Evaluation of User Satisfaction in a new Virtual Reality System for Rehabilitation in Children

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Abstract

In this study, we present a novel virtual reality system for proprioceptive rehabilitation in children with rare diseases. The system is designed to recover gross and fine disorders in upper extremities. To evaluate our system, twenty children (normative population) trained with the system in two different conditions, with and without virtual targets. At the end of the sessions, the participants filled a short questionnaire in terms of satisfaction of the user in virtual rehabilitation systems, the User Satisfaction Evaluation Questionnaire (USEQ). Outcomes indicates a good score in satisfaction for the virtual reality system. In a near future, we will test our system in children with rare diseases that difficulty mobility in upper extremities.

Keywords

Virtual Rehabilitation, Upper Extremities Rehabilitation, Rare Diseases, Quality Movements, Satisfaction.

1. Introduction

Rare Diseases (RD) or also orphan diseases, affect a small proportion of individuals [1]. These pathologies have low prevalence with a high severity, with unique and special characteristics with respect to their recognition and treatment [2]. These pathologies are usually serious, chronic and progressive diseases that produce alterations in activities of daily living (ADL). Thanks to an early and correct diagnosis, it is possible to get improvements in the quality of life of patients [3]. Approximately 80% of rare diseases are produced at the genetic level [4], while the remaining 20% are due to bacterial or viral infections, environmental factors, allergies, and degenerative problems.

The RD includes a set of characteristics, such as: 1) detection in the childhood stage; 2) of genetic origin (between 75 and 80%), affecting from birth; 3) serious, chronic with pain and progressive; 4) high premature morbidity and mortality (35% of deaths before one year, 10% between 1 and 5 years, and 12% between 5 and 15 years); 5) treatment by a multidisciplinary team of experts; 6) irreversible, degenerative and disabling diseases; 7) motor, sensory and intellectual development deficits in 50% of cases; 8) patient quality of life, family environment, and social integration reduced; 9) complicated diagnoses; 10) limited information with few specific and effective treatments; and 11) geographical dispersion of patients with the same pathology [5]. The most common RD in children are: 1)

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osteogenesis, a disorder that causes extremely fragile bones, short stature, dental changes, and premature deafness [6]; 2) phenylketonuria, motor and cognitive disorders, which can produce toxicity in the Central Nervous System (CNS) and Brain Damage [7]; 3) oculocutaneous albinism, alterations in the production of melanin, which causes pigmentation of the hair, skin and eyes, and hair loss [8]; and 4) achondroplasia, bone growth disorders, causing dwarfism [9].

A type of RD is the encephalopathy. This pathology is a disease that affects the brain at a structural or functional level [10]. The causes that can produce encephalopathy are bacterial or viral infections, injuries, chronic or progressive traumas, inadequate nutrition, and lack of oxygen or blood to the brain [11]. The Symptomatology of this disease are described in [12] and there are the following: 1) altered mental status; 2) disorders in cognitive and intellectual capacity; 3) lack of concentration; 4) involuntary muscle spasm; 5) rapid and involuntary eye movement; 6) tremors; 7) muscle atrophy and/or weakness; 8) dementia; 9) seizures; and 10) aphasia. Thanks to the use of blood tests, spinal fluids, magnetic resonance imaging studies of the brain and electroencephalograms (EEG) it is possible to detect this pathology and the type [13]. Quality movements in the rehabilitation processes in patients with neurological diseases and RD is crucial to correctly perform specific move14,15]. Poor Quality movements can produce greater risk for re-injury.

2. Related Work

Traditional treatments based are focused on improvements in functional motor skills, spasticity, or activities [16]. These treatments are based on encouraging and to learn voluntary movements by using feedback in each of these. Proprioceptive traditional training is composed of a group of exercises to improve proprioception, these actions are focused on proprioception definitions such us: 1) force; 2) velocity; and 3) joint position sense. To get improvements it is necessary to perform a "task-intrinsic" feedback or "augmented feedback" [17]. There are few studies related to the effect of Virtual Rehabilitation in upper extremities with Ecological Virtual Environments (EVE) focused on improvements in upper extremities [0]. Virtual Reality (VR) technology shows ecological and interactive virtual scenarios able to represent Activities of Daily Living (ADLs) that usually perform patients [19]. Virtual Environments (VE) can offer multimodal sensory information to use in rehabilitation therapies improving motor, cognitive disorders and social skills [20]. Gross Motor Virtual Rehabilitation (VMR) together in training sessions can improve patient's disorders in upper extremities [21. Fine Motor Virtual Rehabilitation (FVMR) in motor disorders in stroke patients has a good complement in therapeutic sessions [22]. The purpose of this study is to present the new VMR system, evaluating their user satisfaction with children and young people

3. Methods

3.1. CEPIVIRT System

Based on the International Classification of Functioning, Disability and Health (ICF) of the World Health Organization (WHO) (ICF, 2021). The specific activity implemented corresponds to sub-classification d4400: Pick up: "pick up a small object with the hands and fingers, like picking up a pencil". The choice of the exercises and the validation of the functionality requirements were carried out by two specialists in physical therapy and a pediatric neurologist from a health clinic. The suggested rehabilitation exercises were the following: 1) extension; 2) flexion; 3) pinch; and 4) grip. The system addresses a rehabilitation environment through a 2D game focused on controlling the movement's execution in the upper extremities through the Leap Motion device that allows the player's hands to be controlled. The objective of our Ecological Virtual Environment (EVE) is to prepare a pizza with two ingredients, which must be collected and brought to the dough one by one. For each ingredient placed correctly, a point will be added (Figure 1). The system offers different levels to adapt the session to the specific patient's needs. The EVE allows you to configure the time for the exercises, the score per ingredient and the hands that can be used (left or right) in the session. The system allows you to configure whether or not the user can see the ingredients that are going to be used to perform a pizza. The objective of this possibility is to evaluate the trajectory quality with and without the visual input.

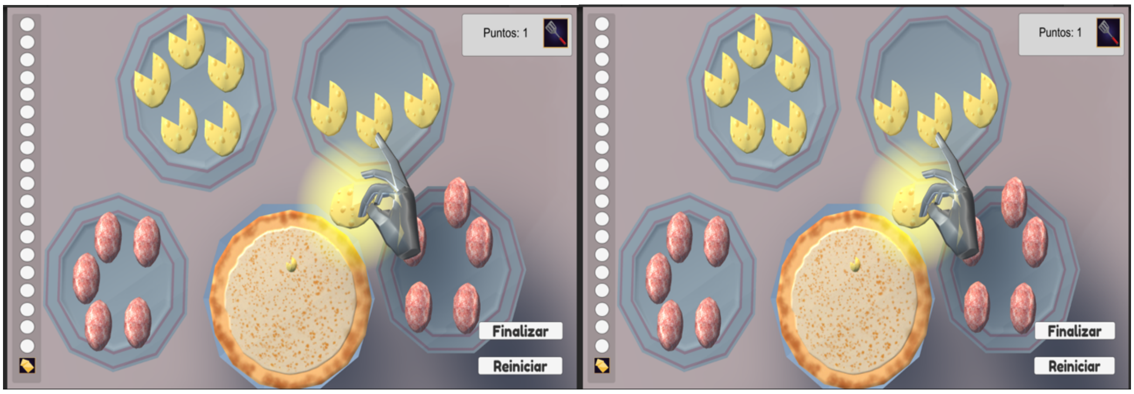

Figure 1: CEPIVIRT system shows Virtual Objects: score, toppings and pizza.

The hardware system is composed on A 42-inch Full HD LCD/LED TV screen, which is connected via HDMI to a Windows computer. This facilitates user interaction with the system. Leap Motion is an optical device without markers aimed at control movements; it detects movements performed with the hands, fingers and even objects that are around its field of vision [24]. Compared to other optical tracking devices, Leap Motion is considered a low-cost system. This advantage allows the therapeutic sessions to be brought at home and removed from the hospital environment, even more so in the context that access to hospitals has been restricted by COVID-19. Regards to the software developed, the system was implemented in Unity 2020.3.23 f1 (C#) and integrated with Leap Motion optical tracking device via Ultra Leap Unity Packages plugin and Ultra Leap Hand (V5.2+) tracking software. The system has been developed with the aim to control the movement's execution in upper extremities at the fine motor level (IFS) through the Leap Motion device.

3.2. Participants

The participants were classified in two experimental groups related to the age. One group was composed of children ranging from 9 to 13 year-old (six girls and four boys, with a mean age of 11±1.56). The other group was made up of ten participants ranging from 17 to 22 year-old young people (five women and five men, with a mean age of 19.2±1.32). We have divided the participants to evaluate satisfaction in children and in young-adults. The inclusion criteria are the following: 1) without cognitive deficits; 2) without motor disorders; 3) with previous experience with Virtual Environments (VE); and 3) no knowledge in Computer Graphics or two-dimensional rehabilitation video games. Informed consents and assets were obtained from the parents or guardians with the agreement to participate in the research. The study was approved by the ethical committee and accomplished the ethical standards of the Declaration of Helsinki (DoH).

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The study was performed at the Center for Research, Technology Transfer and Software Development in a public university. The participants performed a 10-minute session. Before the beginning of the sessions, the researcher explained the set of basic instructions to perform the exercise correctly. Each session was composed of two different stages: 1) participation by showing Virtual Targets (Figure 2. A); and 2) participation without Virtual targets version game hiding Virtual Targets (Figure 2. B). After the session, participants completed the USEQ [25] questionnaire, to evaluate the user satisfaction with the system.

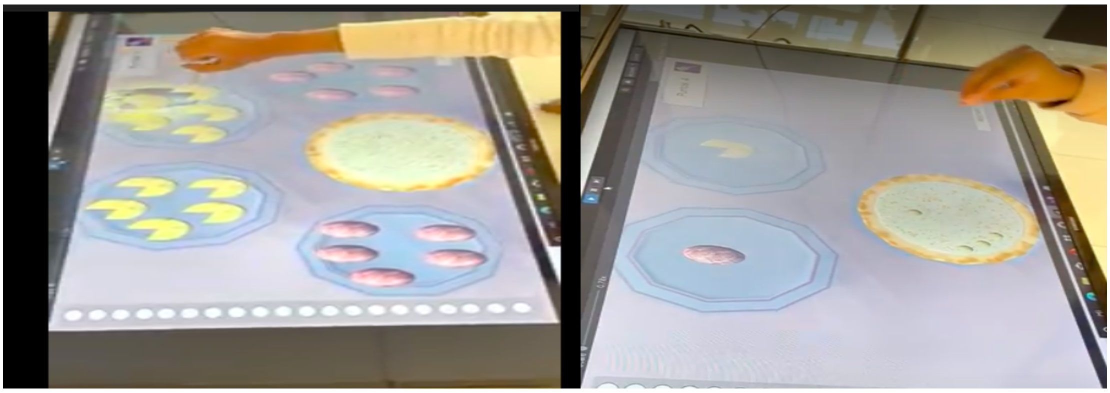

Figure 2: A. Virtual system with virtual targets, B. Virtual system without virtual targets

4. Results and Discussion

The outcomes obtained in the USEQ in this study showed high user satisfaction with the system. The results by showing Virtual Targets and without Virtual Targets are in table one.

Table 1
Outcomes of USEQ of the subjects with and without Virtual Targets.

	With Virtual Targets		Without Virtual Targets	
	Mean	SD	Mean	SD
Q1. Did you enjoy your experience with the system?	4.68	0.58	4.74	0.65
Q2. Were you successful using the system?	4.00	0.75	3.89	0.81
Q3. Were you able to control the system?	4.11	0.81	3.89	0.81
Q4. Is the information provided by the system clear?	4.74	0.65	4.95	0.23
Q5. Did you feel discomfort during your experience with the system?	3.95	1.43	3.74	1.37
Q6. Do you think that this system will be helpful for your rehabilitation?	4.95	0.22	4.95	0.23
TOTAL	**26.42/30**	**0.74**	**26.16/30**	**0.68**

The results showed a high degree of participant satisfaction. The results are in the range "excellent user satisfaction (24-30)", which means that the participants were comfortable and satisfied by using the system. Comments of the participants by using virtual targets were the following: 1) The system was fun and entertaining; 2) In different periods of the session the virtual object was in another position of the hand of the participant; 3) It is possible to perform a better movement showing to the virtual target; 4) it was easy to perform the activities; 5) At the beginning of the session, it was difficult to get used to the system; 6) it was easy to carry out the objective of this study; 7) it would be better to show the virtual hand with more precision; 8) the experience was functional and funny; and 9) it was necessary to control the movement range of the virtual hand.

Comments of the participants by using proprioceptive system were the following: 1) it was a few mistakes by grasping the virtual ingredients; 2) in specific periods of time it was impossible to detect the virtual hand; 3) it was difficult to put the virtual object into the target; 4) it was necessary to recalibrate the virtual hand when the subject grasped another virtual object; 5) it was necessary to recognize the hand of the participant; 6) the experience was functional and funny; 6) it was necessary to reduce the time of the session to avoid that the participant was tired; 7) a good idea would be to increase the mobility and the depth of the virtual hand due to it was difficult to recognize the virtual hand in specific times of the session; 8) this system improved the attention and the quality of movements.

5. Conclusions

In this paper, we have analyzed the user satisfaction of a novel technological system, the CEPIVIRT system, focused on rehabilitation of subjects with gross and fine motor disorders. Satisfaction obtained in this study revealed satisfactory outcomes accomplishing the expectations of the hypothesis (USEQ with visual targets= 81.75% and without visual targets=82.28%). These outcomes are due because our system was designed according to the recommendations of the clinical experts, by showing specific information in our ecological system, easy-to-use and focused on children with RD. In [**Error! Reference source not found.**] revealed that the use of an affordable VMR system, it is possible to get significant improvements in terms of satisfaction with training sessions. We will need to improve the interaction of virtual objects with the subjects, and the quality of movements to get good kinematic outcomes. In a near future, we will test our novel system in children with RD to alleviate their gross and fine motor disorders, analyzing the outcomes of proprioception training sessions.

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