2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-05-2**

HUMAN-CENTERED DESIGN OF THE HUMAN-SYSTEM INTERFACES OF MEDICAL EQUIPMENT: THYROID UPTAKE SYSTEM

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ABSTRACT

Technology plays an important role in modern medical centers, making healthcare increasingly complex, relying on complex technical equipment. This technical complexity is particularly noticeable in the nuclear medicine. Poorly design human–system interfaces can increase the risks for human error. The human-centered approach emphasizes the development of the equipment with a deep understanding of the users activities, current work practices, needs and abilities of the users. An important concept of human-centered design is that the ease-of-use of the equipment can be ensured only if users are actively incorporated in all phases of the life cycle of design process. Representative groups of users are exposed to the equipment at various stages in development, in a variety of testing, evaluation and interviewing situations. The users feedback obtained is then used to refine the design, with the result serving as input to the next interaction of design process. The limits of the approach are that the users cannot address any particular future needs without prior experience or knowledge about the equipment operation. The aim of this paper is to present a methodological framework that contributes to the design of the human-system interfaces, through an approach related to the users and their activities. A case study is described in which the methodological framework is being applied in development of new human-system interfaces of the thyroid uptake system.

1. INTRODUCTION

Human error has many causes such as performance shaping factors, organizational factors and user interface design [1]. The technical complexity and poorly design human–system interfaces may increase the risks for human error. Complex medical equipment can exhibit problems in man-machine interaction that could trigger a human error [2]. An interface can be defined as part of a system with which users carry out contact through the physical and cognitive plan. The user interface is composed of information, data, controls and commands in computer screens. Nuclear medical equipment designed using usability criteria can improve operational reliability and time required to learn how to use the equipment can be reduced. The evaluation process of human-system interfaces has as objective to prove that the functions and tasks can be executed with safety by users. User interfaces must have high usability in order to create prerequisites for safe operation, installation, maintenance and increase the efficiency of the interaction..

Usability is 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 [3]. An important concept of human-centered design is that usefulness and ease-of-use can be ensured only if users are actively incorporated in the equipment design cycle. The most accepted way of involving users in the design of equipment is through a process of iterative refinement [4]. Representative groups of users are exposed to the equipment at various stages in development, in a variety of tests. The users feedback obtained is then used to refine the design, with the result serving as input to the next interaction of design process.

Participatory ergonomics involves users actively engaged in system development and analysis of ergonomics problems. It emphasizes system development with a deep understanding of the activities performed by users, of their current work practices, of their needs and skills. The goal is to encourage and support work force participation in the analysis, redesign and evaluation of their own tasks, workplaces and work practices by applying different methods and techniques [5].

The human-centered design requires design activities that should take place during the system development. These activities are: to understand and specify the context of use; to specify the users and organizational requirements; to produce design solutions and to evaluate designs against requirements. The human-centered design process should start at the earliest stage of the project (e.g. when the initial concept for the product or system is being formulated), and should be repeated iteratively until the system meets the requirements [3]. Human-centered design needs a variety of skills. A range of personnel is necessary to address the human aspects of the design. This means that a multi-disciplinary team should be involved in a human-centered design process.

The aim of this paper is to present a methodological framework that contributes to the human-system interfaces design of the thyroid uptake system, through an approach related to the users and their activities. The methodology includes human factors standards, questionnaires and the participation of a multidisciplinary team. The research is based on field studies in the Clementino Fraga Hospital, UFRJ, in Rio de Janeiro and includes the thyroid uptake system developed in Nuclear Engineering Institute.

2. THE THYROID UPTAKE SYSTEM

The actual model of the thyroid uptake system is a nuclear pulse counting digital system compact, of easy operation and low power consumption, capable to assist mainly the activities related to nuclear medicine. The equipment is intended for measuring of counting of ionizing radiation in diagnosis exams “in - vivo” and radiotherapy in experiences "in-vitro". It is operated through one personal computer and specific software that comes together the equipment. The useful graphic interface developed for thyroid uptake exams makes possible to the user the system operation. It allows the user to select the desired function, such as, verification and calibration of the system, and updating of the data of the exam. Once defined the function that the user has chosen, a corresponding window will appear in the screen. At the end of the procedure, the graphic interface informs to the user, through the main screen, the value of the percentile uptake of the iodine absorbed by the thyroid gland. The main screen is shown in figure 1. Figure 2 shows the screen of data entry. This screen is shown when the option selected in the main screen is UP TO DATE.

Figure 1. Main screen

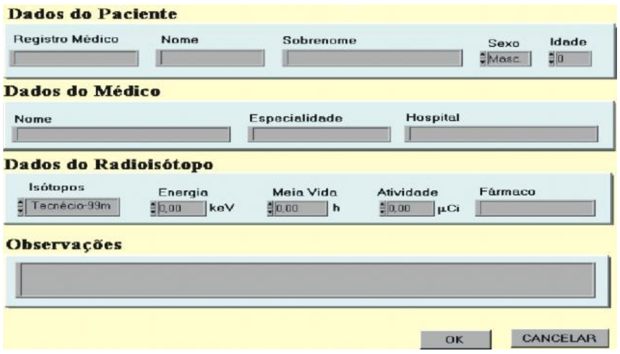

Figure 2. Data entry screen

3. METHODOLOGICAL FRAMEWORK

The principal objective of the methodological framework is to present a specific approach for the human-system interfaces development of the thyroid uptake system. It include the use of human factors and ergonomics standards, human factors guidelines and the participation of multidisciplinary team that actively participates in development of the system, bringing together different information sources, representations, perspectives and fundamental principles.

The first level concerns the definition of a multidisciplinary team. The composition of the team should reflect the relationship between the organization responsible for technical development and the users. It includes human factors experts, industrial designers and electronic and nuclear engineers.

The second level concerns the assignment of the responsibilities and tasks to the multidisciplinary team. The tasks and responsibilities are assigned to each team member according to their technical capabilities. The human factors experts are required to coordinate the overall discussion related to human factors requirement and to carry out the methodology. Users provide information in response to questions related to their needs, work practices and the operation of similar equipment. All the necessary activities for the identification of system mission are carried out and safety aspects, technological restrictions and users performance are discussed. The second level summarizes various activities, such as choice of the human factors and ergonomics standards and guidelines.

The third level concerns the identification of the conceptual design requirements. It is related to the following item such as definition of operational system; definition of visual identity of new interfaces; organization and information grouping and use of colors.

3.1. Definition of operational system

The choice of operational system influences directly on the layout of the interface, as well as their basic control commands. The operational system chosen is Microsoft operating system, Windows 8 .

3.2. Definition of visual identity of new interfaces

Windows 8 presents layout of straight lines and primary colors. This kind of visual identity is more practical and consistent with the development of an interface for nuclear medicine, except for the great variety of colors, which can confuse the user. Windows 8 presents the information organization through visible icons, aiding in navigation with little cognitive effort. The interface framework is designed using full screen. It enables the use of any control layout of the window, such as maximize, minimize and close. It occupies the entire active area of 1280 x 1024 pixels. The choice implies in the development of new window commands and the use of specific keys by users to control the Windows. Several studies were made in black and white color (maximum contrast and readability), so that there was no interference in the perception of color. Buttons and displays were applied to sketches and its contours and position were changed. The screens layout was designed in order to help the users to carry out of the tasks and tries to occupy the smallest space possible without compromising the reading. The use of the buttons and displays remains equal as the existing interfaces, using the standard rectangular format accepted on interfaces for nuclear area, and according to the recommendations of the ISO 9241 [3] and NUREG-0700 [6].

3.3. Organization and information grouping

The organization of the information grouping was kept as close as possible to the original interfaces, in order to facilitate the learning and training. The information is grouped by blocks, represented by icons that facilitate navigation and reduce the amount of information displayed, reducing visual fatigue and possible errors caused by navigation difficulty. The icons organization on the screen follows a order, closely linked to the tasks performed by users.

3.4. Use of colors

According to NUREG-0700 guideline [6], there are eight acceptable colors that can be used in the interfaces development. The colors are red, yellow, green, cyan, blue, magenta, white and black. Each one is represented by the level of attention and contrast relations among themselves. For good level of attention is necessary to use red and yellow.

4. RESULTS

In this item results of the methodological framework application are presented. The multidisciplinary team included two human factors experts, one industrial design, one electronic engineer and two users. The tasks and responsibilities were assigned to each team member according to their technical capabilities.

The multidisciplinary team decided to use the standard ISO 9241 and guideline NUREG 700 [6] as references. The NUREG 700 provides one section dedicated to basic human system interface elements. The basic human system interfaces elements are: information display, user-interface interaction and controls.

ISO9241 [3] series are the first HCI related ISO standards. It provides the definition of usability and explanations how to identify the information when specifying or evaluating usability. The principal information are: designing user-system dialogues and interface navigation; selecting displays; designing or selecting alphanumeric keyboard; keyboards and other input devices; designing workplaces for display screen users and recommendations for the design and evaluation of user guidance attributes of software user interfaces

The multidisciplinary team decided to choose an old version of thyroid uptake system, as reference equipment to be analyzed. This analysis was used to discover salient features of the reference equipment that should be similar to those under development.

The industrial design is responsible for the initial sketch of the interfaces framework layout and details about the information to be presented. The following interfaces were developed: Initial screen; equipment calibration; general information of the patient, isotope and doctor; particular information of the patient; particular information of the doctor; particular information of the isotope; radiation counting results; background radiation counting; results report. Figure 3 shows the initial screen. Figure 4 shows the calibration screen. Figure 5 shows patient information.

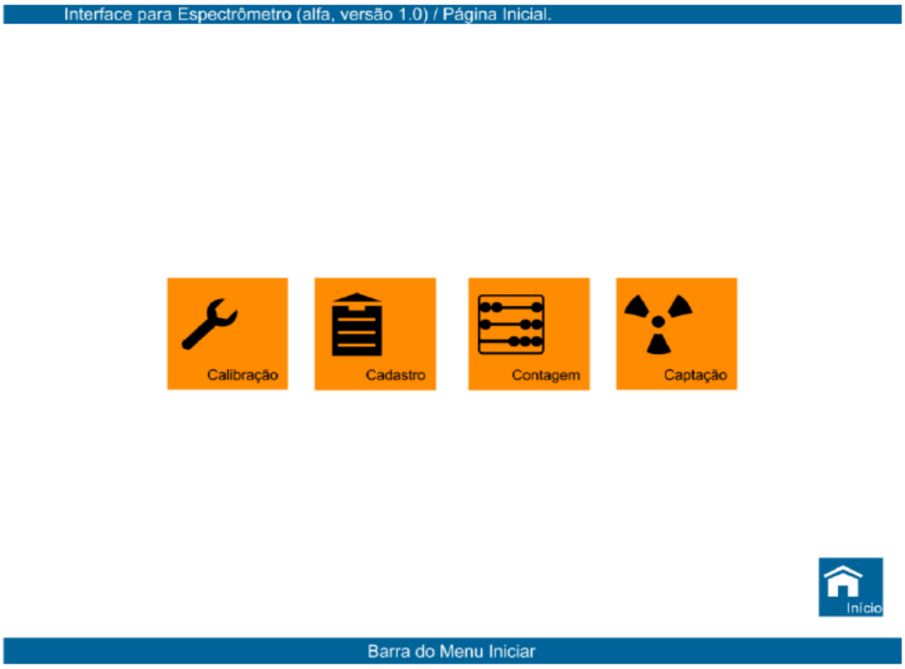

Figure 3. Initial screen

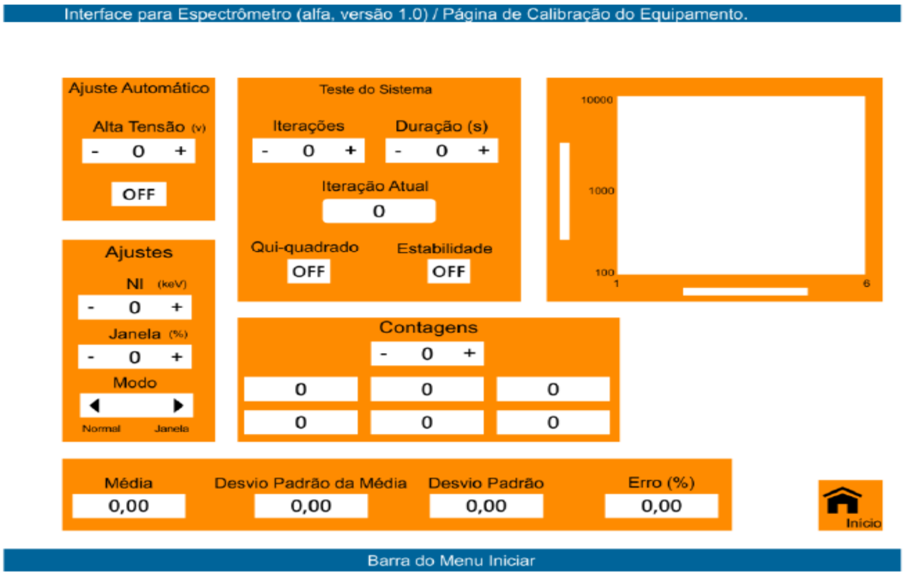

Figure 4. Calibration screen

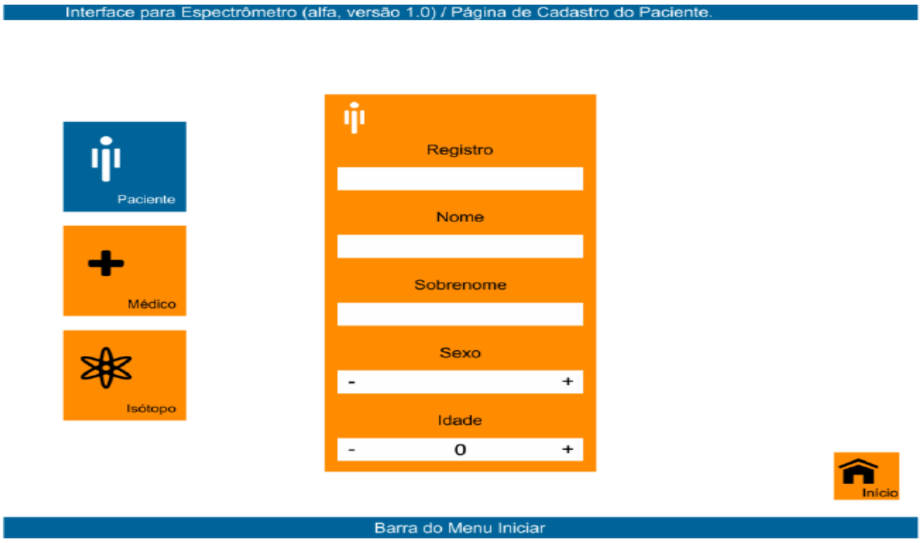

Figure 5. Patient information

5. CONCLUSIONS

Human-centered design must actively involve the users in product development in all phases of the design process. Users are not simply consulted at the beginning and called in to evaluate the system at the end. They must be treated as partners throughout the design process. Receiving user feedback at each phase of the process also changes the nature of the final evaluation, which is used to refine the interface rather than discover major usability problems. The main purpose of this study is to investigate the use of usability and ergonomic criteria as powerful tool for nuclear medical equipment development. Design decisions made in the early phases, such as requisite functionality, choice of platform and software architecture, does affect the usability of the system. If effective evaluations are carried out during all design process, problems can be discovered before too much investment in the design has been made. The final objective of this paper was to present and apply a methodological framework that contributes to the design of the human-system interfaces, through an approach related to the users. The methodology includes human factors standards, questionnaires and the participation of a multidisciplinary team. The research is based on field studies and includes the development of new human-system interfaces of thyroid uptake system, developed in Nuclear Engineering Institute.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of National Advice of Scientific and Technological Development (CNPQ-Conselho Nacional de Desenvolvimento Científico e Tecnológico). The research was performed at Laboratory of Usability and Human Reliability (LABUCH), Rio de Janeiro, Brazil (SEESC / IEN).

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