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# Introduction

# Aims

The primary aim of this project is to explore the viability of Virtual Reality (VR) to assist people with learning disabilities with independent travelling.

A subsequent aim of this project is to demo a suitable system through a VR1 study and a VR2 trial (Birckhead et al. 2019) that enables individuals with learning disabilities to navigate a virtual space with minimal risk of experiencing motion sickness.

# Objectives

* Examine and analyse the current Independent Travel Training process by reviewing the positive impact it has had and its current limitations.
* Investigate the current effectiveness of VR as a Travel Training tool through comprehensive research into Travel Training studies and the predecessors to this application.
* Learn and gain an in-depth understanding of the experiences of those with learning disabilities, especially regarding independent travel.
* Prototype a VR Travel Training application that aligns with existing research and includes new ideas to create a useful tool that can be used by people with learning disabilities to build up their independent travel confidence.
* Conduct research and testing ethically, legally, and professionally in compliance with the British Computing Society’s (BCS) Code of Conduct.
* Document and report on the findings of this project in a detailed and comprehensive manner so that it may be used to supplement the understanding of interaction paradigms and locomotion in future research.

# Context

## Virtual Reality for People with Learning Disabilities

In addition to VR’s role in treating and educating neurotypicals (Mantovani et al. 2004; Van Wyk, De Villiers 2009; Aïm et al. 2016), applications of VR in this context can also be seen in studies on neurodivergent individuals with phobias (Coelho et al. 2009), autism (Welch et al. 2009; Strickland et al. 1996) and traumatic brain injuries (Mondello et al. 2018).

This is primarily due to VR’s ability to model the real world in a safer and more controlled manner. Moreover, studies (Brooks et al. 2002; Rose et al. 2002) investigating the efficacy of VR in training people with learning disabilities found that participants “enjoyed the experience” and that for certain task scenarios “virtual training and real training were found to be equivalent” in effectiveness. The virtual learning environment (VLE) allows the user to repetitively simulate the same scenario as many times as they need without the influence of extraneous variables.

## Virtual Reality in Travel Training

Independent Travel Training is another example of an area where VR has begun to thrive in its application. Travel training is a form of therapy for individuals with learning disabilities to help them achieve independence concerning unaccompanied travel. The effectiveness of VR in this area has found that it can lead to more confidence (Bernardes et al. 2015) with independent travel and that it can also significantly reduce electrodermal activity (metric for anxiety) (Simões et al. 2018) in those scenarios with the addition of a high success rate for the application at an impressive 93.8%.

The results from the predecessors to this project echo similar conclusions. In order to expand upon the existing knowledge of VR’s efficacy in this area, a review of relevant publications has revealed two reoccurring themes.

### Navigation and Interaction Paradigms

The first of the two themes is that navigation methods and interaction paradigms for individuals with learning disabilities are often under-reported or under-researched. This is especially prominent in the case of full immersion into the virtual environment wherein a keyboard and mouse are no longer feasible options for navigation.

For non-immersive environments, these findings have been well documented (Standen et al. 2006). The results of the study found that in “the vertical plane only” the use of a mouse resulted in “better performance” compared to the joystick but the joystick did perform better when compared to “arrows on the keyboard” as it “enabled participants to gain consistently higher scores”.

Brown et al. 2002 found that most participants struggled to use a keyboard and mouse to navigate the virtual world with one participant finding “keyboard control very difficult”. A potential solution to this was identified via the joystick in which one participant had “almost instant success using joystick” on the Zebra crossing level. Subsequent iterations of this project then built upon this by having users walk in place while using the joystick to navigate forwards within the virtual space. Feedback from a few users on this approach found that this resulted in motion sickness and nausea. An alternative to this was to have the user stand still and use a back-and-forth swinging gesture of one arm to trigger movement in the virtual world. This resulted in a reduced reporting of motion sickness, however, no measure of motion sickness (i.e. simulator sickness questionnaire) was used to quantify this.

Similarly, a few other studies (Checa et al. in Lucio Tommaso De Paolis, Patrick Bourdot 2019; Cobbs et al. in Sharkey et al. 1998; Shopland et al. 2004) discuss the difficulties participants had with the interaction paradigms surrounding joystick-based navigation and player point of views (POVs) in the virtual learning environments (VLEs). However, no further investigation into navigation methods is pursued in these studies. At most questionnaire answers revealed that despite navigation being “one of the most difficult tasks to do” it was often indicated to be the “most enjoyable aspect” when using the VLE in some cases. Most notably, there seems to be conflicting views on whether joysticks are an ideal method for navigation; this may be due to each individual’s unique needs and experiences. Moreover, through participant feedback a user’s personal preference for first and third person perspectives was noted to be yet another element of navigation that dictates user experience, thus emphasising the need for perspective and controller flexibility when implementing locomotion into the application.

The remaining studies (Strickland et al. 1996; Simões et al. 2018; Bernardes et al. 2015) do not discuss the user’s experience with navigation and locomotion within the virtual world as they primarily focus on the effectiveness of the VLE itself as a learning tool.

The reoccurring theme discussed above leads into this project’s aim of determining the most effective method of navigation from the perspective of people with learning disabilities. To measure its efficacy one other element of virtual reality needs to be considered, motion sickness. As highlighted above, it is often brought about as a result of navigating within a virtual environment.

## Motion Sickness

**(Define Motion Sickness)**

In the review of all the studies discussed above, none measure the potential occurrence of motion sickness as a result of the chosen navigation method/interaction paradigm.

When considering motion sickness, it is important to note that its occurrence isn’t entirely uncommon when brought about because of an individual’s immersion into a VR application. One study (Munafo et al. 2017) found in an experiment involving games presented through the Oculus Rift that the “overall incidence of motion sickness” was 56% among its 36 participants. The article by Chang et al. notes that there are a few different causes of motion sickness in a VR application (Chang et al. 2020). These can be broken down into three main categories: “hardware”, “content” and “human factors”.

With regards to hardware, it is believed that motion sickness can be brought about due to delays generated by the latency effect present within the VR headset’s display as seen in the study by DiZio and Lackner in 1997 (as cited in Chang et al., 2020). The delay between what the user does and what is displayed to them does make for a rather disorientating experience. In recent years, several different solutions have been identified some involving hardware (Nguyen 2020) while others use algorithms (Kumar Kundu et al. 2021) to reduce latency rates.

However, studies such as the ones above on latency may not apply to this project’s travel training user base. Similarly, studies (Ibáñez, Peinado 2016; Wilson 2016) from a “content” perspective on motion sickness via navigation methods and interaction paradigms like most others, employs a sample of what can be assumed to be a majority group of neurotypicals and thus, without express investigation into its application with those who have learning disabilities it cannot be so easily concluded that better hardware for lower latency or a particular navigation method would result in a reduction of motion sickness and thus an improved experience of the application.

Through the combination of these two prevalent themes in similar studies within the topic area, the project’s aim begins to take shape. The motion sickness experienced by the user can be quantified through scales such as the Simulator Sickness Questionnaire (SSQ) and thus can be used to measure the efficacy of navigation methods and varying latency levels.

# New ideas

Through trialling different methods of navigating via the application’s content with the inclusion of varying latency rates using different VR hardware this project intends to determine the most suitable combination of hardware and content for its VR application based on conclusions drawn from the testing results with the participant group (Oak Field School 2022).

## Hardware

To investigate the role of hardware in relation to motion sickness experience by the participant it requires the comparison of varying latency rates against each other. To achieve this, the project will use Oculus Quest 2 and Pico 3 Pro VR kits instead of attempting to modify the latency rates manually. As a result, in the case a higher latency level results in a reduced rate of motion sickness it can be concluded that with further technological hardware advancements and improved latency rates that motion sickness might not be as prevalent.

## Content

Navigation players a key role in how the user experiences the VLE. Thus, by designing and implementing a variety of alternative navigation methods, this project can compare each ones effectiveness against the other using motion sickness (SSQ) scores. In addition to this, the speed at which a user completes a level will also be taken into consideration as a means of quantifying the effectiveness of the navigation method.

To determine a series of navigation modes for the VLE, a thorough review of existing solutions must first be discussed. Methods of navigation that are relevant to this project’s focus on travel training have been divided into two categories of analysis: easily accessible and financially unviable.

#### Financially Unviable

This project intends to make the VR application accessiblethrough the standard VR kit that is the head mounted display (HMD) and the hand-held motion controllers. Thus, any solution that involves an additional expense cannot be considered feasible in the context of this project.

The omnidirectional threadmill is a prime example of this. The threadmill is equipped to allow for a full range of motion (360 degrees) within a set area. This immediately solves our issues of having a wide open area to allow the player to simply just walk as they would within the virtual world. The freedom to mimic their actions in the virtual world could potentially resolve issues with the disconnect between the virtual world and reality that typically results in motion sickness. Similarly, there are VR Mats and Cybershoes, all of which achieve the same outcome of providing the user with navigation space without actually requiring a large play area but in slightly different ways.

The issue with all three is that they are financially unviable for this project. They are either quite expensive or are simply not available to a consumer market yet. Thus, more accessible alternatives are needed.

#### Easily Accessible

Previous iterations of this project have explored a variety of different navigation methods such as mouse and keyboard, steering wheel, gamepads, teleportation and walking in place. As this VLE intends to help teach its users how to walk and cross roads safely, the project aims to simulate this behaviour as closely as possible. To achieve this, the method of navigating using the motion controllers should try to mimic the act of walking. User feedback on teleportation found that it did not cause as much motion sickness as walking in place did. Teleporting, however, seems to defeat the purpose of teaching good walking and road safety practices as the user just has to stand still and let the teleportation function do all the work. Similarly, using a mouse and keyboard or a steering wheel does not get the user to mimic the act of walking either.

A potential solution to the above would be to simply let the user mimic the VLE experience in the real world. However, due to space constraints this isn’t a feasible option. With a limited working area to be considered, the application’s navigation modes should be designed to be functional and effective when the user remains in one spot for the entire duration.

In an earlier version of this project, user feedback found that walking via the swinging of one’s arm gesture captured by the motion controller was a more favourable form of navigation that resulted in reduced reporting of motion sickness. Similarly, there is the potential to have the motion controllers mapped to trigger movement when the user moves their arms back and forth in a jogging motion. This allows them to mimic real world behaviour without overstepping the limited space boundary.

In addition to this, the implementation of walking speed might allow the user more flexibility in how they’d like to experience their movement within the VLE. A customisable speed might be more favourable for some users as it could lead to them feeling their in-game speed is more representative of their actual walking speed. Each user’s experience and abilities are unique, it is impossible to determine the best value for in-game speed to set as a general standard for all users. Thus, the accessibility of the overall application can be improved by providing the users with control over how fast they ‘walk’ within the VLE.

**(Section on latency + navigation)**

Steering wheel to walk (original tech available)

* Teleportation (defeats the purpose – we need walking simulation)
* Walking around in an open space (we don’t have that much-unrestricted space to work with)
* Walking via the swinging of one's arms (existing project's solution)
* Low-latency VR games: Latency refers to the amount of time it takes for an in-app motion to register in the brain. The lower the latency, the less delay there is between what’s happening and your brain’s perception of it.
  + Low latency mixed with walking in place to combat the existing sickness – use this combination and compare it against the current solution and the original use of walking in place to see which one is far more effective at reducing motion sickness.

# Research Methodology

* Participatory Design, User Centric Design

Approach to Testing

* Compare Hardware – Oculus vs PICO – Does hardware determine the level of motion sickness? Let’s find the better option between the two
* Using published measurement tools – SSQ (Simulation Sickness Questionnaire) and the FMS (Fast Motion Scale)

# Tasks and Deliverables

## Project Milestones

The primary milestones for the project are listed below:

* Project Planning Document Submission (Review Point 1)
* Non-Invasive Ethics Application Submission (Review point 2)
* Prototype 1 (Pre-Testing)
* Prototype 2 (Post-Testing)
* Showcase Entry and Report Review (Review Point 3)
* Final Prototype and Project Submission
* Project Showcase

## Scope

The minimum viable product (MVP) of this project is a VR application that contains at least four types of road crossing levels and includes two forms of locomotion – walking in place with the help of hand gestures and joystick-controlled walking. All relevant tasks will be identified and prioritised to achieve the MVP within the project deadline before any effort is put into exploring the out-of-scope features.

Deliverables outside of this scope would include the addition of more forms of locomotion such as the ability to hop within the VR world or float using a hoverboard as an alternative form of locomotion. Furthermore, the development of a custom set of 3D assets would also be outside of the scope due to how time-consuming the process tends to be. However, in the case that the project is ahead of its schedule, an attempt will be made to create more relevant 3D assets (e.g. houses that fit the local scene instead of using American assets).

## Project Outcome

Upon successful completion of the development and testing of the MVP of this project, the VR application will be prepared to be handed on to the client, the NICER group, to be used at Oak Field School.

## Project Tasks

### Research and Planning

* Conduct interviews with subject experts within the field to gain a more in-depth understanding of the experiences of individuals with learning disabilities and of how the travel training application can be used to supplement their learning.
* Conduct a literature review of the topic area’s background and discuss the findings with regard to the aims and objectives of the project.
* Research the various alternative methods of navigation within the virtual world using the library and other online resources and research databases. Summarise these findings within the report with the key ideas identified being used to formulate the new ideas section of the report.
* Divide the different application features based on level of importance and create a Gantt Chart to better visualise the project timeline with other commitments.

### Implementation

* Design and implement the automated traffic system
* Design and implement the application levels
* Design and implement the interaction paradigms and new navigation methods
* Design and implement the menu functionality
* Design and model or source all the necessary 3D assets required for this project
* Complete development of the initial prototype based on the scope MVP to be used during the testing phase.
* Complete development of the second prototype using feedback received from the participants during the testing phase.
* Complete development of the final prototype before the project submission deadline which may include additional features depending on time constraints.

### Testing

* Ensure all necessary ethics documentation is complete and clearance to begin testing has been received.
* Recruit participants using the method outlined in the ethics declaration via the NICER group.
* Conduct a review of all the testing equipment a couple of days before the testing session to ensure that all the necessary equipment is functional.
* Conduct the testing session in line with the BCS Code of Conduct and the process specified in the non-invasive ethics application.
* Obtain post-testing session feedback from both the participants and their trainers to be used in the development of the second prototype.

### Ethics

* Review the BCS Code of Conduct in relation to the project and outline the findings in the relevant report section.
* Research an appropriate methodology for the project and outline the project’s testing process in detail.
* Complete and submit the ethics declaration document by the specified deadline.
* Submit all the necessary paperwork for the non-invasive ethics application.
* Receive clearance to begin the non-invasive ethical testing phase for the project.
* Continually review the project’s progress in conjunction with the BCS Code of Conduct.

### Documentation

* Document the findings from the research phase in the project concisely and cohesively within the report.
* Document and discuss challenges and hurdles during the project implementation phase and the methods used to solve them.
* Document and report on the findings of the testing phase.
* Review and compare this project's results against its predecessors' research and draw conclusions based on the findings.
* Discuss any remaining questions that can be explored in future work.
* Conduct thorough and frequent revisions of the project documentation. Additionally, submit draft versions of the documentation to the project’s supervisor for feedback.

# Gantt Chart

A computer screen capture

Description automatically generated with medium confidence

Graphical user interface

Description automatically generated

# Resources

## Information

* Google Scholar – A well-known search engine designed for academia. It also contains author profiles which allows one to look for ways to contact them when needed.
* Library One Search – This is a good resource to access articles of research that are locked behind a paywall.
* Connected papers – Allows a user to find interconnected papers by displaying a mind map network of papers by similar authors or topics.

## Implementation

* 3DS Max – This will be used to design and animate the 3D models that will be placed within the Unreal Engine VR project.
* Unreal Engine 4 (UE4) – The game development engine that will be used to build the VR world. The implementation of locomotion methods and modification to latency levels will be done through this application. UE4 is a well-known tool for virtual reality world-building (previous iterations of this project have used this too).
* Photoshop or Pixlr – Both will be used to edit textures and create materials for the 3D models and world to achieve a level of realism.

## Testing

* NICER – Individuals with learning disabilities and their trainers who will participate in the testing process of the application. Their feedback will be used to further improve upon the application.
* Virtual reality lab in ISTEC – This will be the location used for the testing phase as it is quite spacious and well-equipped with the necessary kit for testing. This includes the Quest 2 and Pico 3 Pro VR headsets for the participants.

# Risk and Mitigation

Each risk is assessed based on its probability and impact using a scale of 1 to 5 wherein a value of 1 implies that this risk has either a high probability of occurrence or that if this risk were to happen it will have little to no impact on the project’s progress. A value of 5 implies either a very high probability of occurrence or if this risk were to happen it will seriously impact the project’s progress.

The risk score is calculated by multiplying the probability by the impact score to determine its overall potential influence on the project’s progress with a higher score indicating greater severity. In certain cases, with high-impact risks, the mitigative cost might be far greater than others and thus the risk will still need to be taken for the project to continue.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.** | **Risk Description** | **Probability**  **(1 – 5)** | **Impact**  **(1 - 5)** | **Risk Score**  **(P x I)** | **Mitigative Action** |
| 1. | Insufficient knowledge and background research on virtual reality or travel training methodologies. | 1 | 4 | 4 | All the necessary background research will be conducted before the implementation of the solution through a wide variety of sources as highlighted in the Resource section of this document. |
| 2. | The project suffers from scope creep due to objectives not being well-defined and thus the project becomes too complex. | 2 | 5 | 10 | Clear objectives will be established during the early stages of the project and with the use of Agile methodology, any required changes will be thoroughly and frequently reviewed before approval. |
| 3. | The chosen resources are not suitable for the project. | 2 | 3 | 6 | A thorough review of the required resources will be conducted, and a justification will be provided based on research done before the start of the project. |
| 4. | The project suffers from a time crunch due to poor scheduling. | 2 | 5 | 10 | A Gantt chart will be used to map out key deliverable dates and will include the necessary flexibility in case a certain element requires more time than previously anticipated. |
| 5. | Loss of some or all of the project’s 3D assets. | 2 | 4 | 8 | All assets will be backed-up via a hard drive in addition to being stored on a private GitHub repository. |
| 6. | Loss of some or all the project’s documentation. | 2 | 4 | 8 | All documentation will be backed-up via a hard drive in addition to being stored on a private GitHub repository. |
| 7. | Loss of some or all parts of the Unreal Engine project files. | 2 | 4 | 8 | All Unreal Engine project files will be backed-up via a hard drive in addition to being stored on a private GitHub repository. |
| 8. | Equipment malfunctions during the testing stage | 3 | 4 | 12 | All equipment will be tested a day before the actual testing session in addition to being tested once again before the session begins to ensure everything is still functional. A backup set of equipment will be prepared when possible. |
| 9. | A major bug is found during the testing stage. | 2 | 4 | 8 | The project will have two testing phases in which the initial one will be used to gather feedback from the clients on any bugs or requirements that they would like the project to address. |
| 10. | Due to the shared use of Virtual Reality headsets and gear, participants might be at risk of COVID-19. | 3 | 3 | 9 | All equipment will be sanitised before and after each testing session in addition to being sanitised between use by testing participants. All participants will also be asked if they’ve had any symptoms before joining the testing session. |
| 11. | Participants experience some form of headache or eye strain because of the extended use of the VR application. | 3 | 2 | 6 | Participants’ time spent immersed in the application will also be limited as a means of reducing the probability of the risk’s occurrence. |
| 12. | Participants experience some form of motion sickness, nausea, or vertigo because of the VR application. | 3 | 2 | 6 | A discussion will be had with the participant before, during and after the testing stage to identify and mitigate any risks. Their well-being will be monitored to spot any adverse reactions to the application during the session. Participants’ time spent immersed in the application will also be limited as a means of reducing the probability of the risk’s occurrence. In the case they do experience any of the risk’s symptoms, they will be invited to have a break and allowed to continue later once they have recovered. |

# Legal, Social, Ethical and Professional Issues

## Legal

This project will include the use of participant test result data alongside interview feedback data during its implementation phase. Thus, in compliance with the existing General Data Protection Regulation (GDPR) (Proton AG 2022) and the Data Protection Act 2018 (The National Archives 2018) surrounding data collection and use, all participants involved in the project will be made aware of how their data will be processed in a “concise” and “transparent” manner (GDPR, Article 12). Additionally, participants will be allowed to request the deletion of any information we have on them at any point during or after the project (GDPR, Article 17). Furthermore, the collected information will not be used for “personal gain” or to “benefit a third party” as confidential information will not be shared without the “permission of a relevant authority or as required by legislation” (British Computing Society 2022, Section 3.4).

## Social

A crucial element of the BCS Code of Conduct is the use of technology with “public interest” in mind. From the perspective of this project, the development of a new and improved version of independent travel training technology can help counter obstacles that individuals with learning disabilities tend to face when it comes to gaining independence through travel. The findings of this project will be methodically documented so that it may supplement existing research into this topic area as this project constitutes a small part of a wide array of VR adaptations to ensure those with disabilities have equal access to educational tools that can benefit them. Furthermore, the final prototype developed will be shared with members of the NICER (Oak Field School 2022) group so that they have access to a more up-to-date version of the application.

## Ethical

This project aims to “treat all persons fairly and with respect” and intends to “not engage in harassment or discrimination, and to avoid injuring others” in line with the IEEE (Institute of Electrical and Electronics Engineers 2020) Code of Ethics as a key aspect of this project will involve user acceptance testing via a session with its actual user group. As the project’s target group are individuals with learning disabilities there is an additional level of care that must go into the overall process to ensure that there is “due regard for public health, privacy, security and wellbeing of others” (British Computing Society 2022, Section 1.1). To guarantee this, a thorough document highlighting the methods and procedures of this project will be submitted as part of the Non-Invasive Ethics application to obtain a sign-off from the relevant academic body.

## Professional

To ensure the maintenance of the professional integrity of this project with the aim of “upholding the reputation and good standing of BCS” (British Computing Society 2022, Section 4.3), several different guidelines shall be considered. The BCS highlights that one’s “duty to the profession” involves acting with “respect” and integrity” in addition to seeking to “improve professional standards”. To achieve this, the project will adhere to the university’s Student Code of Conduct (Nottingham Trent University 2022). This includes ensuring that throughout the lifecycle of the project that there will be no engagement in plagiarism, collusion or other actions that would result in a violation of the NTU Academic Irregularities Code of Practice. Subsequently, as this project will rely on the facilities provided by the university, the adoption of good practices based on the NTU Computer Use Regulations will be incorporated as well.

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