, and terms lacking precise definitions, making it challenging for users to discern their functionality.

Information Architecture theme reveals structural issues within the system that impact the user's tasks. This encompasses two categories, elucidating scenarios where task execution could be streamlined for users, such as actions easily performed with the

Table 2: Problem categories organized into themes

Code	Category	Occurrences	Example
Visual Presentation			
visu1	Unclear or confusing layout	6	Toolbar for windowing task has different options that accomplish the same goal (U4-P5)
visu2	Text/interactive element is not clear/distinguished enough to identify its functionality	10	The user did not realize that there is another interactive element to describe the side and the radiological incidence that inserts only the text without the indicative arrow (U2-P2)
visu3	Interactive elements with different functionality have similar icons	3	The icon of the "reset" element is confused with the icon of the "rotate image" element (U4-P2)
visu4	It takes time to find the desired interactive element	7	It took a long time for the user to find the text tool that allows describing the side and radiological incidence (U3-P4)
Content			
cont1	Layout with too much content confuses the user	2	Mouse action drop-down menu presents many unnecessary options (U6-P4)
cont2	Content is not clear enough	7	Radiology image viewing software content is not available in other languages (U2-P7)
cont3	Duplicate or contradictory content	1	The "reset" interactive element exists in two places, but performs different actions (U5-P9)
cont4	Undefined terms	1	The interactive element represented by the floppy disk icon does not make it clear what the user is saving (U5-P10)
Information Architecture			
arch1	There is not enough structure for the content	3	The actions performed with the mouse can be changed, but require several steps that hinder the user (U5-P11)
arch2	Purpose of the structure is unclear	4	There are two options to display more than one radiology exam image on the screen with different objectives that confuse the user (U5-P8)
Interactivity			
inte1	Lack of information on how to proceed and why things are happening	2	In the radiology image viewer, the user does not know how he activated and how to close the full-screen mode (U3-P8)
inte2	Excessive effort required by the user	2	If the user makes a mistake in a procedure, it is necessary to reset and redo everything again (U4-P9)
inte3	System does not allow user to revert wrongly performed action	5	If there is any misfit in the radiology image during the editing process, the user cannot revert to the previous action (U5-P2)
inte4	Software does not generate feedback on user actions	3	The software does not provide visual feedback when switching between one radiology image and another (U4-P1)
inte5	Illogical interaction sequence	7	Opening the same radiology image in the layout with more than one image preview (U3-P10)
inte6	Result of the action performed does not meet the user's expectation	11	The "ESC" key, by default, coincides with the action to exit full-screen mode, which does not occur in this radiology image viewer (U6-P8)
inte7	Expected interactive functionality is absent	3	The option to undo the last action is missing in this radiology image viewer (U1-P3)
inte8	Security issues not highlighted	1	Software allows opening images of different patients in the same work window and does not have a division to identify these images (U4-P11)
inte9	Missing error/warning messages	4	When resetting the radiology image to the initial state, the software does not ask if the user wants to proceed with the action (U1-P3)
inte10	Delay to perform a task	4	The user took a long time to perform a task because he could not use the tool properly (U5-P5)

mouse. The other category highlights instances where the user may find it less intuitive to utilize multi-layout options for displaying images.

Interactivity theme is the one that most presents problem situations, encompassing ten categories to delineate each scenario. Notably, four categories deserve emphasis: "Lack of information on how to proceed and why things are happening", "System does not allow the user to revert wrongly performed action", "Illogical interaction sequence", and "Result of the action performed does not meet the user's expectation". During the tests, it became evident that a majority of users encountered challenges. For instance, upon entering full screen, users found themselves disoriented, lacking guidance on what had transpired and how to revert. Additionally, users faced difficulty undoing incorrectly performed actions and experienced instances where the outcomes did not align with their expectations. These challenges necessitated users to navigate through unnecessary steps to resolve or complete tasks.

4.2 Usability Problems Encountered

This section describes some categories obtained by analyzing the usability test data, to exemplify how the problem affected the user.

4.2.1 Text or interactive element is not clear enough to identify its functionality. The design must speak the user's language. It is necessary to ensure that the user understands the meaning without looking for a definition or remembering what it means [29].

During the tests, several users used a text tool to write the incidence on the exam image. There are two tools with the same purpose, but one of these tools includes an arrow, and some users tried to remove the arrow without success. Others took a while to realize that the other tool did not include the arrow. Figure 2 shows the detail of each tool.

Figure 2: Interactive element is not distinguished enough to identify its functionality

Source: Screenshot of JiveX DICOM Viewer software

We had ten hits for this category that violated the following Nielsen heuristics: "Aesthetic and minimalist design", "Match between system and real world", "Recognition rather than recall", and "Consistency and standards".

4.2.2 Content is not clear enough. We had seven problem situations in this category, and we understand that five violated the heuristic "Match between system and the real world". The leading cause is users' difficulty with the English language.

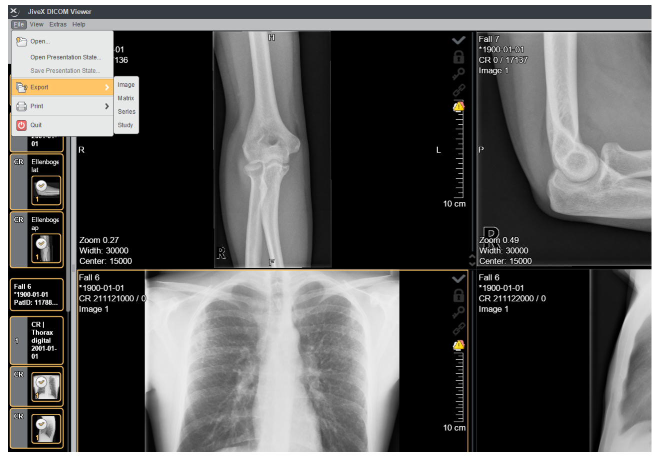

Figure 3: Content is not clear enough

Source: Screenshot of JiveX DICOM Viewer software

For the example, let us use the problem situation that violated the "Consistency and standards" heuristic. Figure 3 shows four options for exporting exam images, and the task was to export four exams. The user chose the option he understood to be exporting all exams but ended up exporting only one.

4.2.3 Purpose of the structure is unclear. Improving the ability to learn by keeping the types of consistency (internal and external) helps the user to understand and perform tasks. In this category, we had four problem occurrences that affect this "Consistency and patterns" heuristic and another two: "Match between system and the real world" and "Visibility of system status".

In Figure 4 is the options for exporting exams, and the result did not match what the user expected.

4.2.4 Result of the action performed does not meet the user's expectation. This category describes when the result of the action performed by the user is unexpected. Eleven problem situations were found in the tests with the radiology software that did not correspond to what the user expected. We had six violations of the "Consistency and standards" heuristic, the others violated the "Flexibility and efficiency of use", "Match between the system and the real world" and "User control and freedom" heuristics.

Some examples mentioned above also fall into this category. For example, the user tried to zoom in on the exam with the mouse and the result ended up changing the contrast in the image. In another case, they exported four exams and the result only exports one. By mistake, the user enters in full screen and tries to exit by pressing the "ESC" key, which does not work.

4.3 Violated Nielsen's heuristics

In addition to categorization, each problem was analyzed by assigning the violated heuristic on the Nielsen scale [29]. For more

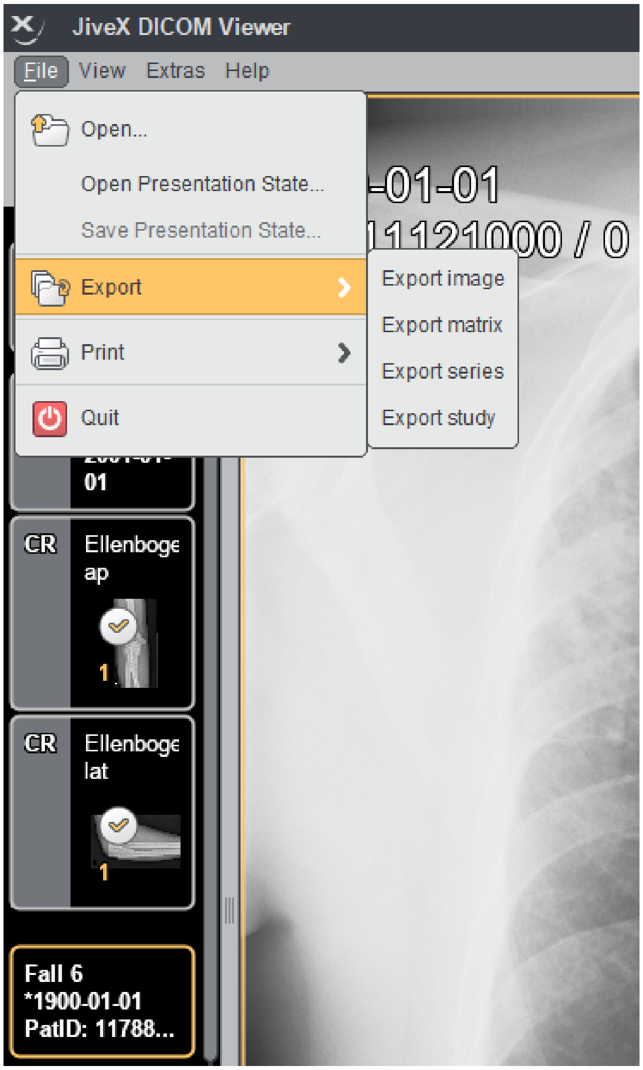

Figure 4: Purpose of the structure is unclear

Source: Screenshot of JiveX DICOM Viewer software

details, see the complete table (https://bit.ly/tab-categorization), which contains the problem situations characterized with the respective violated heuristics.

The results of the analysis that are based on Nielsen's [29] heuristics, reference usability issues. Of Nielsen's ten heuristics, the study presented a violation in 7 of these heuristics, and they are: **Visibility of System Status** (3 occurrences); **Match Between System and the Real World** (13 occurrences); **User Control and Freedom** (8 occurrences); **Consistency and Standards** (14 occurrences); **Recognition Rather than Recall** (4 occurrences); **Flexibility and Efficiency of Use** (8 occurrences); and **Aesthetic and Minimalist Design** (14 occurrences).

4.4 Post study questionnaire

After the usability test, participants received a link to the PSSUQ[4] post-study questionnaire to assess their satisfaction with the software's usability. The questionnaire brought some interesting insights, as shown the number of responses for each question show in Figure 5. Overall, all participants say they are satisfied with the system they used in the test. Most (83%) understand that the system has a pleasant interface, easy to understand and learn. However, two participants understood that they could complete the tasks efficiently. Only one participant said that the information the system presented was clear. Moreover, none of the participants agreed that the system indicated an error and helped resolve it.

Analyzing the aspect of user acceptance of the tested system, it is possible to see that users will adhere to the system, as they understand that over time they will be able to get used to the system, minimizing the problems faced during testing.

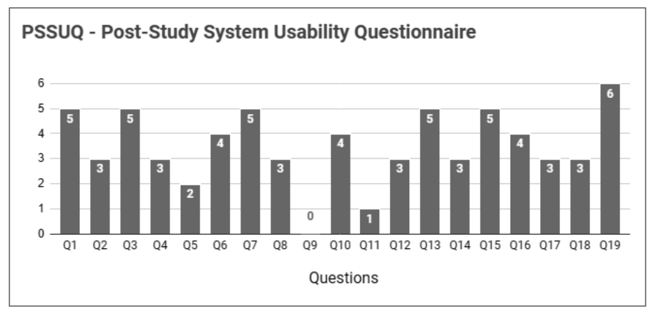

Figure 5: PSSUQ questionnaire result

4.5 Research limitations

The ideal scenario for usability testing would be "in loco", however, there were still many restrictions imposed by the COVID-19 pandemic at the time. Therefore, the way found to carry out the usability tests was to provide commercial software for public and free use, with medical images used from a public and free image bank. The chosen software works with the process of refining the exam images before being sent to the PACS, which allows the doctor to analyze and write the report. However, this is another limitation, we did not have a PACS system or an HIS or RIS system to integrate. With this, we mitigate usability testing tasks, specifically for radiology technicians. As most of the participants had experience only with X-ray exams, we chose to work only with this scenario, as MRI and CT exams are more complex. Thus, it was impossible to mitigate tasks such as collecting patient data from the RIS and sending the exam to PACS, because the software also does not have a patient registration module. On the other hand, carrying out the tests remotely allowed us to have a greater diversity of participants, given their professional characteristics, location and experience.

5 DISCUSSION

This section discusses the problems observed in analyzing usability tests with radiology systems, mapping the different issues that can affect the tasks of radiology professionals, analysis processes and

[4] https://bit.ly/questionnaires-pssuq

patient exam results. This study brought four essential aspects: the visual presentation of the system, the content, the information architecture and the interactivity with the system.

The visual presentation of the radiology system is overloaded, confusing users due to elements with unclear functionality and similar icons with different purposes. Users faced difficulty in locating hidden elements or identifying them visually. Content-related issues, such as unnecessary information in drop-down menus and unclear options for exporting exams, also impeded task completion. Duplicate or contradictory content, poorly defined terms, and incongruent representation of actions, like saving a custom layout with a floppy disk icon, are some examples. The lack of a coherent information architecture resulted in inconsistencies, requiring users to switch between mouse actions and disrupting workflow. Some system structures lacked clarity, with redundant options that seemingly served the same purpose, difficult complicating usability.

In the systematic mapping of the literature carried out in 2017 by Dias et al. [9], the heuristics "Match between system and the real world" and "Consistency and standards" also appear with many occurrences in the current study. A good example is the category "(inte6) Result of the action performed does not meet the user's expectation" which has ten occurrences if we look at the table 2.

The other two studies in the literature [2, 11] are more related to PACS systems, but the current study may indicate aspects regarding integration with PACS and RIS systems. Although there was no such integration in the tests, it is still possible to discuss some aspects. The example of the category "(inte8) Security issues not highlighted" reveals that the software allows opening images of different patients in the same work area without separating. We can only imagine how serious this situation would be.

In the qualitative study [7] performed out with an analysis of the needs and experience of doctors who use PACS, it presented results that describe factors like tasks and resources; workflow; performance issues; and training. In addition, the author addresses the situations where usability problems may occur but does not go into detail. In contrast, the usability tests of the current study delve deeper into the topic of tasks and features. While the study related presents reports from the participants, the present study reports the situations as they emerged in an actual simulated test, with the problems highlighted and contextualized.

Another aspect is related to the study [8] on the routine of health professionals, as a clinical and hospital environment defines an intense work routine and well-defined processes in which users who interact with health information systems are conditioned on this process and the characteristics of the systems.

To answer which usability factors influence the use of radiology systems in the Brazilian context, this study reveals the difficulties users have in completing some of the tasks, due to some facts: Many radiology equipment and software are not available in Portuguese, especially when deals with tomography and magnetic resonance systems. This is an important aspect, as many visual presentation and content problems appeared in the tests and compromised users with little knowledge of the English language. The medical image manipulation software used in the tests is different from what the participants were used to. This explain the difficulties in carrying out the tasks that they normally carry out on a daily basis at work.

Responding to another question in this study, what would be the impact of these problems on the radiology service provided, we note that the usability problems reported in this study can directly impact several aspects, such as, for example, changes to patient exams, delays in carrying out of a simple task, errors in handling the exam image, not being able to correct a basic error, often becoming dependent on support. Many of these problems may be related to adaptation to a specific process, need for training, difficulties with a foreign language, lack of standardization of layout and icons of radiology systems and optimization of the resources presented.

6 CONCLUSION

The paper studied a radiology system to find instances of problems affecting users in their medical tasks and how these problems can become severe enough to affect the clinical process. A moderated usability test was conducted remotely with six radiology technical professionals using radiology image visualization software that allowed editing and refining of the image before sending it for analysis and medical report. Analysis of the study resulted in 64 usability issues, organized into 20 categories that provide essential insights to evolve current usability practices and recommendations to support the design of complex medical systems used in radiology practice.

The paper argued that usability factors in radiology systems need attention, even if the tests were done in non-commercial software, but present the essential tools for the tasks performed by radiology technicians. The results were significant to denote which usability aspects violate Nielsen's usability heuristics and how these problems can interfere with the clinical process. Adjustments to the problems found can improve and speed up the execution of tasks, prevent the user from making errors, ensure that the system is organized and secure with patient data and exams, and ensure that physicians receive this data consistently to carry out the analysis and report. As a contribution to the area of Multimedia, Hypermedia and Web, although the software used in this study is not a web version, this study shows opportunities for new research on complex medical systems and greater reflection on interaction needs and understanding the specificities of the Brazilian context, understanding that several of these systems are based on web technology, such as RPACS (https://rpacs.com.br) and Vue PACS (used several by hospitals and clinics), as well as DICOM image viewers (https://dicomviewer.net and https://medevel.com/dwv/).

For future work, we want to conduct studies with a more significant number of professionals, include more systems for testing and validate of severity of usability, as the safety severity scale by Kennedy et al. [19] and Lowry et al. [24], and patient safety based on the "rating" made by professionals in the medical field. Additionally, a severity scale should encourage user-centric development processes with a focus on security, facilitating the design of interfaces with good usability, with more secure, and providing methods to measure and validate user performance before deployment.

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