2023 7th International Conference on Computer, Software and Modeling (ICCSM) | 979-8-3503-0581-4/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICCSM60247.2023.00022

Suitability of Dynamic Environments in Virtual Reality for Schizophrenia Therapies

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***Abstract*—Serious Games (SG) have a significant positive impact on a wide range of purposes. Serious virtual games focused on the rehabilitation of schizophrenia are able to bring improvements to patients who require constant and individualized rehabilitation. Schizophrenia is a mental illness that has no cure and requires intensive rehabilitation for symptoms relief. Virtual Reality (VR) has gained acceptance in the medical field for a variety of rehabilitation by virtue of its immersiveness and versatility. Virtual environments can assist this process, seeking to contemplate important topics for their daily lives, facilitating the understanding of their situation and difficulties. To achieve more effective results, a virtual scenario must be dynamic and suitable to each patient. Nonplayable Character (NPC), which in this work can be human-like or pet-like representations, tasks, varied and objective interactions, and the ambiance all play an important role in determining the expected result. The work described in this paper approaches previously mentioned topics by investigating the contribution of previous works in this context for approaching multiple elements that control the dynamic environment, bringing new modalities and research for the development of a SG for VR focused on the rehabilitation of schizophrenia by facilitating schizophrenics' daily lives.**

Keywords—Serious Game, Schizophrenia Rehabilitation, Virtual Reality, Dynamic Environment, Nonplayable Character

I. Introduction

With technology being used to solve many of a person's needs, it is useful to investigate the opportunities offered by electronic devices. Exploring games for purposes other than entertainment was realized to be of great benefit as one seeks to accelerate each area of research and broaden positive outcomes [1–5].

The term Serious Game (SG) was used to describe games that use the psychological characteristics of games for teaching and learning. Gamification challenges the player to explore a new reality and meet important objectives that can culminate in training, study, therapy, or challenge for the player, while retaining the emotions that a game provides. SGs are already widely accepted by medical professionals in health care as having real effectiveness, whether in more general issues such as sports, habits, and relaxation, or in training issues such as surgical operations, dental operations, or in therapies such as physical therapy rehabilitation, emotional behavior, and mental illness rehabilitation. Autism, Down syndrome, schizophrenia, and other mental illnesses have all been largely explored in SGs.

Following the perception of such advantages, the search for the intensification of therapy processes became critical for the progression of results. When it comes to games, immersion is vital for the player's experience. Virtual Reality (VR) is becoming a key technology for immersive experiences, opening up new possibilities. As a result, SGs have been widely developed in VR because they combine several important aspects while remaining entertaining.

The current work belongs to the GreenHealth[1] project and investigates these mentioned areas and creates a dynamic virtual environment in VR based SG focused on schizophrenia rehabilitation [6, 7]. To accomplish this, it explores aspects of the environment for the player's experience, requiring to complete several tasks involving interaction with Nonplayable Character (NPC)s and other elements of the scenario. Because the focus is on rehabilitating the patient, it is also investigated the use of devices that can increase immersion in the game and measure vital signs in real time, allowing the game to adapt to each type of player. The following section will discuss significant researches done within the scope of this work.

II. State of the Art

VR permits a wide range of applications in SGs for the health sector, which necessitates scientific research to study and document the development, tests, and results obtained. Macedo, Queirós, and Marques conducted a systematic review to assess the advancement of the use of VR for the rehabilitation of schizophrenia [8], concluding that all studies show an effective combination. This is consistent with the findings of Shen, Liu, Wu, Lin and Wang [9], who tested social cognition and interaction training using traditional methods and with the addition of VR, and discovered that the use of VR improved emotion perception and metacognition in schizophrenics.

The use of VR based SG has also been shown to improve cognitive function, as demonstrated by the work of Amado et al. [10], who reported decreased stress, improved planning and resolution of daily tasks, and improved rhythm in the lives of schizophrenics. A study conducted by Rus-Calafell, Gutiérrez-Maldonado, and Ribas-Sabaté [11] on the use of a VR program

GreenHealth, Norte-01-0145-FEDER-000042.

[1]The GreenHealth project intends to increase human health, environmental sustainability and economic development by utilizing digital and biological technology.

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DOI 10.1109/ICCSM60247.2023.00022

focused on social skill and cognition revealed an improvement in anxiety, discomfort, and social avoidance. Fitzgerald and Ratcliffe focused on the gamification of a SG in order to engage people with serious mental illnesses and improve rehabilitation outcomes [12]. Wang, Kou, Meng and Yu conducted a study [13] with sixty-four schizophrenics under psychiatric care to investigate the effects of a serious virtual reality game on the patients' cognitive function. When they analyzed the study's results, they noticed a significant improvement in the schizophrenics' working memory and executive function, nevertheless they recognize the need for more research on this correlation of technology and serious goal.

Curtis et al., investigated the use of a quadruped with intelligent autonomous movement and actions [14], exploring several relevant issues to the main theme, such as suspension of disbelief, believability, and emotions, as well as presenting thirteen principles of believability for the NPC and procedural animations corresponding to each player action to the quadruped's actions and emotions. Focusing on its movement, Kim, Lee and Kim proposed a new method for generating a path for the NPC using the player's movement information, providing a more interesting locomotion of the scenario [15], and it uses the same tools as the current work, as shown in section 4, VR Dynamic Scenario.

Lovreglio et al. presented two prototypes for evaluating how people behave when evacuating buildings in emergency situations [16], specifically in a hospital during earthquakes, they use a VR based SG to verify how NPCs should act and interact with the player, among other things. Other works are also interesting, such as the one by Ding et al. [17], which creates a behavioral simulation of a virtual cyclist, using several characteristics such as the virtual player's exhaustion, path, air resistance, temperature, humidity, distance traveled, and so on, in addition to using Newton's second law and tools similar to the present work, which can be seen in section 4, VR Dynamic Scenario.

III. Related Work

This section discusses previous work developed within the same project named GreenHealth[1]. The main goal is to create a SG to aid in the rehabilitation of schizophrenia [6], for which various tests were required. The game will address characteristics and serve as the foundation for the current work.

A. Scenario Testing - VR Scenarios to Treat Mental Health

The first research sought to design a virtual scenario for development to the VR based SG that would be beneficial in schizophrenia rehabilitation procedures [18]. The possibilities raised were a house, a park, and a subway station that served as a starting point for the project. The house scenario was first selected, because it is a safe environment and under control by the patient. This improves the application's familiarity, comprehension, and effectiveness.

B. Equipment Testing - Virtual Reality Haptic Device for Mental Illness Treatment

The second one, focusing on testing new equipment for the main purpose, provided new ideas for implementation using a haptic vest to verify that it could increase the immersiveness of the player when using VR, kicking off research with the goal of improving schizophrenia rehabilitation in a SG using haptic devices [19]. The NPCs were already important because of their potential interaction with the player, such as such as bumping something or simulate a real hug through the virtual one.

Also, experimenting with the vest's interaction with virtual walls. When tested on students who did not have schizophrenia, both tests were shown to increase immersion by a certain percentage. Various positive and negative emotions were felt for these set of devices, opening up new possibilities for future works.

C. Vital Signs Capture Testing - Measuring Vital Signs for Virtual Reality Health Application

The last one focused on smart devices for vital measurements as a smartwatch to record vital signs in real time, while playing the SG, specially the heartbeat rate [20]. Such devices offer a variety of possibilities and applications that could be combined with the other ones used in previous research to provide new opportunities for the project.

It is of great benefit to receive the schizophrenic's vital signs while in rehabilitation. These measurements are stored for medical analysis and will be returned to the SG, making it more adaptable to each player and improving the rehabilitation by the science of the patient's situation in real time. This necessitated the development of a method to enable and facilitate the use of such data for medical purposes, which could then be presented in an attractive way.

The collected data is displayed on a monitoring dashboard (Fig. 1), where the technical therapist can track the progress of the rehabilitation. The screen was divided into modules, each of which is responsible for displaying a specific set of data. The dashboard displays the data in an organized and intuitive manner as a result.

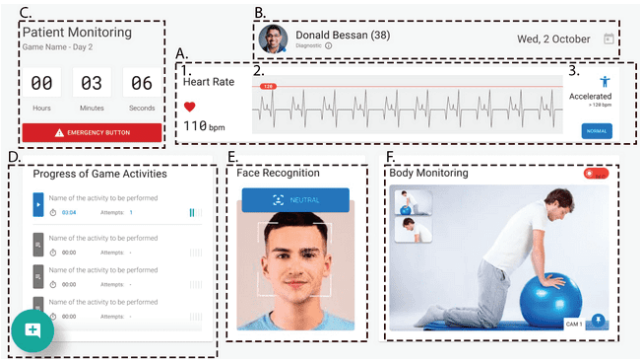

Fig. 1. Monitoring dashboard: (A) Heart Rate; (B) Patient and date information; (C) Current section; (D) Activities; (E) Facial monitoring; (F) Body monitoring.

Fig 1 (A) depicts the module focused on displaying heart rate variation was divided into three sections: (1) current heart rate, (2) variation graph, and (3) current amount of movement. The heart rate is recorded every 5 seconds, and the value appears outside the graph to emphasize the current moment. The graph chosen for the presentation was a line graph with points representing each reading. The graph also includes a horizontal

line that defines the maximum heart rate based on the amount of movement shown on the right side of the graph, allowing the therapist technician to determine whether the person being treated has a high heart rate or is within the expected range.

The dashboard will also display other information, as shown in Fig. 1, such as (B) data of the patient playing the SG and the current date, (C) data of the current section by showing the duration and the possibility for the doctor to press the emergency button in case the patient panics, (D) stipulated activities for the game and their information, (E) facial expression recognition using Artificial Intelligence (AI) with behavior information, and (F) use of cameras to check the body movement during the section.

IV. VR Dynamic Scenario

Several updates were made during the development process of the SG by decision of the GreenHealth[1] project members, which include researches and medical team, as well as considering the results and understandings of the tests done with each implemented feature. Focusing on the rehabilitation of schizophrenics, it was decided that the initial rehabilitation procedures would take place in a virtual house, going through several tasks that must be complete daily. The scenario and implementations were created in Unity, and modeling was done in Blender or retrieved from Three-dimensional (3D) model repositories [21–27].

Such tasks also extend to the exterior of the house, allowing for the implementation of a garden, as seen in Fig. 2, with important daily actions, as discussed later in subsection 4.2, Scenario Interactions. Aside from the house itself, the garden includes a domestic animal, plants, and other complementary objects and sounds, as well as the area outside the house, which includes vehicles, houses, trees, various ambiance objects and sounds, and the NPCs, which is one of the work's main subjects, as seen in Fig. 2 (A), (B) and (C).

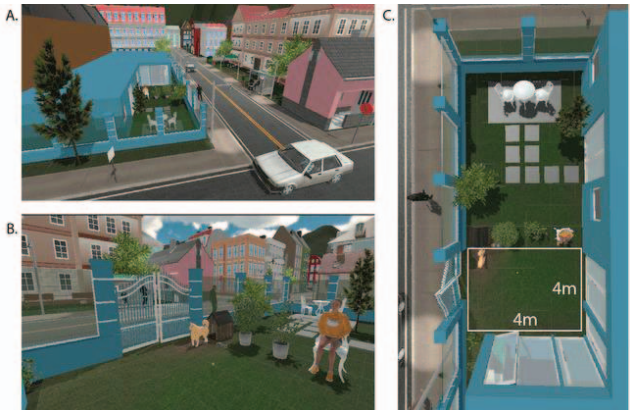

Fig. 2. Scenario Viewpoints: (A) General View; (B) Player View; (C) Garden Top View.

VR goggles have limited processing power when compared to modern computers, which must always be considered to ensure fluid gameplay. As a result, the 3D objects were polygonally reduced using Blender's Decimate modification tool, making them lighter [22, 28]. Objects closer to the player had little polygon reduction, while those further away had more significant one, so that the player would not notice the decrease in graphic quality of the objects. Because the playable space has a real and virtual area of 4 meters by 4 meters, illustrated in the white square of Fig 2 (C), 3D objects near this space have higher graphical quality.

A. NonPlayable Characters and its Features

A Nonplayable Character, abbreviated as NPC, is an entity in the game which cannot be controlled by the player. As a result, it must be programmed to behave in a particular manner, which will be covered throughout this section. As shown in Fig. 3, there are two types of NPCs in the garden scenario: pet-like ones with the option of being a dog (Fig. 3 (A)) or a cat (Fig. 3 (B)) [29–31], and human-like ones with textures representing men and women inside the garden area (Fig. 3 (C)) or other ones outside it (Fig. 3 (D)) [27].

Fig. 3. NPC: (A) Dog; (B) Cat: (C) Internal humans; (D) External humans.

Pet animations can include moving, lying down, spinning around, eating or drinking something, while humans walk, wait at a crossroads, and talk, among other things. Each one also has sounds assigned, being for dogs the bark, cats the meow, and humans the voice and music for those with some musical device, as well as sounds for vehicles, birds, and others to complement the environment. This allows to create a more dynamic scenario in which several events occur without the player's intervention, however actions during gameplay can change aspects of the environment, such as NPC interaction. All of the details discussed will be thoroughly evaluated and used only with the assistance and approval of a specialized medical team, which is critical in transforming the dynamic scenario suitable for therapy and achieving the desired goals of being the most beneficial rehabilitation for schizophrenics.

Since each NPC must behave differently, distinctive implementations were created for their various purposes. Some of them can move randomly through the scenery, others on a predetermined path, and still others do not move but have standard animations assigned to them.

The random movement was defined for the pets so that they could freely walk through the garden space, which is the 4 meters by 4 meters area shown in Fig. 1 (C), giving the NPCs a more organic and realistic sensation. It used the Navigation Mesh framework, also known as NavMesh, Unity's native AI implementation for virtual character movement [21, 32]. Such implementations can help schizophrenics relieve stress when interacting with a pet.

Fig. 4 (A) depicts simple reduced code for such an implementation, which makes use of the `UnityEngine.AI`

library, using the `SetRandomDestination` function to find a point within the scene's allowed travel area and uses the `SetDestination` command to move the NPC there. The `Update` function manages the random destination substitution, in which it sets the water bowl as the point of interest every 40 Seconds (secs) and triggers the pet to go to the water bowl, resetting the time and randomly setting new destinations, as well as retrieving the player's thrown ball, as shown in Fig 4 (B).

A.

```
using UnityEngine;
using UnityEngine.AI;

public class FreeMovement : MonoBehaviour{
 private void SetRandomDestination(){
  float rx = Random.Range(floorBounds.min.x, floorBounds.max.x);
  float rz = Random.Range(floorBounds.min.z, floorBounds.max.z);

  Vector3 moveTo = new Vector3(rx, transform.position.y, rz);
  agent.SetDestination(moveTo);
 }

 private void Update(){
  timer += Time.deltaTime;

  if(timer <= 40)
   SetRandomDestination();
  else{
   agent.SetDestination(petWaterBowl.transform.position
                        + new Vector3(0f, 0, 1.2f));
   timer = 0;
  }}}
```

B.

Fig. 4. Random movement: (A) Random movement code; (B) Dog movement.

The predetermined movement was defined for the vehicles and NPCs representing humans that walk along the sidewalks outside the garden, as seen in Fig. 5 (A) and (B) respectively. The Bézier curve [33] was used to accomplish this, in which control points (yellow circles with numbers) are defined and connected by curves (white cubes) that can be adjusted by control rods (cyan circles), allowing objects to move along this defined path. To better control the objects along the path, a collision check with invisible objects (green cubes) on the path was implemented, to which commands such as stop and restart movement can be defined. All of these settings are only visible in Unity, not in the game.

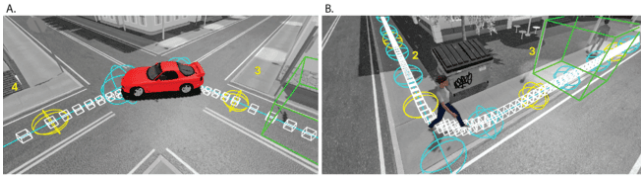

Fig. 5. Predetermined movement: (A) Car; (B) Human.

It allows vehicles to stop at crossroads or NPCs to stop walking, for example, which is useful for interaction where the NPC stops to talk to the player. To avoid the schizophrenic experiencing a sense of space invasion, the NPC remains on the sidewalk and does not enter the garden. The interactions for the garden scenario are described in the following subsection.

B. Scenario Interactions

The interaction between the player and the game is one of the most important aspects of gameplay, and it is essential for good engagement and enjoyment [34]. Several interactions were defined for the garden, focusing primarily on the rehabilitation of schizophrenia by performing various daily tasks. As shown in Fig. 6 (A), such interactions are displayed on a cell phone and organized into groups. Each interaction has a specific goal and is designed to aid in the rehabilitation of the schizophrenic.

It is possible to receive instructions from a housemate sitting in the garden who can help remember pending tasks (Fig. 6 (B)) and some goals were designed for tasks, such as having human contact by waving and interacting with someone passing by on the street (Fig. 6 (C)), or cleaning by removing leaves from the ground and weeding from the plants, as well as petting, feeding, and putting water to the pet, watering the plants, observing and hearing the environment.

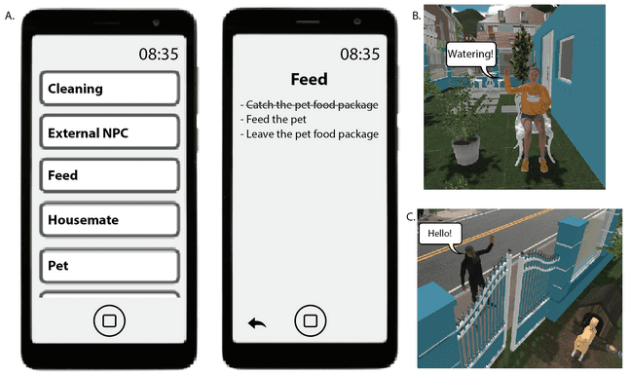

Fig. 6. Interactions: (A) Tasks; (B) Tips; (C) Conversation.

To improve clarity and comprehension, such tasks were assigned an average time in secs for total execution, including the average time of thought and action of the player, and categorized into goals such as Cleaning, External NPC, Feed, Housemate, Pet, Scenario, and Water, as shown in Tab. 1. In addition, it is also exposed the adaptation of the scenario or NPCs for such actions and their respective average time, which makes the developed scenario more dynamic, improving the game experience to the player, reflecting on a better experience for schizophrenics. Some tasks are dependent on others, such as the need to get the hose before watering the plants, but the majority of them are independent, allowing the player to complete them in different orders.

TABLE I. SCENARIO INTERACTIONS

Goal	Player task		Environment response		[a]
	Player action	*~Time*	*Activity response*	*~Time*	
Cleaning	Catch the rake, clean the leaves and leave the rake	17 secs	Leaves disappear	5 secs	→
	Remove weeds from plants	20 secs	Weeds disappear	12 secs	→
External NPC	Walk towards the NPC	8 secs	NPC waits	10 secs	→
	Respond "Hey friend!"	7 secs	NPC says "Good morning!"	4 secs	←
	Respond "Great, thanks!"	7 secs	NPC says "How are you?"	4 secs	←
	Respond "See you!"	7 secs	NPC says "See you later!"	4 secs	←
Feed	Catch the pet food package, feed the	18 secs	Pet approaches when with the	15 secs	→

Goal	Player task		Environment response		[a]
	Player action	*~Time*	*Activity response*	*~Time*	
	pet and leave the pet food package		package, bowl fills with food and pet eats the food if hungry		
Housemate	Walk towards the housemate	8 secs	Housemate says "Hey my friend!"	4 secs	←
	Hug the housemate	5 secs	Housemate stands up to hug	5 secs	←
Pet	Circular hand gesture to the right to make the pet roll over	4 secs	Pet approaches and rolls over	8 secs	→
	Circular hand gesture to the left to make the pet spin around	4 secs	Pet approaches and spins around	8 secs	→
	Top to bottom hand gesture to make the pet lie down	4 secs	Pet approaches and lies down	6 secs	→
	Catch and throw the ball	8 secs	Pet seeks for the ball and returns it near the player	10 secs	→
Scenario	Approach the gate and observe the scenario	15 secs	Increases the flow of cars and NPCs in the environment	15 secs	→
Water	Take the hose, give water to the pet and leave the hose	15 secs	Bowl fills with water and pet drinks the water if thirsty	8 secs	→
	Take the hose, give water to the plants and leave the hose	15 secs	Plants change to a more vivid color	10 secs	→

[a.] Direction of Action: Right arrow indicates initial player action and environment response, while left arrow indicates initial environment action and subsequent need of player action.

Both options can be used multiple times, allowing for continuous interaction in the game, though only one resolution of the interactions is required. During tests with the medical team, it was discovered that the pet becomes a major attraction in the scenario, so its interactions are possible at any time. The hand gestures mentioned in Tab. 1, such as circular hand move to the right for rolling over, circular hand move to the left for spinning around and top to bottom move for lying down, as shown in Fig. 7 (A), (B) and (C) respectively, can provide a pleasant experience to the player.

After completing all of the required tasks, the player may be directed to a new environment, either indoors or outdoors, that explores other important points to consider regarding schizophrenia rehabilitation. Because the external environment can change for circumstances such as light, time, and weather, among other factors, its dynamization becomes even more extensive.

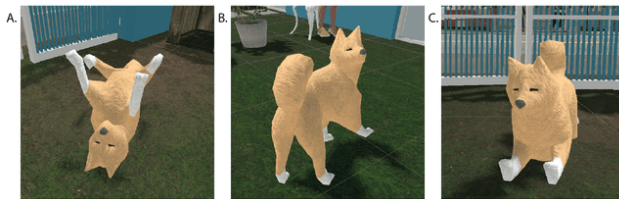

Fig. 7. Gestures: (A) Roll over; (B) Spin around; (C) Lie down.

With this, it is possible to explore new opportunities as well as better manage the emotions of the players by the dynamic environment, becoming interesting the implementation of AI to command such definitions, and also taking as a basis vital signs of the player, taken by the smartwatch and sent to the game in real time.

V. Conclusions and Future Works

The present research explored the process of planning and developing a dynamic 3D scenario for VR based SG, focused on schizophrenia rehabilitation. To accomplish this, it addressed the significance and outcomes of previous works that culminated in the current one, as well as the characteristics of the virtual environment and its potential applications, providing several common interactions of everyday life. The game seeks to be suitable to the patient by the response to the actions taken throughout the gameplay for a better adaptability and experience to the schizophrenic patient.

The scenario takes place in a safe house's garden, measuring 4 meters by 4 meters, and invites the player to participate by exploring and performing tasks, as well as interactions with NPCs, which can be pet-like or human-like, with each having specific behavior. A predetermined movement implementation was carried out, using paths defined by Bézier curves, and random ones. The predetermined movement has points of interest where the object can be stopped or restarted, whereas the random movement has points of interest where the pet-like moves more frequently. The human-like NPCs can be found outside the garden, complementing the scenery or interacting with the player in a simple dialog, or inside the garden, acting as a friendly housemate who can provide tips or remind the player of pending tasks. The pet-like ones provide emotional relief by allowing the player to interact, feed, give water, and command it to perform an action using gestures.

As shown in the study of the art section, VR based SGs have been standing out in the health field due to the growing demand for research in the area and the good results obtained. The work has complex aims, so having the support of a medical team is essential to ensure the studies result in an improved and effective rehabilitation that is adaptable and respectful to each schizophrenia patient. Making the virtual scenario dynamic is also important so that the game does not become too tiring or repetitive, resulting in a more interesting and suitable experience.

Future work will concentrate on improving the scenario, adding more interactions, and improving the existing implementations. Following its evolution, tests first with people without any mental illnesses and later with schizophrenics will

have a fundamental role in the decision of insertions, changes or removals of characteristics of the SG, something that will be widely verified and tested by the work's medical team. Furthermore, we intend to incorporate previously developed work on larger scales, enabling us to create new scenarios with new situations and interactions, use haptic devices for new purposes, and smart devices for better measurement and analysis of schizophrenics' vital signs, all culminating in a more effective VR based SG to aid in rehabilitation of schizophrenia.

ACKNOWLEDGMENT

This work is funded by the European Regional Development Fund (ERDF) through the Regional Operational Program North 2020, within the scope of Project GreenHealth - Digital strategies in biological assets to improve well-being and promote Green health, Norte-01-0145-FEDER-000042.

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