Table of Contents

[Chapter 1 - Introduction 3](#_Toc121757210)

[1.1 Introduction 3](#_Toc121757211)

[1.2 Aims 4](#_Toc121757212)

[1.3 Objectives 4](#_Toc121757213)

[Chapter 2 - Context 5](#_Toc121757214)

[2.1 Virtual Reality for People with Learning Disabilities 5](#_Toc121757215)

[2.2 Virtual Reality in Travel Training 5](#_Toc121757216)

[2.2.1 Navigation and Interaction Paradigms 5](#_Toc121757217)

[2.3 Discomfort and User Experience 7](#_Toc121757218)

[2.3.1 Hardware 7](#_Toc121757219)

[2.3.2 Human Factors 8](#_Toc121757220)

[2.3.3 Content 9](#_Toc121757221)

[2.4 User-Centred Design 11](#_Toc121757222)

[Chapter 3 - New ideas 13](#_Toc121757223)

[3.1 Application Design 13](#_Toc121757224)

[3.1.1 Controllability 13](#_Toc121757225)

[3.1.2 Optical Flow 14](#_Toc121757226)

[3.2 Primary Interaction Paradigm Features 15](#_Toc121757227)

[3.2.1 Walk to Point Navigation 15](#_Toc121757228)

[3.2.2 Arm-Swinging Gesture Navigation 15](#_Toc121757229)

[3.2.3 Thumb-stick Navigation 16](#_Toc121757230)

[3.3 Additional Paradigm Modifications 16](#_Toc121757231)

[3.3.1 Flexible Player Speed 16](#_Toc121757232)

[3.3.2 Application Delivery 16](#_Toc121757233)

[3.3.3 Modular Content FOV 16](#_Toc121757234)

[3.3.4 Application Levels 16](#_Toc121757235)

[Chapter 4 - Implementation 18](#_Toc121757236)

[Appendices 19](#_Toc121757237)

[Appendix 1 - Legal, Social, Ethical and Professional Issues 19](#_Toc121757238)

[Legal 19](#_Toc121757239)

[Social 19](#_Toc121757240)

[Ethical 20](#_Toc121757241)

[Professional 20](#_Toc121757242)

[Appendix 2 - Risk and Mitigation 21](#_Toc121757243)

[Appendix 3 – Gantt Chart 24](#_Toc121757244)

[References 25](#_Toc121757245)

# 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 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.

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 reportedly “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) describe their navigation paradigms, however, they do not provide an evaluation or additional comments surrounding the user’s experience with navigation and locomotion within the virtual world.

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.

## 2.3 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).

### 2.3.1 Hardware

From a hardware perspective, it is believed that motion sickness can be brought about due to factors such as display type and mode (Harvey, Howarth 2007), hardware field of view (FOV) (Seay et al. 2001), latency (DiZio and Lackner 1997 in Chang et al. 2020; Bronstein et al. 2020), and flickering (Renkewitz, Alexander 2007). As interest in VR experiences continues to grow significantly **(ref here)**, there is now a need to overcome these issues “to allow broader people” access to “enjoy VR in their daily lives” (Chang et al. 2020, p.1660). Recent technological advancements and research have facilitated the development of a variety of different solutions (Pohl et al. 2013; van Waveren 2016; Nguyen 2020; Kumar Kundu et al. 2021); some of which now come as part of the consumer-grade HMD devices available to the public.

One such solution is the implementation of Asynchronous TimeWarp (ATW) within the Meta Quest 2 HMD (Meta 2020). The TimeWarp technique works by warping a rendered image before it is sent to the display. This is done to account for head motion that occurs once a scene is rendered, thus, reducing the perceived latency (Michael Antonov, Meta 2015). The asynchronous version of this simply handles the warp on another thread that runs in parallel with rendering. Another solution involves reducing the hardware FOV as it was found to alleviate discomfort in users. In Y. Y. Kim’s implementation, a detection system was designed to detect ‘biosignal’ feedback and respond accordingly by reducing the field of view; the method is called the Cybersickness Relief Virtual Environment (CRVE). The study reported lower cybersickness levels for participants in the CRVE condition compared to those in the non-CRVE condition (Kim et al. 2008). Finally, modular latency or HMD refresh rates is a solution that’s both accessible to the user and VR developers. Within the Oculus app, users can pick from a range of different refresh rates (i.e., 60Hz to 120Hz) while a developer can set the desired refresh rate of their app via their development tools (i.e., Unreal Engine).

Based on the studies discussed above, hardware is an area that’s been thoroughly investigated. Moreover, as has been established in the analysis of existing solutions, most of these have been integrated into present-day HMD devices or are in the process of being implemented. Thus, there is no need to further investigate hardware as a cause for motion sickness and discomfort in relation to this project.

### 2.3.2 Human Factors

Human factors are another area that can potentially impact a user’s level of comfort within a VLE. Studies (Stanney et al. 2016; Chang et al. 2020; Saredakis et al. 2020) have found that factors such as gender and age can potentially have a considerable impact on cybersickness though others (Melo et al. 2021) argue that there is insufficient evidence. In a review of studies **(ref here)** that investigate the influence of age, findings returned mixed results. Results of studies **(ref here)** on gender echo a similar sentiment. **(Include data)** Thus, it is still difficult to conclude whether these factors influence a user’s level of comfort in VR despite having a few different studies looking to quantify them as factors.

Learning disabilities as a human factor, however, are still underreported, especially when compared to the factors discussed above. The studies (Wang, Reid 2011; Bian et al. 2013; Glaser et al. 2022) that are currently available do touch upon concerns surrounding the relationship between learning disabilities and motion sickness but there is a lack of quantifiable data available. This project intends to be a pilot study into quantifying learning disabilities as a motion sickness human factor from a travel training simulator perspective. Based on existing research into vestibular dysfunction in adults with autism (Stankiewicz et al. 2020) it can be theorised that individuals with autism might be more susceptible to experiencing cybersickness in the virtual world because of ocular vestibular mismatch.

### 2.3.3 Content

There are a variety of different content elements that have been found to contribute to cybersickness. This includes optical flow **(ref here)**, controllability (Jaeger, Mourant 2001; Dong, Stoffregen 2010; Chen et al. 2011), graphic realism (Golding et al. 2012; Davis et al. 2015; Carnegie, Rhee 2015), and content FOV (Fernandes, Feiner 2016; Kobayashi et al. 2015).

#### Content FOV

As outlined in the hardware discussion, the FOV plays a role in influencing a player’s level of discomfort within the virtual world. Another method of modifying the FOV is through the content. In the studies by Fernandes et al. and Kobayashi et al., both concluded that narrowing the FOV via content was also an effective method of reducing a user’s VR sickness symptoms. However, as this is out of the scope of the project, content FOV modifications will need to be investigated further in future work to determine its potential role as a motion sickness content factor.

#### Graphic Realism

Graphic realism is another content factor that has been thoroughly investigated to reduce user discomfort. However, contrary to what was expected, the studies found that improved graphics and degree of realism in the virtual environments did not lead to reduced reporting of cybersickness (Golding et al. 2012; Davis et al. 2015; Carnegie, Rhee 2015). Chang et al. suggest that this may be due to the “sensory discrepancy” between “visual and vestibular information” (Chang et al. 2020, p.1669) that relate to other content factors such as optical flow and controllability. As this project is building upon the foundations of its predecessors it will 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. It will not, however, investigate in-depth the relationship between graphic realism and user discomfort. Instead, the project will look towards examining the successfulness of the navigation paradigm implementations derived from an understanding of the remaining content factors discussed below.

#### Controllability

Controllability as a content factor can be divided into two categories, passive and active experiences. Passive navigation in a virtual world typically limits the user’s interactions and has been found to be the cause of motion sickness (Jaeger, Mourant 2001). It was also concluded that a user’s experience would become worse when controllability was lost, and they were forced to experience the virtual environment passively (Chen et al. 2011; Dong, Stoffregen 2010). Thus, this emphasises the need for well-designed interaction paradigms that keep the user engaged and comfortable throughout the experience. From the perspective of the project’s application, this relates to its use of navigation paradigms to teach the user good road-crossing habits. This can be implemented using the VR hand controllers and HMD as trackers for a player’s movement and gestures, thus, encouraging them to actively move about and interact with the VLE. Moreover, by having the user interact with the virtual world to navigate within it, the user simulates real-world behaviours (i.e., walking and crossing roads) that are required as part of the learning experience of the travel training simulation.

#### Optical Flow

The final content factor is optical flow; it has been observed that humans are more likely to become nauseous when they see moving content than static content **(ref here)**. A potential reason for this is that “moving stimuli produces the optical flow of a VR scene” thus enabling the user to “experience illusionary self-motion”. (Chang et al. 2020, p.1668). Speed has been noted to be a potential parameter that can influence the optical flow of a VR scene. In the study by Lo et al., it was determined that navigational speed can influence a user’s level of discomfort in VR wherein when speeds were raised from 3 m/s to 10 m/s it resulted in increased reporting of nausea. However, it was also noted that if the speed of the VR speed was too high, a user’s level of discomfort might not be as severe due to a reduced sense of presence (Lo, So 2001). The findings of Lu et al. echo this; when attempting to determine an interaction method to alleviate cybersickness, the study found that participants “are extremely sensitive to speed in VR” (Lu, Mao 2021, p.369). In addition to this, player feedback highlighted the need for a controllable speed as it was believed it might improve their comfort levels and reduce vertigo. From the perspective of the study, having navigational paradigms with controllable speeds as a design decision might benefit the application’s users as they can adjust the speed of their player character to a degree that’s far more comfortable for them to experience.

The other parameter of optical flow involves rotational movements. Studies **(ref here)** found that users show a higher level of discomfort when subjected to rotational movements in comparison to translational movements. This feeling of discomfort is further exacerbated when the user is exposed to rotational movement across multiple axes **(ref here)**. This parameter further amplifies the occurrence of ocular vestibular mismatch (Bos et al. 2008) based on the conflicting stimuli a user receives from the real and virtual world. A solution to this from the perspective of the project is to limit these rotational movements in the VLE. Instead, any rotation of the player’s point of view is strictly produced in correlation with the HMD tracking data. Any movement of their head in the real world will be translated into the virtual world thus preventing them from experiencing the navigation from a counter-intuitive angle. Another method that incorporates both the speed and rotational movement parameters would be to implement a modified version of popular ‘out-of-body’ locomotion methods such as “holoport” and “ghosting” (VRChat 2016; Griffin, Folmer 2019). Instead of watching a player character walk to the point in the third person and then resuming the first-person perspective once at the endpoint, the modification would have the person ‘walk’ to the point from the first-person perspective with their HMD allowing them to rotate their head freely as their character moves to the endpoint.

## 2.4 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.

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.

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

## 3.1 Application Design

To design an application that effectively reduces the likelihood of user discomfort caused by these paradigms, the application must utilise the relevant content factors as design decisions. To ensure the scope of the project isn’t exceeded, this pilot study will focus on the optical flow and controllability factors first.

### 3.1.1 Controllability

The project intends to create a training VLE that simulates the experience of crossing roads; therefore, the user should remain engaged by the content throughout the travel training process. Ideally, the game would provide the user with active experiences so that user engagement and comfortability are maintained. In previous iterations of the project, active experiences have been implemented using first-person perspectives in addition to the use of VR HMDs to deliver the VLE. Another solution would be to utilise the user’s real-world movements and gestures to simulate in-game actions which in the application’s context would be primarily for player locomotion. There is, however, a limitation to this in which the application needs to deliver its VLE within spaces that don’t necessarily have enough area to allow for free roaming.

There are a few different existing solutions that are known to successfully translate a player’s physical walking movements into virtual locomotion using limited space. These solutions include items such as linear and omnidirectional treadmills **[ref here]**. These treadmills allow the user to experience the same locomotion in the real world as they would in the VLE, thus, potentially reducing the impact of user discomfort factors. The omnidirectional treadmills especially with the full range of motion (360 degrees) provide a user with the ability to both walk and rotate themselves in any given direction without the need for an additional player rotation controller. While this is an interesting solution, it is, however, not portable. Moreover, most implementations of omnidirectional treadmills have yet to be made widely available to the consumer market.

On the other hand, Cybershoes (Cybershoes 2022) are a portable alternative that is available to the everyday VR user. These shoes allow the user to simulate locomotion from a seated position, and it captures rotation through the rotation of the user’s seat. Despite their portability and much cheaper price tag in comparison to the treadmills, they still do come at a cost. To design an application that’s accessible to a wider user group, the VLE needs to utilise affordable solutions; hence the need for in-built content-based navigation paradigms. These existing solutions can be utilised in future work as comparison factors when attempting to quantify user discomfort levels as a means of determining the most suitable navigation paradigms for the application.

### 3.1.2 Optical Flow

As indicated in an earlier section, speed and rotational movement are parameters that influence how optical flow can negatively impact a user’s comfort level in a virtual environment. In most VR games and simulations, teleportation has become the preferred mode of navigation. Within the application’s context, however, this navigation paradigm defeats its primary learning objective which is to be a travel training simulator wherein it gets the users to mimic real-world behaviours via the VLE. Hence, the need for an alternative solution that accounts for speed and rotational movement parameters.

One such solution can be seen in VRChat which is its use of a modified version of teleportation known as “holoporting” (VRChat 2016). The user watches their player character navigate to the selected endpoint from the third person before then being teleported to this new location. A more relevant implementation of this for this project would be to attempt to implement a similar version that utilises the first-person perspective instead. Moreover, modular speeds across all navigation paradigms are another solution that might improve user experience. Providing the user with the flexibility to control how quickly they experience locomotion within the VLE has the potential to reduce vertigo and other negative side effects of motion sickness. This could be done using gesture tracking or through thumb stick movement.

## 3.2 Primary Interaction Paradigm Features

Based on the design factors discussed above, this application will include the implementation of three main navigation paradigms that’ll be tested via the project’s user group. In addition to this, the application will also include revised versions of the different road crossing levels and their relevant assets.

### 3.2.1 Walk to Point Navigation

A potential modification to the teleportation method is using it to facilitate the ‘Walk to Point’ functionality instead. This concept utilises similar existing implementations wherein during the act of teleporting, a user can view a ghost of themselves moving to the endpoint (VRChat 2016). Similarly, in this new implementation, the user can use the teleportation tool to select a point they’d like to navigate to. Once selected, the player will begin to walk in that direction. Instead of seeing a ghost of oneself from a third-person perspective, the HMD would allow for free movement of the head to look in any direction from a first-person POV 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.

### 3.2.2 Arm-Swinging Gesture Navigation

Another navigation paradigm that will be implemented would employ the use of arm-swinging gestures as a means of capturing locomotion input. In a previous iteration of the project, this paradigm appeared to be the more favourable form of navigation based on user feedback. The paradigm successfully creates an active user experience in addition to staying within the limited space boundary. Moreover, this paradigm provides users with an alternative navigation method, especially for users with learning disabilities that might not be as experienced with controllers and buttons. The downside of the method is the ambiguity behind the acceleration and deceleration mechanics being a potential disruptor to the optical flow of the scene as it is difficult to determine at what point during the arm swing the user would like to begin deceleration. Modification of this paradigm might involve the use of a formula to calculate the rate at which the arm swinging changes to determine whether the player’s speed is accelerating or decelerating.

### 3.2.3 Thumb-stick Navigation

Despite previous iterations of a similar implementation using a joystick garnering feedback that reported increased levels of discomfort via motion sickness, thumb-stick navigation has the potential to become a feasible navigation paradigm through a few different design modifications. The implementation of this paradigm would utilise the axis of thumb-stick movement to dictate the back-and-forth and side-to-side player movement. The delivery of this paradigm, however, will allow for flexibility. The user can choose to either remain seated and swing their legs back and forth on a chair like the Cybershoes approach or they could stand up and walk in place using an additional rotation controller to dictate the direction of their player’s movement. The other design modification applied is the speed parameter which is discussed in the following section (Section 3.2.4).

## 3.3 Additional Paradigm Modifications

### 3.3.1 Flexible Player Speed

A supplementary modification to all three navigation paradigms will include the ability to change one’s maximum locomotion speed as it could potentially reduce the influence of vertigo (Lu, Mao 2021). The customisable maximum 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.

The user’s speed within the VLE will increase till it reaches the maximum depending on their chosen navigation paradigm and decelerate when they either get closer to their endpoint or indicate via the tracking metrics that they’re slowing down.

### 3.3.2 Application Delivery

[Take bit from earlier sections on how they will be delivered or instructed to use them

### 3.3.3 Modular Content FOV

### 3.3.4 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.

# Chapter 4 - Implementation

# 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

# References

Aïm, F. et al., 2016. Effectiveness of Virtual Reality Training in Orthopaedic Surgery. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, 32(1), pp.224–232. 10.1016/J.ARTHRO.2015.07.023.

Barbieri, L., Bruno, F., Muzzupappa, M., 2018. User-centered design of a virtual reality exhibit for archaeological museums. *International Journal on Interactive Design and Manufacturing*, 12(2), pp.561–571. 10.1007/s12008-017-0414-z.

Bayor, A.A. et al., 2021. Toward a Competency-based Approach to Co-designing Technologies with People with Intellectual Disability [online]. *ACM Transactions on Accessible Computing (TACCESS)*, 14(2). Available at: https://dl.acm.org/doi/10.1145/3450355 [Accessed 22 November 2022].

Bernardes, M. et al., 2015. A serious game with virtual reality for travel training with Autism Spectrum Disorder. In: *International Conference on Virtual Rehabilitation, ICVR*. Institute of Electrical and Electronics Engineers Inc., pp. 127–128. 10.1109/ICVR.2015.7358609.

Bian, D. et al., 2013. A novel virtual reality driving environment for autism intervention [online]. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 8010 LNCS(PART 2), pp.474–483. Available at: https://link.springer.com/chapter/10.1007/978-3-642-39191-0\_52 [Accessed 5 December 2022].

Birckhead, B. et al., 2019. Recommendations for methodology of virtual reality clinical trials in health care by an international working group: Iterative study. *JMIR Mental Health*, 6(1). 10.2196/11973.

Bos, J.E., Bles, W., Groen, E.L., 2008. A theory on visually induced motion sickness. *Displays*, 29(2), pp.47–57. 10.1016/J.DISPLA.2007.09.002.

British Computing Society, 2022. BCS Code of Conduct [online]. Available at: https://www.bcs.org/membership-and-registrations/become-a-member/bcs-code-of-conduct/ [Accessed 12 October 2022].

Bronstein, A.M., Golding, J.F., Gresty, M.A., 2020. Visual Vertigo, Motion Sickness, and Disorientation in Vehicles [online]. *Seminars in Neurology*, 40(1), pp.116–129. Available at: http://www.thieme-connect.com/products/ejournals/html/10.1055/s-0040-1701653 [Accessed 30 November 2022].

Brooks, B.M. et al., 2002. An evaluation of the efficacy of training people with learning disabilities in a virtual environment. *International Journal of Disability and Rehabilitation*, 24(11–12), pp.622–626. 10.1080/09638280110111397.

Brown, D.J., Shopland, N., Lewis, J., 2002. Flexible and Virtual Travel Training Environments. , pp.181–188.

Carnegie, K., Rhee, T., 2015. Reducing Visual Discomfort with HMDs Using Dynamic Depth of Field. *IEEE Computer Graphics and Applications*, 35(5), pp.34–41. 10.1109/MCG.2015.98.

Chang, E., Kim, H.T., Yoo, B., 2020. Virtual Reality Sickness: A Review of Causes and Measurements. *International Journal of Human-Computer Interaction*, pp.1658–1682. 10.1080/10447318.2020.1778351.

Chen, W., Chen, J.Z., So, R.H.Y., 2011. Visually induced motion sickness: Effects of translational visual motion along different axes [online]. *Contemporary Ergonomics and Human Factors 2011*, pp.281–287. Available at: https://www.taylorfrancis.com/chapters/edit/10.1201/b11337-40/visually-induced-motion-sickness-effects-translational-visual-motion-along-different-axes-chen-chen [Accessed 4 December 2022].

Coelho, C.M. et al., 2009. The use of virtual reality in acrophobia research and treatment. *Journal of Anxiety Disorders*, 23(5), pp.563–574. 10.1016/J.JANXDIS.2009.01.014.

Cybershoes, 2022. Cybershoes for Quest & SteamVR - Cybershoes [online]. Available at: https://www.cybershoes.com/product/cybershoes-for-quest-steamvr/ [Accessed 24 November 2022].

Davis, S., Nesbitt, K., Nalivaiko, E., 2015. *Comparing the onset of cybersickness using the Oculus Rift and two virtual roller coasters*.

Dong, X., Stoffregen, T.A., 2010. Postural activity and motion sickness among drivers and passengers in a console video game. 10.1518/107118110X12829369835680.

Fernandes, A.S., Feiner, S.K., 2016. Combating VR sickness through subtle dynamic field-of-view modification. *2016 IEEE Symposium on 3D User Interfaces, 3DUI 2016 - Proceedings*, pp.201–210. 10.1109/3DUI.2016.7460053.

Gabbard, J.L., Hix, D., Swan, J.E., 1999. User-centered design and evaluation of virtual environments. *IEEE Computer Graphics and Applications*, 19(6), pp.51–59. 10.1109/38.799740.

Glaser, N., Schmidt, M., Schmidt, C., 2022. Learner experience and evidence of cybersickness: design tensions in a virtual reality public transportation intervention for autistic adults [online]. *Virtual Reality*, 26, pp.1705–1724. Available at: https://doi.org/10.1007/s10055-022-00661-3.

Golding, J.F. et al., 2012. Cognitive Cues and Visually Induced Motion Sickness. *Aviation Space and Environmental Medicine*, 83(5), pp.477–482. 10.3357/ASEM.3095.2012.

Griffin, N.N., Folmer, E., 2019. Out-of-body locomotion: Vectionless navigation with a continuous avatar representation [online]. *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*. Available at: https://dl.acm.org/doi/10.1145/3359996.3364243 [Accessed 27 November 2022].

Harris, M.C. et al., 2022. A Methodology for the Co-design of Shared VR Environments with People with Intellectual Disabilities: Insights from the Preparation Phase. In: *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. Springer Science and Business Media Deutschland GmbH, pp. 217–230. 10.1007/978-3-031-05039-8\_15.

Harvey, C., Howarth, P.A., 2007. The Effect of Display Size on Visually-Induced Motion Sickness (VIMS) and Skin Temperature. In: *Proceedings of the 1st international symposium on visually induced motion sickness, fatigue, and photosensitive epileptic seizures*. pp. 96–103.

Institute of Electrical and Electronics Engineers, 2020. IEEE Code of Ethics [online]. Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 12 October 2022].

Jaeger, B.K., Mourant, R.R., 2001. Comparison of Simulator Sickness using Static and Dynamic Walking Simulators. In: *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting*. pp. 1896–1900.

Kennedy, R.S. et al., 1993. Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology*, 3(3), pp.203–220. 10.1207/s15327108ijap0303\_3.

Kim, H.K. et al., 2018. Virtual reality sickness questionnaire (VRSQ): Motion sickness measurement index in a virtual reality environment. *Applied Ergonomics*, 69, pp.66–73. 10.1016/j.apergo.2017.12.016.

Kim, Y.Y. et al., 2008. The Application of Biosignal Feedback for Reducing Cybersickness from Exposure to a Virtual Environment [online]. *Presence: Teleoperators and Virtual Environments*, 17(1), pp.1–16. Available at: https://direct.mit.edu/pvar/article/17/1/1/18706/The-Application-of-Biosignal-Feedback-for-Reducing [Accessed 30 November 2022].

Kobayashi, N. et al., 2015. *Using bio-signals to evaluate multi discomfort in image viewing - balancing visually induced motion sickness and field of view*. 10.1109/EMBC.2015.7319808.

Kumar Kundu, R., Rahman, A., Paul, S., 2021. A Study on Sensor System Latency in VR Motion Sickness. *Journal of Sensor and Actuator Networks*. 10.3390/jsan10030053.

Lo, W.T., So, R.H.Y., 2001. Cybersickness in the presence of scene rotational movements along different axes. *Applied Ergonomics*, 32(1), pp.1–14. 10.1016/S0003-6870(00)00059-4.

Lu, Z., Mao, R., 2021. Research on the Interaction Method that Can Alleviate Cybersickness in Virtual Reality Games. In: *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. Springer Science and Business Media Deutschland GmbH, pp. 355–371. 10.1007/978-3-030-77414-1\_26.

Lucio Tommaso De Paolis, Patrick Bourdot, 2019. *Augmented Reality, Virtual Reality, and Computer Graphics* [eBook] de Paolis, L. T., Bourdot, P., eds. Italy: Springer International Publishing. Available at: http://link.springer.com/10.1007/978-3-030-25965-5.

Mantovani, F. et al., 2004. Virtual Reality Training for Health-Care Professionals [online]. *http://www.liebertpub.com/cpb*, 6(4), pp.389–395. Available at: https://www.liebertpub.com/doi/10.1089/109493103322278772 [Accessed 9 October 2022].

Melo, M. et al., 2021. Impact of Different Role Types and Gender on Presence and Cybersickness in Immersive Virtual Reality Setups. In: *ICGI 2021 - 2021 International Conference on Graphics and Interaction, Proceedings*. Institute of Electrical and Electronics Engineers Inc. 10.1109/ICGI54032.2021.9655281.

Meta, 2020. Asynchronous TimeWarp (ATW) [online]. Available at: https://developer.oculus.com/documentation/native/android/mobile-timewarp-overview [Accessed 30 November 2022].

Michael Antonov, Meta, 2015. Asynchronous Timewarp Examined [online]. Available at: https://developer.oculus.com/blog/asynchronous-timewarp-examined/ [Accessed 30 November 2022].

Nguyen, T., 2020. Low-latency Mixed Reality Headset. *Low-latency VR/AR Headset project from Conix Research Center, Computing On Network Infrastructure for Pervasive Perception, Cognition and Action*.

Nottingham Trent University, 2022. Student Code of Behaviour [online]. Available at: https://www.ntu.ac.uk/studenthub/my-course/student-handbook/student-code-of-behaviour [Accessed 12 October 2022].

Oak Field School, 2022. NICER Group Nottingham [online]. Available at: https://www.oakfieldschool.org.uk/nicer-group-nottingham-interactive-community-for-e/ [Accessed 2 October 2022].

Pohl, D., Johnson, G.S., Bolkart, T., 2013. Improved pre-warping for wide angle, head mounted displays [online]. *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*, pp.259–262. Available at: https://dl.acm.org/doi/10.1145/2503713.2503752 [Accessed 30 November 2022].

Proton AG, 2022. GDPR [online]. Available at: https://gdpr.eu/data-privacy/ [Accessed 12 October 2022].

Renkewitz, H., Alexander, T., 2007. Perceptual Issues of Augmented and Virtual Environments. In: Research Institute for Communication Information Processing, and Ergonomics (FKIE).

Rose, F.D., Brooks, B.M., Attree, E.A., 2002. An exploratory investigation into the usability and usefulness of training people with learning disabilities in a virtual environment [online]. *International Journal of Disability and Rehabilitation*, 24(11–12), pp.627–633. Available at: https://www.tandfonline.com/action/journalInformation?journalCode=idre20.

Saredakis, D. et al., 2020. Factors associated with virtual reality sickness in head-mounted displays: A systematic review and meta-analysis. *Frontiers in Human Neuroscience*, 14. 10.3389/fnhum.2020.00096.

Seay, A.F. et al., 2001. *Simulator Sickness and Presence in a High FOV Virtual Environment*. 10.1109/VR.2001.913806.

Sharkey, P., Rose, D., Lingström, J.-I., 1998. The 2nd European Conference on Disability, Virtual Reality and Associated Technologies. In: *European Conference on Disability, Virtual Reality and Associated Technologies*. Sweden: University of Reading.

Shopland, N. et al., 2005. Design and evaluation of a flexible travel training environment for use in a supported employment setting. *International Journal on Disability and Human Development*.

Simões, M. et al., 2018. Virtual Travel Training for Autism Spectrum Disorder: Proof-of-Concept Interventional Study [online]. *JMIR Serious Games 2018*, 6(1). Available at: https://games.jmir.org/2018/1/e5 [Accessed 2 October 2022].

Spencer González, H. et al., 2020. Including intellectual disability in participatory design processes: Methodological adaptations and supports [online]. *ACM International Conference Proceeding Series*, 1, pp.55–63. Available at: https://dl.acm.org/doi/10.1145/3385010.3385023 [Accessed 22 November 2022].

Standen, P.J. et al., 2006. Systematic evaluation of current control devices used by people with intellectual disabilities in non-immersive virtual environments [online]. *Cyberpsychology and Behavior*, 9(5), pp.608–613. Available at: www.liebertpub.com [Accessed 16 October 2022].

Stankiewicz, T. et al., 2020. Virtual Reality Vestibular Rehabilitation in 20 Patients with Vertigo Due to Peripheral Vestibular Dysfunction [online]. Available at: https://www.medscimonit.com/abstract/index/idArt/930182.

Stanney, K.M. et al., 2016. What to Expect from Immersive Virtual Environment Exposure: Influences of Gender, Body Mass Index, and Past Experience [online]. *https://doi.org/10.1518/hfes.45.3.504.27254*, 45(3), pp.504–520. Available at: https://journals.sagepub.com/doi/abs/10.1518/hfes.45.3.504.27254?casa\_token=KSAcyLSEFsoAAAAA%3AS-vyJ5i6Q2a6fTmIzeyCSdl6v72TjvsqMdjZE-7f0ud6frmYyogmVVXRZQrYt-c9JJLewWlr4IWCVg [Accessed 27 November 2022].

Strickland, D. et al., 1996. Brief Report: Two Case Studies Using Virtual Reality as a Learning Tool for Autistic Children. *Journal of Autism and Developmental Disorders*, 26(6).

The National Archives, 2018. Data Protection Act 2018 [online]. Available at: https://www.legislation.gov.uk/ukpga/2018/12/contents/enacted [Accessed 12 October 2022].

VRChat, 2016. Introducing “Holoport” Locomotion [online]. Available at: https://medium.com/@vrchat/introducing-holoport-locomotion-9ada3abec63 [Accessed 27 November 2022].

Wang, M., Reid, D., 2011. Virtual Reality in Pediatric Neurorehabilitation: Attention Deficit Hyperactivity Disorder, Autism and Cerebral Palsy [online]. *Neuroepidemiology*, 36(1), pp.2–18. Available at: https://www.karger.com/Article/FullText/320847 [Accessed 5 December 2022].

van Waveren, J.M.P., 2016. The asynchronous time warp for virtual reality on consumer hardware [online]. *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*, 02-04-November-2016, pp.37–46. Available at: https://dl.acm.org/doi/10.1145/2993369.2993375 [Accessed 30 November 2022].

Welch, K.C. et al., 2009. An affect-sensitive social interaction paradigm utilizing virtual reality environments for autism intervention. In: pp. 703–712. 10.1007/978-3-642-02580-8\_77.

van Wyk, E., de Villiers, R., 2009. Virtual reality training applications for the mining industry. *Proceedings of AFRIGRAPH 2009: 6th International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa*, pp.53–64. 10.1145/1503454.1503465.

Zanier, E.R. et al., 2018. Virtual Reality for Traumatic Brain Injury. *Frontiers in Neurology*. 10.3389/fneur.2018.00345.