Design of virtual reality for students with autism, developed in a special school setting

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A thesis submitted to Middlesex University in partial fulfilment of the requirements for the degree of Master of Science

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July 2022

Abstract

Virtual Reality (VR) has been used to augment physical systems or to provide virtual environments that are accessible via head displays. The Department of Education have initialised a special curriculum for students with special needs. In this project it will include people with autism spectrum disorder (Autism) between the ages of 8 and 17 described as "Students with special needs". The curriculum has 4 sections: Employment, Independent Living, Community Inclusion and Health. For these purposes the specific virtual reality (VR) prototype was developed to cover the requirements of the "Employment" and "Community Inclusion" sections. It achieves that by simulating common working and recreation areas which are commonly met and used in real life. VR environment has two locations representing mentioned areas: supermarket and caffe. Due to the diverse nature of autism, it requires certain precautions which are very problematic to implement since it is generally assumed that each case of Autism is unique for each individual and can cause different stimuli reactions which could cause discomfort, panic etc. Therefore, the feedback was required to develop further and narrow down the focus of the VR environment's features. The investigation was conducted in the form of interviews with teachers who combined are responsible for over 100 students with different types of Autism in a school for people with special needs. The obtained results have increased the understanding of features required for development of the VR application for people with special needs and potential issues in its current state as well as its viability in teaching the students with special needs.

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Acknowledgments

Thank you to teachers and staff of Daventry Hill school who took part in the testing/interviews and helped organise it. Additional thanks to my advisors and staff from Middlesex university who supported me during the course of the program, especially during Covid-19 outbreak.

Introduction

Autism spectral disorder (ASD) or Autism is a medical condition which may occur in children from the age of 6 and has different life-long conditions. Some scientists have observed quite strong reactions to light, smell, colours, social interactions. (*Autism.* 2004) There are many ASD types and each case is unique for each individual. Because of that, the majority of people with autism cannot live alone/support themselves or socially interact with other people. Apart from that, it costs different institutions/government a significant amount of money to support them.(Knapp, Romeo and Beecham, 2009) Different academy trusts try to find the way to improve the situation by conducting various experiments and training sessions including people with ASD. In this case Creating Tomorrow Multi Academy Trust assists the research. The project took place at Daventry Hill school for people with special needs located in the UK. They have been instructed with the covering of the special curriculum which contain the following topics: Employment, Independent Living, Community Inclusion and Health. To satisfy some of the curriculum's requirements the school has made a request to develop a virtual reality (VR) prototype. It should simulate touch, visuals and smell if possible and be relatable to the locations which are commonly met in real life. Development of such task poses a challenge since unlike usual VR applications this one has to fulfil the study curriculum and most importantly be safe for students with ASD to be used on daily basis. This study tries to evaluate the possible features which would help in teaching students with ASD using the VR headset. Also, could it be used by people with special needs without causing discomfort due to ASD. It would be achieved by developing a VR prototype which would simulate two "commonly met" locations and will be tested by teachers who are responsible for students with ASD on daily basis.

1. Literature Review

1.1 Virtual Reality

Virtual reality/Virtual environment has different meanings but all of them share one thing in common, it is a digital space, program or game, designed to be interacted with by different means and for different purposes like entertainment, study, problem solving etc. Nowadays this term is more commonly used to describe a three-dimensional(3D), computer generated environment which can be explored and interacted with by user/player. Virtual environment is usually created using software which is called "game engine". Also known as "game architecture" or "game frame", "game engine" is a software-development environment designed for people to build video games/virtual spaces/programmes. There are several game engines developed by various companies and have different properties e.g., Unreal engine, Unity, CryEngine (Karaoğlu, Tükel and Arthaya, 2019; Lee, Ryoo and Seo, 2019). Virtual environments, computer programmes/games can either be 2-dimensional(2D) and 3-dimensional(3D) on some occasions 2- dimensional space with the 3- dimensional elements, but it depends on the program requirements and aims. Different digital objects like characters/tools/familiar surroundings can be created, used and interacted with there. Design of such is usually limited by imagination, time availability and game engine capabilities.

Game engines are used to create environments but to be able to interact with them there are several input/output types of hardware which acts as a medium between the user and the

program/environment in it. Depending on the type of disability additional input devices may be used like foot mouse or microphone/speakers for voice commands. The Virtual Reality (VR) headset has become more popular in the past 5 years. (Petrock, 2019) The main idea is that the user wears a helmet with goggles which act like a screen and immerses the user into virtual space. The movement inside is supported by the pair of controllers with the one to two pairs of sensors one for the controllers and other for the helmet itself. It allows the user to experience the unique level of digital immersion which nothing else can do out of all common input/output devices today.

1.2 Existing studies with VR and students with ASD.

In the past several years studies have been conducted with Virtual Reality. They included a software program to study the behaviour of the participants or training purposes. Many people who used the Virtual reality have mentioned that it had positive effect on the participants after the conduction of several training sessions in a row.(Kandalaft *et al.,* 2013) In that article 8 young adults diagnosed with ASD took part in the VR social cognition training. They have completed 10 sessions across 5 weeks. VR environment there was created using Second life (Linden Lab 2003), the 3D world which is available publicly for everyone. The specially designed "Island" for the purpose of the research included several locations including an office, a pool hall, a coffee house and many other places. The participants have created and used avatars there and were required to participate in different social situations with the help of coach "clinicians". After that they have completed a survey and successfully passed the specifically designed social perception test.

However due to ASD, members of the experiments show difficulties and delay in understanding which was described by Gerardo Herrera and others in theirs' study regarding difficulties with symbolism.(Herrera *et al.,* 2008) By using the imaginary transformations they have examined the effectiveness of using a VR tool which was designed for teaching of the understanding of "pretend play". The researchers have created the simple but quite practical program to test the participants. For example, in this program they have used set of three pictures- a "Magic" tree, a magician and a normal tree. On the top of it there was a question asking, "In which picture is there magic?". Participants have chosen the answers which have been recorded after that. The results were confirmed by the independent observers and showed progress in understanding. For people with ASD that test, has been a great challenge to complete and any positive changes in understanding such symbolism was a step forward.

Other VR related article was done by Yufang Cheng and Jun Ye(Cheng and Ye, 2010). It involved the use of a virtual environment to help people with ASD increase their social interaction. The name of the environment was CVLE -collaborative virtual learning environment. It included 3D animated avatars and social situations with verbal and text communications respectively. Three volunteers diagnosed with ASD took part in the research and the study has showed significant improvement on the participants' performance within the system and in terms of social interaction learning.

Another study has involved 6 students to experience a café. (Mitchell *et al.,* 2007) In addition to that they watched 3 sets of videos including a bus to define and explain where they would sit and try to explain why. Participants were separated in two groups, one experienced the VE between 1st and 2nd sets of videos, other between 2nd and 3rd.The study

had time limit. During the course of the experiment there were significant improvement of judgements and explanations about where to sit in both video and a bus.

All studies have shown that by using Virtual environments the result could be achieved and participants have shown improvement in every direction or at least it is stated in the articles mentioned before. The project containing Second Life (Linden Lab 2003) VR environment was particularly interesting to cover since it is the article which featured complex VR locations and involved people with ASD using them without changes in mental or physical health (Kandalaft *et al.*, 2013).

The studies mentioned before, have used VR applications projected on the flat panel displays/monitors. They offered a limited level of immersion and different in nature from the VR headset applications. There are two different types of head displays -augmented reality (AR) and VR (Virtual reality). AR display projects the required application or image over the existing real-life view. The VR display offers full immersion and projects the application via head display completely isolating visually the user from the reality. (Xiong *et al.*, 2021) While the AR was a feasible option for the planed VR prototype it was very important to place the user outside the accustomed classroom or familiar places at the school grounds.

In the next article the VR headset and unity application were used by people with ASD to learn the social interactions. (Stewart Rosenfield *et al.*, 2019) The application featured a voice recognition system with the location which resembled a shop space with the cashier. The voice recognition consisted of several scripts and applications interacting together which would react to the specific words pronounced by the user. The cashier had several voiced lines pre-recorded and replied to them according to the user's request. The study's consisted of two children who completed several tasks using microphone while wearing VR headset and looking around. The study demonstrated that the developed VR application is acceptable to be used by people with ASD. The author also mentioned that the VR environment can provide various unique experiences regardless of one's needs. During the course of the experiment, the participants did not have any problems connected with the VR or negative reactions caused by ASD.

Next article where the VR headset was used, featured 3 scenes resembling "typical" Hong Kong apartment, elevator and lobby. (Li, Yuan and Ip, 2018) The participants were four primary school children diagnosed with ASD of different severity. They had to complete a series of fourteen tasks using VR Oculus Rift. The example of such task included: Washing hands where student was expected to navigate to the sink in the apartment, turn on the tap and wash his/her hands. All four of them completed the tasks and required "minimal" assistance from the researchers. All of them wanted to use the VR prototype again and had no troubles wearing the VR headset. In addition to that the project explored optimal safety precautions for conducting the experiments using the VR gear.

1.3 VR Ergonomics

Ergonomics is an area of science which explores the interaction between person and their work environment. In case of VR, the primary example would be the right way of setting up the sensor area and the head gear with the controllers, without the danger of hurting the user. Usually, studies define three main areas of ergonomics: Physical, cognitive and organisational. (Nichols, 1999; Chen, Wang and Xu, 2021; Favi *et al.*, 2019) All three of them are applicable to the use of the VR headset. The efficient VR head gear workspace should be 4 meters in length including the desk with the PC and sensors and 3 meters in width. The area of the user wearing the VR headset should be 2.5 in length and width. (Li, Yuan and Ip, 2018) That particular area is needed to prevent the user from hitting the surroundings while using the headset. The cognitive area is more complex, since the VR headset could be a common cause for a motion sickness. It can appear in users from different reasons, one of them when their eyes cannot properly measure the distance between the in-game objects and themselves, another one connected with the chaotic movements of the user's VR avatar, could be caused by improper placement of the VR tracking sensors which would result in sudden jumps or mispositions in the VR environment. Some studies have discovered corelation between fear levels of the user and severity of motion sickness (U. A. Chattha *et al.*, 2020). It has also mentioned that the female users more receptive to motions sickness when using the VR headset than males the study suggested that this happened because females ruminate sensations more than males. Moreover, the motion sickness symptoms were more acute in females. The article evaluated correlation between fear levels, blood sugar levels, heart rate and motion sickness symptoms while participants (23 females and 28 males) undertook several tasks in different VR environments wearing headset. (U. A. Chattha *et al.*, 2020) There was a limited availability of the articles focused on the physical part of the VR headset ergonomics. Physical ergonomics focuses on the physical load on human body during the use of the mentioned device. Since the VR headset could be used in seated and standing positions, some rules from the use of the PC could be applied. (Nichols, 1999) Unfortunately such claim could not be supported by any covered article/study which fully focuses on the VR headset effects on human body for now and opens opportunity for the future research.

1.4 Autism

At the beginning of the chapter the Autism was briefly mentioned. Due to it being a crucial part of the research, it requires a proper introduction. There is no one clear way of properly describing the disability in the UK. Some studies have been conducted to determine how the autism should be described. One of the studies has taken both the qualitative and quantitative approach by selecting members from the UK autism community and summing them up into four groups (People with Autism, parents of the previous group, other family members/friends and professionals (researchers, teachers etc.)). The common terms describing Autism were selected by the mentioned groups. The results showed that the descriptive terms "Autism", "Person with autism" and "Autistic" were "endorsed" by the most when communicating about autism. But each of these three terms were "endorsed" differently by each participated group. The "Autistic" term was endorsed more by autistic adults when the term "Person with Autism" was more popular within professionals. The study explained that there is no single way of describing autism that is universally accepted since that some of the disagreements appear "deeply entrenched". E.g. In 1975 the term

"Autism spectrum" was the most endorsed by all groups, but it changed. The acceptance of specific terms could be affected by many things from personal beliefs to the specific situation it is used. (Kenny *et al.*, 2016) As mentioned in the paragraphs before, autism spectrum disorder/autism is a medical condition which generally appear at young age. It appears more frequently in males. The word "spectrum" means that it is commonly cause a combination of several mental issues in one individual. (Rutter, 2011; 'Autism (Online)', 1997; *Autism.* 2004; Charles, Harrison and Britt, 2011). It is considered a genetically related disorder but there were cases when it developed in individuals during the lifetime. ASD cases are hard to categorise due to each case being unique per individual. Nevertheless, several studies mentioned DSM-5, which stands for Diagnostic and Statistical Manual of Mental Disorders fifth edition. It is a major revision publication since DSM-4 which was published in 1997 and covers several advancements in neuroscience. DSM-5 was published in May 2013. It provides the standard language by which physicians, clinicians, researchers and other health officials in the US communicate about mental disorders. In this particular case with ASD, it is common to use 3 severity levels: 1- requiring support, 2- requiring substantial support, 3- requiring very substantial support. (Regier, Kuhl and Kupfer, 2013;Volkmar and McPartland, 2014; Li, Yuan and Ip, 2018) Symptoms and sighs of autism can be categorised by the following sections and may include:

Social communication and interaction skills	**Restricted or Repetitive Behaviours or Interests**	**Other Characteristics**
No response to his/her name by the age of 9 months	Lining up of toys or other objects and anxious reaction when order is changed	Delayed language skills
Lack of social expressions e.g happy, sad, angry etc. by the age of 9 months	Repetitions or words and phrases over and over (echolalia)	Delayed movements skills
Does not point on something interesting by the age of 18 months	Obsessive interests	Delayed cognitive/learning skills
Does not notice when someone is hurt or upset by the age of 24 months	The existence of certain routines which must be followed	Hyperactivity, inattentive behaviour
Does not engage with other children in games or social activities by the age of 36 months	Exactly or almost the same way of plying with toys	Epilepsy or seizure disorder
Do not act, sing or dance by the age of 60 months		Lack of fear or vice versa

ASD can cause other various mentally related difficulties such as understanding of speech or ability to relate him/herself to different social interactions. Depending on the severity, it could also cause extremely negative reactions to different sound and visual stimuli. (Volkmar and McPartland, 2014; Charles, Harrison and Britt, 2011; CDC, 2022)

1.5 Summary/Reflections

Based on the articles covered before there have been a lot of examples which have conducted VR studies with the students/children/participants with ASD. All of them has shown that ASD can be taught with the use of VR. However, only two of the articles included VR headset as medium in the research. (Stewart Rosenfield *et al.,* 2019; Li, Yuan and Ip, 2018) Furthermore, out of all covered articles only one has mentioned the severity of the ASD in participants (Li, Yuan and Ip, 2018). Furthermore, the total number of participants for the mentioned studies with VR headset is 6 (2 in the first one and 4 in the second one) In both articles it has been mentioned that all participants has used VR headset without a problem. 6 is a relatively small number to reliably tell that the students at the Daventry Hill school would be able to do the same since the sample number is low to guarantee the results. (Burmeister and Aitken, 2012). It is further supported due to fact that each case of ASD is unique, the ability of students to wear the VR helmet must be checked. The VR headset could be a cause of motion sickness. The proper set up rules should be followed to prevent some potential ways. It applies both to the VR headset and the prototype features e.g., controls, VR environment set up. Overall, there is a limited availability of the articles with the use of the VR headset and the participants with ASD which creates opportunities for the future research. For the current research the augmented reality would not be used. The prototype should fully simulate the created environment and take the participant out of the regular places.

2. Method

2.1 Aims

The method tried to cover several objectives which were the derivatives from the literature review summary. First aim was to test the designed VR application by teachers from the school for students with special needs (autism spectrum disorder and would be referred by ASD from this point). Next, it was important to determine whether their students could use it without reactions which are commonly met for people with the mentioned disability. The mentioned reactions may include panic, irritation, discomfort to several environmental factors such as light, touch, smell, even look of different specific objects. The prototype should follow the ergonomic principles. It should be properly set up to reduce the chance of causing motion sickness.

Next objective is using the transcribed feedback from teachers, assume what can be added apart from already presented features. How it would allow students with special needs to study the real-life locations using VR application as simulation. Additionally, it is important to know the opinion about what can be expected from the current version of the prototype if it is used by people with ASD. Furthermore, the mentioned futures could be related to the proposed curriculum's sections: Employment, Independent Living, Community Inclusion and Health.

2.2 Equipment

VR capable laptop (Alienware) with Nvidia GeForce 1070 Intel i7-7700HQ
Unity engine version 2019.4.x
Oculus Rift headset with right- and left-hand controllers

2.3 Requirements

From the Daventry Hill school the main requirements were to simulate touch and visuals for the environments which are used/ visited in daily lives and can be commonly met on the daily basis. These environments could be then used by the students with special needs to study and practice.

2.4 Preparation of the prototype

The created VR environment consisted of two locations: a supermarket and a coffee shop, with a menu with settings and the ability to switch the scenes. Each of the locations were filled with different interactable objects respectful to theirs' real-life counterparts. Supermarket includes books/different kinds of groceries: meat, fresh vegetables, bottles with soda etc. Coffee shop(caffe) includes tables, different objects for dressing the table (salt, black pepper, wiping tissues, food menus), coffee machine, stands with food (sandwiches, desserts) etc. Figures 1 and 2 represent the supermarket. Figure 3 and figure 4 represent the caffe. The interior in coffee shop was tighter than in supermarket. The surroundings in a caffe were darker and the colour panel was represented in less brighter colours in contrast to the colourful and well lighted supermarket interior. It was done to simulate two differently spaced, lighted and coloured interiors. The main aim of such action was to check whether it could cause any issues for people with Autism and add variety of the situations to be adjusted to. Such conditions were implemented to simulate as much different conditions as possible and to check if it would cause any ASD conditions' stimuli if applicable.

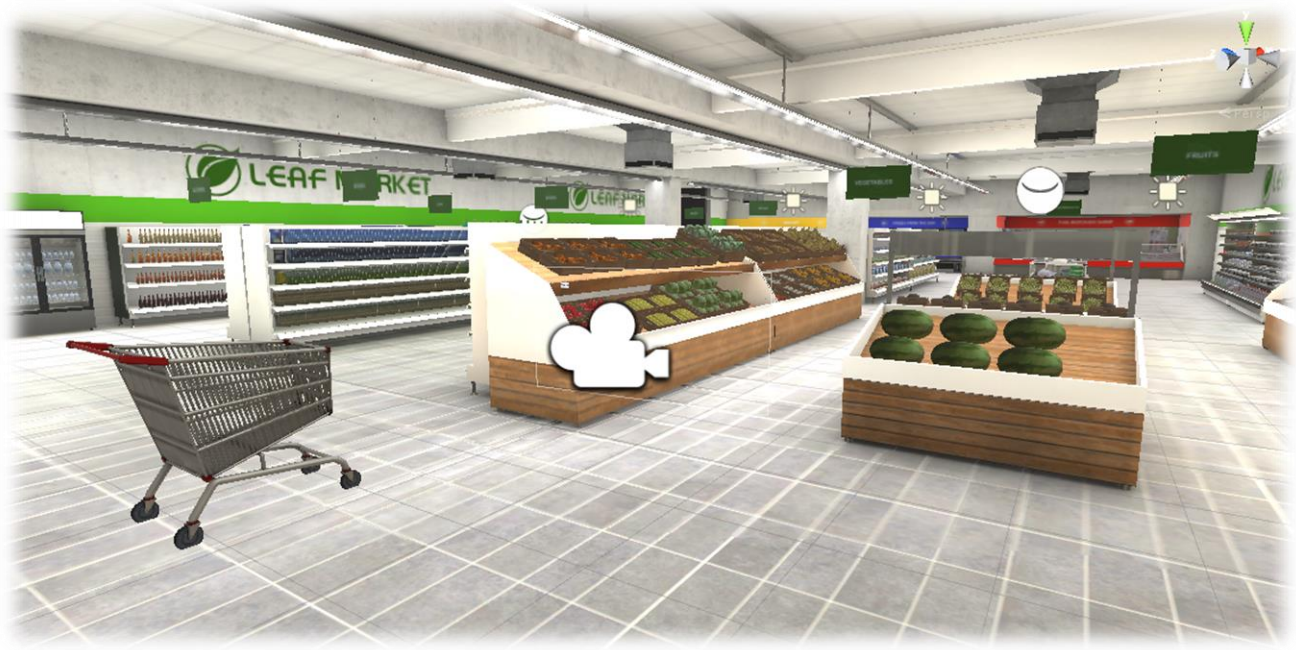

Figure 1 VR Supermarket overview

Figure 2 Shelves

Figure 3 VR Caffe overview

Figure 4 Caffe table

The supermarket scene was created in the previous project. Since then, colliders were modified and a few objects were placed e.g., shopping tray and trolley. The first part of the café development was to put the terrain in the 3D space, Figure 5 represents it. After that, the walls and assets were put in place. The majority of assets were used from the open source. It was done to reduce development time. Otherwise, it would take several additional months just for the assets to be created. The scenes were built from scratch. Assets are usually done with the help of side applications like Blender. Figure 6 shows the complete interior as a result. The reflection probe can be seen there (round object at the top of the screenshot between the tables). The probe is like a camera that captures a spherical view of its surroundings in all directions. It is then stored as a "cube map" that would be used by the objects with the reflective materials attached. Any object placed in the scene can be attached with the certain properties like colliders, physics behaviour, light properties etc.

The avatar with the camera is then placed in the scene. It was the main method for the user to interact with the application. It had two "anchors" which were connected to the respective controller and were used to grab objects. Figures 7 and 8 represent it. Objects with the with "light projection" properties can be seen there as well. They look like a lamp with light on indicator on the mentioned figure. The canvas is located in front of the camera and shown on Figure 7. It is effectively a transparent screen with the attached movement with the head display's camera. It is needed for the interaction between the user and the menu regardless of the headset position. The menu can be called by pointing to the left top corner with the right-hand controller. It has four buttons with the respective function. Figure 9 shows it. Same menu present in both locations. The purple laser pointer would appear when there is a button that can be pressed.

Each interactable object had a collider attached. It was needed to trigger the physical behaviour of that object, otherwise it would float and cannot be grabbed or collided with. It usually has a squared shape unless the mesh collider is attached. Since the Unity version 19.x does not support any round shaped collider apart from the sphered shaped, the creation of the proper collider for the round table was a problem. In that case the set of squared shaped colliders were used to minimise the area unrelated to object. The Figure 10 represent it.

In summary there are two locations which resemble their real-life counter parts. They have multiple interactable objects. The user can move and look freely around each location using headset and two controllers where left joystick is used for movement and the right one for turning around. The majority of objects there could be taken using controllers by imitating the "grab" action with both hands and individually with each one. When the application starts the user would be placed in front of the main menu and select the location using respective button. The selection was done by pointing at the button with the controller, the direction has been shown with the help of the purple line as shown on the Figure 11. The selected button changes colour to red when pointed at.

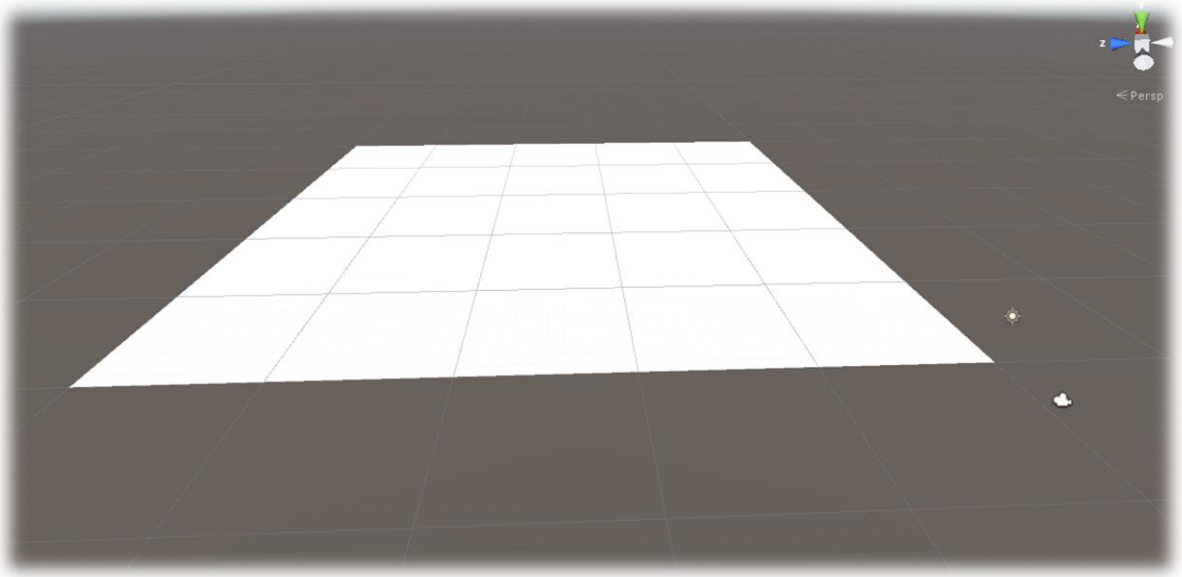

Figure 5 Terrain

Figure 6 Caffe final interior

Figure 7 Player Avatar, Canvas and light objects.

Figure 8 Grabbing

Figure 9 Menu

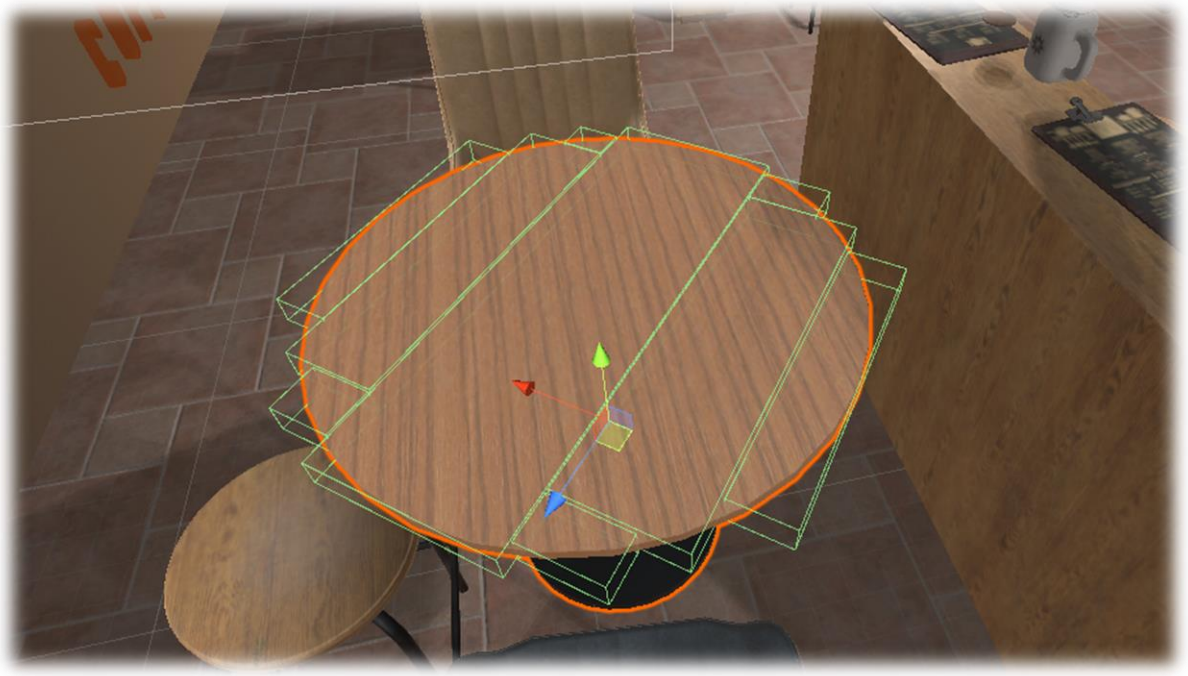

Figure 10 Colliders

Figure 11 Main menu

2.5 Interviews

The collection of data consisted of two parts:
1. Testing the prototype by the participants – referred as "first stage"
2. Interview after the testing – referred as "second stage"

Both stages took place on the grounds of Daventry Hill School for students with special needs. Participants included teachers and staff members who teach students with ASD directly. There was no selection by sex, age or any other characteristic as school staff is about 6-10 teachers in total. Four volunteers took part in the mentioned tasks and could have withdrawn from them at any moment. This particular number of volunteers was enough to interview within one visit to the school grounds which is located on quite remote location from big cities. Due to Covid outbreak it was difficult to visit the school multiple times.

The area for the VR headset with a lot of free space to prevent participants from hitting the surroundings were prepared. The VR set up was similar to the article mentioned before. 4 meters in length including desk with the laptop and sensors and 3 meters in width. The participants were placed in 2.5 square meter area (Li, Yuan and Ip, 2018) Then each participant was instructed with the settings, tasks and controls. They had real time assistance all the time if needed.

During the first stage participants were required to make a full circle around the supermarket VR environment and through the different sections making occasional stops and interacting with the present objects. The following objects were included groceries/moving trays/books etc. Last task was to pick anything from the shelf and reach the cashier and put the object on cahier line finalising the "shopping" process. Shortly after that they were asked to use in app menu to proceed to the coffee shop and make a full walkthrough the area. Interacting with the objects the same way as they did on the previous location. The last task was to dress a table and prepare it for the customers. They were required to put salt, black pepper, menu and plates with a kettle. The whole session took about 10 to 15 minutes for each participant.

- During the second stage the participants took part in the short interview which was recorded. It was transcribed and used for feedback purpose by the researcher. During the interview the recordings from the first stage of the participants' demo trials were used as reference to theirs' respective actions. The numbers from 1 to 4 were assigned to the participants before the interview. The interview included the following questions:

1. Do you feel any discomfort/motion sickness after the use of the prototype? After what action did you start to feel it?
2. Were the controls easy to adapt to?
3. What was the hardest part?
4. How many students are in you class/group that you teach/are responsible for?
5. Do you think the environments which you have visited can cause any discomfort for any of your students?
6. What features do you think may improve the experience for students with special needs (Includes people with autism spectrum disorder only)?
7. What features do you think can be added to assist in teaching students with special needs, help them to adapt for real life situation?

8. Do you think it is possible for students with ASD to wear VR headset?
9. Do you think that the current version of the application may be used by the students with special needs without causing them irritation/discomfort?
10. After all the questions do you want to add something to the experience you have just had?

This particular set of questions was created based on results gained from literature review. From ergonomics point of view the well-being of the participants was put into priority and they were asked about the motion sickness. Even after the covered articles which demonstrated the ability for people with ASD to benefit from the VR applications in gaining knowledge. The total number of participants in the covered studies was too small to guarantee that the prototype used in this research would have the same effect. It was further supported by the fact that each case of the ASD supposed to be unique.

3. Evaluation

3.1 Analysis and Interview results

The answers from the interviews were transcribed. Then the data was annotated, where words phrases/sentences were labelled according to their relevance and the segments were created. The segments were related to the following categories:

1. Variation of ASD most commonly present in the group.
2. number of students in class/group,
3. technical features suggested by participants
4. motion sickness
5. Ease of controls
6. Features of the VR environment (VR objects/spaces/interactable objects/controls)
7. Possibility of use VR environment by people with ASD
8. The use of the current version of the VR by the students

Connections were established between categories: types of ASD present and technical features suggested by participants (numbers 1 and 3), proportions of types of ASD in class/groups (numbers 1 and 2 respectively), types of ASD and possible changes to the prototype, motion sickness and controls (numbers 4 and 5), environmental features and types of ASD present (numbers 1 and 6), Possible use of VR environment and types of ASD (numbers 1 and 7). Since each participant represents a different class/group of students they could contain different proportions of people with various types of ASD.

After analysing the transcribed interviews and comparing with each other the following replies can be summarised regarding the participants:

Participant 1

Number of students the participant was responsible for: 195
Variation of ASD mentioned: unspecified/multiple variations.
Each student has unique condition.
The participant did not experience any form of motion sickness after the completion of the tasks. It was pointed out that the hardest thing in controls was the menu selection by point on

it in the upper left corner. But overall, the controls were easy to adapt to. Many of the students have motor problems, in other words issues with coordination. Picking up things using grab action with the controllers would be much easier for them than pointing.
When the participant was asked about the effects of the current VR environment on the students with special needs, he/she pointed out that it is hard to categorise since each student has individual issue or barrier. But the majority of the students could use it without any problems. For those who cannot, the school staff is trained to support them in that case.
Further speaking about controls, the participant has pointed out the smooth walking with the left sticker(joystick) around both areas. Whereas the turning with the right sticker felt "differently and odd" and if the degree of the turn could be reduced or become as smooth as moving around that would be much better.

Regarding the possible content, judging by the participant's words, the school had special curriculum and the part of that was called "independent living". This was a part where they taught students how to leave independently. The experience of shopper with the shopping list telling the students what they need to buy and what area of the supermarket they should visit to find that would be ideal. (Shopping baskets and trolleys were mentioned as well) The school used to have a lot of tours to such locations before the Covid outbreak. But even after the situation has changed to the better way, some students who have high level of anxiety due to ASD would greatly benefit from such activity using the VR headset.

The participant has mentioned that the use of current version of the VR environment and VR as a whole in teaching is "absolutely" possible for people with ASD. Regarding the use of VR headset itself, it was explained that this is a relatively new technology for the school staff and it would be "their journey to solve that" in case of students who cannot wear them. But the majority of students would not have a problem doing that.

Both locations were favourable since each of them "would fit the purpose". The supermarket would be ideal for independent living mentioned before whereas the coffee shop would be great for adopting the role of the someone who works there. E.g. dressing the table and then have some form of interaction with the customer, it could be in any form.

Participant 2

Number of students the participant was responsible for: 19.
Variation of ASD mentioned: Troubles of understanding the speech.
The participant did not experience any form of motion sickness after the completion of the tasks. The controls were easy to adapt to, but the hardest part was opening the menu by pointing to the left top corner. The participant said that the current state of the VR prototype would not cause any discomfort for students with special needs and can be used by them. Out of possible features the participant has mentioned that it would be crucial if menu could pop up with one press of a button with the detailed instructions. E.g., "You press a button, and it would tell you that this is a plate, and it needs to be put on the table". Additionally, some form of labelling would be helpful. e.g., when the user point at the object and the special notification would tell him what this object is etc. The participant has mentioned video instructions as well. When he/she was asked about the possibility of using the VR environment for teaching the students with special needs, the participant replied positively. According to the participant both locations were very nicely set up, but it would be nice to be

able to touch the chairs or to have an ability to “clean up a table”. For the last thing mentioned, some form of tips could also benefit to the current version of the VR environment saying what the students have to do and congratulating them after successfully doing so.

Participant 3

Number of students the participant was responsible for: 19.
Variation of the ASD mentioned: Various troubles with reading, High anxiety.
The participant did not experience any form of motion sickness after the completion of the tasks. There were no issues with the controls. The hardest part was the grabbing the object since “all main buttons on the controller responsible for the mentioned action were closely placed together”. The participant has mentioned that the current version of the VR environment would not cause any discomfort for students and that they would adapt to it “quite fast”. Regarding to the features sound instruction or verbal guidance during the tasks would help a lot. When the participant was asked about the viability of teaching students with special needs using VR, he/she has mentioned that a lot of students would love to visit some new places but because of the increased level of anxiety due to ASD they cannot do it by leaving the school grounds. That is why the VR could be very useful in fulfilling such tasks. Out of two locations the participant liked the caffe more since it had more challenges in a way of dressing the table.

Participant 4

Number of students the participant was responsible for:15-25.
Variation of the ASD mentioned: High anxiety, Low confidence issues.
The participant has experienced “a slight bit of disorientation, but nothing uncomfortable” after the completion of the tasks. There were no issues with the controls. The hard parts were initially the grabbing of an object and pointing to the left to open the menu. After some practice it became easier to do. Additionally, the participant has mentioned that the controls felt naturally but the grabbing felt a bit off. The current version of the VR environment would not cause any discomfort for the students with special needs. According to the participant, with the right guidance it could become beneficial to them at the current state. Out of suggested features the “grabbing” process with one press of a button was mentioned. Apart of that, the participant has explained that some form encouragement/positivity was essential. It was connected with the disabilities present group. He/she has further mentioned that a lot of students in the group suffer from “low self-esteem” and “low confidence issues”. The encouragement can be done in the form of words, pictures, videos or combination of them. To the question asking about the viability of the VR environment/kit used in teaching of students with special needs the participant has replied positively. The current version of the VR can be used by about fifty percent of the students in class others would need some form of encouragement present before that. Out of two locations the participant has preferred the supermarket due to its bright colour panel. Apart from that he/she has mentioned that it was peculiar how the VR headset can accurately imitate different conditions such as human height (due to different camera levels), it made a realistic impression of a person using wheelchair.

3.2 Summary

Considering the information gathered from the interviews the following conclusions can be made:

- The current version of the VR prototype can be used by students with special needs, at least with the supervision of a designated teacher.
- The VR environment can be used to assist in teaching the students with ASD. The assumption that each case is unique was right from the start of the research, but it does not require full overhaul of the system and not as crucial as was assumed at first. Small adjustments could be made to help narrow down the coverage of different variations of ASD. E.g. adding voiced instructions and written ones would help students with difficulties understanding written text and students who cannot comprehend speech respectively.
- Some form of encouragement in the VR environment is essential for students with ASD. According to some participants some attention is required to create "Positive atmosphere". It can be done by additional notifications which congratulate the user or provide some way to emotionally encourage. This should lead to help students with low self-esteem/confidence issues mentioned in the interviews.
- Not all the students can wear the headset, but the teaching staff is perfectly aware who can and cannot participate in the tasks, in case of planning feature research which would involve students with special needs. Speaking about how to adapt the VR headset to the students who cannot wear due to ASD, the staff is not fully understand it yet due to this being novelty in their practice, but they are working on it.

After the mentioned features the plan to further develop the VR prototype became more apparent. Some things can be added without technical difficulties e.g. Interactive written or voiced instructions of the tasks(mainly written since the voiced instruction require a suitable voice actor), notification windows which would appear when the user points at the object. Some features are more complex from the technical point of view like simulating employee and customer situations in the coffee shop, which would require character models, animations and some form of communication between the characters. It is a large-scale task since it would require both written and voiced dialogues since there are students with hearing and reading problems. At the end of each successful task e.g. completion of the dressing the table in the coffee shop or reaching the cash register at the supermarket the notification congratulating the user would help students with low confidence.

Difficulties

It should be mentioned that participant one has mentioned shopping baskets and trolleys in the possible features in the interview when such objects have already been present in the VR environment. On the evening before the visit to the school, after the final check of the VR headset, it has stopped working completely and required reinstall of the system, with some drivers missing from the system, the trolley and the basket could not be used properly. Therefore, the original plan for tasks in the supermarket and coffee shop were changed to simpler ones overnight and it excluded the shopping trolley and basket from the list of tasks. To organise another school visit would not possible as it was the ending of the 2021 and beginning of the 2022. The Covid and travel rules were still strict and the time planned for the project was running out. Therefore, the second school visit to present the full features

prototype before the deadlines was not feasible. The Covid 19 had a significant impact on the course of the research since it made the school grounds virtually inaccessible until the beginning of 2022. The school was forced to reorganise classes and teachers into corresponding “bubbles". They had occasional exchange between them, but no outsiders were allowed. It continued until the January 2022 the school has relaxed the rules.

4. Conclusion

During the course of the study, the assumption that each case of the ASD is unique for each individual was right. The obtained results corresponds with the stated information in numerous sources regarding Autism ('Autism (Online)', 1997). However, the need for individual adjustments was expected and the possibility of enabling additional functionals was provided for this purpose. These additional features, when properly configured, can improve the perception of the VR environment by students. Basic features as written instructions or integrated voiced guidance (pre-recorded) would be sufficient to help the largest portion of the students in the school. Encouragement and positivity should be a priority when choosing the possible range of emotions which the designer should consider causing by in game features for the students with special needs due to some variations of ASD which cause low self-esteem and confidence. The smooth movements in controls should take priority over field of view change by the degrees. The VR environment is a great way for people with high level of anxiety (which is caused by ASD) to help visit and learn about different places without them leaving the school grounds. Any additional issues should be consulted with the designated teachers/members of staff. At such educational establishments (for students/people with special needs) the staff is trained to handle them, it does not mean however, that the designer/creator of the VR environment/space should not exercise caution in planning different features. The colour or light panel can be kept both ways but for the sake of causing greater “positivity” it is preferred to be kept brighter and more colourful than usual. Overall, the design of VR environment for students with special needs is forgiving and not as strict as could be expected at the start.
The following development of the prototype would focus on adding tasks and features suggested by the participants. They include:

1. Written instructions for the majority of the interactable objects implying their purpose and how are they called in the respected environment. The text will pop up whenever the object would be grabbed by the user.
2. Adding the menu or help window explaining the current task and how to do it.
3. Adding the exchange mechanic to the supermarket to create the shopper -buyer scenario, possibly with the addition of the Cashier as a NPC(non- playable character)
4. Adding the NPC who would sit in the caffe and ask for an order.

The list of features would be gradually expanded once the timeline for the next project would be formed. These enhancements take about two months to implement. From the technical point of view, the tasks three and four should possess a greater challenge to implement than one and two since they require character models, animations, possible scripted reactions on user’s movement or actions. E.g. thanking the user for the order if it is in the caffe or giving change in the supermarket/asking if the user need a bag.

It should be noted that as mentioned in the literature review, the number of the participants in covered projects and the current one has a low number of participants to state that the results

gained from them are guaranteed.
The current version of the VR prototype can already be used by students with autism but requires supervision by teachers with specific training (including VR technology). A variety of settings allows to work with students with a wide number of disability and does not require a comprehensive redesign of the system. The existing functionality allows for the addition of optional spoken and written instructions, which can help students with the respective disability. The development of such instructions should take place in close cooperation with specialists and teachers working with student with autism. Creating a "positive environment" and stronger cognitive feedback in VR is only possible with close cross-disciplinary work. The need for additional education for the teaching staff should be emphasised, as it may be difficult for teachers to match their knowledge of students' disabilities with the settings of VR environment and equipment. There is a clear opportunity for various VR headset projects which include participants/students with ASD since the number of available articles was limited. The future projects may include higher participant size excluding the bias if it could be identified and present in the data. The greatest challenge however in these types of projects is the ethical approval. In some countries like the UK, to gain the approval to conduct such experiments increases exponentially with the number of participants present with the ASD since they qualify as highly vulnerable and cannot make decisions for themselves, not to mention if they are considered underaged/young students.
But from the results covered in studies and the interviews done in the current research, it can be assumed that students with ASD generally can use VR headset without problems. But this depends on individual and should be consulted with the corresponding participant's guardian or responsible person. It is also can be assumed that the VR environment used with the headset is an effective way to teach students with ASD.
If the research would be conducted again, the newer version of the headset will be used since it has less wired parts which require USB connections. The oculus rift with the controllers and the sensors uses 3 USB ports and one HDMI cable respectively. It created a lot of wired connections which in the case of the headset itself required a separate USB port without the USB separator (The laptop has only 2 ports) since the data traffic was very high and demanded unused port. Oculus Quest is a viable option since the software and scripts used in the prototype should be compatible.
Furthermore, the original plan for study involved the participants with ASD but the ethical and organisational pressure connected with Covid 19 outbreak forced to change it. This is another thing which could have been done differently if the mentioned events have not occurred. The next project would include participants with ASD and more complex tasks in the enhanced VR prototype.

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Appendix Interviews

Researcher (R)

Participant one(P1)

R-Do you feel discomfort any motion sickness
P1-No, absolutely not
R-Were the controls easy to adapt to?
P1-It took a little bit of time for pointing. However the functionality of moving around and picking of objects were very easy.
R-How many students are in your class, that you supervise and teach?
P1-I do not supervise, I am a head teacher but the school has 195 students with special education needs(ASD).
R-Do you think the environments which you have visited can cause any discomfort for any of your students with special needs?
P1-It is very hard to categorise since each student has an individual issue or individual barriers that they experience what I would say in the main that it would not cause any issues for students. For students that may experience concerns, for them the staff is trained to support. I would say for what I have seen so far very large percentage of our students will be able to access it without problems.
R-If there would be any difficulties that you have mentioned, what would it be out of staff that you have tried? It was probably pointing?
P1-Yea, pointing at things. If we look again at functionality, some of our students have motor problems as well as they have physical problems. So problems with small things like fingers, coordination issues etc. I think that most of functionality, picking things up etc. because they are quite large movements, e.g. push button they will be able to manage that. The thing like pointing this thing is quite difficult. -A lot of students with coordination movements will struggle with that.
R-What solution do you think would improve the experience for students with special needs? Which could have come to your mind while you were experiencing the prototype? From the technical point of view?
P1-You mean the technical functionality, not content?
R-Yes.
P1-So from the technical… So being able to walk around the store with your left hand that was really good, the controls were very sensitive but actually very easy to use. What we then had was turning left and right with blocks of 90 degrees wasn't it?
R-Yes, but not 90, 45 degrees.
P1-45 degrees, well if the degree could be smaller. That would be fantastic.
R-So it should be as smooth as possible.
P1-Yes when you are turning left or right
R-Alright, thank you.
R-Next question, what features do you think may be added to assist in teaching for students with special needs. So basically …

P1-The curriculum, the content?
R-Yes
P1-Ok, so if we will look at the supermarket, two things that will support our curriculum. What I can see straight away that this is very closely relate to our independent living curriculum this is where we will teach students how to leave independently, so for them the experience as a shopper, it would be good to have a basket or trolley then set tasks with

shopping lists where it would mention for example if I need meat I need to go for the meat stand etc. if I need milk I need to go to this particular part of the supermarket. So actually, a challenge for them to find specific areas of the supermarket and put them with a trolley, that would be really supportive. Now, we do that a lot in real life we take our students in the supermarket so we been struggling with the covid recently but for our students who has very high anxiety and we struggle to get them off site this would be really really supportive.

R-Ok, next question, do you think it is possible to teach students with special needs using VR?
P1-Oh absolutely. Now I can certainly see the benefit of it.
R-Do you think there would be troubles for some of them to wear the VR headset?
P1-Some of our students will struggle with that. And again, this will be a new technology for us. It would be our job to work out and learn how to support those who cannot. From this point I would say it would be our journey to solve this.
R-Next question, after you visited locations, have you liked something visually or which locations did you like the most? Because one of them was sparce and other one was tight.
P1-Absolutely, yes. I would say both. It is interesting because they would both fit the purpose that's the key to it.
P1-I would say each environment would fit the purpose. The way both coffee shop and supermarket is set out, each can be used for different things. I would say both.

R-After all the questions do you want to add something to the experience you ve just had?
P1-So the supermarket would be good for independent living, having multiple items in there and challenges.
P1-From the coffee shop point of view when we mention the functionality of moving staff from the table so actually you more adopting the role of someone who is working there. What would be really good it the ability for someone in the coffee shop actually playing the role of employee to be able to interact with somebody.
R-You mean the two people present at the same time?
P1-…Basically customer, so if we gonna set up the table and we would have a customer. So, an ability to take an order.
R-Ok, does it have to be a real person or NPC would be enough. By that I mean non playable character.
P1-Just the process will be good.
R-I think I got it. Thank you very much for the interview.

Participant two(P2)
R-Do you feel discomfort any motion sickness?
P2-No
R-Were the controls easy to adapt to?
P2-Yes
R-What was the hardest part?
P2-Pointing to the left.
R-How many students in your class/group?
P2-A base of 19 students
R- Do you think the environments which you have visited can cause any discomfort for any of your students with special needs?

P2-No
R-What solution may improve…. In content
P2-It may be good to have instructions that the students can look at. May be an action that will bring menu/instructions which will tell them what to do.
R-You mean the controls?
P2-Yes, so maybe I could press a button and it would say you need to pick up a plate and put it on the table, so that I knew I have done this task and when I have done this task the notification popped up saying you have completed that task and also the things I could interact with may be if I point at them it could say "this is a plate you need to put it on the table".
R-What features could be added….?
P2-Communication improvement, e.g. visual rather than lots of words with instructions. So may be a video could come up. It would be easier for the student to get the information they need.
R-Do you think it is possible to teach students with special needs using this VR environment?
P2-Yes.
R-Do you think current version of the application could cause any discomfort….?
P2-Depends on the student, but for the majority it would be fine.
R-After you have completed the tasks what location did you like thew most visually?
P2-well, I liked the both environments, really nicely set out, in coffee shop it could be very nice touch the chairs or clean up the table .
R-Could you add anything that can be missing to the experience?
P2-The main thing for the special needs student would be having a way for them to understand what they have to do and some kind of tip when they've done it. Overall, very good work.
R-Thank you and thank you very much for the interview.

Participant three(P3)

R-Do you feel discomfort any motion sickness?
P3-No
R-Were the controls easy to adapt to?
P3-Yes
R-What was the hardest part?
P3- Picking up the objects, because of all buttons on the controller are close together at the back
R-How many students in your class/group?
P3-A base of 19 students
R-Do you think it would cause any discomfort……
P3-No, they would adapt really well I think.
R-What features could be added….?
P3-May be someone speaking giving them instructions, when they pick up things. Like how you have been giving me instructions. Something like that could be great if it is incorporated in the program. Or make some sort of symbols.
R-Do you think it is possible to teach students with special needs using this VR environment?
P3-We have got a lot of students here who d love to go to the supermarket because of theirs anxiety or other issues they do not want to leave the environments of school;. So bringing

that environments to them here is excellent. So yes.
R-Do you think current version of the application could be used by….?
P3-Yes, 100 percent
R-After you have completed the tasks what location did you like thew most visually?
P3-They were both excellent, but I prefer the caffe.
R-Why?
P3-It was more interactive since I had a challenge of dressing the table.
R-Could you add anything that can be missing to the experience?
P3-No, I think that was excellent. Thank you. That was very exciting.
R-Thank you very much for the interview.

Participant four(P4)

R-Do you feel discomfort any motion sickness?
P4-Slight bit of disorientation, but nothing uncomfortable
R-Were the controls easy to adapt to?
P4-With a few minutes of practice it would be pretty easy to use.
R-What was the hardest part?
P4-Pointing and grabbing initially. Getting used to grabbing motion was the hardest thing in the beginning.
R-How many students in your class/group?
P4-15-25 students
R-Do you think it would cause any discomfort……
P4-No, I think most of students will find that interesting even. It would be good for them. Potentially with the right guidance.
R-What solutions may improve…. In content
P4-The controls felt naturally to use. I didn't like the grabbing motion just because was a bit complicated and if it is possible to make it one button. That aside this is ideal for me since I am dyslexic myself, I had no problems orientate left or right. In the second location I felt much smaller which felt odd and unusual as if I had no legs which felt very peculiar if though I knew I was standing up. For dressing the table, it came naturally moving and orientating and with practice you can place items very comfortably which is good. It would be a very good way to see something you going to visit or do something like a visual tour. Something like that would be amazing.
R-What features could be added….?
P4-You see, for me it is a new experience. It is a cold environment to step into. You do not feel rewarded, there is no happiness. For example, the notification which pops up saying "well done".
Some positivity would be nice, a lot of students suffer from low self-esteem and low confidence issues. That would really help. Some audio feed to thank them/complement them. Well done you got this right, good etc. In plain English. It can be written or voiced out. Picture, words or combination. Positivity reinforces it doing well. Frustration can kick in and I know that personally from my experience.
R-Do you think it is possible to teach students with special needs using this VR environment?
P4-Absolutely, yes, it is.
R- Do you think current version of the application could cause any discomfort….?
P4-50/50. 50 percent of students will pick it up. Other would not be able to easily do it. It

would need other encouragement.
R-After you have completed the tasks what location did you like thew most visually?
P4- I did not like the coffee shop because it was very dark. And dressing the table in this darker environment felt very cold. It did not feel right. The same could be said in a way like in what location do I want to return to? I would say supermarket because the colours felt right, the light felt right, I wanted to explore it more.
R-Could you add anything that can be missing to the experience?
P4-I think this is a very useful piece of kit, it has a lot of applications. As a de-escalation tool with the right kind of students in the right kind of moments it could be of a great help. It makes me feel shorter. to the point that I can feel that, obviously I am not because I am standing up. That created a point of view by person in wheelchair. That is a very powerful tool.
R-Thank you very much for the interview, you have been of a very big help.