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Development and Evaluation of a Virtual Reality Game

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Abstract. With the ever-expanding digital gaming market and the ever more sophisticated and affordable Virtual Reality (VR) apparatus, it has been possible to apply these technologies in different areas beyond research. In education, the development of VR has grown significantly evidencing contributions to the teaching and learning processes. In Brazil, only a few research groups have developed projects that involve the development of VR for education due to technical difficulties and high costs. This article presents the development and evaluation of an VR game to support the learning of neuroanatomy. The results of the evaluation suggest that the game created is easy to use, even by inexperienced subjects in VR, and is potentially useful for teaching and learning processes. In addition, the game was considered fun and did not cause discomfort, which is common in many RV applications. Considering the results of the questionnaire on the feeling of presence, a high average was obtained (5.8), and for three of the six questions, averages above 6.1 were obtained on a scale of 1 to 7, with 7 representing the real sensation of being present in a certain place. In addition, through the open questions, suggestions for improvement have been provided for the next versions of the game.

Keywords: Virtual Reality; Educational Games; Neuroanatomy.

1 Introduction

The digital gaming market is a key player in the global media and entertainment industry and, according to Netscribes Gaming Market Research, is expected to grow significantly by $ 323.91 billion by 2023. At the same time, Virtual Reality (VR) software and hardware are increasingly sophisticated and inexpensive, allowing them to be applied in different areas, beyond research, such as training, therapy, marketing, and entertainment [2]. According to the International Data Corporation (IDC) report, global RV spending is expected to reach $ 17.8 billion by 2018, an increase of almost 95% over 2017.

According to Burdea and Coiffet [4], VR is a computational application in which users can interact with three-dimensional virtual digital environments, which reproduce

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existing or imagined situations involving the senses such as sight, hearing and touch. For Slater, VR is able to create the user's sense of being transposed into a three-dimensional virtual digital world and provide a visceral and immersive experience, although this does not always occur.

The applications of VR in education are many and there is a consensus of its benefits in the teaching and learning processes. Among the possible benefits are the possibility of expanding the perceptions of the five senses, representing more than the real state of affairs, greater engagement with the student, appropriation according to each person's rhythm, exploration instead of deduction, active learning, interacting and facilitating a global analysis and their interrelationships. The available technology and cost limitations will define the type of application to be developed in each case [5].

In addition, VR used in education in a playful way, can enhance learning through the exploitation of information, for example, proposals as clues in an immersive game, favoring the development of desired skills. [6].

In the health area, VR has been used in the simulation of surgeries, mainly for operative training of video-laparoscopic surgery, in the preoperative planning and in the intraoperative support. The images of virtual digital models have the advantage of being able to evaluate the organs three-dimensional, to observe the internal structure of the organ, to evaluate the relations between the organs with their topographies and to produce selective visions of the body. In addition, there is no time limitation for use [7].

Currently in Brazil, only a few research groups have developed projects with VR application for teaching and learning in the medical field due to technical difficulties and high cost. However, some proposals are emerging to minimize the difficulties of developing and maintaining the required systems and programs. In addition, skilled human resources, involving interaction between different areas, are being prepared for optimization and democratization in the use of this technology in teaching and learning processes [8].

Thus, this article aims to develop and evaluate VR applications to support the teaching and learning processes of neuroanatomy in order to minimize the need for management of real anatomical parts. In addition, to provide an innovative and engaging experience for the learning of neuroanatomy that allows the development of pedagogical activities with low cost, both in the classroom context, with the use of virtual reality glasses, as at home, with the use of and your smartphone.

2 The game

For simple gameplay, with few commands and rules, the first version of the game was based on puzzle games. The puzzles to be solved can test various player skills, such as logic, strategy, pattern recognition, sequencing and part-whole relationships. Games in this category involve a variety of logic and concept challenges, occasionally adding time pressure and other elements of action [8].

The game takes place in a futuristic virtual digital room, in which the brains (frontal lobe, parietal lobe, occipital lobe, temporal lobe, cerebellum, corpus callosum and brainstem and diencephalon) are randomly arranged on a table (Figure 1a). The main

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purpose of the game is to assemble the brain by joining the arranged parts, whose colors are also randomly defined with each game. The randomness of position and color of the pieces aims to maintain the challenge between matches, minimizing the possibility of solution by mere memorization of colors and positioning. Players visualize a brain as a reference and use virtual 3D virtual hands to pick up the parts by rotating and translating each part to make the fit between the parts until the whole is complete (Figure 1c). The parts being held by the player through the virtual 3D virtual hand change color as a way to provide visual feedback to the user (Figure 1b).

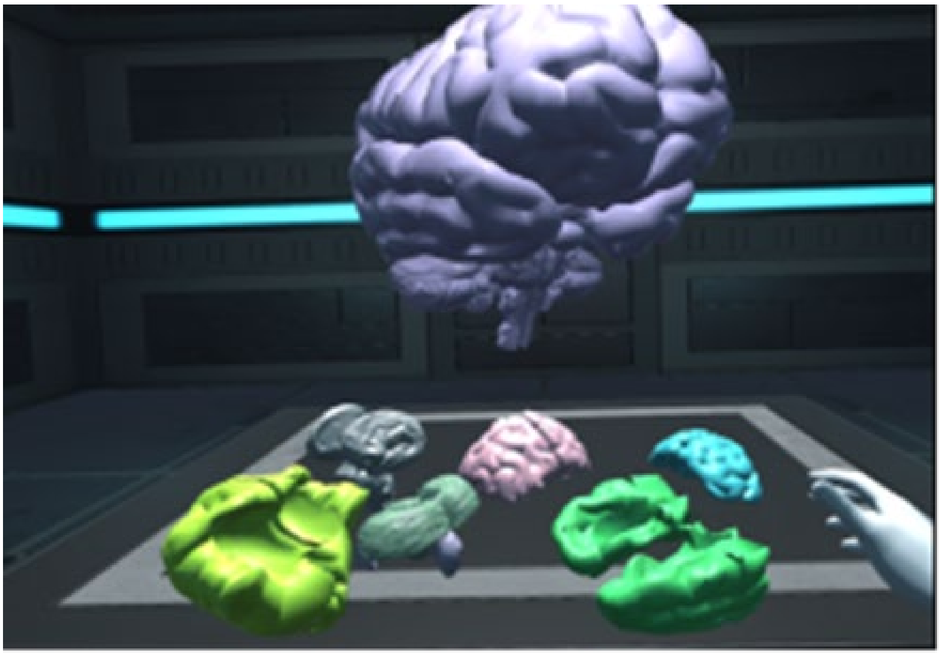

Fig. 1a. Parts to be assembled

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Figure 1b. Partial assembly

Figure 1c. Full brain

3 Evaluation

In order to carry out a first evaluation with users, the game was used by a group of 10 students from courses in health and education at a university in the south of Brazil. The

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objective of the evaluation was to identify limitations and potentialities of the game, as well as to obtain suggestions that could contribute to future versions.

3.1 Participants

A total of 10 people participated in the evaluation of the game, being 6 men and 5 women. The age range was 17 to 20 years (M = 21.8 SD = 4.8). Among the participants, there were eight students of the discipline of Neuroanatomy, two of them from the undergraduate course in Physical Education, one from Physical Therapy and five from the Psychology course. In addition to these, a student of the Social Sciences course and a master's degree in Education participated in the evaluation. As for vision problems, six subjects had no vision problems, one had only astigmatism, one nearsightedness, one astigmatism and myopia, and one with astigmatism and farsightedness.

As for the video game experience, the participants evaluated themselves on a 5-point Likert scale, 2 of whom considered themselves to be very inexperienced, 5 inexperienced, one with medium experience, one experienced and one very experienced. Regarding the VR experience, the majority of participants considered themselves to be very inexperienced, with only one participant self-rated experienced in VR. As to previous knowledge about neuroanatomy, 2 considered themselves very inexperienced, 6 inexperienced, one with medium experience and one experienced.

3.2 Materials

The game was developed at Unity3D and for evaluation a Dell XPS 8900 computer with 3.6 GHz Intel (R) Core i7-7700 processor, 16 Gb RAM and NVIDIA Gforce GTX 1060 6GB graphics card was used. For the visualization we used the Oculus Rift CV1 and for the interaction the Oculus Touch controls.

3.3 Procedure

The procedure used followed a typical protocol of evaluation with users. It began with a general explanation, followed by the signing of the informed consent form and the term of use of the image. Subsequently, a questionnaire was applied to characterize the participants and, shortly thereafter, the virtual reality glasses and the controls were adjusted in the participant to begin the test (Figure 2a). After completing the game, each subject answered a questionnaire, with open and closed questions, to evaluate the experience. Through a 5-point Likert scale, participants expressed their opinion about ease of use, fun, utility, and possible discomfort caused by VR. Already on a scale of 7 points, each participant answered 6 questions from the SUS questionnaire about the feeling of presence in the game [9]. In addition, participants recorded their understandings about the potentials and limitations of the game in open-ended questions. All matches were recorded for further analysis of player behavior by a camera attached to a tripod to the left side of the player (Figure 2a).

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Figure 2a. Student playing with the Oculus Rift and Oculus Touch controls.

Figure 2b. Graduate student using the game and the teacher and classmates watching and commenting on the game on the big screen and TV.

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4 Results and Discussion

Participants answered questions about the ease of play, the degree of fun (I had fun playing), possible discomfort caused by VR (I felt discomfort playing), on a 5-point Likert scale, varying between fully disagree and fully agree. Also, on a 5-point scale, the participants expressed their opinion on the usefulness of the game in relation to the possibilities of use for learning neuroanatomy, ranging from little useful to very useful.

As can be seen in figure 3, the game was considered easy to use (M = 4.0), even though the majority of the participants had no previous VR experience, and potentially useful (M = 4.3) for the teaching and learning process of neuroanatomy. In addition, the game was considered fun (M = 4.7) and did not cause discomfort (M = 1.9), commonly known as cybersickness in VR. Ease of use is potentially associated with the intuitive and natural way of picking up and dropping parts, provided by the use of the Oculus Touch controls, which control virtual hands. While the fun is possibly associated with the immersive experience provided by Oculus Rift and the fact of learning to play.

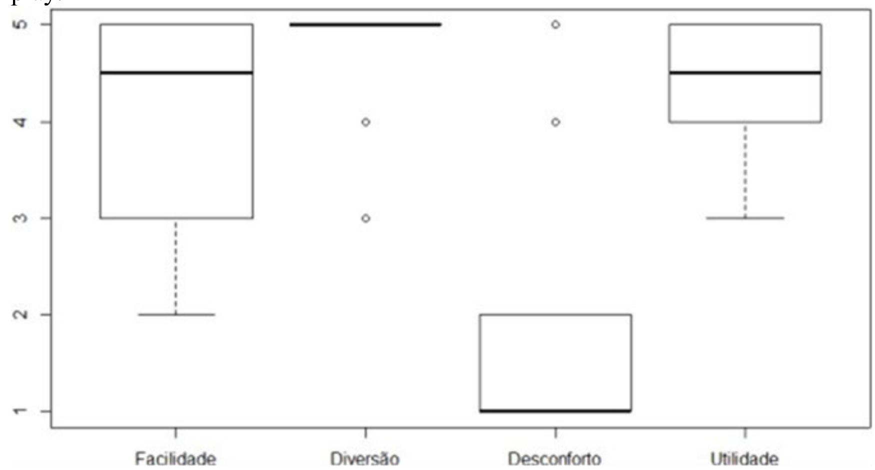

Figure 3. Bar chart referring to ease of use, fun, discomfort and usefulness of the game. The bold lines are the medians and the boxes are interquartis bands.

Considering the results of the presence questionnaire (Table 1), a high average was obtained (5.8), and for averages out of the six questions, averages above 6.1 were obtained. The SUS scale ranges from 1 to 7, with 7 being the real sensation of being in a certain location.

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Table 1: Average SUS questions on presence

SUS Question	M
1. Indicate how much you felt about the environment virtual.	6.5
2. State how much the experience seemed to be real.	5.8
3. Do you remember the virtual environment more like photos you saw or more like a place you visited?	6.1
4. During the test, your strongest feeling was being in the room where it is now or in the virtual environment?	6.1
5. Consider your memory of being in the virtual environment. What is the similarity of this memory to the memory from other real places you've been to today?	4.6
6. During the experiment, at some point you thought was really in the virtual environment?	5.0
Average SUS	**5.68**

About the potentialities of the game, it is possible to emphasize that the participants valued the experience of manipulating the parts of the brain, considered very close to reality. The verisimilitude of the virtual pieces in 3D gave confidence to the players allowing to relate the knowledge acquired previously, with the new information worked in the context of the game itself. Participants stated that the game can aid in learning neuroanatomy in a different, engaging and easier-to-understand way. When questioned about how they felt during the game, participants reported that they felt as if they were actually in another environment, a calm environment that facilitates concentration, and one participant reported that it felt like a real practical class. Among the reports, these were the most striking: subject A - "I felt as if I were actually somewhere else, as if the pieces were actually falling or making some sound"; subject C - "As if in fact it was in another environment"; subject E - "Comfortable and easy to play. It's fun to piece together and interact with the elements of the game "; guy G - "It was a fun experience, I felt a bit confused because the hands were not mine." On what each participant learned from the game, answers were obtained such as "I learned the parts of the brain", "certain positions of some structures that did not exactly remind me of their place", "Where the parts of the brain are located", besides of some records about learning the VR itself, which is the first experience for most of the participants. As in the experiments developed by Schlemmer [6], the game was understood by the players as a technology that potentiates the learning in neuroanatomy due to the possibilities of handling the anatomical parts in VR, as well as the opportunity to restart whenever necessary, recognizing and exploring the relationships of the anatomical structures and the knowledge involved. In this way, the player is allowed to learn through experimentation, interacting with the object of study, in the construction knowledge. Still, immersion in the game provided the engagement of the players who felt instigated to solve the puzzle. In this way, the immersive environment served as a triggering factor for the exploration and search for the solution of the proposed problem. The possibility of manipulating structures and their relationships enabled the emergence of knowledge in many players, generating skills that had not yet been generated before immersion in VR. From this, there is interaction and complementarity of the previous knowledge of neuroanatomy and the

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proposal of the game in VR, not being an end in itself, but with potentiality to complement the competences of the player.

As for the limitations, some difficulties related to the fitting of the pieces, the lack of sound in the virtual 3D virtual environment were recorded, not being able to undo the pieces already in place and on the precision to get the parts of the brain with virtual hands. In addition, it was recorded that the internal view of the parts is not adequately comprehensible.

In the last open question, in which the participant was invited to register comments, criticisms or suggestions, the following comments stand out: "I felt very comfortable during the game, learning this way stimulated me to want to know more about it", "It was "I think it's going to be very good for students who have no idea what these pieces are, it's easier to understand," "I suggest more information about what has and what is happening in the game (such as sound, writing, animation and / or effect ", and" it would be interesting to be able to move the reference brain for better orientation " .

5 Final Considerations

This study aimed to develop and evaluate an application of VR to subsidize the teaching and learning processes of neuroanatomy in higher education Some of these comments corroborate results obtained in closed questions, as well as suggest important improvements for the systematic use of the game in the teaching and learning processes of neuroanatomy. All suggestions are being analyzed and considered for future versions of the game, which is intended to be used as learning technology for neuroanatomy in the coming semesters, providing an innovative and engaging experience for students. A total of 10 students evaluated the game and the results suggest that the game is easy to use, fun and potentially useful and engaging for the teaching and learning processes of neuroanatomy. Participants felt strongly present in the virtual 3D virtual environment, developed for the game, according to SUS questionnaire, and valued the experience of manipulating the parts of the brain, considered very close to reality. Regarding the limitations, there was difficulty in the fitting action, lack of sound, the name of the pieces and low internal visualization of the pieces. In the next version of the game, it is intended to create clues that contribute so that the players can assign greater meaning to the functions and relations of each mounted segment. In the future, players will be able to make use of a virtual digital library to seek subsidies and broaden the process of meaning.

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