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USABILITY ASSESSMENT OF AN IMMERSIVE VIRTUAL REALITY GAME IN ELDERLY PEOPLE

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Abstract: Introduction: The decline in functional capacity is expected in aging, but therapeutic exercises prevent the decline. To avoid disinterest in therapy there is virtual reality, which stimulates motor and cognitive skills. Objective: To assess usability and performance of elderly people in immersive virtual reality game. Materials and Methods: Cross-sectional study with eleven elderly people of both sexes, aged between 60 and 80 years old, using the commercial immersive virtual game (Beat Saber®, Sony PlayStation 4). The protocol was divided into three stages: 1st: sociodemographic and health condition screening - Snellen Optometric Scale, Global Side Preference Inventory, Dynamometry, Mini Mental State Examination and Functional Independence Measure; 2nd: three attempts were made, with the collection of vital signs (HR and BP) after each one, also noting the scores; 3rd: System Usability Scale (SUS) and Simulator Disease Questionnaire (SSQ). The data analysis was performed in a descriptive way, for the dependent variables the Anova test was used, with 95% CI and p-value <0.05. Results: Participants were 6 women and 5 men, mean age 66.3, right-handed, with no visual and / or cognitive and independent changes (FIM = 124). The average score for correct attempts was 142.09. There was a high usability index (SUS), with an average score of 97.27 and absence of cybersickness. Conclusion: Although the average score does not present statistically significant differences, the absolute values and usability results suggest that Beat Saber is safe and promising.
Keywords: Virtual Reality; Health services for the aged; Physical Therapy Modalities; Physical Functional Performance.

INTRODUCTION

Worldwide, the age group of sixty years old and older is growing faster than any other group (Halaweh et al., 2018). According to the World Health Organization, the world population will keep increasing in the coming years, currently Brazil has approximately 19.8 million older people, however, projections indicate that this number should exceed 41.4 million by the year 2050 (Who, 2015).

The effects of this demographic transition outweigh issues related to the natural biological aging process. The complexity of this phenomenon brings challenges to individuals, families and public management due to aspects such as biopsychosocial changes, dependencies and disabilities and, consequently, implies new responsibilities for society, managers and health professionals, since health and welfare are making it a priority to age well (Minayo, 2012).

The aging process may cause the fragility, which induces the individual to physical dependence. The fragility involves various physical capabilities, such as gait, balance, mobility, cognition, muscle strength, feelings of fatigue, and reduction of physical activity (Zhang et al., 2020).

However, despite functional changes related to senescence, studies show that older adults can acquire new performance skills similarly to young adults. Therefore, technology can be useful to minimize age conditions and improve performance and the discovery of new skills (Skjæret et al., 2016).

Although the conventional therapeutic exercises used for training are varied and simulate activities of daily living, many elderly people feel apathetic with monotony and lack of perception of the therapy, therefore not having many parameters to measure the evolution (Meekes; Stanmore, 2017; Matallaoui et al., 2017). In this way, the performance of professionals in order

to optimize and accelerate the process of functional recovery and readaptation of individuals can be strengthened with the use of innovative devices complementary to conventional practices and approaches (Rosa; Guimarães; Domingues, 2017).

In this regard, new technologies have been used in research and practical applications such as virtual reality (VR), which helps the development and stimulates motor and cognitive skills. For the elderly population, it tends to contribute to improving performance, as it allows the interaction and contact of the elderly with new technologies (Bezerra et al., 2018).

RV is defined as an objective property of a system. Immersion, within VR, occurs due to the individual's perception through natural movement within the game. An immersion in the experience of presence, that is, feeling inside the game. For immersive VR to make or participate to behave realistically, it must promote the individual feeling of being nowhere and the feeling that events exposed in the VR are happening (Slater, 2018; Brown et al., 2017).-

Studies have shown that the application of virtual reality (VR) games in a therapeutic way, also called exergames, acts to improve postural control and decrease the number of falls in elderly people, which demonstrates the effectiveness and potential of the applications of exergames in this portion of the population (Ahn; Hwang, 2019; Matallaoui et al., 2017; Neri et al., 2017). Exergames are as active video game that require exercises, that capture the player's body movements, actively involving him, providing a pleasurable and intense exercise (Neri et al., 2017).

When using an exergame several sensory information (visual, auditory and somatosensory) is processed. The interaction promoted by virtual reality has a sublime capacity to attract the attention off any individual to the game. In the literature, the term to designate such a characteristic is "gameplay", in which aspects such as: the virtual environment itself, the game's settings, objectives, challenges, rules, feedback system, interaction and immersion that together contribute to stimulate cognitive, sensorimotor functions and emotions (Ahn; Hwang, 2019; Brown et al., 2017).

There are many advantages, described in the literature, about exergames when compared to conventional exercises, for example, exergames can motivate the practice of exercises through interaction, enabling the training of motor and cognitive skills, through double tasks (Meekes; Stanmore, 2017; Matallaoui et al., 2017) players can focus their attention on the movements of the game and not on their own movements (Neri et al., 2017); exergames can be practiced at home, alone or in a small group, which can make the activity more accessible to many elderly people (Zangirolami-Raimundo et al., 2019; Li et al., 2018).

There is a greater interest from the scientific community in the use of VR for therapeutic purposes (Li et al., 2018). Systematic reviews on VR have already been carried out in individuals with specific health conditions and with different therapeutic conditions, showing small or inconclusive improvements. However, they also revealed the notable lack of significant studies of methodological quality, little evidence regarding the efficacy and effectiveness of the use of VR through games, alone or in addition to conventional motor therapies in the elderly population (Tuena et al., 2020; Zangirolami-Raimundo et al., 2019; Li et al., 2018; Prasertsakul et al., 2018).

OBJECTIVE

This study sought to assess usability and join strategies to improve motor performance with modernity arising from technological advances in order to list the benefits that technology can provide for the functionality and quality of life of the elderly, in addition to verifying the performance of the elderly during the practice of immersive virtual reality game.

METHODS

STUDY DESIGN

This is a cross-sectional study that is part of a teaching research project entitled "Health Care Technology: usability of virtual games and analysis of motor performance by users with reduced mobility". The study is analytical and was developed with elderly people from the local community whose design is summarized in figure 1.

PARTICIPANTS

Eleven elderly people of both genders, aged between 60 and 80 years old belonging to the local community were invited to participate. The screening was carried out with those who met the eligibility criteria and accepted to participate in the study by signing the Informed Consent Form (ICF), approved by the Ethics Committee on Human Research at Mackenzie Presbyterian University under CAAE: 96008518.0 .0000.0084.

As inclusion criteria were considered: (1) signing the informed consent form; (2) elderly aged between 60 and 80 years; (3) normal visual acuity (20/12 to 20/25) or close to normal (20/30 to 20/60) with or without corrective lenses; (4) they do not have acute or chronic health conditions that interfere with mobility and/or performance of the task - Functional Independence Measure = 104 to 126 – complete/modified independence. To the participants were ensured confidentiality, informed that participation was voluntary and that they could drop out of the study at any time.

Participants who gave up participating during the protocol, or who did not understand the commands required to perform the tests, were therefore unable to perform the proposed activities.

SAMPLE CHARACTERIZATION

The sample characterization protocol, evaluations and tests were applied in one day, individually, with an average duration of 1 hour and 30 minutes, subdivided into two stages. The first stage of the protocol included the characterization of the sample, which consisted of: (1) sociodemographic screening; (2) clinical and functional screening.

(1) Sociodemographic screening: questionnaire prepared by the author himself. The instrument includes 3 (three) sections: I - Personal data, such as: identification, age, sex, marital status and address; II - Sociodemographic information: occupation, income, education, type of housing, with whom they live, social security situation; III - Health Condition: comorbidities, medications in use and treatments in progress.

(2) Clinical Screening: Snellen Optometric Scale (visual acuity), GSPI - Global Side Preference Inventory (dominance), Dynamometry (handgrip strength), MMSE (cognition) and FIM - Functional Independence Measure (functionality).

Optometric Snellen Scale: assessment of visual acuity without diagnostic purpose, that can be used by any health professional after training (Kronbauer; Schor; Carvalho, 2008). The scale is placed at a height of 1.5m on a clean wall and a bright room, and there must be a space of 5 meters between the place where the person is sitting and the wall where

Figure 1. Representative research design. Own source (2023).

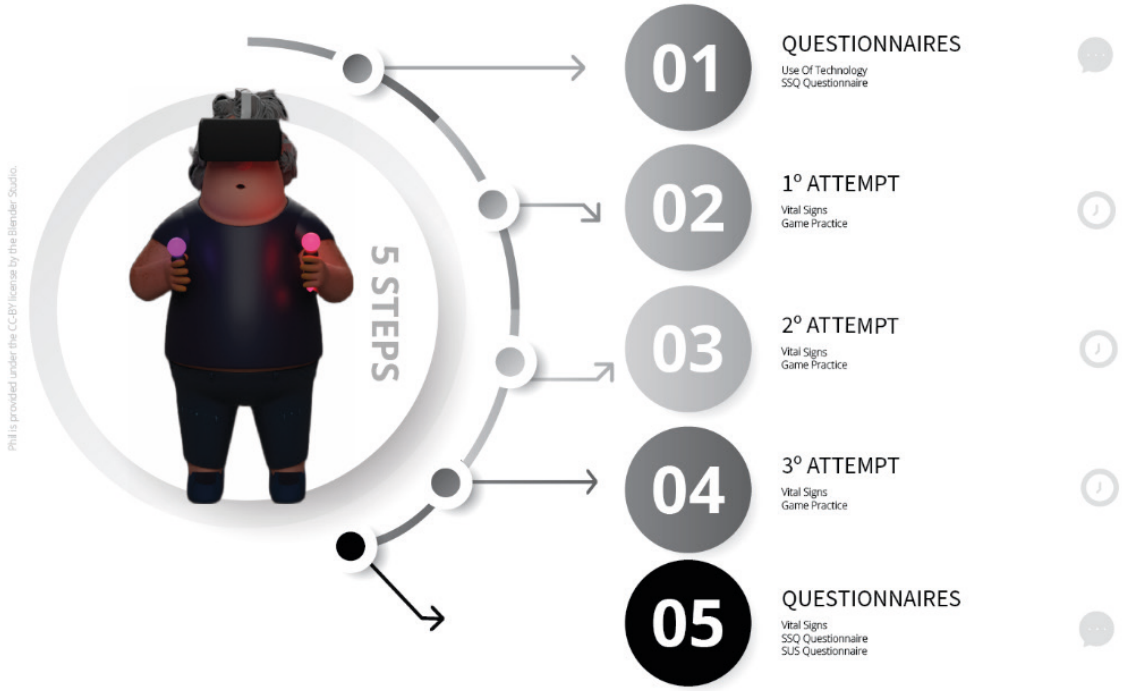

Figure 2. Design of the research protocol. Own souce (2023).

the scale is exposed. The participant is placed comfortably seated, with glasses (if used), and asked to identify the pointed figure starting from the largest to the smallest. The bilateral view is evaluated by identifying the line to which the subject is able to clearly distinguish the symbols. The last line clearly identified is the one that should be marked as a result. Only individuals who distinguished the symbols up to the 8th line (20/20) with corrective lenses were included in the study (Brasil, 2008).

GSPI: Global Side Preference Inventory (GSPI) used to determine laterality - the individual's preferred body, more agile and proficient for carrying out activities (Marim; Lafasse; Okazaki, 2011).

It is a self-assessment, divided into 8 stages, whose tasks represent everyday life and contemplate five dimensions, such as preferences (a) manual, (b) foot, (c) auditory, (d) visual and (e) trunk. The GSPI Software (v.1.0), a single executable file in Windows system, was used to collect data with automatically calculated variables.

Dynamometry: Measurement of handgrip strength, quantified by the Jamar® hydraulic dynamometer, as recommended by the American Society of Hand Therapists – SATM. Performed in a sitting position in an armless chair, with feet resting on the floor, hips and knees positioned at approximately 90 degrees of flexion. Participants are instructed on placement during the test and corrected by the examiner when necessary. Accessories such as watches, bracelets, rings and bracelets are removed from both upper limbs of the participants before the start of the tests (Reis; Arantes, 2011).

In the first session the test was performed initially with the right hand and then with the left hand in a no alternating way. Participants were instructed to make a maximum contraction for 3 seconds in each test. There was a rest period of 30 seconds between each test and a rest period of 2 minutes between the tests of each hand. The average of the values of the three tests of each hand was used for data analysis.

Mini Mental State Examination: screening index of cognitive loss is used as a measure of cognitive function in studies with adults, validated for the Brazilian population. Contains questions grouped into seven categories with respective punctuation, namely: temporal orientation (5 points), spatial orientation (5 points), three-word record (3 points), attention and calculation (5 points), three-word recall (3 points), language ability (8 points) and visual constructive capacity (1 point). The MMSE score can vary from 0 points, which indicates the highest degree of cognitive impairment of individuals, up to a maximum total of 30 points, which, in turn, corresponds to better cognitive ability. The cutoff point most used to indicate cognitive impairment that deserves investigation is 24 (Lourenço; Veras, 2006).

Functional Independence Measure: developed in North America and translated and adapted for the Brazilian population, with the objective of quantitatively evaluating the care load demanded by a person in carrying out a series of motor and cognitive tasks of daily living. Among the activities evaluated are self-care; transfers; locomotion; sphincter control; communication; cognition, including memory, social interaction and problem solving. Each of these activities, after being evaluated, receives a score from 1 (total dependence) to 7 (complete independence), thus varying the total score between 18 and 126 points. Dependency levels are classified according to the total score: 18 - complete dependence; 19 to 60 - modified dependency (assistance for up to 50% of tasks); 61 to 103 - modified dependency (assistance for up to 25% of tasks); and 104 to 126 - complete/ modified independence (Riberto et al., 2004).

VIRTUAL PRACTICE

The game called Beat Saber® (Beat Games, Czech Republic) was used as a virtual task, a virtual reality rhythm, available on Sony PlayStation® 4 (Sony, Japan) and Microsoft Windows® (United States of America) platforms. The game environment consists of blocks that move towards the player, who will use two lightsabers, one blue and one red, in order to "cut" the blocks according to the corresponding color, following the rhythm established by the chosen song, in a futuristic setting.

The tests were conducted using a Sony PlayStation® 4 Slim, 500GB, Model CUH 2215A; Sony PlayStation® VR Bundle, Model CUH-ZVR2; PlayStation® Move Motion Controller, model CECH-ZCM1E; pulse oximeter Risingmed, model RPO-8C; digital wrist blood pressure monitor Microlife, model BP 3BU1-3.

EVALUATION PROTOCOL

The tests were applied by the researcher in the following order:

a) *Technology Use Questionnaire*: Prepared by the author with questions to track the affinity and usability of devices and technological resources in everyday life, such as: computer, cell phone, video game, among others. The questionnaire does not contain quantitative values for scoring.

b) *Simulator Sickness Questionnaire* (SSQ) – adapted. Translated and adapted for the Brazilian population it is an instrument for assessing symptoms of discomfort related to interaction in virtual environments (cybersickness) before and after contact with the immersive experience. SSQ consists of symptoms that can be classified as: absent, mild, moderate or severe (Carvalho; Costa; Nardi, 2011). Questions regarding cybersickness in means of transport and use of large screens were added.

c) *System Usability Scale* (SUS) – adapted. The SUS measures the system's usability. This instrument is a Likert scale, usually applied immediately after interaction with the system, allowing the registration of users' initial opinions. Scores range from 0 to 100, with values below 50 indicating bad or unacceptable usability, values above 70 are considered acceptable or good, while values above 85 have a high level of usability (Lewis, 2018).

IMMERSIVE INTERVENTION PROTOCOL

The participants were positioned upright, with a standardized distance of 1.5 meters from the television. Before starting, the task and handling of the devices were explained verbally. No test was offered for understanding and practicing the game.

Among the available tracks, the song Country Rounds - Kings & Folk (Squeepo Remix) was chosen, with the following specifications: enabled options no failures, no obstacles, no bombs, no arrows, easy mode, 70% speed and this song has a maximum number of hits 151.

Three attempts were made, vital signs (heart rate, saturation and blood pressure) were measured before and after each attempt, totaling 4 measurements. In each round, participants performed the Beat Saber game for 270 seconds, without interruption. The performance data in the game, such as number of correct answers, errors and score were recorded in an Excel spreadsheet. The protocol used was the same for all participants, as shown in figure 2.

Optometric Snellen Scale	n (%)	Evaluation of Results
20/20	6 (54,5)	Normal Vision
20/25	5 (45,5)	Normal Vision
Global Side Preference Inventory	**Average (standart deviation)**	**Evaluation of Results**
Global Perceived Preference	3,9 (+/- 0,31)	Right-handed Moderate
Global Side Preference	3,79 (+/- 1,23)	Right-handed Moderate
Perception Coherence Scale	0,79 (+/- 0,36)	Very Good
Dynamometry	**Average (standart deviation)**	**Evaluation of Results**
Women – Right Hand	25,55 (+/- 5,02)	-
Women – Left Hand	22,66 (+/- 5,24)	-
Men – Right Hand	36,26 (+/- 6,84)	-
Men – Left Hand	34,53 (+/- 4,95)	-
Mini Mental State Examination	28,45 (+/- 1)	Normal
Functional Independence Measure	124 (+/- 4,62)	Maximum Score 126 -Independent

Table 1. Sample Characterization – Clinical Screening (n=11). Sao Paulo/SP, 2023

DATA ANALYSIS

Descriptive analysis was performed to characterize the sample and the results obtained in the usability questionnaires, considering the average values of the responses among the total participants. The data are presented in mean and standard deviation values.

For analysis of game performance, the average number of correct answers between each attempt (1st attempt; 2nd attempt and 3rd attempt) was considered in the total sample. For this purpose, the ANOVA statistical test was performed with a post-test of multiple comparisons performed with the Tukey HSD (Honestly Significant Difference) statistical test.

In addition, the results obtained by gender were compared, for this purpose the ANOVA statistical test with a single factor (group: MEN, WOMEN) of repeated measures (correct answers: 1st attempt, 2nd attempt, 3rd attempt) with post-test of pairwise comparisons (for the gender factor) performed with the Bonferroni LSD test (Least Significant Difference) and analyzing individual attempts by gender with the post-test of multiple comparisons performed with the Tukey HSD test (Honestly Significant Difference).

The statistical program used was SPSS (Statistical Package for Social Sciences), version 20.0. A significance level of 0.05 (5%) was defined and all intervals constructed throughout the work were 95% statistically confident.

RESULTS

Eleven elderly people participated in the study, six of them were (54.5%) women and five (45.5%) men, with an average age of 66.3 years (+/- 5.88). Regarding body weight, only 1 (9.09%) considered themselves to be of adequate weight, the rest reported being overweight 10 (90.9%). As for the practice of physical activity, 5 (45.5%) reported doing it weekly and 6 (54.5%) reported having a sedentary life. The participants had an average schooling of 10.9 years (+/- 4.15). Only 2 of the 11 elderly people are not retired, however 3 (27.7%) of them are still in the labor market, while the remaining 8 (72.72%) do not exercise paid activities.

The results for health conditions and insertion in the study are summarized in table 1.

It was observed that 100% of individuals made use of cell phones and television sets and only 6 individuals made or makes use of computers. Regarding the use of video games for at least once in their lives, no individual had contact with the device. The participants' level of computer literacy was also asked, in which it was found that most individuals (54.5%) had basic knowledge of this tool, as shown in table 2.

Level of computer knowledge	n (%)
Nenhum	3 (27,2)
Basic	6 (54,5)
Intermediate	2 (18,18)
Advanced	0 (0)

Table 2. Computer Skills (n=11). Sao Paulo/ SP, 2023.

All participants completed the usability questionnaire (SUS) after playing the game. The average obtained from the total score was 97.27 (± 3.25), which, according to the criteria, places the application with the best possible usability for the proposed context.

The results obtained for symptoms of cybersickness (SSQ) filled in before and immediately after the practice of the last attempt of the game showed in the pre-game 06 reports (6/17) characterized as mild: tiredness, eye pain, headache, difficulty concentration, blurred vision and reflux. In the post-game, only 02 participants reported sweating or dizziness with their eyes closed (2/17) categorized as mild.

In the game performance analysis, the average score achieved between the three attempts for the total sample was considered, as shown in figure 4. The results of the attempts were compared using the ANOVA test with Tukey's post-test, with no significant effect for any factor (p = 0.516). Regarding the amount of misses, the result was the same as the hits, being inversely proportional, including with the same p-value (p= 0.516).

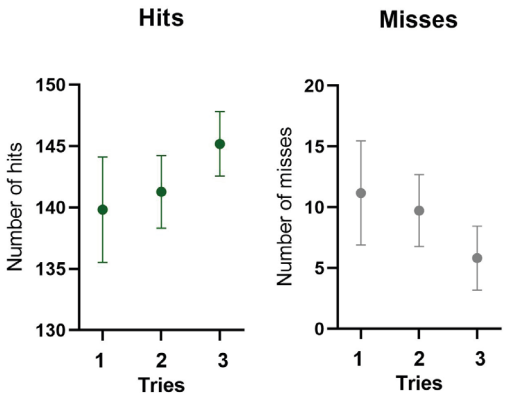

Figure 3. Representation of the average number of hits and errors in the sample in the 3 attempts (n = 11). Own source (2023)

In addition, a comparison was made between the attempts considering the total sample (n = 11). ANOVA with Tukey's post-test did not reveal a significant effect for any factor [T1 - 2 = p = 0.950; T1 - 3 = p = 0.507; T2 - 1 = p = 0.950; T2 - 3 = p = 0.694; T3– 1 = p = 0.507; T3 - 2 = p = 0.694].

Finally, the performance analysis by gender was performed considering the values reached in the three attempts, in a multiple comparison of the ANOVA test with Bonferroni post test as summarized in figure 4. ANOVA did not show any significant effect for any factor (p = 0.426).

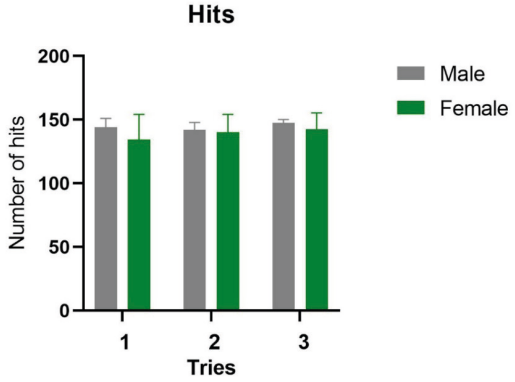

Figure 4. Representation of the average number of correct answers between genders in the 3 attempts (n=11).

DISCUSSION

The present study investigated the usability and performance of the elderly in an immersive virtual reality commercial game. The results obtained for usability considering the measures of effectiveness, efficiency and satisfaction on the user's perception were classified as the best possible usability (97.27%) for the Beat Saber® game.

These findings are in accordance with Marcilly and collaborators (2015), that's determine usability as which determines usability as elements of the user's graphical interface, structures for navigation, the system's response to the user's behavior, as well as the integrity of the system. Circumstances and context, such as demographic factors, level of knowledge and affinity with technology, did not influence the result obtained in the SUS score.

SUS consists of 10 questions capable of providing the user's view of the object in question, presenting reliable results, regardless of the system or task. The structure of the questions with short statements and positive and negative items presented alternately, avoids response biases with the purpose of the participants really agreeing or disagreeing with the questions after reading and interpreting (Lewis, 2018).

In addition, to the results obtained in the SUS, it was noted that the values achieved in the performance of the participants in this study, in the three attempts, presented an average of 142 hits, values very close to the ceiling score of the game (151 hits), without previous training, suggesting ease of learning, efficiency of use, ease of memorization, low error rate and subjective satisfaction meeting Nielsen's five usability requirements (Lewis, 2018).

Also, cybersickness symptoms were evaluated. In the results, only two among the eleven participants reported symptoms related to sweating in the post-test (n = 1) and another to dizziness with eyes closed (n = 1), classified as mild.

These findings are supported by the SSQ cultural adaptation study, in which Carvalho and collaborators (2011) report that virtual environments can generate uncomfortable symptoms because of exacerbated sensory interaction. The authors relate changes such as disorientation and balance disorders such as tired eyes, fatigue, dizziness.

Kim and collaborators (2017) conducted a study regarding the potential of the adverse effects of immersive gait training in the elderly and elderly with Parkinson's disease. They found that the scores increased by 3 points, after VR, for the feeling of nausea both in young, elderly or with parkinson's disease. However, the groups quickly adapted to VR.-

An interesting finding in this study refers to the greater number of symptoms reported in the initial SSQ (6/17), that is, before exposure to the game, than those reported after exposure (2/17). The greater number of symptoms reported in the pre-game may be related to apprehension for being exposed for the first time to a technology, while being aware that your performance in this task will be evaluated.

The findings corroborate the study De Vries and collaborators (2018), in which it was found that the elderly have tension in the face of virtual reality games, especially when games have fast movements. Thus, the games must be adaptable to individuals, proposing challenges, but allowing for success, as was done with the elderly participants in the present study.-

Although the usability findings are satisfactory in this study, it was decided to realize a performance analysis considering the number of correct answers, that is, the score obtained in the three attempts. There is a difference in the total obtained in the

scores between the 1st and 3rd attempts in all evaluated conditions. However, when considering the total sample (Figure 3), as well as the analysis by gender (Figure 4), the findings did not reveal statistically significant differences between the values achieved in any of the evaluated conditions.

This finding indicates that the performance of the elderly was similar and very close to the maximum score allowed by the game, which can confirm the satisfactory usability result of the Beat Saber® game of Immersive Virtual Reality in the elderly, proving to be an effective therapeutic tool. However, these findings for the performance achieved in the game must be analyzed with caution. Mainly, if we consider that the parameters of the game have been changed to easy mode in order to reduce motor and cognitive requirements. As an example, the options for failures, obstacles, pumps, steering were removed and the speed was reduced to 70%.

In addition, the number of participants may have been a limitation of this study. It is suggested that further research be carried out by increasing the number of participants and preserving the parameters of the game.

The practice of physical activity offers important benefits to the elderly population. However, engagement or adherence to physical activity is unsatisfactory due to multiple factors that may include the lack of pleasure in performing such activity. Exergames are an emerging tool that incorporates not only technology to the game and fun, but also brings sensory feedbacks to the user (Liu et al., 2019; De Vries et al., 2018).

It is important to note that when interacting with a new technology not previously experienced, the elderly in this study, although apprehensive at first, felt confident and motivated throughout the task. This demonstrates that technologies can be used to improve health and well-being.

CONCLUSION

The results obtained in this study revealed that Beat Saber® presented the best possible usability. It was shown to be safe and promising as another therapeutic tool in immersive virtual reality for the geriatric population, presenting measures of effectiveness, efficiency and satisfaction. The findings of cybersickness were sweating and dizziness with eyes closed and classified as mild. In addition, the use of technology has contributed to motivation and adherence to exercise in the elderly, especially due to the multimodal feedback existing in immersive virtual reality.

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