Heuristics for interface design in telemedicine systems

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Abstract

The usability heuristics proposed by Jakob Nielsen were initially proposed for desktop systems. Over time, it has become necessary to adapt these usability principles to different contexts, such as websites, mobile applications, and educational applications. Based on the mentioned heuristics, this research proposes a set of usability heuristics to guide the design of user interfaces in a particular field, telemedicine systems. The methodology used is the one proposed by Cristian Rusu, which clearly explains how to specify the heuristics through six steps that must be applied iteratively and also presents a standard template to define the set of proposed usability heuristics formally. As a result, a total of eleven usability heuristics were obtained. Subsequently, two telemedical prototypes were designed using the proposed heuristics and the Nielsen heuristics and tested to contrast the level of usability in the designs. Finally, a successful result was obtained in the chosen case study. However, further experiments are needed to generate a more robust set of heuristics. It is concluded that the set of usability heuristics generated could help the designers of user interfaces for telemedical systems to take into account aspects that support the design of a usable software product since system engineers and potential users tested it.

Keywords

Heuristics, usability, ease of learning, telemedicine, user interfaces.

1. Introduction

The World Health Organization has adopted the following definition of telemedicine [1]: "The provision of health care services, where distance is a critical factor, by all health professionals using information and communication technologies for the interchange of valid information for the diagnosis, treatment, and prevention of disease and injury, research and evaluation, and for the continuing education of health care providers, all to improve the health of individuals and their communities." Therefore, in the provision of tele-medical services, it is of utmost importance that the health personnel in charge take appropriate actions that lead to improving or maintaining the individual's health status.

One of the most frequent scenarios is transporting the patient in an ambulance. Suppose the patient's health condition is complex. In that case, the personnel in charge of the ambulance may need to establish communication with the medical team waiting at the medical center to transmit vital information and receive recommendations from health professionals appropriate to preserve the patient's life.

Suppose a telemedicine system is used to contribute to the problem above. In that case, this system must allow the transmission of data in a reliable way and in real-time, and it must also make it easier for users to enter and visualize the information through user-friendly interfaces. This scenery involves having a usable product, a fundamental component in the design of interactive systems. Usability refers to the degree to which specific users can use a product to achieve specific goals effectively, efficiently, and satisfactorily given one particular use context [2].

Usability has the following characteristics:

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1. *Ease of learning*. The system should be easy to learn so that the user can quickly start working with the system. Ease of learning is related [3] to the following terms:
    a. Predictability
    b. Synthesis
    c. Familiarity
    d. Generalization of previous knowledge
    e. Consistency
2. *Efficiency*. The system must be efficient so that productivity increases once the user has learned to use the system.
3. *Ease of remembering how it works*. The system must be easy to remember so that the user can interact with the system after a period of not using it.
4. *Error frequency and severity*. The system should have a low error rate; it should be easy to recover if the user makes errors.
5. *Satisfaction*. The system must be pleasant to use so that users are subjectively satisfied.

One way in which usability can be achieved is by using a series of heuristics that guide the process of building the application to generate a quality product that meets user expectations. Heuristics, or heuristic principles, are general rules of thumb that aim to create a "communicational bridge" in which the person and the system understand each other and work together towards a goal to be achieved [4]. Jakob Nielsen formulated ten usability principles [5], which are applied and adapted to different fields.

A software solution that is responsible for transmitting, from remote locations, information regarding a person's health must have clear interfaces for users, easy to understand and use, in addition to providing the necessary tools to execute the required functions and minimize errors through its user-friendly interface. The user interface is an essential part of a system. If it is tedious, obsolete, or confusing for the user, they will probably not want to use the system and will discard it [6]. In the medical field, an error can mean the death of a human being, so technology mustn't be an obstacle to preserve life. However, the evaluation heuristics proposed by Nielsen cannot be applied to all scenarios, since there are very specific aspects in each type of application that need to be evaluated differently.

Based on the above, this article proposes a set of usability heuristics to guide the design of telemedical systems. Because usability is extensive, the evaluation of such design focuses on ease of learning.

2. Methodology

Step 1: An exploratory stage to collect literature related to the main topics of the research: specific applications, their characteristics, general and related usability heuristics (if any).

Step 2: A descriptive stage to highlight the most essential features of the previously collected information to formalize the principal concepts associated with the research.

Step 3: A correlational stage to identify usability heuristics' characteristics should be based on traditional heuristics and case study analysis.

Step 4: An explanatory stage to formally specify the proposed heuristics using a standard model.

Step 5: A validation (experimental) stage to verify the new heuristics against traditional heuristics by experiments, through heuristic evaluations, performed on selected case studies, complemented by user testing.

Step 6: A refinement stage based on feedback from the validation stage.

3. Results and discussion

3.1. Characterization of telemedical interfaces

As a result of the first step of the methodology, a string-based search was performed in sources such as Science Direct, IEE Digital Library, and ACM Digital Library, and several articles relevant to the research were obtained (see Table 1) as well as specific applications and relevant concepts. It was found that telemedicine is divided into different types of applications [9], which are:

1. Tele-prevention
2. Tele-diagnosis
3. Tele-monitoring
4. Tele-consultation
5. Tele-epidemiological surveillance
6. Areas of action

Table 1
Related work.

Reference	Approach	Contributions and/or differences
B. Almadami [10], T. Klingeberg[11], R. Hervás [12], A. Tanguay [13], M. Cardier [9]	Remote health monitoring	These works highlight telemedicine's progress in developing for different devices and environments, thus allowing a contextualization of the subject. Although these works propose telemedical solutions, B. Almadami [10], T. Klingeberg [11], and A. Tanguay [13] do not take usability into account.
J. Zhang [14], A. J. Chan [15], A. Tariq [16]	Evaluation of medical systems using heuristics	These articles show that heuristic evaluation is a powerful technique to identify usability problems. The proposed heuristics [14] are used to perform heuristic evaluation of medical systems.
S. AlDossary [17], S. Orozhiyathumana [18], B. Klaasen [19]	Evaluation of telemedical systems	These papers highlight the place that usability has taken in telemedicine systems. They also provide a contextualization of the most commonly used methods for assessing usability.
C. Rusu [7], D. Quiñones [8]	Methodologies for establishing usability heuristics	These articles show methodologies used to establish usability heuristics. They provide the methodology used in the pre to establish heuristics in a specific context, in this case, telemedicine.

Specific applications related to the research were selected from the "Google Play Store" platform. For this selection, telemedical applications with a rating of four or more stars were considered. Each application was installed and evaluated, leaving those of interest for the research. In the end, seven applications were chosen (see Table 2). Subsequently, in step 2, the following user interface characteristics of telemedical systems were defined based on the authors' knowledge:

1. In analyzing the case studies found, it is clear that communication is paramount in telemedical applications. Because of this, the different remote telemedical services can be provided. For the users of this type of application, it is essential to visualize the various ways communication can be established.
2. The user must know if there is an established connection. This connection is essential for sending information, whether medical images, documents, or diagnosis, among others.
3. In telemedical applications such as tele-emergency applications, it is essential that there is a default configuration of values that helps to determine whether the patient's state of health is stable or not and also serves to facilitate the entry of values and patient information.

Table 2
Related telemedical applications.

Name and logo	Type	Version
MyOnCallDoc		
	Tele-consulting	3.1.2
Salus Telemedicine		
	Tele-consulting	2.15.0
Monitorización 24 hrs		
	Tele-consulting	1.0.1
MD.com Telemedicine		
	Tele-consulting	1.1
KIHMARL TeleMed		
	Tele-consulting	8.0
TeleMed		
	Tele-consulting	2.1
TuSaludVirtual		
	Tele-consulting	2.1.68

3.2. Initial proposal

By executing steps 3 and 4 of the methodology, a total of eleven usability heuristics for the design of telemedical interfaces were formulated. It should be noted that the proposed heuristics were the result of adapting Nielsen's usability heuristics to telemedical systems and the characterization of user interfaces of telemedical systems performed in the previous steps. The proposed usability heuristics are mentioned below:

1. Visibility of system status
2. Connection and communication
3. User language
4. Consistency and standards
5. User control and freedom
6. Error management
7. Visibility and cognitive load
8. Flexibility and efficiency of use
9. Dialog aesthetics and minimalist design
10. Default configuration

11. General help and documentation

3.3. Validation

The proposed usability heuristics were subjected to validation in step 5 using the following experiments:

1. A form was created with questions related to each proposed heuristic. Each question was rated quantitatively and qualitatively by graduate students of systems engineering who have knowledge of usability acquired in the course of the program and in the specialization they are currently pursuing.
2. Experimental validation was carried out with two groups of undergraduate students (each group composed of three students) of systems engineering at the Universidad del Cauca (Colombia), who designed telemedical interfaces using paper prototypes (see Figure 1). One group relied on the proposed heuristics for their design. In contrast, the other group was given Jakob Nielsen's heuristics for their design. According to the characterization of telemedical interfaces performed in the first steps of the methodology, it was decided to focus the design on tele-emergency. Therefore, the requirements of the designed system were the following:
    a. The tele-medical system to be designed will be called SIS-I and will be a product designed to allow real-time communication between the medical personnel in the ambulance and the medical personnel in a health care center.
    b. Initially, the medical personnel in the ambulance must connect to the patient with the necessary devices to capture the patient's vital signs. These devices (essential to measure blood pressure, respiration, and temperature, among others) will be part of the tele-medical system.
    c. Subsequently, the patient will be registered in the SIS-I system, indicating the most relevant data such as type of patient (neonate, child, elderly, etc.), description of health status, gender, and other important information. Then, if the health staff considers it necessary, they will communicate with the medical team waiting at the health care center for the patient. Communication can be through different forms such as written, video-call, and phone call, among others. Once the communication is established, the medical personnel at the medical center can visualize through the system the patient's signs and data, as well as the observations made by the ambulance personnel; they can also give suggestions on the medication the patient should receive or the actions to be taken to preserve his life until he arrives at the medical center.
3. The usability of the telemedical interfaces was evaluated with the end users, i.e., people in the health area, using the technique called "Constructive interaction," in which two users are required to explore the interfaces and engage in a conversation about what they observe [20]. Subsequently, each user was given a satisfaction survey in which questions related to ease of learning were defined. In this way, it was observed that the prototype generated from the heuristics proposed in this research improved the ease of learning in consistency and familiarity by 17% each.
4. The suitability of the proposed heuristics was validated using a heuristic evaluation carried out by systems engineering students. In this activity, the participants evaluated the usability of the two designs obtained previously employing the heuristics proposed in this project. Ultimately, it was concluded that the prototype generated from the heuristics proposed in this research presented usability problems in six heuristics. In contrast, the prototype developed from the Nielsen heuristics showed usability problems in eight heuristics (see Table 3).

Table 3
Compliance with the heuristics in each prototype.

Compliance with Heuristics		
Heuristics	**Prototype of proposed heuristics**	**Nielsen heuristics prototype**
H01 Visibility of system status	×	×
H02 Connection and Communication	×	×
H03 User language	✓	✓
H04 Consistency and standards	✓	×
H05 Control and user freedom	×	×
H06 Error handling	×	×
H07 Visibility and cognitive load	×	×
H08 Flexibility	✓	✓
H09 Dialogue aesthetics and minimalist design	✓	✓
H10 Default configuration	✓	×
H11 Help and documentation	×	×
H01 Visibility of system status	×	×

Figure 1: Grupo de estudiantes diseñando el prototipo de la interfaz de usuario de telemedicina

3.4. Usability heuristics for the design of telemedical systems user interfaces.

The heuristics were refined by applying the last step of Rusu's methodology [7], and a total of eleven usability heuristics for the design of user interfaces of telemedical systems were obtained. Each of the resulting heuristics is presented below with its definition:

- *H01 System state visibility*. The system should inform users of system status through appropriate messages within a reasonable time. The system should give feedback to the user whenever changes essential to the user occur.
- *H02 Connection and Communication*. The user needs to know at all times if the connection is active and if there is an established communication. In addition, the appropriate response time for sending and receiving information should be met whenever possible.
- *H03 User language.* The messages that the system uses to inform the user should be familiar to the user whenever possible, and the information should be presented in a natural and logical order.

- *H04 Consistency and Standards.* Users should not wonder whether various words, situations, or actions mean the same thing. Appropriate standards and conventions should be applied, considering the type of tele-medical application and end users.
- *H05 User control and freedom.* The user must feel free to explore the system and its functions, so the system must be designed to respond to the user's actions.
- *H06 Error handling.* The system must be designed so that the user does not provoke errors using elements that guide the users in the process of interaction with the system, to obtain desirable results for the user; there must also be error recovery or error handling mechanisms. On the other hand, it is also important to consider power and connection failures that may occur, ensuring that the user does not lose his work due to such failures or wrong actions.
- *H07 Visibility and cognitive load.* The user should not need to memorize information to perform a task. The user should be able to easily access the data they need, or it should be present in the interface.
- *H08 Flexibility.* The system should be designed for both expert and novice users. Users who interact with the system should be able to customize their frequent actions using shortcuts to improve performance.

3.5. Discussion

In the literature review, it was observed that there are studies in which usability heuristics have been proposed for specific contexts. However, when analyzing several of them, it was found that they do not use a methodology to guide this process or use a methodology that has not been formalized for the development of usability heuristics [8]. This situation generates the possibility that, when comparing the effectiveness of the heuristics formulated with general heuristics, the results are not conclusive [21] since the mechanisms used in the process are not rigorous.

The methodology proposed by Rusu [7], which was applied in this study, presents clearly defined stages, includes a standard template for specifying heuristics, has precise validation methods, and can be used iteratively. This makes it suggested as one of the best methodologies for developing usability heuristics [8].

4. Conclusions and future work

The proposed set of heuristics could help designers of user interfaces for telemedical systems to take into account aspects that support the design of a usable software product since they were tested by system engineers and potential users and were formulated based on Nielsen's heuristics, which are well known, accepted and adapted to different contexts.

In the characterization of telemedical interfaces, communication, connection, information exchange, and default values were highlighted; therefore, the proposed usability heuristics could be used to contribute to creating telemedical applications that comply with these characteristics.

The results were favorable in the case study. However, further experiments are needed to generate a more robust set of heuristics.

Finding people with expertise in usability who have the time to collaborate with the research is quite complex. Heuristic evaluation is a low-cost tool that efficiently evaluates software's usability level.

The "Constructive Interaction" method was convenient for evaluating the prototypes generated in this degree work since it resembles the reality of the end users and, therefore, makes the use of the system more natural. A user-centered design can improve the acceptance of tele-medical systems.

The degree of usability of telemedical systems can make a difference in how quickly a patient's life is preserved, so it is important to consider usability in the design of such systems and, if possible, throughout the development cycle.

Future work is expected to experiment with the proposed usability heuristics through further case studies to refine them. Similarly, to evaluate the usability of existing tele-medical applications using the questions suggested by each proposed heuristic. Additionally, we wish to contrast the degree of usability of applications designed based on the proposed heuristics with those applications where the heuristics have not been used. Finally, to generate tele-medical application designs based on the proposed heuristics and evaluate them on a larger scale, with more users and usability experts.

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