Gear VR and Leap Motion Sensor Applied in Virtual Rehabilitation for Manual Function Training*

An Opportunity for Home Rehabilitation

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ABSTRACT

Virtual reality systems using gestural interfaces are becoming common in treatment of people with disabilities. One reason for this popularity is due to the availability of low cost tracking sensors. We present a serious game interface that uses the Leap Motion sensor (coupled to Gear VR headset) for manual function rehabilitation. A monitoring system was developed so that the patient can use the game at home without losing their data. One therapist and five people with Cerebral Palsy used the system in a virtual rehabilitation. We investigated the individual performance of each participant (through counting points by time), satisfaction (through the System Usability Scale - SUS), cybersickness symptoms (through the Simulation Sickness Questionnaire - SSQ) and the level of active participation measured with the Pittsburgh Rehabilitation Participation Scale (PRPS). Tests allow that the system has a good acceptance to be used in rehabilitation.

CCS CONCEPTS

• **Human-centered computing → Usability testing**; **Empirical studies in interaction design**; *User studies.*

KEYWORDS

virtual reality, leap motion, game therapy, usability, motor rehabilitation, cerebral palsy

ACM Reference Format:
Ana Grasielle D. Corrêa, Natália R. Kintschner, Victor Z. Campos, and Silvana M. Blascovi-Assis. 2019. Gear VR and Leap Motion Sensor Applied in Virtual Rehabilitation for Manual Function Training: An Opportunity for Home Rehabilitation. In *REHAB 2019 : 5th Workshop on ICTs for improving Patients Rehabilitation Research Techniques (REHAB 2019), September 11–13, 2019, Popayan, Colombia.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3364138.3364169

1 INTRODUCTION

Functional use of the hands is often compromised in several neurological conditions, as in the case of people with Cerebral Palsy [6]. The hand is a creative tool and serves as a medium for non-verbal communication. The hand is able to perform very fine and sensitive movements to manipulate small objects quickly and accurately, mainly using the distal ends of the fingers. Quality and performance in daily living activities, related to work and leisure activities, are largely determined by manual dexterity [6], [12].

Traditional therapies for manual function recovery are often repetitive and can often become demotivating to the patient, decreasing adherence to treatment [7]. Therapists need to be creative to achieve a more stimulating and quality environment. They have to consider that patients need new experiences to remain motivated during treatment [5]. It is also important that the patient try to stay busy at home with manual tasks that can speed up the recovery process [2]. On the other hand, unsupervised home rehabilitation training can lead to inefficient or harmful movement sequences or pain and may potentially worsen motor performance [3]. Home therapy should therefore include monitoring the quantity and quality of movement.

Although many developments in hand therapy have been observed in recent years [13], few advances have been achieved in the field of home therapy. Current industrial and medical solutions

*This work was supported by Mackpesquisa, Project N. 181033, cojur-fmp-0286/2018; and Programa de Excelência - Proex 0653/2018

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REHAB 2019, September 11–13, 2019, Popayan, Colombia
© 2019 Association for Computing Machinery.
ACM ISBN 978-1-4503-7151-3/19/08…$15.00
https://doi.org/10.1145/3364138.3364169

require complex and expensive hardware and software that is impractical for home use [11]. Another challenge for home therapy is that therapists cannot confirm whether patients are conducting therapy correctly and by the prescribed number of times. To address these challenges, we propose a hands-on motor rehabilitation system that combines Virtual Reality (VR) and serious gaming, in which the hand-motion sensor called Leap Motion Controller (LMC) that is used to collect therapy data. The user wears an Gear VR headset coupled in LMC to do the exercises proposed by the game. The system compresses the collected data and uploads it to a cloud server. Gear VR headset is an economical VR solution because it uses a smartphone as a display for viewing. The trend is that these technologies are available in people's homes, offering services in the most diverse areas, including health. However, challenges in users' usability of these technologies, such as tiredness and discomfort, need to be further investigated because the integrated Gear VR and LMC should represent a promising VR option to ensure protracted home rehabilitation [1].

We did a pilot study with five people with Cerebral Palsy using our system. At this time, we were interested in investigating: (a) the performance of the participants in the game; (b) symptoms of cybersickness; (c) the usability of the serious game; (d) level of active participation of participants in virtual rehabilitation. We tested the system at institution dedicated to care people with Cerebral Palsy and asked that a therapist use the system with patients. We found that although the system allows remote patient performance data collection, serious game usability with LMC usage still needs to be improved. We discuss these aspects in this paper.

2 METHODOLOGY

2.1 System Design

Our system consists of three parts: a serious game with hand exercises; a mobile app to set up the game and to show patient performance data; a database for storing therapist and patient profile, and patient performance data. The serious game has a grocery store scenario (Figure 1a). It was designed with the support of a hand therapy specialist. When the participant wears the Gear VR headset, he sees the game in the first person and sees himself sitting in front of a table with baskets of fruit (Figure 1b). The user's goal is to pick up fruit and drop them into their baskets by grasp movement. In addition to the motor task, we implement cognitive tasks to capture the user's attention: red fruits should be placed into the red basket and green fruits into the green basket.

The hands-on sequence determines the configuration of the game steps and is defined by the therapist through the app: step 1 only the dominant hand (e.g. left hand); step 2 only the non-dominant hand (e.g. right hand); step 3 both hands. The therapist through the app also sets the exercise time in each step. After registering the patient in the app and setting up their exercise plan with the game, the system generates a password for the patient to access the game on their computer. After the participant uses the game, data such as game time, total points and errors are sent to the database and can be accessed by the therapist through the app.

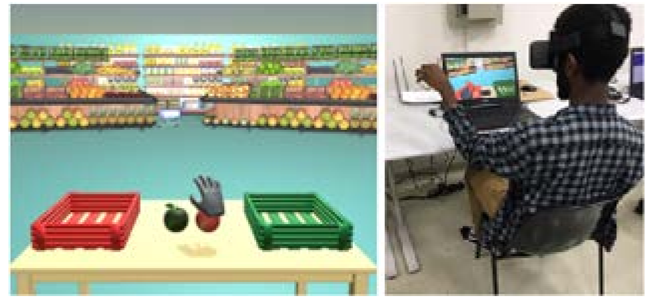

Figure 1: (a) serious game; (b) user interacting with the game

2.2 Participants

Participated in the study five adults (1 man and 4 women) with Cerebral Palsy between 26 and 41 ages. Two participants wore wheelchairs and the others wandered on crutches and needed support to sit down. Two patients had difficulty performing both the pinch and grasp movement; one patient had dyskinesia, dysfunction that caused involuntary movements and made upper limb motor control difficult [10]; and two patients had good upper limb mobility. Participants use computers, but with low frequency, three of which require assistive technology. None of the participants had previously used a LMC or VR system.

2.3 Equipment

The tests were conducted using a Dell NVidia GeForce GTX 1060 Core i5, 8GB, gaming notebook running Windows 10. LMC was coupled to the Gear VR headset with Samsung Galaxy S8 smartphone. The app can be used from any mobile device. In this study, the therapist used the app from an iOS 6 smartphone.

2.4 Measures

Individual performance of each participant was measured by counting points by time. Points were counted when the participant was able to pick up the apple and put it in the correct basket. This data was collected from the performance report generated by the app.

The satisfaction of using the system was measured using the System Usability Scale (SUS). Scores were calculated according to the [4] guidelines. Values above 68 indicate serious usability issues that need to be addressed.

Cybersickness symptoms were measured through the Simulator Sickness Questionnaire (SSQ) [8]. The SSQ consists of 16 questions, but in this experiment we have selected only 9 that we think are crucial in an VR experiment: 1-general discomfort, 2-fatigue, 5-headache, 4-eyestrain, 7-difficulty focusing; 10-nausea, 10-fullness of the head, 14-blurred vision, 16-vertigo. The overall value of cybersickness was calculated from the "none", "slight", "moderate" or "severe" ratings and scored with values between 1 and 4 respectively.

The level of active participation was measured through the Pittsburgh Rehabilitation Participation Scale (PRPS) [9]. The PRPS is a six point scale of 1 "refusal to participate" to 6 "excellent participation" which is filled by the therapist after each intervention. The higher the score on this scale, the better the participant's involvement and engagement in the intervention.

2.5 Procedures

Each participant used the game twice (once every week). Each test session lasted approximately 30 minutes (sign consent form, use the game and interviews). In the first week, the participant signed the consent form, was interviewed to fill out the demographic questionnaire and then received the therapist's training to use the game with Gear VR and LMC. After the training, the therapist registered the participant in the app and personalized the game therapy plan (stages of play and time of each stage). Each participant used game for 6 minutes (2 minutes per game step). The therapist completed the PRPS questionnaire for each participant after each test session.

In the second week of testing, the participant repeated the procedure of using the game, but this time, without previous training. After finishing the game (6 minutes), the participant was interviewed by the observer to complete the SSQ and SUS questionnaire. As in the first week, the therapist completed the PRPS questionnaire for each participant after each test session.

3 RESULT AND DISCUSSION

The study was approved by the Ethics Committee (no. 2,901,639) and was carried out at the "*Associação Nosso Sonho de Habilitação e Reabilitação de Pessoas com Deficiência*".

Figure 2 shows the performance result of participants in the first and second test sessions (T1 and T2). It was possible to note that all participants had gains in T2 with both hands. Participant (P5) did not score in T1, but performed better among all participants in T2. Analyzing separately the points made with the dominant and non-dominant hand, it was possible to notice that the average of hits was higher in T2 for all participants: 7.2 to 24.6 points with the dominant hand; and 7.0 to 20.0 points with the non-dominant hand. This results shows that LMC is able to track the impaired hand.

The final score of the SUS usability analysis obtained for the serious game was 77.5 (Figure 3). In general it can be seen that the grocery store meets usability requirements. Items 4 and 10 have low scores and are related to the ease of learning to use the game. We believe that the low score on these two items is due to the fact that the participants had never previously used an immersive VR game with LMC. It was necessary to explain and make demonstrations. Also, they need help dressing Gear VR. Although usability has been evaluated positively, this study has identified opportunities for game improvement: game instructions should be made available through a quick easy-access tutorial; provide feedback of what to do when the hand stops being tracked by the LMC (remove your hand completely from the field of view of the LMC and reposition them again). This instruction is very important to provide a home therapy intervention.

We observed that people with low trunk stability when use the game with Gear VR headset, it is necessary to have the therapist help to support the participant's balance, even if he is sitting in the chair with armrest. This is because one of the participants tried to turn the torso to place their hands on the target (apple) in the game and this could be dangerous to the point where the participant fell out of the chair. This shows that the level of immersion in the game is high because the participant did not realize that he almost fell

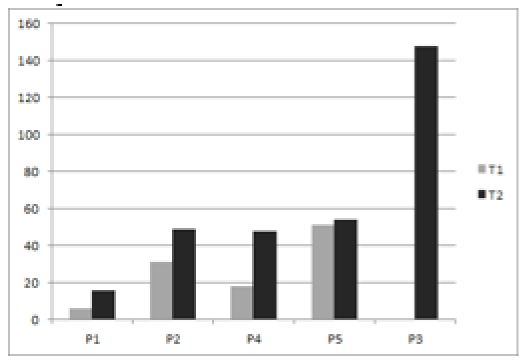

Figure 2: Game points number of participants

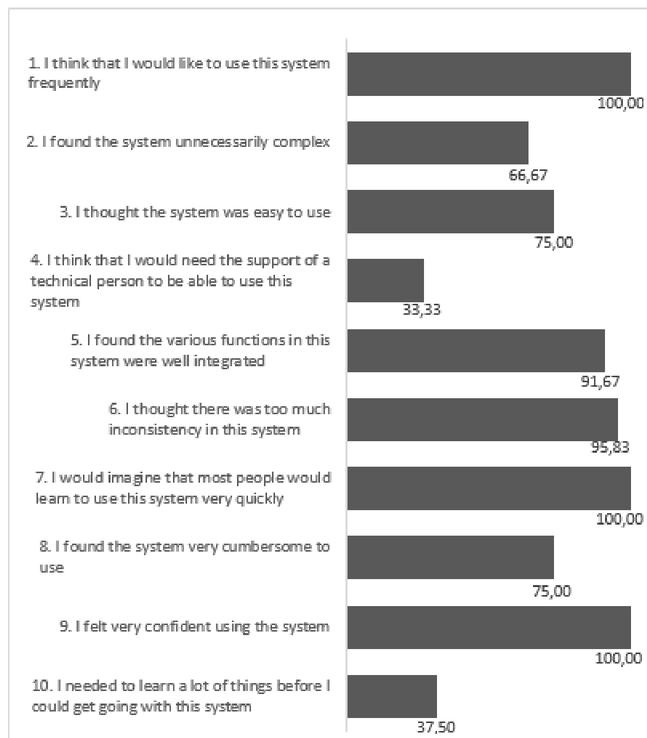

Figure 3: SUS score

out of the chair. In these cases therapist support is needed to help the patient.

The SSQ analysis was performed by a weighted average of the frequencies of responses considering the scores 1, 2, 3 and 4 for "none", "slight", "moderate" and "severe" respectively. In this way, the circle of radius 1 (Figure 4) indicates the lowest possible intensity of the scale. In the gray color region, the weighted averages of the symptoms reported by the participants are show before using the game. None of the participants were feeling anything in the pre–test. For the black line, it's possible see a slight increase in the symptoms "fatigue" and "heavy head", after the test, by the distance to the gray line. The fatigue is due to the tiredness in the arms because it

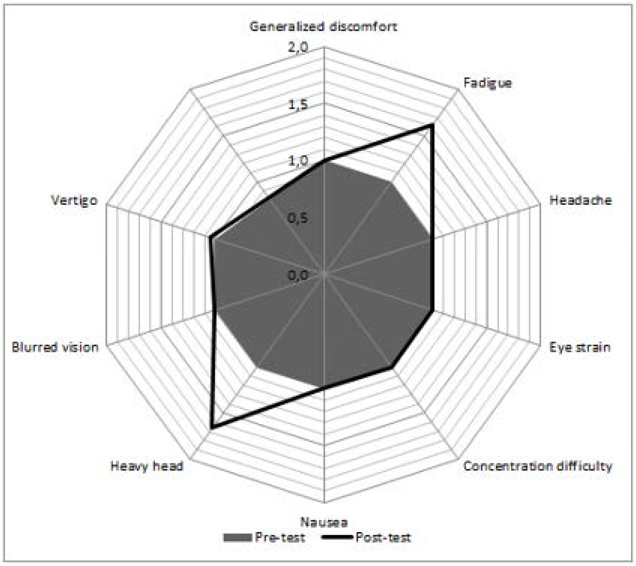

Figure 4: SSQ score

is necessary to remain with them extended on the virtual table so that the LMC correctly detects the gesture of picking and dropping the objects in the fruit baskets. The heavy head occurred due to the use of the Gear VR. Despite mild discomfort, participants said they would like to continue using the device in other situations.

The average level of active participation measured with PRPS ranged from just 3.8 to good 4.8. PRPS scores increased slightly in the second training session. However, more testing sessions are needed to see if this designed system actually helps increase participant engagement.

4 CONCLUSIONS

The analysis of the SUS allowed to conclude that the game has good usability, but that needs adjustments, mainly with regard to the mechanisms of help (instructions of how to play) and issues of ergonomics like dressing VR headset and chair support. SSQ indicated that participants had no oculomotor symptoms caused by the use of Gear VR, but felt a slight tiredness in the arms due to the use of CML. Three participants reported feeling slight neck fatigue due to the weight of the VR Gear. We can assume that the time of use of the game, about 6 minutes, alternating hands between stages, may be adequate to carry out a similar protocol at home, but a study with a larger number of participants should be conducted to prove this hypothesis.

We note that the LMC was able to track the impaired hand indicating that more solutions to this population can be developed. As future work, after game adjustments, evaluations will be performed with the same patients to evaluate the motor gain after a 12-week test protocol. We are developing three more games so that patients will not be bored in using the same game in all sessions. The idea is to go alternating the days with each game similar to what was presented.

5 ACKNOWLEDGMENTS

Thanks to the research sponsor Mackpesquisa and PROEX to supported this project; to the patients attending the "*Associação Nosso Sonho de Habilitação e Reabilitação de Pessoas com Deficiência*" who freely consented to participate in the tests with the system and their respective responsible ones; to the students Gabriel Henrique Sarapião and Gabriel Kenzo Hirata Camargo.

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