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Development of a Virtual Reality Tool for Therapy and Diagnosis of Schizophrenia

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Abstract: Schizophrenia is a serious mental disorder in which people interpret reality abnormally, often requiring lifelong treatment. In recent years new treatment methods have been tested, which include serious gaming, in particular, with virtual reality technologies. This project aims to develop a virtual reality tool capable of assisting in the therapy of schizophrenia patients. As a starting point, a systematic review was conducted in March 2021 using IEEE Xplore, Science Direct and dl.acm databases, from which 53 results were obtained, and 17 were filtered, revealing both, common aspects, as well as the differences, between healthy individuals and patients with schizophrenia when exposed to the technology and to different scenarios in virtual reality. Continued exposure to virtual reality exercises revealed improvements in the patient's quality of life, in some studies. This demonstrates that virtual reality can be used as a diagnosis and therapy tool for patients with schizophrenia. This project hopes to develop one such tool, and have it tested with schizophrenia patients while supervised by a medical team, to determine whether it is a viable alternative to traditional therapy, since it is easy and convenient to use.

Keywords: Virtual reality, Schizophrenia, Serious Games, Therapy, Unity.

1. Introduction

Schizophrenia is a serious mental disorder in which people interpret reality abnormally. Schizophrenia may result in some combination of hallucinations, delusions, and extremely disordered thinking and behavior that impairs daily functioning, and can be disabling, often requiring lifelong treatment.

Serious games are games designed to fulfil a serious goal. These games are already used in several ways, such as learning aid for children (e.g., mathematical games), or the practice of physical exercise (e.g., football).

Virtual reality (VR) technology is a type of technology that puts the user in a virtual world, with the use of VR glasses and controllers that detect the movements of the hands and head. Using VR grants the user as a feeling of immersion and presence on a" new level". VR has been evolving rapidly, being already used in several video games (e.g., Beat Saber, Minecraft, among others), as well as, in some cases, used for simulation of specific situations and environments for training (e.g., aircraft navigation simulation). However, the use of VR as a means of therapy is still a little studied topic, partly because the technology has a much faster evolution than the testing and approval period of the scientific community.

Studies comparing the use of VR in patients with schizophrenia and volunteers without any psychiatric disorder in various social, memory and spatial navigation exercises, demonstrated tendency-negative performance in patients with schizophrenia due to lack of motivation, when compared to volunteers without psychiatric disorders [1]. On some studies, continued exposure to these exercises also revealed positive improvements in test performance and quality of life on patients with schizophrenia [2]. This demonstrates that it is possible to use VR as a diagnosis and therapy tool for schizophrenia. VR can provide easily accessible realistic exercises and environments for therapy and testing, as well as supervising and recording data about the patient, which can save a lot of resources when compared to creating and finetuning exercises to each patient in real life.

This paper is organized in six sections. Section 2 defines the research methods used for this paper; Section 3 analyses various studies made on the use of VR on patients with schizophrenia; Section 4 describes the project development; Section 5 explores the problems and changes during the development process and finally, Section 6 enunciates the current and future stages of the project.

2. Methods

For this research, the terms “Virtual Reality”, and “Schizophrenia” or “Schizophrenic” were researched as keywords to be included on the abstract of all articles, or on all contents of the article for sources with few (-10) results. Sources included IEEE Xplore (yielding 13 results), Science Direct (yielding 31 results) and dl.acm (yielding 9 results), from which 53 papers in total were obtained.

Inclusion criteria were then applied as follows:

- The paper is written in English or Portuguese;
- The paper is clear and accessible;
- The paper mentions practical use of VR;
- The paper mentions solutions for therapy and/or diagnosing schizophrenia.

After inclusion criteria was applied, 38 paper remained and 15 were rejected.

Furthermore, papers were further selected if they could answer:

- How can VR help patients with Schizophrenia?
- How were VR solutions tested with schizophrenic patients?
- What were the test’s results?
- Did the tests results favor or not the use of VR as a therapy/diagnostic tool for schizophrenia?

From these questions, 17 final papers were selected, and 21 more were rejected. Lastly, they were sorted into categories relevant to the kind of research performed, including spatial navigation, task simulation, facial expression recognition, social exercises, and memory exercises.

3. Literature Review

3.1. VR Task Simulation

This consists of challenging patients with common day-today tasks in a virtual world and analyze their performance. This exercise is particularly easy to translate into their daily tasks. Some studies use a virtual store, a virtual city, or even a virtual house where tasks are performed such as shopping with an item list, exploring and navigating an area, among others. It is remarkable that the use of VR for treatment and/or diagnosis of schizophrenia was a method generally accepted by patients on some studies, with them having noted that the virtual world was pleasant, learned to use the technology without difficulties, and kept focused on the world and the tasks requested, revealing even enthusiasm for them (Fig. 1) [3].

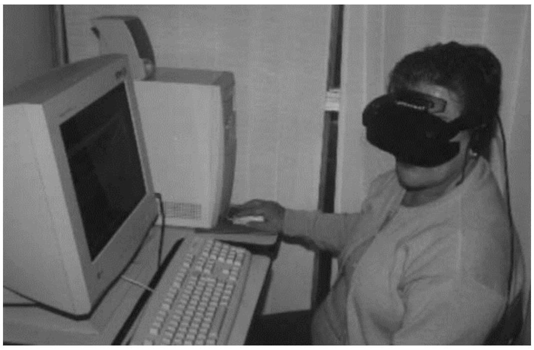

Fig. 1. Patient using the HMD (I-glasses) [3].

In several studies, the performance of patients with schizophrenia is compared to the performance of healthy volunteers in a virtual store. In each challenge, a shopping list is given, and after some time, it is withdrawn, and the challenge begins. The goal is to find all the items in the list, and “pay” for these items at the end. The results showed significant performance differences between volunteers and patients, possibly even finding different severities of schizophrenia depending on performance (Number of correct items, time spent...). In a similar study with the same task of purchasing multiple items in a store, performance in a virtual environment was compared to performance in reality, on patients with schizophrenia. The results were similar in terms of correct items collected, and very similar in terms of efficiency (distance traveled), this given that the task in the real world included a more intense social variable compared to the virtual task (existence of other customers, it was permitted to request help from the shop workers) [4].

3.2. VR Spatial Navigation

This consists of virtual world navigation, and performance analysis. This translates into the spatial cognition capacity of the patient. One of the studies carried out consists of the appropriation of the “Virtual Morris water maze” test (traditionally used for the testing of spatial cognition in animals), using VR (which has the advantage of easily creating and using environments difficult to experience in the real world). This test consists of patients repeatedly finding an invisible point in an arena using landmarks, changing their starting position in each iteration. A second test was performed, the only difference being the arena, which rotated slowly. The time spent on the task and the used route are analyzed. Patients with schizophrenia showed worse results when compared to a control group (time spent, distance traveled, among others), which demonstrates spatial cognition deficits. This was especially accentuated in the rotating arena [5, 6].

Another study consists of navigating a virtual housing area and maze. Patients received a 3D map of their virtual environment with a marked goal, and after a period of study, they navigated the virtual environment starting on a random initial position. The time used and the success or failure of the tasks are analyzed here. The results reveal that schizophrenia and schizoaffective patients have a lower performance in general when compared to a healthy group. There was also a noticeable difference in the performance of schizoaffective and schizophrenic patients, the latter having a worse performance overall [7].

In a study using an eight-arm radial maze (consisting of a center and eight possible "arms" Fig. 2) in VR, one group of patients with schizophrenia and another group of healthy volunteers were observed. Four of the eight arms contain rewards, and in each iteration the rewards are placed on the same arms. These tests working memory and operational memory, with re-entering an arm already visited correlating to working memory errors, and entering an arm that has never had a reward correlating to operational memory errors. The results reveal a significant difference between the two groups, being the schizophrenia patients group the one with the most errors of both types. Interestingly, after some iterations of the test, the number of errors in the operating memory on the schizophrenia patients group decreases, while the number of errors of working memory remained [8].

Fig. 2. View of the eight-arm radial maze [8].

Another study compared two navigation tests, one in a virtual park and the other in a virtual maze, the virtual park being rich in references, and the maze void of any references, with the goal of finding a pot of gold. The objective of this test is to observe the difference in the processing capacity of object-to-object navigation (virtual park with references) and individual-to-object navigation (virtual maze without references). Two groups participated in the tests, a control group with healthy individuals and a group of patients with schizophrenia. The results revealed significant differences in performance in the park test, with patients with schizophrenia having significantly lower performance than the control group. However, the virtual maze test revealed no significant performance differences between the two groups [9].

A similar study evaluates navigation in a virtual labyrinth without references, with the objective of comparing the processing capacity of the individual-to-object navigation in patients with schizophrenia to healthy volunteers. This test had several iterations. In general, in the first and second iteration there was not much difference between the groups, then from the third iteration the performance of the group with schizophrenia was significantly worse. Magnetic resonance imaging of the brain in each iteration revealed that the area dedicated to individual-to-object navigation was significantly decreasing over iterations in the healthy group, and the area dedicated to object-to-object navigation was increasing significantly. In patients with schizophrenia, the object-to-object navigation area remained inactive, and the individual-to-object navigation area kept similar levels of activity at each iteration. This may be because, in each iteration, the healthy group was building a mental map of the maze, effectively transitioning to object-to-object navigation, while the group with schizophrenia used only individual-to-object navigation, since schizophrenia particularly affects object-to-object navigation [10].

One study compared the performance of patients with schizophrenia with a group of healthy volunteers in a series of tasks in a virtual city, including a planning phase where you can analyze the city map and the tasks to be performed. This test analyzes the navigation phase in particular and provides the map and to-do list during the test to avoid overloading working memory, thus considering only the efficiency of the route (distance traveled when compared to a pathing algorithm A*), the amount of errors and successes achieved, and their association with demotivation in schizophrenia. The study showed that only patients with schizophrenia had strong associations in demotivation and navigation efficiency, revealing a deficiency in goal-oriented motivation. This can be caused by the inability to execute a plan efficiently, which causes demotivation [1].

3.3. VR Facial Expression Recognition Exercises

In one study, software was developed that contained human models capable of producing various expressions linked to certain emotions (angry, fear, sad, contented, satisfied, neutral), delivering context linked to this emotion in a story format told by the avatars (with lip movement). The reactions of a group of patients with schizophrenia were compared to a group of healthy volunteers. It was observed that the group of patients with schizophrenia had an abnormal fixation at sites like the avatar's forehead, or completely off the face area. This was quite different from the control group, which settled mostly on the eyes and mouth of the avatar (Fig. 3). These results have not changed even without the context told by the avatars (facial expressions only) [11].

A similar study challenged a group of patients with schizophrenia and a group of healthy volunteers to detect emotions on different pictures containing faces, including real and virtual faces, as soon as possible. The objective of this test is to understand if there is a difference between the sense of virtual and real faces in individuals with schizophrenia and/or healthy individuals.

The group of patients with schizophrenia performed generally worse in the correct identification of emotions, and there were no significant differences between the identification of emotions of real and virtual faces, except for revulsion, which was significantly more mistaken with other emotions by both groups on the virtual faces. This can be explained by the low number of polygons on the virtual face, which caused wrinkles in the nasal area to not be so pronounced (which is a major feature of revulsion) [12].

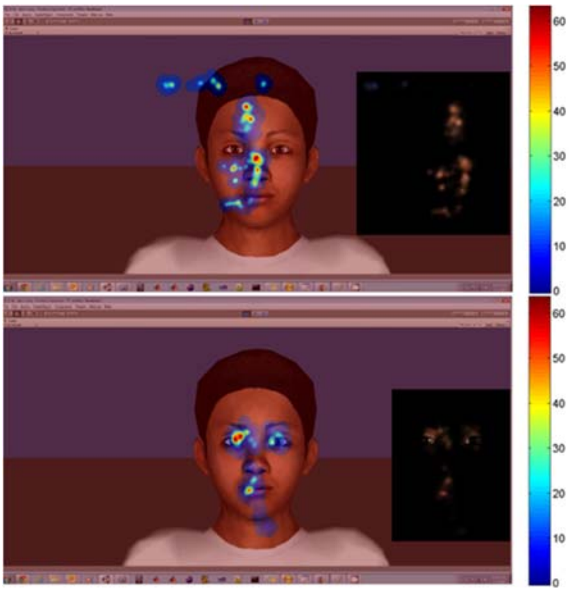

Fig. 3. Masked maps overlaid on at the side of heat map visualizations. Top figure shows the SZ group gaze while the lower figure depicts the control group gaze aggregated across subjects and trials [11].

3.4. VR Memory Exercises

In one study, it was observed the performance of a group of patients with schizophrenia and another group of healthy volunteers in an exercise that consisted of picking up objects in various locations in a virtual dwelling, and then returning them to the same place, in a given order and after a certain time, with a number of variable objects. This test revealed that the group of patients with schizophrenia generally performed worse, in terms of errors and time spent in the challenge [13].

Another study analyzed the associations of memory between objects, places, and people. The test consisted of traveling through a virtual city, to a specific place where a person (virtual avatar) and an object were waiting. After some time, users traveled to another place, with another person and object, and repeated this process several times (Fig. 4). In the end, the user tried to remember which parameter was associated to which another parameter (person, object and place).

Fig. 4. (A) Aerial view showing the layout of the virtual city, with green dashes indicating the path taken; (B) Encounter with a character paired with an object at a location; (C) An example of a recognition trial from the "Person" condition [14].

Two groups, one with patients with schizophrenia, and the other with healthy volunteers performed the test. The brain activity of the participants was analyzed, which revealed that the group of patients with schizophrenia generally had less activity around object-oriented memory, but still managed to complete the tasks, which can be explained by the main processing area of object-oriented memory not being very affected, but being the related peripheral areas affected, which make the processing faster and more efficient [14].

3.5. VR Social Exercises

In one study, a virtual boutique was created, where patients with schizophrenia performed various levels of shop worker training (organize inventory, deal with sales). The store includes a virtual manager, as well as virtual customers who interact with each other, and with the patient, in the case of the manager. Before and after these tests, the cognitive abilities of the patient were analyzed, and compared with that of patients who performed a similar exercise in a real store with a therapist as a manager. The performance study revealed that the VR group generally had better performance and more confidence in its capabilities, which can be explained by the VR environment being a safe medium when compared to real life, while allowing for an immersive experience and presence in the requested challenge [15].

In one study, the behavior of a group of patients and a group of healthy volunteers was compared in an exercise that consisted of asking all avatars in a virtual office if they could help using a new software, and later asking for money to buy a gift for the head of that office. Avatars could respond negatively or neutrally, and the dialogue was triggered manually by an examiner. The purpose of this test was to observe whether a virtual environment can create stress in patients with schizophrenia. After the tests it was remarkable that a number of patients with schizophrenia gave up on the tests due to the VR system, the task, or private issues. However, the sample of patients is not sufficient to ascertain whether the side effects of VR use caused this situation. The group of patients with schizophrenia reported, in general, having suffered more stress than the healthy group. This reveals that virtual worlds can simulate difficult situations to challenge patients with schizophrenia [16].

One study used realistic virtual avatars to simulate VR conversations with patients with schizophrenia. This was part of several therapy sessions, accompanied by a therapist. After the sessions, social tests revealed changes and improvement in social performance, with fewer negative symptoms and less social anxiety [2].

Another study challenged patients with schizophrenia to join a social context presented in the virtual world, considering the situation presented (e.g. joining a table in a canteen Fig. 5). This exercise increased in difficulty, between easy, medium and difficult. After the tests there were observed decreases in the negative symptoms of patients with schizophrenia, as well as patients reporting their satisfaction with the technology used, and the intention to continue with the tests [17].

3.6. Analysis of the Literature Review

The tests analyzed between SP and HI reveal a significant difference in performance [1, 5-7, 9-15], which demonstrates the feasibility of using VR as a diagnosis tool, since the difference in performance allows the identification of SP when compared to HI. On some studies, it was also possible to observe improvements in the quality of life of SP when continually exposed to exercises in VR [2, 15, 17], which demonstrates this could be used as a means of therapy for schizophrenia.

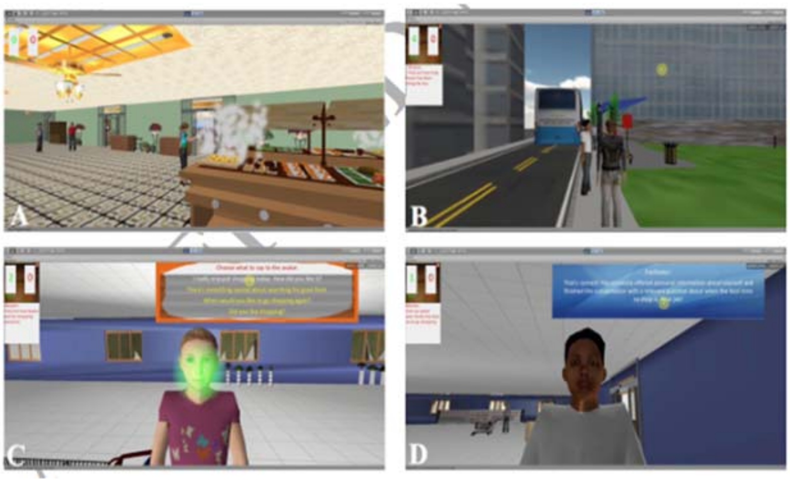

Fig. 5. Sample scenes from the virtual tool [17].

Schizophrenia is usually treated with an individually tailored combination of therapy and medicine. Personalizing therapy exercises for each SP is resource and time consuming, whereas VR therapy benefits of being easily customizable, as well as offers a safe and pleasant virtual environment for SP to try exercises they wouldn't otherwise be comfortable with, in a more exciting and engaging way [3, 15, 17]. It's notable that in some studies the VR environment was so realistic as to induce stress in virtual social environments, as it would in the real world [16], as well as produced similar results to non-VR methods [4].

Therefore, a VR therapy tool could be a valuable asset for the treatment of schizophrenia, providing safe, yet realistic environments, while being accessible and convenient to use.

The use of a VR tool in schizophrenia therapy is a novelty project, even more so considering the lack of practical tests performed in the area. Even among the few researched tests, some couldn't provide reliability to draw accurate conclusions [4, 12, 16, 18].

4. Project Development

This project aims to develop a VR tool, in the form of a serious game, capable of assisting medical professionals on the therapy sessions of patients with schizophrenia, in a convenient and interactive way.

The development of this project will receive guidance from a medical team, which will later validate the game's capability as a therapy tool with schizophrenia patients. The specific requirements that will specify the game are currently being evaluated. Patient interaction will be recorded to allow the game a continuous development and patient engagement.

The game will make use of the Oculus Quest 2 device, since it is wireless and easy to use, as well as it supports hand tracking. The game will consist of two main environments: A home environment and a city environment, where the player will be tasked with performing day-to-day tasks, of customizable and adaptive difficulty, and have its performance evaluated [18].

4.1. VR Hardware

Firstly, a choice had to be made regarding which VR system would be chosen to play the game on.

Initially it was intended for the game to be able to be played on as many VR systems as possible, however, this was later abandoned since there wasn't a universal software that would work for all platforms. Each VR brand has their own software, and with the VR systems being a relatively new technology, no universal software had yet been fully developed. This then led to focusing on the most important aspect the game required: It was relevant that the game be as immersive as possible, so the Oculus 2 Quest was chosen, which is wireless and supports *handtracking*, as well as being among the most accessible VR systems.

4.2. VR Software

For the development of the game, the Unity platform was chosen, since it supports development for the Oculus Quest 2, as well as it has ready to use frameworks with practical examples available. Three frameworks were explored during the development process: XR Toolkit (XR), OVR toolkit (OVR) and Mixed reality toolkit (MRTK). Initially, XR and OVR were both being used, with XR being the one most generally used, since XR allows integration with many VR systems, while OVR was specifically used on situations where *handtracking* was required, since XR does not support it. Later, XR was abandoned since it wasn't compatible with HTTC Vive (another VR system by steam), and replaced with MRTK, which had very similar capabilities, while being compatible with that system. It should be noted that at this point, the game was being developed to be played with either controllers or *handtracking*, so it was important to be compatible with many systems. This was later abandoned to focus solely on the Oculus Quest 2 system and *handtracking* only.

4.3. Game Specifications

The game will consist of going through a normal day and performing all kinds of daily tasks throughout. For this reason, the game will take place in a home environment (including a bedroom, bathroom, kitchen, living area and garden) as well as a city environment (including a marketplace). The tasks are to be done reflecting a day-to-day order, which means some areas or tasks may be repeated (for example, having lunch in the living area, and later returning for dinner). They are also divided into different time frames, such as morning, afternoon, and night, and they must be performed in a specific order in their specific area (teeth must be brushed in the bathroom) to be completed.

When all tasks are completed in an area in the current timeframe, the player may move on to the next area and/or timeframe.

The garden area has no tasks associated with it, being instead a general area where the player first starts the game, and calibrates the game as needed. It also serves as a general relaxing area that the player may visit to take any necessary breaks.

When all tasks in all areas and timeframes are completed, the day is completed, and the game ends.

The medical team will have access to an application in a separate computer where they can supervise and manipulate the game in real time (in the form of task difficulty). The game will also provide information about itself and the player to this application in real time (such has current progress, performance, among others.).

5. Discussion

Some changes had to be made as the development process evolved.

As stated before, initially it was intended for the game to be playable on as many VR systems as possible, which was not doable due to the lack of a common development software, so one specific VR system had to be chosen.

There were, however, other problems and details which had to be changed within the game plan itself.

Some assets within the environment had to be changed or removed, since it could be dangerous for schizophrenia patients to interact with these elements while forgetting they are in a virtual environment (for example, attempting to sit in a chair that exists in the game, but not in reality).

A calibration process had to be created to keep the player within the play area in the real world. During the game, the player can move in real space to move in game as part of the normal gameplay. However, when the area changes, the place the player is standing in, although it could be recorded for the next area, could be intersecting, or fully immersed in that area's assets (for example, appearing inside a table). To combat this, the player starts a new area in a specific position, in the centre of the area. However, this now means that there is a disparity between where the player is standing in real life (where they were before the area changed), and in game (the centre of the area). For this reason, a calibration process is required every time there is an area change, asking the player to return to the middle of the play area in real life, synchronizing the positions in real life and in game.

Some tasks also had to be entirely removed due to system limitations. *Handtracking* is still a fairly recent technology, which means it doesn't properly work in all situations. In particular, the Oculus Quest 2 heavily struggles to detect the hands when they are close to the cameras, which are in the headset, and they must be always visible in front of the cameras in order to be tracked. This meant that tasks that required the hands to be close to the head had to be discarded (for example, brushing teeth).

6. Project Current Stage and Future Work

The game is currently undergoing in its final development stages and will later be sent to a medical team for validation.

The medical team will test the game with schizophrenia patients, and later share the results.

Results are expected to include patient acceptance towards the game, any improvements to daily life provided by continued exposure to the game, comparison to traditional therapy results, among others.

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