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# Chapter 1 - Introduction

## 1.1 Introduction

## 1.2 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 (Birckhead et al. 2019) that enables individuals with learning disabilities to navigate a virtual space with ease and comfort.

## 1.3 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.

# Chapter 2 - Context

## 2.1 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 (Brooks et al. 2002, p.625). 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.

## 2.2 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. To expand upon the existing knowledge of VR’s efficacy in this area, a review of relevant publications has revealed a reoccurring theme.

### 2.2.1 Navigation and Interaction Paradigms

It can be inferred from the literature review 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” (Standen et al. 2006, p.612).

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” (Brown et al. 2002, p.186). A potential solution to this was identified via the joystick in which one participant had “almost instant success using joystick” (Brown et al. 2002, p.186) 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). These studies did not pursue an investigation into navigation methods. However, questionnaire answers revealed contradictory findings wherein despite navigation being “one of the most difficult tasks to do” it was often indicated to be the “most enjoyable aspect” (Cobbs et al. in Sharkey et al. 1998, p.19) when using the VLE in some cases. Most notably, there seem to be conflicting views on whether joysticks are an ideal method for navigation; this may be due to everyone’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.

Thus, the discussion above leads to the 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, discomfort through motion sickness.

### 2.2.2 Discomfort and User Experience

To thoroughly capture the requirements needed to develop comfortable and easy-to-use navigation paradigms, one needs to first analyse the factors that contribute to users experiencing discomfort.

Motion sickness or otherwise known as cybersickness, simulator sickness or virtual reality sickness has long been an area of discussion concerning user experience in VR. The article by Chang et al. notes that there are a few different causes of motion sickness in a VR application. These can be broken down into three main categories: “hardware”, “content” and “human factors” (Chang et al. 2020, p.1660).

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). Another factor could be the occurrence of ocular vestibular mismatch wherein there is a disconnect between visual and motor signals (Bos et al. 2008). Through technological advancements over recent years, several different solutions have been identified. Some involve hardware modifications (Nguyen 2020) while others use algorithms (Kumar Kundu et al. 2021).

Human factors are another area that can potentially impact a user’s level of comfort within a VLE. Some studies (Stanney et al. 2016; Chang et al. 2020; Saredakis et al. 2020) have found that factors such as gender, age and BMI can have a considerable impact on cyber sickness while others argue that there is insufficient evidence (Melo et al. 2021; Lawson 2014 in Lu, Mao 2021). However, due to the scope of this project, human and hardware factors will need to be considered in future work as the primary focus of this project is to conduct a pilot study into ways to improve upon the application via its content.

Thus, this brings us to the final factor, content. There are a variety of different content elements that can contribute to cyber sickness. This includes the relationship between VR “picture quality” and VR sickness wherein it was believed that a higher quality, more immersive VR experience would reduce the extent to which a user would experience VR sickness. The results, however, noted that an increase in quality did not alleviate the symptoms of sickness (Golding et al. 2012; Davis et al. 2015; Carnegie, Rhee 2015). Nevertheless, as this project is building upon the foundations of its predecessors it will also include revised 3D models and textures that represent technological developments over the years that have allowed for an overall improvement in the quality of the VLE. This will be in addition to the primary content changes made to improve user experience.

As discussed in the previous section and can be seen in a few additional studies (Ibáñez, Peinado 2016; Standen et al. 2006), user comfort and immersion brought about through the interaction paradigms have a significant impact on one’s sense of “presence” within a VLE. As noted in the study by Cobbs et al., navigation can be a difficult task for individuals with learning disabilities, but it was often also found to be the “most enjoyable aspect” of the VLE. There is, however, a lack of studies focusing on how individuals with learning disabilities respond to different navigation paradigms within an immersive VLE.

Thus, by concentrating on designing and implementing navigation paradigms with a particular focus towards user comfort, the project will be able to thoroughly capture the needs of its users first before further pursuing an investigation into quantifying the effectiveness of each in future work. This includes modifications made to existing approaches to navigation paradigms such as joystick navigation and the implementation of novel solutions such as walking to point based on similar designs such as “Holoport” or “Ghosting” (Griffin, Folmer 2019; VRChat 2016).

Lead with ocular vestibular mismatch is it content or human factor?

Speed of movement? – field of view? – anchoring (fake nose?) - visual congestion

What are the design decisions that minimise of maximise sickness?

Cant accept the acceptability factors will reach to all other devices? A limitation of this project

Score my ideas itself on diserability and effectiveness?

Navigational archetypes

SSQ - Evaluating the input system

## 2.3 User-Centred Design

User-centred Design and the inclusion of users as “co-designers” takes advantage of how they are “experts by experience” (Harris et al. 2022, p.218). This experience can be used to facilitate the design and development of prototypes that are more in line with user needs (Barbieri et al. 2018; Gabbard et al. 1999).

To thoroughly capture and evaluate user experiences surrounding navigation paradigms in VLEs, the project will employ the use of feedback from travel training experts and individuals with learning disabilities via UCD methods (Spencer González et al. 2020; Bayor et al. 2021; Harris et al. 2022) such as interviews and focus groups.

The interviews with experts will look to gather requirements concerning navigation paradigms and ways in which existing solutions can be modified to provide greater levels of comfort and overall improved user experiences.

Subsequently, this feedback will be used to inform the design and implementation process for the initial prototype. The prototype will include all the key navigational requirements in addition to a few travel training elements (i.e., crossing levels and road hazards) as outlined in the New Ideas section.

The focus group will be an opportunity for the target user group to trial the prototype and provide user experience feedback on the application. The focus group questions will have a particular emphasis on how different navigation paradigms made users feel and what their preferences might be and why. This is so that the project can analyse and discuss in more depth the influence certain navigation paradigms have on the user experience of people with learning disabilities. Moreover, observations made during the session will be noted and will also be utilised during the development of the second stage prototype. This prototype will include the necessary changes derived from the feedback and all the minimum viable product (MVP) features as outlined during the requirements gathering stage.

Subsequently, these findings of the pilot study can then be used to supplement future work involving a long-term investigation into a user’s preferred navigation paradigm and the reported levels of discomfort via motion sickness as assessed by a Simulator Sickness Questionnaire (SSQ) (Kennedy et al. 1993) or VR Sickness Questionnaire (VRSQ) (Kim et al. 2018).

# Chapter 3 - New ideas

Navigation plays a key role in how the user experiences the VLE. Thus, by designing and implementing a variety of alternative navigation methods based on the existing understanding of the efficacy of previous navigation paradigm implementations, the project can then gather more detailed feedback on the user experience with each 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.

## 3.1 Financially Unviable

This project intends to make the VR application accessible through the standard VR kit which 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 treadmill is a prime example of this. The treadmill is equipped to allow for a full range of motion (360 degrees) within a set area. This immediately solves the issue 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 surrounding the disconnect between the virtual world and reality that typically results in motion sickness. Similarly, there are VR Mats and Cybershoes (Cybershoes 2022), all of which achieve the same outcome of providing the user with navigation space without 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.

## 3.2 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 crossroads 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.

### 3.2.1 Walk to Point

A potential modification to the teleportation method is using it to facilitate the ‘Walk to Point’ functionality instead. The user can use the teleportation tool to select a point they’re like to navigate to. Once selected, the player will begin to walk in that direction. The HMD would allow for free movement of the head to look in any direction as the player's body moves towards the selected destination. This method as a navigation paradigm would work quite well with static targets (i.e., crossing the road to reach the endpoint).

Challenges of using this method might arise when the user needs to follow a dynamic target (i.e., an NPC guide as they navigate roads). The process of selecting a target to walk towards could be too distracting, thus, resulting in the user ignoring active hazards in their surroundings.

Hence, this highlights the need for additional alternative navigation paradigms to be assessed in terms of their ease of use and comfort. While a possible solution to the above would be to simply let the user mimic the VLE experience in the real world, this isn’t a feasible option due to space constraints. 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.

### 3.2.2 Arm-Swinging Gestures

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 alternative form of navigation that resulted in reduced reporting of motion sickness. Moreover, this implementation of navigation allows the user to mimic some degree of real-world behaviour without overstepping the limited space boundary.

*[ Alternative to the deceleration and acceleration implementation of the previous version? ]*

### 3.2.3 Joystick Navigation

Despite previous iterations of this implementation garnering feedback that reported increased levels of discomfort via motion sickness, walking in place and navigating the VLE via a joystick is still a potential navigation paradigm option for users. This is primarily due to user experience with regards to the paradigm not being thoroughly reported on in other studies (Section 2.2.1) and thus the extent of discomfort is not well understood, especially when compared against alternative navigation options.

Furthermore, a modification to the paradigm concerning a user’s walking speed within the VLE could potentially reduce the influence of vertigo (Lu, Mao 2021). 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. Moreover, if a user feels that their speed in the VLE is what’s causing them to feel discomfort while they’re within a level, the application can offer them the flexibility to change their speed whenever they need to.

### 3.2.4 Application Levels

As the application is being designed to investigate the efficacy of different navigation paradigms within a travel training context, there will be several different level options for the users to trial. This includes plain crossing, pelican crossing, zebra crossing and crossroads crossing. The application will also include a base ‘main-menu’ level wherein users can trial out different navigation paradigms before beginning a crossing level of their choosing. Each level will include a start and end point, wherein the endpoint will include a visualiser to highlight the target point to the user.

# Appendices

## Appendix 1 - 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.

## Appendix 2 - 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. |

## Appendix 3 – Gantt Chart

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