

Applicability and evaluation of the GestureChair virtual game: comparison between people with and without spinal cord injury

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**Abstract— Introduction:** Spinal cord injury rehabilitation requires updating from professionals regarding the possible interventions that can enhance recovery. Virtual reality (VR) games have become evident as a resource used in the rehabilitation process. Their effectiveness is based on the theory of neuronal reorganization, mediated by mirror neurons, responsible for motor imagery. **Objectives:** To test the applicability and evaluation of the virtual game Gesture Chair by people with and without spinal cord injury, to identify users' perceptions about the characteristics and demands of the VR game after its use and compare the immediate effects of the game on motor performance components in both groups. **Method:** We analyzed upper limb range of motion (ROM) after performing a practice using the exergame in a sample of five subjects with spinal cord injury and a comparative group with five other participants. The game was applied for 15 minutes, counting periods of activity and rest, while the subject remained seated. **Results:** The number of subjects in the sample does not allow statistically significant results on changes in shoulder ROM; however, factors that interfered with performance, perceptions about initial contact with the activity, presence of muscular fatigue and pain that may be present related to the increase of energy expenditure during the action were identified. Regarding the interest, there were reports of demotivation and disinterest, but there were also reports considering the activity motivating. **Conclusion:** The study implies the importance of the process of choosing individualized resources during the rehabilitation process and the need for adaptation among users of novel technologies. Future studies will be able to analyze the enhancement of the game with different users.

**Keywords—** virtual reality, rehabilitation, spinal cord injury, evaluation, occupational therapy

## I. INTRODUCTION

Spinal cord injury is considered a severe disabling syndrome that affects human beings [1], [2]. It is a condition of partial or total failure of the spinal cord, due to an interruption of nerve fibers, which can lead to motor alterations and superficial or severe sensory deficits in the body segments that are below the level of the lesion. It causes visceral and autonomic alterations, and vasomotor, sphincteric, sexual and trophic dysfunctions [3].

The etiology of spinal cord injuries can be classified as traumatic (injuries from firearms, car accidents, falls, shallow water diving, sport accidents, among others) or non-traumatic

(tumor, infectious, vascular and degenerative causes, or others). The clinical manifestations depend on the level (tetraplegia or paraplegia) and degree of the injury (complete or varying degrees of incomplete lesion), which aid in the prognosis and rehabilitation [1], [3], [4].

For Silva et al. [5], after a spinal cord injury, the individual needs to relearn from the simplest things like dressing, feeding or bathing, to the more complex ones, such as climbing and descending stairs and relating to others. Physical, emotional, occupational, social, relational, evaluative and self-perception aspects are significantly altered, leading to feelings such as fear, disbelief and inferiority, resulting in social isolation and rupture of occupational identity [6], [7].

In view of the various alterations caused by spinal cord injury, the rehabilitation of affected individuals is challenging. They require intervention with resources that empower them for maximum recovery and participation in daily life activities that are often limited due to pain, spasticity, decreased strength and need to save energy [8].

In this process of rehabilitation, Occupational Therapy plays an important role in minimizing functional limitations, aiming at greater independence, taking into account the time, level and degree of the injury, as well as cultural, social and economic factors. In order to do so, the professionals evaluate the subjects' abilities, their limitations and the need for assistive technologies and/or environmental interventions that can directly interfere with functionality. These professionals act so that the occupational roles of the subjects can be maintained or recovered and they are able to perform well in their daily activities, instrumental activities of daily living, work and leisure [9], [10], [11].

The traditional rehabilitation process is based on physical tasks that can often be repetitive and tiring for the subjects, discouraging them [12]. Professionals must constantly gain knowledge and be up to date on new resources that increase motivation and that can keep patients persevering in treatment [13].

With regard to motivation in rehabilitation, Nunes et al. [14] point out that virtual reality (VR) games and exergames have gained attention as new resources, studied and used in the process of rehabilitation of people with disabilities, by

covering the repertoire of daily tasks, promoting leisure and other benefits to the subject.

VR is generally conceptualized as an immersive and interactive experience that is based on real-time computer-generated 3D images simulating the real world or an imaginary world. With the use of such technologies, the intention is for the user to feel part of the environment, interacting with this three-dimensional world and its objects, configuring a human-machine interface [15], [16].

Reproducing real situations without risk to patients and with minimal costs due to the little need for physical objects, the opportunity to simulate and visualize situations impossible to be seen in the real world, the possibility of graduating the complexity of the tasks, among other factors, are some of the justifications for VR applied to health be a promising area of interest [14], [17], [18]. The effectiveness of the use of this resource in rehabilitation is further supported by the theory of neuronal reorganization mediated by mirror neurons, which are responsible for motor imagery, i.e. the imagination or visualization of movements that facilitate learning [19], [20].

Exergames, or active videogaming (AVG), represent a category of video games that stimulate the movement of large body parts (trunk, upper or lower extremity) through an immersion experience. Dance mats or balancing platforms that capture the user's movements through motion sensor cameras or external devices, for specific game control or for real motion reproduction [21] are used in exergames. The effect on players makes it possible to measure additional data such as game challenges, player movements and performance levels that influence aerobic activity [22], making the rehabilitation process more attractive than that obtained through conventional means [23].

Games created specifically for rehabilitation purposes may also be called serious games, developed to address training aspects because they have specific rules and not just entertainment [24]. They can also be used for the training of professionals in situations of extreme risk, as well as training focused on education, health, public policies and strategic communication objectives [25].

Thus, for an effective intervention using VR with disabled people, it is important to support the decision-making on the best scientific evidence, as well as on the constant updating of professionals, in order to structure and to ground intervention programs and research in this field [14], [26].

Before the different uses of virtual rehabilitation and the development of research in the area, a gap in knowledge production related to wheelchair users has been identified. The present study aimed to test the applicability and evaluation of the virtual game *Gesture Chair* by people with and without spinal cord injury; identify the users' perceptions about the characteristics and demands of the VR game after its use; and compare the immediate effects of the game on motor performance components (shoulder range of motion) in both groups during game performance. In addition, we also sought to identify the self-report of both groups about the evaluation of the game.

## II. METHODOLOGY

### A. Selection of participants and inclusion and exclusion criteria

The invitation of volunteers was made through a Non-Governmental Organization (NGO) for people with disabilities in the city of São Carlos, São Paulo, Brazil. Ten subjects participated; five had paraplegia or tetraplegia, sequelae of spinal cord injury, and five participants had no disabilities (comparative group).

As inclusion criteria, we considered: age over 18 years; presence of motor sequelae due to spinal cord injury. As exclusion criteria: presence of musculoskeletal deformities in the upper limbs; inability to perform active shoulder and elbow movements; or contraindication for performing physical exercises with the upper limbs.

### B. Materials and tools for data collection

The instruments and equipment used to carry out the study were:

1) Anamnesis card: created by the researchers to identify personal data, data on the injury, medication use, routine, physical activity performed and previous contact with virtual/electronic games.

2) Microsoft Kinect® device: real-time motion-sensing gesture recognition sensor, consisting of the following components: a) an RGB camera (characterized as an additive color system consisting of red, green and blue used for color reproduction in electronic devices such as monitors, overhead projectors, scanners and digital cameras), b) a depth sensor (emitter and receiver of infrared rays); c) a vector of microphones; d) a tilting motor and; e) a three-axis accelerometer. The connection interface of the sensor is USB, standard 2.0, allowing it to be used in the development of computational applications [24].

3) VR game *KapMan*: is a free version of the game *PacMan* (popular maze game in the 80's, in which the player must drive the character through a maze, turning away from ghosts). This game is found in the *GestureChair* application [24] and aims to provide people who use a wheelchair interaction with the virtual environment in the seated position. This interaction allows the control of the game character from the movements of elbow flexion and extension and lateral and medial rotation of the arm, with the elbow flexed, and the recognition of movements of the player's hand occurs from a gesture similar to the movement for "bye" (waving), which are picked up by the depth sensor of the Microsoft Kinect® device. If, for some reason, the user's control movements are not fast enough, no gesture is interpreted, thus avoiding the recognition of undesirable gestures [24]. The *GestureChair* application allows the *KapMan* game to be controlled by means of gestures of the upper limbs and was developed in the Immersive, Interactive and Collaborative Visualization Laboratory (LaVIIC) of the Computing Department (CC) of the UFSCar.

4) Game evaluation questionnaire: composed of open and closed questions about the user's perceptions of the game, also

involving questions related to tiredness, motivation, suitability to the age group, degree of difficulty, discomfort, ability to control the game, perceived visual demands and need for trunk balance. It should be emphasized that the questionnaire was previously evaluated by five researchers and specialists. In addition, a pre-test was performed with a subject, in order to verify the clarity and understanding of each question.

5) RehabGesture software: it allowed the measurement of the range of motion (ROM) of glenohumeral joint abduction (plus the movements of the scapular girdle). The current version of the software was developed and implemented from the KinectSpace open-source software, plus real-time recording of ROM measurements of the shoulder and elbow joints in the coronal plane. KinectSpace is software that performs the recording and recognition of gestures from a Kinect® sensor, providing visual feedback that allows the user to identify if the gesture is the same movement that was previously standardized, although it does not present real-time ROM values, which emphasizes the innovation presented by RehabGesture [27].

6) Field diary: to record the observations regarding the participants' performance during the game, their reports during the session, as well as the limiting and variable factors that could interfere with the research.

A computer was used in the collection, a Semp Toshiba notebook model IS 1414 with Intel® Pentium T4500 processor, with 2 GB of RAM, 14.0" WIDE screen and Windows® 8.1 operating system; Speakers: Multilaser 2.0 3w Rms Speaker Black Sp144; and a projector: BenQ MS524B 3200 Lumens Projector - Native Resolution 800x600 HDMI USB.

### III. DATA COLLECTION

The collection took place in the Laboratory of Functional Analysis and Technical Aids, Department of Occupational Therapy, Federal University of São Carlos – LAFATec/DTO/UFSCar, São Carlos, São Paulo, Brazil. Initially, the anamnesis form was applied, seeking to verify the inclusion and exclusion criteria and a date was scheduled with the participants that met the established criteria. On the scheduled date, all the information regarding the research was presented and, after the participants' agreement to participate, they read and signed the Informed Consent Form (ICF).

The researcher presented the game and demonstrated to participants how it is used. Then the participants were positioned, with their wheelchair, at a distance of 1.50 m from the screen in which the game was projected and in front of the Kinect® sensor (connected to a computer containing the software), responsible for the capture and transformation of upper limb movements in game control commands. A trial phase of about 5 minutes was conducted in which the subject received instructions on the best position of the body and movements with the upper limb and better strategies to achieve the goals in the game. The data collection process started after the participants demonstrated that they had understood how to control the game and that they were familiar with the game. Each participant attended a single

session, approximately one hour long, with 15 minutes spent during the game.

Both groups (the spinal injury group and the comparative group) underwent the same procedures, and the comparative group used a standardized chair to perform the activity.

At the beginning and at the end of the game, the shoulder ROM (Range of Motion) was measured, in which the participant performed shoulder flexion and abduction movements, three repetitions each. This measurement was recorded through the RehabGesture application.

During the activity evaluated, the participant used both upper limbs alternately, for five minutes each, with two minutes of rest between them, when necessary. After the activity was completed, the participants answered the questionnaire of evaluation of the software.

### IV. DATA ANALYSIS

The data referring to the questionnaire were analyzed in a descriptive way, with a quantitative-qualitative approach.

To analyze the data obtained with the RehabGesture application, the data recorded during 10 minutes of game were used. This recording was done at an acquisition rate of 30 hertz, that is, the software allows the recording of 30 frames per second. A Microsoft Excel spreadsheet was used to organize the data obtained in this time interval, including the pre-game and post-game ROM values for the abduction and flexion movements of the right and left shoulders. Statistical analysis used a T-test to compare the effects of the factors on the results in the SPSS Statistics 23 software (IBM, New York, USA).

The information collected through the field diary contributed to the analysis of the data obtained using the presented and proposed instruments.

### V. RESULTS

#### A. Sample characterization data

The group of participants with spinal cord injury (IG) was composed of one woman ( $n = 1$ ) and four ( $n = 4$ ) men, all right-handed, with a mean age of 43.4 years  $\pm$  6.8 years. Regarding the level of the injury, there were: C5/C6; C6; C6/C7; C6/T1; T12. The mean time elapsed after since the injury was 16.6 years  $\pm$  12.6 years.

The group of participants without motor impairment, the comparative group (CG), was composed of four women ( $n = 4$ ) and one man ( $n = 1$ ), all right-handed, with a mean age of 32.6  $\pm$  10.19 years.

#### B. Results of the shoulder range of motion during the game between the two groups

Data recorded by the RehabGesture software are presented through the means of range of motion in shoulder abduction and flexion and before- and after the activity.

Regarding the abduction ROM in the IG, a mean of 119.20  $\pm$  35.80° pre-game and 126.70°  $\pm$  36.68° post-game was

observed in the right shoulder, with an average increase of  $7.50^\circ$ . In the left shoulder, the mean ROM was  $135.70 \pm 23.75^\circ$  pre-game, and  $126.00 \pm 40.35^\circ$  post-game, with an average decrease of  $9.70^\circ$ . Both variations did not present significant difference between the measures ( $p > 0.05$ ).

With regard to flexion ROM, in the right shoulder, the mean was  $142.20 \pm 17.19^\circ$  pre-game, and  $140.40 \pm 17.32^\circ$  post-game, with an average decrease of  $1.80^\circ$ . In the left shoulder, the mean was  $144.6 \pm 7.12^\circ$  pre-game and  $139.10 \pm 20.97^\circ$  post-game, with an average decrease of  $5.50^\circ$ . Both variations did not present significant difference between the measures ( $p > 0.05$ ). A possible reason for the ROM decrease is that the tiredness and pain, reported by some participants, may have interfered. These reports will be better presented forward, in this paper.

In the CG, the abduction ROM in the right shoulder was  $141.30 \pm 9.30^\circ$  pre-game, and  $147.00 \pm 7.43^\circ$  post-game, with an average increase of  $5.70^\circ$ . In the left shoulder, the mean ROM was  $140.10 \pm 11.24^\circ$  pre-game and  $146.50 \pm 5.34^\circ$  post-game, with an average increase of  $6.40^\circ$ . Both variations did not present significant difference between the measures ( $p > 0.05$ ).

In the case of flexion ROM, the mean was  $159.50 \pm 7.77^\circ$  pre-game and  $157.00 \pm 7.99^\circ$  post-game, with an average decrease of  $2.50^\circ$  in the right shoulder; and  $158.10 \pm 12.45^\circ$  pre-game and  $158.60 \pm 10.19^\circ$  post-game, with an average increase of  $0.50^\circ$  in the left shoulder. Both variations did not present significant difference between the measures ( $p > 0.05$ ).

The normality of data was tested from graphs (histogram, boxplot and scatter plots). The analysis of normality of post-game data was similar to the pre-game data, with range of movement presenting a normal distribution according to the Shapiro-Wilk test and graphs. Therefore, a t-test for independent samples was used to compare the two groups after the game, in order to identify if there was a difference between groups. Because this is a parametric test, it is applied only to data presenting normal distribution.

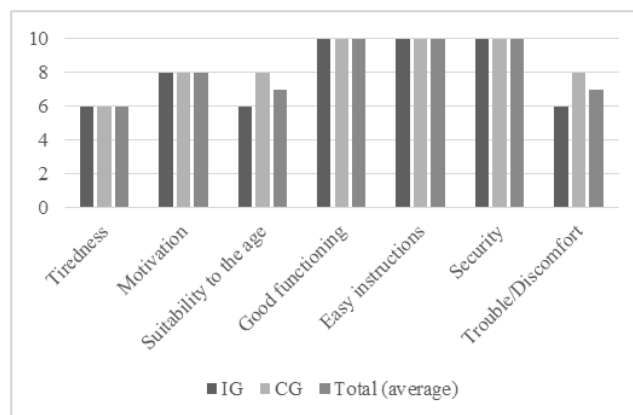
In order to statistically prove the difference between the groups, the calculated "t" value should be greater than the tabulated "t" value and in this case the tabulated "t" value is 2.306. It was observed that there were no significant differences between the groups for any of the variables that had normal distribution. Table 1 shows the values obtained with the t-test calculated for pre- and post-game abduction of the left shoulder.

### C. Game evaluation results by the participants

The questionnaire for evaluation of the game was answered by participants shortly after the gaming experience.

Figure 1 presents the positive responses to the following questions: tiredness, motivation, suitability to the age of the player, good functioning of the game, ease of understanding of the instructions, security during the game and troubles and discomfort sensed.

Fig. 1. Positive responses to the game evaluation questionnaire



As for tiredness, the reports relate to the sensation of pain: "In a short time I was tired, mainly due to the lack of support in the upper limb that performed the action" (CG3); "The movements end up tiresome" (IG2).

When evaluating tiredness on a scale of 0 to 10, 0 = no tiredness and 10 = extremely tiring, four participants evaluated with note 5, two of them being from the CG and two from the IG. The highest rate was 8, corresponding to the opinion of one IG person.

Motivation is demonstrated by the following account: "I believe that because it is a game that involves different levels of difficulty, it is good because it is based on another game very well known" (CG3). As the causes for lack of motivation to continue playing, lack of interaction with other people, tiredness and boredom were cited.

Regarding the suitability to the age group, three participants considered the game to be inappropriate for their age group. One of the reports said: "Although I believe it is challenging, I think it would be more appropriate if there were cognitive challenges" (CG3).

As for the game's operation, understanding of the instructions and the sense of security during the game, all participants responded positively: "Interesting game, the dynamics of the game is nice" (IG2); "It is physically and psychologically attractive" (IG3); "It's encouraging" (sic) (CG2).

Troubles and/or discomforts during the game were frequent. As justification, the reports refer to pain in shoulders, arms and low back.

TABLE I. INDEPENDENT SAMPLE TESTING - INITIAL AND FINAL ABDUCTION OF THE LEFT SHOULDER

		Levene test for equality of variances		T-test for equality of means						
		F	Sig.	t	gl	Sig. (bilateral)	Mean difference	Standard error of difference	95% confidence interval of the difference	
									Inferior	Superior
CEABDIpos	a	1.07	.228	1.071	8	.315	6.38466	5.96051	-7.36031	20.12963
	b	2		1.071	5.398	.330	6.38466	5.96051	-8.60387	21.37319
CEABDFpos	a	5.92	.041	-2.011	8	.079	-27.05868	13.45465	-58.08517	3.96781
	b	4		-2.011	4.426	.108	-27.05868	13.45465	-63.03994	8.92258

CEabdipos: initial abduction of the left shoulder; ceabdfpos: final abduction of the left shoulder; a: equal variances assumed; b: equal variances not assumed)

Regarding the participants' opinion about the game, eight evaluated it as 'Excellent' (n = 4 in the CG, n = 4 in the IG) and two, as 'Good' (n = 1 in the CG, n = 1 in the IG). No one rated it as 'Bad' or 'Very bad'.

Participants could tick all the options they wanted while characterizing the game. Thus, the term 'Challenging' was the most frequently signaled, with seven indications, followed by the terms 'Exciting' and 'Fun' (with five evaluations each). These opinions were similar between the two groups. The terms 'tiresome' and 'boring' were recorded once each, corresponding to the opinion of one IG person.

Regarding the level of difficulty, seven participants evaluated the game as 'Intermediate', with four evaluations from CG participants, and three from IG participants. Their opinions can be observed in some reports such as: "Considering the levels I played, and the demand for movements from this activity, I believe there is an intermediate level of difficulty" (CG3); "It requires skills and coordination of the upper limbs" (CG5); "Because it requires different movements of the upper limbs" (IG1); "You do not always know the right way the little ball goes" (IG5)

Two out of the all participants rated the game as 'Difficult'. They belonged to IG. All were subjects with tetraplegia (between C5-C6) and consequent limitation of movement in upper limbs: "making the right movement to hit the character is difficult" (IG2); "... moving the upper limb is difficult" (IG3). Notably, no participant classified the game as 'Very easy' or 'Very difficult'.

Volunteers also assessed specific game requirements such as: visual appearance, content, the possibility to control the games with the game with the hands, the level of interest, and the requirement of trunk balance during the game.

It was observed that the visual aspect and the content of the game pleased the participants. Opinions were divided between 'Good' (n = 2), 'Very good' (n = 4) and 'Excellent' (n = 4): "It's fun" (CG4); "The game is interactive and attractive" (CG1).

As for the ability to control the game, there was a balance in the opinions of the participants: 'Very good' (n = 3 from the CG), 'Good' (n = 2 from the CG, n = 1 from the IG), 'Excellent' (n = 2, IG) and 'Bad' (n = 2, IG).

With regard to the interest raised by the game, the evaluations were: 'Very good' (n = 4), 'Excellent' (n = 3) and 'Good' (n = 2). Only one subject considered it 'Bad', being a participant of the IG (IG3), who had previously rated the game as 'Tiresome' and 'Boring'.

When questioned about requirement for trunk balance during the game, IG members evaluated the game as 'Very good' (n = 2); including one participant who had low thoracic injury and one with cervical injury; and as 'Good' (n = 3). No participant rated the game as 'Excellent' or 'Bad'.

Suggestions for improving the game included: increasing the image size of some elements of the game, such as bonus items; increasing the complexity of the game; possibility of playing against another player; and increasing the projection screen size of the game, making it more attractive.

## VI. DISCUSSION

The KapMan VR game demonstrated to be useful for the people with spinal cord injury who participated in this research. Quadriplegic people, although missing active hand movement, were able to play, because the Kinect® sensor recognized the movements performed by the participants' fist, triggering the beginning of the game. The major lesion among observed among participants was at C5 level, in which the movements of the deltoid muscles and biceps were preserved, with control of the deficient fist. However, people with spinal cord injury at this level are able to learn to feed themselves, manipulate newspapers, use the computer, and play games. In the case of C6 level lesions, the subjects have the radial extensor carpi preserved, allowing them to pick up objects using tenodesis movement. Patients with C7 level lesions have active elbow extension and fist flexion allowing greater dexterity in all activities [28].

When the spinal cord injury is incomplete, motor and/or sensory function below the neurological level, including muscle groups and sensitive areas, are preserved [1], [3], [29], enabling participation in this activity.

The collections were carried out at the residence or in the workplace of people with spinal cord injury, as the equipment is portable (notebook, sensor, image projector and speakers) and easy to handle. This procedure allowed the participants to feel more at ease and comfortable during the collection, so that the environment factor interfered less in the result. For the

comparative group, due to the necessity of the wheelchair, the collections were made at the LAFATec, UFSCar, which has a wheelchair for research purposes.

Considering the sample size, however, this study did not obtain statistically significant results to assert that the KapMan VR kit assists in the rehabilitation of upper limbs, based on the evaluation of shoulder ROM by the RehabGesture software. Some factors were observed to have interfered with the participants' performance and, consequently, with the results of the survey.

In addition to the small sample size, the short collection period, i.e. only one 15-minute session setoff game, did not provide enough time for significant changes in shoulder ROM. The study, however, made it possible to analyze the users' perception of the initial contact with the activity, since only four people had already experienced virtual reality games, one from the IG and three from the CG; this may have interfered in performance of the players and in the evaluation of the shoulder ROM, as well as in the evaluation on the game.

An important aspect to consider is the perception of muscle tiredness, pain in the upper limbs and lower back after five minutes of activity. Muscle tiredness is very common in sport activities and daily activities, resulting in worsening motor performance, reducing the ability of the neuromuscular system to generate force, involving several processes that start with cortical control in the brain and end with the formation of cross-bridges within the muscle fiber. Muscle tiredness may then result from the failure of any of the processes involved in muscle contraction [30].

It is noteworthy that two participants of the CG felt more pain in the dominant limb, and had a better performance in the game with the non-dominant limb. With the other participants of both groups the effect was the opposite, since they had better performance with the dominant limb and felt more pain in the non-dominant limb, demonstrating the importance to use the limb in tasks with the goal to improve and maintain the range of motion and muscle strength (in this case, related to sensation of tiredness).

One complaint brought up by both groups was the lack of support for the upper limb and the need for a large amount of movement to complete the game, causing some discomfort during use. A solution to avoid this fatigue would be the alternating use of the limbs during the game; however, this could cause the loss of signal capture by the Kinect® sensor. Thus, it is necessary to use adaptations and modifications in the activity in order to allow the rest of the limb in the test position with the subsequent continuation without interrupting the game, ensuring the minimization of exhaustion and pain.

Malone et al. [21] found that participants with severely and moderately affected upper extremities had a greater increase in energy expenditure in Wii games when compared to the adapted upper extremity version of the "dance-revolution" (DDR) dance game, while participants with no upper extremity limitation had greater energy with the DDR than with the Wii. Although the increase in energy expenditure of the games differs according to the severity of the disability, the changes could provide an opportunity for these

populations to perform physical activity, offering a choice of strengthening exercises for people with physical disabilities if customized adaptations are made.

In the same direction, Kizony et al. [31] reported that four people with spinal cord injury tested the Gesture Xtreme VR system and the results show an increase of effort related to balance training and postural adjustment compared to conventional training.

With respect to the comfort, convenience and opportunity to perform physical activity and to assist in rehabilitation, Matrosly et al. [32] found significant physiological responses with the Exergaming boxe game, compatible with the conventional boxe bag. The intensity of both exercise modalities reached recommended intensities for health benefits. As an impact on rehabilitation, Exergaming boxe has shown to have the potential to provide a pleasant, self-regulating environment for vigorous moderate exercise that can be used in homes.

Regarding the motivation provided by the game, few subjects reported not feeling motivated to play and two IG participants indicated a preference for high-performance activities. Most participants considered the activity as motivational, and showed interest in acquiring the equipment for this activity.

Barzilay and Wolf [13] consider motivation as extremely important in the rehabilitation process, as it is a stimulating element for subjects to participate actively in their recovery process. The authors emphasize that, even in the traditional rehabilitation process, the results depend largely on the individual's motivation.

Other aspects that also received a positive feedback from the participants refer to the visual aspect, operation and instructions for easy understanding of the game, although most of the participants considered as having an intermediate level of difficulty. It was also observed that the report of difficulty is related to the fact that the game requires much movement of the upper limbs.

This result was already expected because, according to Turci et al. [1], in cases of spinal cord injury, people have partially innervated and/or atrophied muscles, and they consequently make use of the preserved musculature, overloading it.

With regard to the participants' suggestions, it was seen that they are directed to making the game more attractive and to increase the motivation, as previously discussed.

It is important to emphasize that, although the game can be used individually for therapeutic purpose, the person needs to be guided regarding the intensity of the exercises, signs of fatigue, pauses to relax the muscles, stretching, among others. Pirovano et al. [33] point out that the therapist's orientation is fundamental during the exercises in order to prevent harmful effects caused by maladaptation, wrong posture and overload. The study also emphasizes that an increase in the degree of challenge should never violate the primary and secondary objectives of the exercises, thus preventing it from becoming useless or even harmful.

## VII. CONCLUSION

The present research reached the objectives proposed of analyzing the use of a virtual reality game developed for wheelchair users as a resource for gaining range of motion in the upper limbs.

In order to broaden this discussion and to obtain a more reliable analysis of the RehabGesture and of the evaluation of the game as a resource for Occupational Therapy, it would be necessary to conduct surveys with a larger number of participants, for a longer period of time, with more sessions with the game. We believe also that adjustments to the software are needed to make it work more satisfactorily, with fewer disruptions.

The literature on the role of Occupational Therapy with the use of virtual games with spinal cord injury patients is increasing [31], [34], and this research can contribute, since made it possible to observe that the game represents a form of leisure, of re-signification of doing, and a potential resource in the rehabilitation process. The game promotes and requires intense shoulder movement and can be used for occupational therapy, in addition to rehabilitation treatment.

The present study produced evidence of relevant aspects of the use of VR games among people with spinal cord injury sequelae and comparative group, through the analysis of the users' perception about the characteristics and demands of the VR game and the recognition of the immediate effects produced in motor performance components. We hope that the results of this study contribute to the improvement of the game for wheelchair users, as well as to direct future research on the development and evaluation of protocols for its use accordingly the needs of this population.

## Acknowledgment

Research Grant: Conselho Nacional de Desenvolvimento Científico e Tecnológico- CNPq.

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