OSJ | OPEN SCIENCE JOURNAL

RESEARCH ARTICLE

Simulating Schizophrenia through Virtual Reality and Artificial Intelligence

Andrew Cachia Msc[1], Vanessa Camilleri PhD[1], Alexiei Dingli PhD[1], Josianne Scerri PhD[2], Paulann Grech PhD*[2], Alexei Sammut PhD[2]

[1]Deparment of artificial intelligence, Faculty of ICT, University of Malta, Malta
[2]Department of Mental Health, Faculty of health science, University of Malta, Malta

*Corresponding author: Paulann Grech: paulann.grech@um.edu.mt

Citation: Cachia A., Camilleri V., Dingli A., Scerri J., Grech P., Sammut A.. (2024) Simulating Schizophrenia through Virtual Reality and Artificial Intelligence. Open Science Journal 9(1)

Received: 16th April 2023

Accepted: 24th November 2023

Published: 13th February 2024

Funding: The author(s) received no specific funding for this work

Competing Interests: The authors have declared that no competing interests exists.

Abstract:

This research project presents the use of Artificial Intelligence in a Virtual Reality simulation to immerse the player in a virtual world and experience the symptoms that a person with Schizophrenia would experience. The simulation features a number of simple tasks which the player needs to attempt, whilst at the same time facing challenges due to the effects of Schizophrenia, taking place in the form of both visual and auditory hallucinations. Artificial Intelligence is applied to the interactive narrative to allow the storyline and characters to adapt to the user's actions, thus increasing the immersiveness of the experience. A pilot study with 58 mental health nursing students was carried out at the Department of Mental Health, University of Malta. Participant feedback from the evaluation sessions give indications that the project was well accepted and achieved the desired outcomes of increasing awareness and fostering empathy for people living with Schizophrenia. 91.4% of users who evaluated the system stated that the simulation has helped increase their understanding of Schizophrenia.

Keywords: Schizophrenia, Psychosis, Hallucinations, Virtual Reality, Artificial Intelligence, Mental Health Simulation

Introduction

Schizophrenia is a mental disorder characterized by a distorted perception of reality. This includes hallucinations, confused thinking and distorted emotions. Throughout the years, researchers have repeatedly attempted to incorporate technology to improve mental health as well as public understanding of it. Virtual Reality (VR) and Artificial Intelligence (AI) are two technologies that are rapidly gaining popularity, especially in their use in simulations and training. However, not only are these two technologies rarely used in conjunction but so far, they have not been examined for specific use in schizophrenia.

Creating a truly immersive experience using a combination of these two technologies could allow one to really understand and feel what a person suffering from schizophrenia experiences, giving the user more insight on how best to assist the person suffering from those symptoms.

The integration between AI and VR seems to manifest itself in two main forms. Intelligent Virtual Environments are environments within the virtual world that are dynamically designed and created through the use of AI, using techniques such as Genetic Algorithms [1] or where the environment takes the role of an actor and dynamically responds to the user's actions [2].

On the other hand, Intelligent Virtual Agents refer to actors within the virtual world who can observe and react to the user's actions in an advanced manner. The role of autonomous agents has become increasingly important throughout various different industries, especially for training. Examples of such systems include STEVE (Soar Training Expert for Virtual Environments) [3] and Jacob [4], which are autonomous pedagogical agents who monitor students and provide feedback, whilst training them to use specific machinery.

Virtual Reality has already seen adoption within the sphere of mental health, with one particular emphasis being that of treating anxiety disorders through virtual exposure therapy [5]. The person suffering from anxiety can be exposed to the specific feared situations that trigger anxiety through a VR simulation. This allows them to face up to their triggers and learn coping mechanisms.

Another successful application of Virtual Reality for mental health was a project done to raise awareness for children with autism [6]. The authors created a virtual reality application that mimics the experience of an autistic child whilst at school. The objective is to foster empathy for children suffering with autism, as well as provide education and increase awareness about the mental illness. The results showed an increase in the users' level of understanding about autism of 32%.

Virtual Reality has also been used to aid persons with AutismSpectrum Disorder (ASD) [7] or children with high-functioning autism [8]. Since these persons tend to have difficulties in learning, a virtual reality environment was created that provided the necessary training required for the patients, in an environment that was free from distractions that may provide negative triggers to the patients.

Freeman [9] claims that the occurrence and intensity of hallucinations is affected by the social context. In this view, he proposed the use of virtual environments to study the environments and contexts which trigger patients suffering from schizophrenia. Such environments may also act as a platform on which professionals and the people who they support can begin working on treatments and test out their effectiveness.

Another example of using Virtual Reality in relation to Schizophrenia was described in a study where authors used Virtual Reality for social skills training (SST) for persons living with Schizophrenia [10]. The results showed that the SST using VR role-playing (SST-VR) group improved more in conversational skills and assertiveness after the STT session than the SST using traditional role-playing (SST-TR) group, but less in nonverbal skills.

An increasingly popular use of AI within the entertainment medium such as games or movies is the concept of interactive narrative, or interactive storytelling. The idea is that rather than having a set storyline, or a set sequence of events or actions occurring, the story should adapt to the user's actions and change accordingly. This also means that each time the story is run, a different outcome should occur.

Charles et al. [11] describe two different techniques for performing AI planning. The first one is a Hierarchical Task Network (HTN), in which each task that can be achieved by a character within the game is broken down into smaller subtasks until they are primitive actions that can be performed. A basic temporal structure is preserved for the high-level actions or goals, while offering flexibility within the lower-level actions. On the other hand, a Heuristic Search Planning (HSP) algorithm operates differently. HSP uses a STRIPS (STanford Research Institute Problem Solver) based approach to represent the problem description. A number of actions are specifed, along with the pre-conditions required to execute that action, as well as the effect on the world-state conditions of that action. This algorithm instead takes a bottom-up approach, by performing a heuristic search across the different actions, to determine the combination of actions that will achieve the desired narrative goal. The authors go on to conclude that although a HTN does have a number of benefits, an HSP will not only provide more flexibility in terms of storylines but could also result in a number of unforeseen circumstances and interactions occurring, which could create comical situations as well as enhance the credibility of the story.

Whilst Pizzi and Cavazza [12] also make use of HSPs, they explore it in a more advance manner. Thus, rather than defining story events as the narrative goal, the system incorporates the virtual characters' psychology and feelings into the equation. The goal is now a desired state or feeling for the character, and the story will unfold according to the desired state the character is trying to achieve.

Current project

The current project is part of an ongoing collaboration between the Department of Artificial Intelligence and the Department of Mental Health at the University of Malta, to provide support and foster empathy for person-centred care. New and innovative technologies are being explored as part of the approach to enhance the student's learning experience.

The aim of this study was to create a tool that can be used by students to allow them to experience an immersive simulation of what suffering from certain symptoms of schizophrenia would be like. This project was a pilot study, and it was decided to recruit psychiatric nursing students who have already been exposed to dealing with such mental health illnesses.

Current techniques used to increase understanding around these mental illnesses usually involve role-playing. One such example would be having the student attempting to have a conversation with another student, whilst someone would talk behind the person's ear to mimic the effect of auditory hallucinations. This project aims to not only automate this whole process, but also to enhance the level of immersiveness and realism of the scenario.

The current project involves a virtual simulation that allows the user to experience specific symptoms of a person suffering from schizophrenia, specifically visual and auditory hallucinations. Artificial Intelligence is used in the form of an Interactive Narrative to enhance the immersion of the simulation, with the outcome of the story being influenced by the user's actions and decisions. To achieve this, the following objectives were identified, to:

Create an immersive simulation experience designed to facilitate an increased empathic behaviour towards patients diagnosed as suffering from schizophrenia.

Embed Artificial Intelligence within the system to monitor the user's actions and adapt the storyline and virtual environment accordingly. The concepts of Interactive Storytelling and Autonomous Agents were used to allow the creation of multiple believable storylines within the simulation.

Use Artificial Intelligence to control the hallucinations and enhance their realistic aspect.

Investigate the participants' reactions to the simulation and determine any differences in reactions between different categories of participants.

Due to the sensitive nature of the topic of this study, as well as the various ethical challenges present, several measures were taken to safeguard the participants. The highly immersive effect of the experience could easily have negative consequences on the users. For this reason, we limited the participants of this study to a mental health nursing cohort consisting of individuals who are already exposed to the various kinds of mental illnesses. The participation and data collection were performed in line with the recommendations suggested by Cyr et al. [13]. Gate keepers were appointment for the participant recruitment process to prevent any form of coercion by the main researchers.

Technical challenges arose due to the innovative combination of Virtual Reality and Artificial Intelligence. So far, there has been a dearth of research done in this area. Apart from this, another major issue in determining the whole success of this project was that of truly capturing the experience of a person suffering from Schizophrenia, imitating it in a realistic and convincing fashion, and conveying that experience to the user.

The user should also need to feel engaged and immersed in order to be able to empathise with people who have been diagnosed with Schizophrenia. This is not trivial since emotional responses vary between different users, therefore impacting their level of engagement. In this view, another issue to be tackled was that of tailoring the experience to each user, enabling within them the right level of engagement - meaning the user should not be too overwhelmed or too bored. To measure the outcome of this goal, we were reliant on user feedback, and needed to collect it in a structured and explainable format.

Materials and methods

In the current project, an Interactive Narrative in the form of Autonomous Agents driven by HSPs was implemented. This decision was based on recommendations derived from literature on the topic and on the researchers' conclusion that this would be the most favourable choice for this type of scenario. The use of an Interactive Narrative was intended to enhance the Virtual Reality experience by making it more realistic and helping to increase awareness around the symptoms present when dealing with Schizophrenia.

AI in the form of an interactive narrative was used to control the outcome of the storyline and the actions taken by the agents within the simulation. In this manner, the user's actions and voice commands are fed to the system, allowing the agents and environment to react accordingly.

The diagram in Figure 1 demonstrates the various components that make up the system, and how they integrate together.

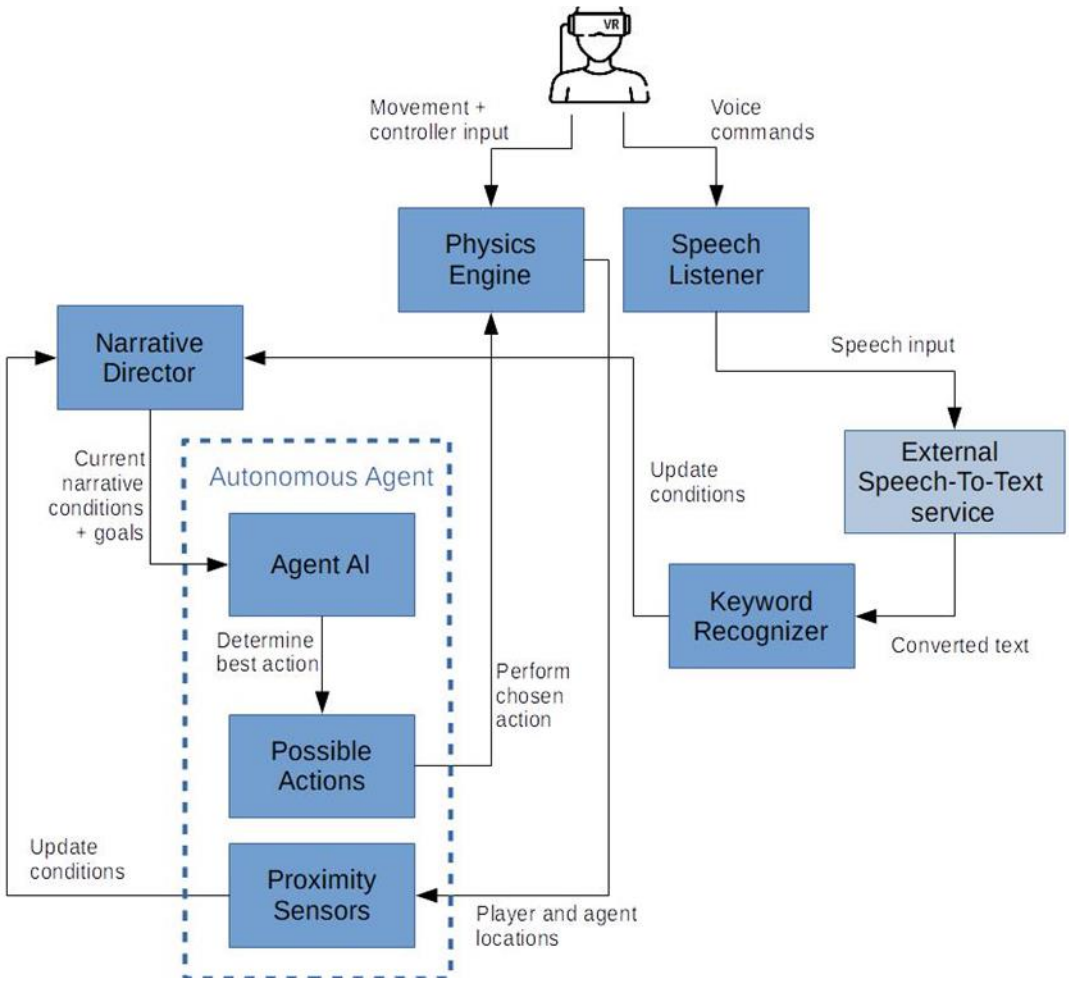

Figure. 1: Overview of the various software components within the system. (Source: self)

Platforms and technologies

Oculus Rift - The Oculus Rift is one of the most popular Virtual Reality devices available. It is comprised of a VR headset, an inbuilt microphone, headphones, external sensors, and controllers. Two types of input controllers were used due to resources that were currently available to the research team. One system made use of an Xbox controller, whilst the other used the more recent Oculus Touch controllers. There were two main reasons for choosing the Oculus Rift as the Virtual Reality platform of choice. The first reason is that Oculus is a high end, powerful VR system, that can maintain a high graphics quality. This is advantageous as the better the quality, the more realistic the simulation will seem. The Oculus Rift is also a system that has been tried and tested, and has been in the market for a relatively long time. Using a portable but lower end system, such as the Samsung Gear VR or Google Cardboard, might have raised quality issues, which would have outweighed the advantages of having a mobile and less cumbersome system.

Unity 3D - Unity 3D is a 3D game engine, widely popular and used to develop 3D games and applications. We chose this as our platform to develop the virtual environment. The reason for choosing Unity3D over other platforms were various. Primarily, it is a powerful platform that can allow highly quality gameplay and visuals and can allow developers to create highly modular and robust systems. Other 3D game engines such as Unreal Engine may be slightly more powerful and can create higher quality applications, but also take longer to learn and are harder to use. Another reason is that Unity comes with inbuilt functionality that allowed us to easily port the application onto VR. Finally, Unity also contains one of the most popular 3D asset stores, which allows one to download or purchase 3D models and other assets and import them into the virtual environment. This was a considerable advantage as it allowed us to time-manage effectively by purchasing all the ready-made assets from the store.

User interaction

The user can interact with the system through physical input as well as voice commands:

Physical Input - Physical input is used to move the character around the virtual environment, as well as interact with objects such as boxes or the telephone. Physical input is done through either the Xbox controller, or the Oculus touch controllers. The Oculus Rift VR headset provides the user a 360-degree view of the virtual environment as they navigate through it.

Voice Input - the user can also interact with the virtual environment through their voice. If a character within the virtual environment approaches the user and asks a question, the user should respond accordingly. Unity 3D contains a number of different libraries for dealing with speech input. The speech input recognizer library that was used is called: 'UnityEngine.Windows.Speech.DictationRecognizer'.

This library is actually a wrapper around the Watson IBM API, which provides a service to translate speech input into text. This therefore requires that the device running the VR application has an active internet connection. Once the resulting text has been returned, it is then passed to a keyword recognizer. This is a simple service that contains a list of pre-defined keywords. The keyword recognizer searches the resulting text for any of the pre-specified keywords, and if a match is found, the action corresponding to that keyword will be executed. Some of the keywords also include a list of synonyms, meaning that if the text includes one of the synonyms rather than the main keyword, that keyword's respective action will still be executed. The list of keywords, their synonyms, and their respective actions are shown in Table 1.

In most cases, the action that would be executed is setting the appropriate narrative condition respective to the keyword. In other cases, direct functions will be executed. For example, if the user says "repeat", the character will repeat the question.

Table 1: Keywords that can be recognized through the user's voice commands, and their corresponding actions that will be executed.

Main Keyword	Synonyms	Action
Yes	Sure, ok, okay, ne	Set narrative condition 'Yes'
No	Nope	Set narrative condition 'No'
Good	Great, Fantastic, Excellent, Amazing	Set narrative condition 'Good'
Bad	Terrible, Horrible	Set narrative condition 'Bad'
Repeat	-	Replay last voice clip spoken to user
Scared	-	Lower intensity
Bored	Board	Increase intensity

Narrative director

The Narrative Director is an entity responsible for maintaining the current state of the world, as well as defining the narrative goals to be achieved. Narrative conditions describe any actions that have been performed, or the state that has been achieved, by the characters (or agents) within the virtual environment. Narrative goals indicate the desired narrative conditions that should be achieved. This will drive the agents' actions in a matter so as to achieve these conditions.

We have two types of narrative goals. The first type are storyline goals. These basically define story events which should occur, and which the agent should drive towards. On the other hand, narrative goals can also be based on emotions, similar to the approach taken by Pizzi and Cavazza [12]. To adjust the level of intensity of the experience, different emotional states can be set as goals accordingly.

Autonomous agents

Agents include any characters or objects within the game that the user can interact with, or that can perform some sort of action. Within this particular scenario, agents can include Non-Playable Characters (NPCs), the telephone, boxes to be picked up, auditory hallucinations and visual hallucinations. To achieve our desired objective of having an interactive storyline, we required our agents within the simulation to perform different actions depending on the user's actions and on the current events that have unfolded within the story. Since there are many agents that can each perform a variety of actions, trying to manually specify each and every interaction between all the characters, factoring in the current world state and past events, would have been cumbersome and unpractical.

Instead, we opted to use AI to handle the decision making to determine which action each agent should perform at any given time. Simultaneously, we needed to specify all the possible actions that each particular agent can perform. Each action included both the pre-conditions, and the effects. The pre-conditions specify the narrative conditions that need to occur in order to allow an action to be eligible to be executed. The effects show the narrative conditions that will be set after the action has been executed. The role of the AI is to determine the sequence of actions that will arrive at the desired narrative goal.

The agents are also equipped with sensors. These are scripts that continuously determine the proximity of the agent in relation to other agents within the environment. The data from the sensor will be reflected with the condition, which will allow the appropriate actions to be taken by the agents.

Agent architecture

The agents make use of an AI planning algorithm known as a Heuristic Search Planner (HSP), in the form of a STRIPS formalism. The Autonomous Agents contain actions which model our state space.

A planning task P in STRIPS is defined as follows:

$$P = (A;O;I;G) \quad (1)$$

The atoms A refer to the narrative conditions, the operators O refer to the agents' actions, the initial situation I 2 A refer to the current narrative conditions, whilst the goal situation G 2 A refer to the narrative goal conditions.

Each action, or operator o 2 O is comprised of pre-conditions and effects. Effects can be of two types: positive eff^{+} or negative eff. State change is derived through a transition function f, which includes the operator (or action) as well as the initial state S_I:

$$f(S_I ; o) = S_I + eff^{+}(o) \;\; eff \;\; (o) \quad (2)$$

A plan is a sequence of actions that causes a trajectory of state changes, as follows:

$$S_1 = f(o_0; S_0); S_2 = f(o_1; S_1); ::::::; S_n = f(o_{n \;\; 1}; S_{n \;\; 1}) \quad (3)$$

With S_1 being the initial state, and S_n being the resulting state.

A plan is successful, or solves a planning task, when generates a resulting state S_n that satisfies the given goal situation G.

Using AI to allow interaction between agents

Since the idea is to create a realistic environment, ideally a number of activities and interactions should be going on in the background to make the environment livelier. Pre-specifying all these interactions beforehand would be cumbersome and create a scripted, monotonous effect.

Therefore, the architecture of the implementation was designed not only for the agents to interact with the user but was set up in a way so as to allow the agents to interact and communicate autonomously between themselves. The sensors that the agents were equipped with are not only capable of determining the proximity of the agent to the user, but also the agent's proximity to any other agent. They can also differentiate between the type of entity that has entered proximity - meaning whether the entity is the user, another agent, or an object.

To achieve this, a structure was set up whereby certain actions can have pre-conditions where the second party is left generic, for example Greeted (NPC, NULL, False). In this case, since the second parameter is left null, the AI will replace the associated party with any entity that is within proximity to the agent, as noted by the agent's sensors.

Using AI to simulate hallucinations

One of the primary objectives of this application was to simulate some of the symptoms of Schizophrenia in a realistic manner. The first step therefore was to retrieve information about common experiences of auditory and visual hallucinations. This information was provided by academic staff with the required expertise in mental health.

The auditory hallucinations involve an imaginary voice which is only heard by the user. This takes the form of a childish voice, who continuously speaks to the user, occasionally drowning out the voices of other characters within the simulation. The visual hallucinations involve a young boy, covered with wounds and blood giving the appearance of a zombie, who randomly appears through the simulation and simply stares at the user, keeping his gaze following the user's position.

The hallucinations should be aware of the actions being performed and words being spoken by the user and react accordingly. To achieve this, the hallucinations are also defined as autonomous agents, and work using the same principles mentioned above.

As an example, a character within the virtual environment may walk up to the user and asks a question, such as "How was your weekend?". Depending on the user's response, the imaginary voice coming from the auditory hallucination will reply accordingly, as shown in Figure 2.

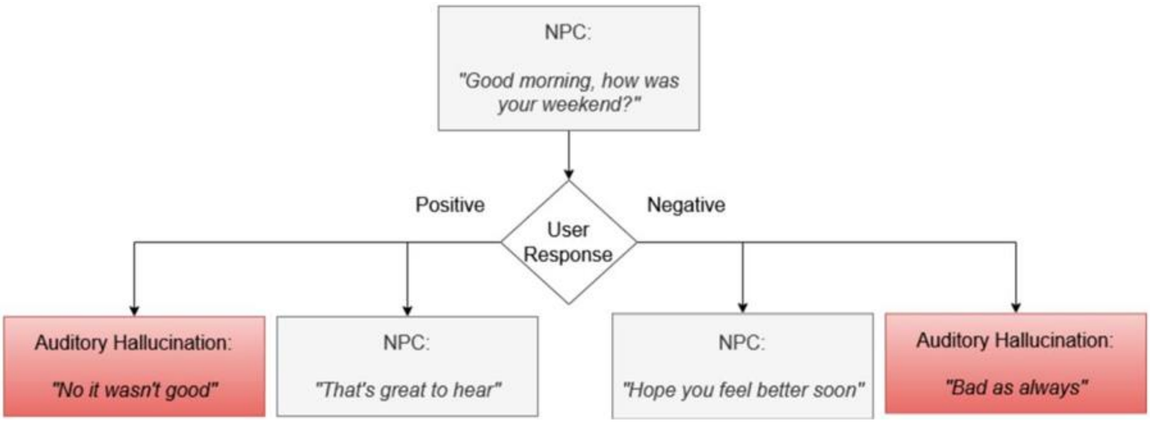

Figure. 2: Agents varying their reaction based on user's response. (Source: self)

Using AI to control intensity and user engagement

The aim of the project was to expose the user to hallucinations and to instil a certain level of engagement and emotion within the user. However, users may have different reactions to the experience, as well as a different level of familiarity with using virtual reality. Therefore, using AI to control the level of emotion and tailor each user's experience could prove to be very beneficial.

To address this, we can use the same structure as above, including the narrative director and the autonomous agents. We then set specific emotions as narrative goals. The narrative director will change the emotional goal as needed, depending on the user's current level of engagement. At any point in time, the user can change the intensity of the simulation through voice commands. For example, if the user is feeling overwhelmed, the user may simply say "I'm scared", and the AI will understand that it needs to lower the intensity of the experience. On the other hand, if the user says "I'm bored", it will increase the intensity accordingly.

User trials

The Department of Mental Health organised a few days over which psychiatric nursing students attended to take part in the evaluation of the system. These students were in training to become psychiatric nurses dealing with mental health persons, and therefore this experience also served as a trial to determine whether simulations such as the one we have created can enhance their learning experience.

Sample - The total number of participants was 58. Most of the participants were females (n=34, 58.6%). Regarding age distribution, most of the males were aged be-tween 25-34 years (n=14, 58.3%) while most of the females were aged between 18-24years (n=21, 61.7%). 62.1% of the participants had never experienced VR before. This demographic information was required to determine whether age, gender and experience with VR would have a significant impact on the overall immersiveness of the experience for the user. This was crucial is allowing us to gauge whether there are any different reactions between participants from the different categories, thus allowing us to measure more effectively the outcome of the simulation by demographic status and exposure to VR. A breakdown of the distribution of the participants is shown in table 2.

Table 2: Participant responses by age, gender and experience with VR

	Male n=24	Female n=34	Total n=58
Age (years)			
18-24	2	21	23
25-34	14	6	20
35+	8	7	15
Have you experienced VR before?			
Never	12	24	36
One or Two Times	8	8	16
3 or more times	4	2	6
Total	24	34	58

Figure. 3: Breakdown of participants by age, gender and experience with VR (Source: self)

Data Collection - In order to collect data and analyse user feedback from the experience, a questionnaire was prepared which the students completed after their trial of the simulation.

The user's experience in immersive virtual environments was determined using a standardised tool namely the Questionnaire to Measure the User Experience in Immersive Virtual Environments [14]. This tool consisted of 87 questions and also provides a measure of participant responses on the subdomains specified in Table 3. It has also been shown to be psychometrically reliable through the Cronbach Alpha scores for each subdomain. In addition to the standardized tool, data was collected regarding:

- Demographic data: (e.g., gender) of study participants.
- Open ended questions: these allowed the users to elaborate on the strengths and weaknesses of the system.
- Custom questions - these related to our research goals, specifically targeting the effect of using Interactive Narrative to control the storyline, agents and hallucinations.

Table 3: Subdomains being tested for in user feedback survey (Source: [14])

Subdomains	Description	Cronbach's Alpha
Presence	The user's "sense of being there" in the VE.	0.755
Engagement	The energy in action, the connection between a person and its activity consisting of a behavioral, emotional and cognitive form.	0.759
Immersion	The illusion that the virtual environment technology replaces the user's sensory stimuli by the virtual sensory stimuli.	0.767
Flow	A pleasant psychological state of sense of control, fun and joy that the user feels when interacting with the VE.	0.826
Usability	The ease of learning (learnability and memorizing) and the ease of using (efficiency, effectiveness and satisfaction) the VE.	0.465
Emotion	The feelings including joy, pleasure, satisfaction, frustration, disappointment and anxiety of the user in the VE.	0.718
Skill	The knowledge the user gain in mastering his activity in the virtual environment.	0.820
Judgement	Identifies the user's attraction in a pragmatic and hedonic way towards the system.	0.804
Experience Consequence	The symptoms (such as the "simulator sickness", stress, dizziness, headache, amongst others) that the user can experience in the VE.	0.908
Technology Adoption	The actions and decisions taken by the user for a future use or intention to use of the VE.	0.781

Ethics - to avoid potential participants experiencing any coercion, gatekeepers were appointed to recruit the students on a voluntary basis. The students were first given an information sheet detailing the intervention, the potential risks of participation and the right to withdraw without the need for any justification. Those students demonstrating their willingness to participate were asked to sign a consent form and entered one by one to try out the experience.

Data analysis and results

The results from the custom questions on an individual basis were first analysed so as to gain an overview of the overall experience felt by each user, as well as to explore how whether the intended outcomes of the simulation had been reached.

We then proceeded to analyse the questions taken from the standard tool, using the questions to measure the results for each subdomain, and performing statistical analysis to determine any significant results between the various categories.

Most of the questions use a 5-point likert scale to measure the user's experience regarding several different factors, whilst a few questions use a Dichotomous scale.

From the results of these questions, descriptives for each of the subdomains were computed, the results of which are shown in table 4.

Table 4: Statistics showing the generated results for each subdomain using the questionnaire tool referenced in [14]

	Presence	Engagement	Immersion	Flow	Usability	Emotion	Skill	Judgement	Experience Consequence	Technology Adoption

Valid	58	58	58	58	58	58	58	58	58	58
Mean	2.3	1.8	2.4	2.7	3.2	3.1	2.3	1.8	3.6	2.6
Median	2.7	1.7	2.4	2.7	3.0	3.1	2.3	1.8	3.7	2.6
Std. Deviation	0.4	0.7	0.7	0.6	0.6	0.4	0.9	0.2	1.0	0.6
Range	1.92	3.00	2.86	2.45	2.33	1.87	3.50	0.83	3.56	3.00
Minimum	1.50	1.00	1.29	1.64	2.00	2.13	1.00	1.08	1.44	1.00
Maximum	3.42	4.00	4.14	4.09	4.33	4.00	4.50	1.92	5.00	4.00

Before generating analysis using the statistics generated in Table 4, we first needed to determine whether the distributions were normal or not. A skewed distribution was identified for the following subdomains, namely Presence, Engagement, Usability, Judgement, Experience Consequence using the Shapiro Wilk test (table 5). This indicates that these subdomains contain a deviance of data from normality. Hence, for these specific domains non-parametric statistics were utilised for computations (i.e., Mann Whitney for analysis of participant responses by gender and Kruskal Wallis for computations by age). For subdomains showing a normal distribution, namely emotion and immersion, parametric tests were used - namely the independent t-test and the one-way anova.

Table 5: Testing each subdomain for normality

Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Presence	.934	58	.004
Engagement	.889	58	<.001
Immersion	.967	58	.111
Flow	.982	58	.566
Usability	.958	58	.042
Emotion	.977	58	.346
Skill	.964	58	.087
Judgement	.804	58	<.001
Experience Consequence	.950	58	.018
Technology Adoption	.978	58	.369

Intercorrelations between the subdomains were then computed using the Pearson's product moment correlations for data that are normally distributed and the Spearman's rank order correlations for non-parametric data.

The strongest correlations were identified between Presence and Engagement (.637), between Technology Adoption and Skill (.674), between Presence and Immersion (.549) and finally between Immersion and Flow (.554). We can therefore see that an immersive experience is associated with other factors, especially presence, flow and engagement. We can also see that there was a significant correlation between Immersion and Emotion (.333). Since one goal was to create an immersive experience that would create a feeling of empathy in the user, this signifies that a highly immersive experience is associated with a high level of emotion within the user.

The lack of correlation between Immersion with either Technology Adoption or Skill, indicates that users' familiarity with or attitude towards the technology did not affect the immersion of the experience. This is an important factor to consider when deciding how to proceed. Since Virtual Reality is still a relatively new and innovative technology, if many people struggled to use it, this may have impacted the experience. However, since it did not seem to, moving forward it would be safe to continue to employ this kind of technology.

Participant categories analysis

As stated earlier, participants were grouped according to age, gender and experience with VR. The responses between the different categories of participants were then analysed further to determine whether any significant differences exist.

Gender - A test for significance was performed for each subdomain to determine whether there was any significant difference between the responses by gender. To determine whether there were significant differences, an independent t-test was computed for parametric data and a Mann Whitney test for non-parametric data. The results demonstrate that there were no significant difference in participant responses by gender, except for the domain 'Experience Consequence' in which males scored significantly higher than females ($U=543.00$, $p=.033$). This indicates that women tend to experience more negative physical consequences than men. What we could speculate is that this is most likely due to the fact that a higher percentage of males generally tend to be familiar with and exposed to video games and virtual reality, thus allowing them to feel more comfortable and familiar with the experience. In fact, within our study, 50% of males had experienced virtual reality at least once, in contrast to 29.4% of females.

Experience with VR - Another test for significance was performed between the different categories of people with different levels of experience with Virtual Reality. Participant responses by domain in relation to VR experience were classified into one of 3 categories i.e., Never experienced; once or twice; and three times or more. The Kruskal Wallis test was performed for the non-parametrical subdomains, whilst the one-way ANOVA test was computed for the remaining parametric subdomains.

Having experience with VR had an influence on one domain, namely skill ($F(2,55)=3.853$, $p=.027$).

Post hoc analysis was performed to compare each of the experience levels with one another per subdomain, so as to gain a deeper insight into where the significant difference lies. The results indicate that a significant difference in skill is found between those who have never used Virtual Reality and those who have used it many times ($p=.021$). This signified that those who had previously used VR found it easier to navigate around the virtual environment.

One may also notice that the results for Experience Consequence could also be of interest. Similar to what was speculated in the section above regarding gender, we can see a large difference in the mean result between those who have never used VR, and those who have used it multiple times. If we had a larger sample size, this difference might have been more apparent, to a point that it may have been significant.

Age - Participants were divided into one of three resulting categories namely: 18-24 years; 25-34 years and 35 years and above. Computations exploring age differences for the various domains were conducted using the Kruskal Wallis test (test statistic H) for non-parametric data and the one-way ANOVA for parametric data. Significant differences were identified by age for the skill domain ($F(2,55)=5.939$, $p=.005$) and technology adoption ($F(2,55)=3.929$, $p=.025$). Post hoc analyses indicated that participants aged 25-34 years scored significantly lower on the skills domain than those aged between 18-24 years ($p=.011$) and those aged 35 years and above ($p=.013$). For the technology adoption domain, the 25-34 years old students scored significantly lower than those aged 35 years and over ($p=.045$).

The results seem to show that users within the second category (25-34) seem to be much more at ease with interacting with the system as well as understanding the technology in use in comparison to older users (35 and above).

Open Ended Questions - Open-ended questions were included so as to allow the users to express more openly certain factors regarding their experience. There was a large percentage of positive feedback (98%). Users found the experience innovative, realistic, and as having deepened their understanding and empathy for those who suffer from schizophrenia. Most users also enjoyed experiencing VR, being their first time. However, some users (27.5%) felt dizzy or nauseous during the experience, with some also stating that the movement and controls did not feel particularly intuitive. This shows that perhaps creating an application whereby the user remains in the centre of the virtual environment and can interact with it without having to move might be a better option. Others suggested clearer instructions, by either having them written, or through the user of arrows, as they were sometimes confused with what tasks they were supposed to be performing. However, this was a dilemma for us because it could be that the hallucinations within the experience should have actually been making it difficult for the user to understand what ws being said or what task the user should be performing - this mimics what people having these symptoms actually struggle with.

Evaluation of AI Agents - In our evaluation assessment, we focused on assessing the application as a whole. The effectiveness of the agents was indirectly evaluated through the custom questions within the questionnaire. The questions assessed the users' perception on how natural and realistic the interactions, dialogues and hallucinations felt during the simulation, which are all controlled by the AI agents. The results were mostly positive, seeing that 62% of participants either agreed or strongly agreed that the flow of the storyline felt natural, indicating that the use of Interactive Narrative was probably quite effective.

Positive feedback regarding the hallucinations was also provided, with 72.5% of respondents either agreeing or strongly agreeing that the visual hallucinations seemed realistic, and 81% for the auditory hallucinations. If more effort is made on the AI controlling the physical appearance and physical actions, as well as more content added with regards to physical hallucinations, this could potentially increase the realism of the visual hallucinations. Given more time and resources, we could have opted to perform a more thorough evaluation of the agents themselves. Evaluating the effectiveness of autonomous agents, however, is not always a straightforward task, and a number of studies and projects have addressed this very issue. One possible method that we could have adopted in order to evaluate our Artificial Intelligence agents would be similar to the EvalAI 'human-in-the-loop' setup [15]. A user would be asked to run through the simulation a number of times. Each time, they should engage in specific interactions, and either say particular phrases or perform particular actions. The user should then note the reaction of the respective agent and rate it.

Another test, similar to that performed by Strippgen and Christaller [16], would be to create a new virtual environment, place the autonomous agents within this environment, and analyse whether the agents are still able to effectively identify their surroundings and communicate or interact with other autonomous agents successfully.

Discussion and conclusion

Despite the various challenges we were faced with when implementing, trialling and evaluating this system, we were still successful in reaching our target objectives and overall very positive feedback was provided regarding the experience. Even though the participants were already familiar with Schizophrenia, 91.4% still claimed that the simulation has helped increase their understanding of it. 98.3% also believed that Virtual Reality can be a useful tool to facilitate education about mental illnesses.

It was very clear that the users felt immersed within the virtual environment. A high percentage score was achieved for immersion throughout all the categories (age, gender and experience with VR), with a mean immersion score of 2.38.

The VR Autism simulation [6] generated a lower mean score of 1.55, which signifies that users considered it more immersive. However, the mean score for the Autism simulation project is based on one question, rather than being a breakdown from seven different questions. The lower mean score could possibly indicate that a 360-degree video might be more immersive than a computer 3D generated environment, however further studies are required to explore this speculation. As mentioned previously, 62% of participants either agreed or strongly agreed that the flow of the storyline felt natural, indicating that the use of Interactive Narrative was probably quite effective.

The results of this project cannot be considered empirical as there cannot be a generalisation due to the fact that the notion of immersion is highly subjective. However, considering the outcome of the final product of the system, as well as the feedback provided by users who trialled the system, it is safe to conclude that this project overall turned out to be successful.

This project accentuated the strength of using a general problem solver such as a heuristic search planner, in that it allowed enough flexibility to use AI to control the various elements making up the system, including interaction, hallucinations and user engagement. External factors such as the agents' sensors or the users' voice commands could seamlessly integrated with this setup. The use of Virtual Reality turned out to be a favourable choice, creating a highly immersive effect.

This project also allowed us to explore new territories with regards to combining Artificial Intelligence and Virtual Reality. AI turned out to be effective in making the VR simulation as immersive and realistic as possible, with 81% of respondents either agreeing or strongly agreeing that the auditory hallucinations seemed realistic.

One must also consider the fact that this study was a pilot project. Due to the sensitive nature of the subject, the users testing out the system for evaluation were restricted to a limited group of people who already have experience and training in dealing with mental health illnesses such as Schizophrenia. This may have restricted some of the analysis when comparing feedback across the different categories of users.

In this project, we also began exploring using AI to control the level of user engagement, adjusting the level of intensity with respect to each user based on certain user voice commands.

In the long-term, there are many aspects in which the system can be improved. With regards to the education and Schizophrenia aspect, a lot more content would ideally be added such as more characters, more dialogue, more varied types of hallucinations. The more content that is added, the more dynamic and adaptive the storyline will become.

Although our system is also designed to adapt the intensity of the experience to the user, so far this is still at a very basic stage. Primarily, a more sophisticated approach of measuring the user's current level of engagement should be adopted. Using heartbeat monitors or sweat detectors would allow the AI to adapt the intensity of the experience intuitively for each individual user, creating a much more tailored experience.

Whilst the Virtual Reality system worked relatively well, it would be wise to consider different approaches to prevent the feeling of dizziness or nausea felt by most users, as well as other technologies such as Augmented Reality.

Since the feedback indicates that this approach was very effective for providing education about the symptoms of Schizophrenia, it would be interesting to begin applying this research to other forms of mental illnesses.

References

1.Evers M, Nijholt A. Jacob - An Animated Instruction Agent in Virtual Reality. In: Tan T, Shi Y, Gao W, editors., Berlin, Heidelberg: Springer Berlin Heidelberg; 2000, p. 526–33.
2.Ke F, Im T. Virtual-Reality-Based Social Interaction Training for Children with High-Functioning Autism 2013;106:441–61. https://doi.org/10.1080/00220671.2013.832999.
3.Deshraj Y, Rishabh J, Harsh A, Prithvijit C, Taranjeet S, Akash J, et al. EvalAI: Towards Better Evaluation Systems for AI Agents 2019:ar:1902.03570. https://doi.org/10.48550/arXiv.1902.03570.
4.Gorini A, Riva G. Virtual reality in anxiety disorders: the past and the future 2008;8:215–33. https://doi.org/10.1586/14737175.8.2.215.
5.Pizzi D, Cavazza M. Affective storytelling based on characters' feelings. . 2007.
6.Mallia N. Escape room in VR : an investigation into interaction techniques for immersion. 2018.
7.Haddod F. Empathizing with autistic children : using a virtual reality application as a medium. 2018.
8.Cyr D, Childs R, Elgie S. Recruiting Students for Research in Postsecondary Education: A Guide. Toronto: Higher Education Quality Council of Ontario.; 2013.
9.Tcha-Tokey K, Christmann O, Loup-Escande E, Richir S. Proposition and Validation of a Questionnaire to Measure the User Experience in Immersive Virtual Environments 2016;16:33–48. https://doi.org/10.20870/IJVR.2016.16.1.2880.
10.Rickel J. Intelligent Virtual Agents for Education and Training: Opportunities and Challenges. In: de Antonio A, Aylett R, Ballin D, editors., Berlin, Heidelberg: Springer Berlin Heidelberg; 2001, p. 15–22.
11Lugrin J-L, Cavazza M. AI-Based World Behaviour for Emergent Narratives, New York, NY, USA: Association for Computing Machinery; 2006, p. 25–es. https://doi.org/10.1145/1178823.1178853.
12.Strippgen S, Christaller T. Insight: a virtual laboratory for looking into an autonomous agent., 1994, p. 388–91.
13.Park K, Ku J, Choi S, Jang H, Park J, Kim S, et al. A virtual reality application in role-plays of social skills training for schizophrenia: a randomized, controlled trial. 2011;189:166–172.
14.Bozgeyikli E, Bozgeyikli L, Raij A, Katkoori S, Alqasemi R, Dubey R. Virtual Reality Interaction Techniques for Individuals with Autism Spectrum Disorder: Design Considerations and Preliminary Results. In: Kurosu M, editor., Cham: Springer International Publishing; 2016, p. 127–37.
15.Charles F, Lozano M, Mead S, Fornés A, Cavazza M. Planning Formalisms and Authoring in Interactive Storytelling 2003;3.
16.Freeman D. Studying and treating schizophrenia using virtual reality: a new paradigm 2008;34:605–10. https://doi.org/10.1093/schbul/sbn020.