A first version of Design Guidelines for Virtual Environments to Support Physical Rehabilitation*

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ABSTRACT

This paper presents a description of the first version of a set of guidelines that help in designing therapy-support virtual environments (VE) for patients on physical rehabilitation. The proposed guidelines were mainly identified by understanding the needs of the people involved in the physical therapy process through User-Centered Design (UCD) and based on Human-Computer Interaction (HCI). Initial user research was performed at facilities of the "Center for the Integral development of Families (DIF, in Spanish), a Mexican federal social assistance institution, and complemented by a literature review. Preliminary evaluation by panel of experts suggested good conceptual roots for this proposal but also several enhancements. The summary of these guidelines and the methodology to find them are presented below, ending with following actions for this work.

CCS CONCEPTS

• Human-centered computing ~HCI theory, concepts and models ~Interaction paradigms

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KEYWORDS

User Centered Design, Design Guidelines, Virtual Environments, Physical rehabilitation, Virtual rehabilitation

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1 Introduction

In 2014, according to the results of the "*Encuesta Nacional de la Dinámica Demográfica*" [1], there was approximately 15.9 million people with mild or moderate difficulties to carry out daily activities (people with limitations). However, the prevalence of disability is increasing; therefore, it is important to meet the special needs of this sector of the population, through appropriate rehabilitation therapies [2].

Physical rehabilitation is the set of professional, educational and social measures concerning the diagnosis, evaluation, prevention and treatment of disability aimed to facilitate, maintain or return the greatest degree of capability functional and independence possible [3]. According to Holden [4], a successful physical rehabilitation process highlights three fundamental aspects: repetition, motivation and feedback. Rehabilitation technologies are part of the strategies that facilitate the integration of persons with disabilities. Although the rehabilitation systems constitute a material resource which, in some cases, professionals have at their

disposal, they are who should assess the program settings to adapt to the profile of each of the patients [5].

Technological improvements every day respond more to the needs of the users, thus achieving the integration of projects based on the user-centered design. Their understanding requires conceptual approaches of basic technology, engineering and health are needed, since these converge in their field of study. The UCD approach applied has the potential to help designers to rethink the development of technologies of assistance by listening and focusing on the experience and real-life daily users of such technology. It also reinforces the effective user-centered design doesn't have to be prohibitively expensive and it can be applied to a wide variety of types of products efficiently and cost-effectively [6].

Within the rehabilitation technology has emerged a branch known as the *Virtual Rehabilitation* (VR) [7]. Include VR in the treatment can provide several benefits, some of which has already been tested by scientific studies; for example, several studies shows that patients show improvement in visual perception, the postural control and the alignment of the Centre of gravity and more symmetric medial-lateral weight distribution [8]. Two interesting examples are 1) "*Toyra*" [9], a platform of rehabilitation which integrates technologies of health information, virtual reality and motion capture for the development of interactive exercises for therapy custom; It uses virtual reality to increase the motivation of the patient towards his own therapy. A 3D user interface allows users to interact with elements without sensors and other devices, encouraging engagement and motivation by game mechanics through Kinect. And 2) a framework for physical rehabilitation for upper limbs in patients between 6 and 12 years based on virtual reality [10]. This proposal is based on the creation of a hardware and software architecture where a set of video games foster particular physical-activities and their related neural activations using action / observation. Engagement is promoted by gamification integrating dynamic and entertaining content interactively.

On the other hand, there are several guides addressed to facilitate development of virtual environments. Broadly speaking a design guideline is defined as "*a rule or principle of action, that encapsulates a combination of best practices identified in a domain and ideas based on research on relevant factors in that domain*", its purpose is to capture knowledge of design on small rules that can then be reused and its objective is to respond to a problem typically through the implementation of these rule [11]. However, it is difficult to find specific guidelines for virtual environments for physical rehabilitation; just a few projects take as a reference any guidance in this context, but commonly left aside UCD and UX concepts , and are complex to interpret an apply by developers.

Proposed guidelines in this document contemplated different criteria mainly based on user research including needs, skills and limitations, risks when performing therapy, goals, and main tasks. This core was surrounded by conceptual VR guidelines including Oculus VR UI Guidelines; Microsoft HoloLens Guidelines; Google Cardboard VR UX Guidelines; among others.

2 Methodology

A simple four-stages methodology was followed to conform this first version of guidelines to design virtual environments for rehabilitation supporting. 1) The first step was analyzing literature to identify those previous works for guidance of design interactive technology as support of rehabilitation. This search was targeted on VR technology. 2) Then, a basic user research was conducted; in this case, observation and interviews to stakeholders and users represented the main activities. 3) Information and findings were organized and summarized into a preliminary set of guidelines, which their conceptual meaning 4) were finally evaluated by a panel of experts. Stages are following described in more depth.

2.1 Previous similar proposals review

There are several guides for the development of virtual therapy environments, however, few are the researchers which consider guidance in the design of their projects. Here are some examples that match with this proposal.

Timmermans [12] proposes a work through which the criteria that rehabilitation technology must meet to offer arm and hand training to patients with stroke are identified and reviewed. This paper presents a checklist of guidelines for robotic technology and sensor rehabilitation, based on principles of motor learning, which divides into three criteria: a) Criteria related to therapeutic approaches; b) Criteria related to motivational aspects; and c) Criteria related to feedback on the performance of the exercise. Although this guideline does not present information about virtual environments, it is important because shows the way in which it considers the patient's needs, the way to generate motivation and the way in which it addresses performance in the exercises. Adamides [13] developed a list with 70 design guidelines for the teleoperation of a robot, these guidelines are classified into eight categories: platform architecture and scalability, prevention and recovery of errors, visual design, presentation of information, awareness of the state of the robot, effectiveness and effectiveness of the interaction, awareness of the environment / environment of the robot and cognitive factors. This paper is important taking into account that in some cases you can make use of other support elements such as robots or haptic devices.

In his work, Mehran Kamkarhaghighi [14] in addition to a comprehensive analysis on the different guidelines and situations for game development, lists a series of guidelines to ensure that the system is beneficial both for patients and for health professionals: Ability to create and modify; personalized rehabilitation programs based on the medical needs of patients and their access to entry devices; deliver an attractive set of rehabilitation tools to keep patients interested in pursuing a prescribed rehabilitation route; be non-invasive and protect the privacy of patients; ability to record the progress of patients while using various prescribed rehabilitation games.

Javier Diaz [15] presents his book "Guide of recommendations for design of software centered in the user", in this it presents all the necessary guidelines for the development of software, the chapters 3 to 5 are those that offer us the guidelines that are convenient for the development of the work because it shows the design

recommendations for specific interfaces such as visual interfaces mentioning the manipulation of objects, feedback, animations, among others. Physical rehabilitation is linked to many situations, which is why Willems [16] presented a work in which he identifies that although there are general guidelines for the design of user interfaces for people with physical and cognitive disabilities and feedback, systems evaluated with people without disabilities for which is unknown about the best way to design interactive technologies for disabilities people, in his work he describes the iterative design process of a feedback module for a tangible interactive table technology that supports arm training and the hand. In addition, he developed five design guidelines for patient feedback and in this work he conducted tests with 7 people, obtaining new results even though the guide was incomplete. This guideline addresses the following points: a) Provide multimodal information; b) Provide step-by-step guidance; c) Provide information related to the context; d) Prevent information overflow; e) Allow customization.

2.2 Observation and interviews

From a UCD perspective, the participation of real users in research optimizes their influence on product design and interaction, and maximizes the output of design perception exercises, this analysis was done at this stage. Observation and interviews were performed at facilities of Center **for the Integral development of Families** (DIF**, in Spanish**) as initial user research to understand goals, tasks, and needs of users. DIF provide access to rehabilitation rooms; explanation and observation of the therapy process with patients, tools, and equipment; and interviews with patients, medical staff and physiotherapists.

The observation process is derived in several stages: In this step was observed that there are two main areas, one for patients with brain damage and another in which they treat the rest of the patients; so it was decided to pay attention in this second, here allowed us to know the place and identify the areas of therapy in which it is divided (arm, leg, column, etc.), in the second stage we analyzed the devices and tools with the that is counted in each area, in addition to the operation of the same. Finally, the therapy process in each area identifying the type of injury of the patients as well as the exercises and devices that are used. In this step it was possible to identify that the treatment in an area is applied in the same way independently of the pathology that the patient presents, for which the decision to conduct the guide was taken under this same paradigm.

A semi-structured interview was conducted with ten patients between 50 and 65 years old, analyzing the kind of trauma they present. Based on four questions about his therapy, as well as their knowledge towards the use of technology; with the purpose of obtaining solid answers, we sought to create a state of empathy with patients, for this the interview became a conversation where the questions were incorporated without the patient noticing it directly. Interviews allowed to figure out relevant information based on the rehabilitation processes, advantages and disadvantages that stakeholders and users found during the therapy process. This mainly focus on those aspects that commonly demerit treatment. Most of them occur during a series of exercises the patients perform outside the rehabilitation center being lack of motivation the most common problem. Another problem occurs when patients require medical evaluation after their therapy sessions. The time elapsed between the last session and the medical appointment may be extended several weeks, commonly deriving in a lose-in-progress in the treatment.

2.3 Proposed set of guidelines

After the interview and the observation process, as well as the study of the various bibliographic resources and based on human-computer interaction, an analysis was carried out to identify the design characteristics for virtual environments in VR including the needs of the patients. All this information was integrated into a set of guidelines, then a brief description of these is presented:

1. **Guideline**: User Definition. **Contex**t: Identify the target user, and all the features with which it meets, for this you can follow several techniques such as the development of "persona" and "scenario". In addition, consideration if the patient presents some disability either physical or mental, or some other condition that implicate cannot realize some activity.
2. **Guideline**: Development of environments and scenarios. **Contex**t: Environments must be developed that have the capacity to use at any time and in any place, especially in the comfort zone of the patient. This guideline is responsible for framing all the necessary guidelines for the design, considering the needs of the user, limitations and issues found from the previous guideline, as well as the bases of general virtual environments based on colors, shapes, sizes, positioning of objects, tools, among others.
3. **Guideline**: Interactive media. **Contex**t: Designers should to create environments where users have the feeling of being in charge of the system and the system responds to their actions, for this it is necessary to consider the type of interfaces with which they will work, as well as the devices. The use of multimodal interactive systems and natural user interfaces are a good strategy.
4. **Guideline**: Motivation. **Contex**t: One of the most important situations of virtual environments is the need to motivate the user both to start the activity proposed these environments and continue doing it, this guide contains guidelines that indicate the different ways of preserve the motivation of the user towards the environment. For example, the novelty, surprise, the lack of familiarity and the unexpected are situations that they appeal to the curiosity of users, inquisitive behavior encourages and promotes the repeated participation.
5. **Guideline**: Multimedia Content. **Contex**t: A part linked to motivation is the use of multimedia content, this section indicates the standards and specifications for the use of video, audio and animation at the time of making use of a virtual environment, for example the colors that should be used, volume considerations for sound, type of use, time of animations, audio as well as the output of these devices.
6. **Guideline**: Follow up with Patients. **Contex**t: During the process of rehabilitation using AV, user should receive timely enough information about its performance and progress in therapy. It is important to avoid excess information as this can cause the user to be distracted. Report when the action is

still in process, create a short space of time for performance evaluation before and after giving feedback, provide the patient with a way to point out when an activity is well done through sounds, animations or the managing a score; If you find a problem, motivate you to repair this error in order to avoid future injuries.

7. **Guideline**: Evaluation. **Contex**t: Evaluation is an aspect that should be considered from the beginning of the process. The virtual environment must be evaluated from the point of view of engagement and usability. It is important to consider the heuristic evaluation, as well as the methods of evaluation of usability by checking or testing, the Flow State Scale (FSS), the inspection method or the System Usability Scale (SUS).

2.4 Evaluation by panel of experts

"*Cronbach (1971) suggests a review process whereby experts in the field familiar with the content universe evaluate versions of the instrument again and again until a form of consensus is reached*" (Cited by [17]). In this vein and according to [[18] and [19]]; validation of conceptual proposals could be performed by a panel of experts analyzing the degree of compliment for the following criteria: a) supporting theories for the conceptual proposal; b) logical coherence between conceptual proposal and domain; and c) the conceptual proposal is not a duplication of existing proposals. Considering said strategy, a panel of five experts with over 15 years of experience on UCD, UX Design, and VR was integrated to subjectively determine the coherence of this proposal from a UX and UCD perspective. A Likert scale of five points (1 totally disagree – 5 totally agree) and 7-items questionnaire –based on [20]– was provided to participants. Perceptions of participants is summarized in Table 1.

Table 1. Panel of experts' evaluation summary

Concept	Likert's points (Avg)
Appropriate theoretical support of proposal	4.6
UX and UCD aspects are sufficient	4.2
VR aspects are sufficient	3.6
Coherence between proposal and domain	5.0
Proposal logically match with its purpose	4.8
Acceptable degree of innovation	3.8
Proposal's structure match with available	4.0

After evaluation, participants provided feedback in a debriefing. Evaluators confirmed coherence among the proposal its domain and its purpose (Higher scores in Table 1) since virtual environments foster motivation/engagement and UCD encourage empathy. However, evaluators considered as low the degree of innovation; it was suggested to emphasize the level of value from the proposal specifically justifying how guidelines contribute to satisfy users' needs? E.g. Providing enough information to developers to guide them towards adequate virtual environments that truly support rehabilitation processes. Additionally, they pointed out that even if guidelines address core VR-concepts like engagement, agency, and affordance, it is necessary to emphasize its integration to the proposal.

3 Concluding remarks and future work

Virtual environments have emerged as a new instrument of support/complement in physical rehabilitation offering multiple benefits for patients being motivation and engagement some of the most significant since lack of motivation in patients represent a common cause of quit in rehabilitation treatments. Nevertheless; it is complex to convey said virtues to the users and guidance is necessary to help developers and designers to cover interaction essentials. In this context, a non-exhaustive preliminary set of design guidelines was described here based on information obtained from specialists, patients and related works. Proposed guidelines was conceptually evaluated from the point of view of experts on UX Design, UCD, and VR obtaining feedback to improve their pertinence on this contexts. Feedback suggested a good opportunity for contributions, particularly in health-care and rehabilitation, since VR features could be potentiated by understanding patients' needs during the rehabilitation process being able to encourage empathy and engagement deriving in more effective rehabilitation process.

This was the first step in conforming a proposal aimed to help designers and developers towards well-designed virtual environments for supporting rehabilitation process. There are several aspects to cover as future work, including: Improve the proposal following feedback from panel of experts; assess the proposal by a case study where guidelines will be materialized in Lo-Fi prototype of a virtual-rehabilitation environment, which will be ultimately used and evaluated by patients of DIF Aguascalientes including usability and accessibility tests. Feedback will be implemented to evolve prototype towards a Hi-Fi version, and to enhance the initial set of guidelines by obtaining advanced feedback on aspects as flow experiences in physical activity (e.g. Using the Flow State Scale [21]).

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