Virtual Reality Accessibility with Predictive Trails

An Honors Paper for the Department of Computer Science

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1 Statement of Problem

1.1 Introduction

Navigating 3D environments, especially ones as complex and immersive as virtual reality (VR), can be overwhelming in a number of ways. The prominent risk to participants is simulator sickness, which can result in nausea, fatigue, uneasiness, dizziness, and vomiting. These symptoms can last up to four hours, and are more likely to occur when users experience vection while attempting to traverse digital environments with methods besides natural locomotion (or walking without digital/software aid). More often than not, the most accessible and economically viable locomotive methods for a user require software-enabled movement through the use of controllers, whether they are traditional gamepads or specifically crafted for virtual reality.

In order for VR to be adopted on a wider scale, the accessibility to the technology needs to be increased. Accessibility in this case refers to "an umbrella term for all aspects which influence a person's ability to function within an environment" [7]. VR accessibility suffers in two key ways: vection-induced simulator sickness, and navigational issues. Both are not only prominent, but have been shown to have different effects based on sex differences (specifically, women are more likely to suffer more severe cases of simulator sickness [3][12]).

While simulator sickness mitigation methods do exist, some of the most researched and used methods explicitly use FoV restriction, something that's had a history of sex-biased side-effects on navigational ability when restrictions are prolonged, or implemented in more intense VR activities [3]. Additionally, some alternative mitigation methods require commercial licenses for use. As such, an openly-distributed software solution is required.

The following project presents the idea of using predictive trails, a manner of simulator sickness mitigation and navigational aid that avoids FoV restriction. Built as a module for the widely-used game engine Unity, predictive trails use navigation meshes and pathfinding to create visual trails predicting the path of the user based on their vection, and the navigable space. The visual marker serves as visual grounding to combat vection-based simulator sickness, while providing a navigation aid for the virtual space.

Inclusive methods of simulator sickness mitigation are especially important, given that they are essential for software-enabled locomotion. The economic implications of room-scale, natural locomotion-driven VR are only amplified by the barrier of physical accessibility they offer to users with conditions that affect their ability to maneuver unassisted.

1.2 Locomotion in Virtual Reality

Natural locomotion, or digitally-unaided physical locomotion, offers the most intuitive form of locomotion for most users. By tracking users with a combination of sensors and the user's headset and/or proprietary motion controllers, a user's walking in real life can be translated into locomotion for their virtual avatar. This method has been proven to assist in mitigating simulator sickness in VR experiences in contrast with methods utilizing traditional controllers [11]. However, these advantages come with a variety of caveats. In addition to the requirement of sufficient physical space, natural locomotion is often inaccessible to users with conditions that hinder movement or make it otherwise difficult. As for presence, the use of natural locomotion has been shown to not improve user presence in comparison to other locomotion methods [11]. Additionally, VR experiences for larger virtual spaces will often need software-enabled locomotion methods. However, software-enabled locomotion methods, unlike natural locomotion, often hold far more potential for simulator sickness.

The most comfortable of these software-enabled methods in common use is *teleportation* or *blinking*, in which the most uncomfortable part of VR movement is excised by letting players point at locations and transferring them to said location instantaneously, often with a very short buffering black screen. While useful, the method can also feel very unnatural and presence breaking, and additionally limits the types of experience that can be made if used exclusively.

A more familiar, physically-accessible method exists with *smooth locomotion*, often aided by a control stick of some sort. This translates easiest from 3D traversal methods in traditional game/application spaces, while retaining presence/immersion for users. However, it is far more likely to invoke simulator sickness, as the dissonance between virtual movement and real-life movement can be a jarring experience. A number of methods have been formulated to address this, but with predictive trails, I've aimed to both address issues with simulator sickness and navigating in digital 3D spaces, something that many people unfamiliar with technology can struggle with.

1.3 Simulator Sickness Mitigation

A number of VR mitigation techniques have already been developed, such as vignetting/tunneling (e.g., Nie et al.'s work on dynamic blurring [13]) or virtual noses (Wittinghill et al. [17]). Vignetting's effectiveness lies in limiting the user's field-of-vision (FoV) through blurring or opaque masks. On the other hand, the virtual nose eschews the dynamic FoV restriction approach by instead providing a grounding visual reference point for users. These mitigation methods will be further explored under Related Work (Section 2).

To measure the effect of these kinds of aids, the Virtual Reality Sickness Questionnaire (VRSQ) was developed as an adaptation of the already existing Simulator Sickness Questionnaire (SSQ) [8]. The effectiveness of the aforementioned methods have thus been shown to vary across users, and factors like a user's sex [3] have been shown to have an impact on severity of simulator sickness and navigational issues in VR.

Each of the mitigation methods examined here tackle one major cause of simulator sickness: periphery movement. When moving in virtual reality, particularly when conducting smooth movement, simulator sickness is often set off when there is a dissonance between a user's physical movement in real life, and their vection in the virtual environment. Investigations into other mitigation methods have found that the majority of this dissonance is caused by vection perceived in the periphery of the user's vision, as opposed to their central vision. Each of the inspiring mitigation methods have a different approach to drawing focus towards central vision during vection. Appropriately, methods like FoV restriction have been shown to be effective in mitigating simulator sickness [8]. Additionally, familiarity with VR systems has been shown to mitigate side effects like posture-instability [6].

However, both FoV restriction and familiarity have been shown to have either limited mitigation effects, or alternative side effects for women. In the case of FoV restrictions, concerns around its ability to impact navigational sense have appeared. While navigational ability faced minimal impact in the study "The Effect of Field-of-View Restriction on Sex Bias in VR Sickness and Spatial Navigation Performance", they also argued that previous studies had found substantial differences in performance in when FoV restriction was perpetual rather than dynamic [3]. Familiarity was a far less effective technique in general for women [6], especially when VR tasks were tackled standing as opposed to sitting (a 33.33% difference in the case of the study Munafo et al.'s study [12]).

2 Related Work

2.1 Vignetting

Vignetting retains popularity as one of the most common solutions for simulator sickness mitigation during smooth locomotion. This approach draws focus to the user's central vision by obscuring the user's peripheral vision with a mask when the user would start to experience vection. This method of mitigation is inspired by the fact that one of the most consistently used methods of mitigating simulator sickness in virtual environments involves reducing the user's FoV [10][4].

Often this mask will occupy more of the edge of the user's FoV depending on either the speed or length-of-time of vection [9]. Dynamic, automatic adjustment of this mask has been shown to be an effective method of mitigating simulation sickness, but fine tuning is required to minimize losses in user presence/immersion [5]. This method has also been shown to be effective in seated VR experiences [5][9]. Seated setups mostly avoid differences in posture-related VR sickness onset by a standing position (which disproportionately affects women [12, 3]).

The method is deservedly common given its applicability in a variety of situations, and a number of open source options (such as the VR Tunneling Pro module for Unity [2], or Google VR's tunneling solution [1]). However, vignetting can struggle to retain presence/immersion, given that effective levels of obscuring can feel jarring in certain VR environments. While the primary paper that was referenced when constructing this solution managed to develop a dynamic vignetting subtle enough to avoid detection by most players [5], I aimed to develop a method that entirely eschewed the kind of breaks in presence a change to a user's expected sense of vision often presents.

2.2 Virtual Nose/Nasum Virtualis

The virtual nose is an alternate approach to pulling focus away from the peripheral, but avoids reducing user FoV. Headed by Dr. David Wittinghill, the mitigation method emulates a digital nose in the center of the users vision [17]. More specifically, a 3D model was positioned in the lower center of users' vision, with half of the appendage rendered on the left lens, and the other half rendered to the right lens. While less dynamic than a method like vignetting, the method has been proven to be effective within Wittinghill's study, with, on average, more users being able to complete tasks in VR without needing to stop due to simulator sickness [17].

The virtual nose approach presents a number of distinct advantages. While the nose is rendered and effective, most users are unable to detect it, given that much like a real nose, user vision will lean towards omitting it. Additionally, as it doesn't affect FoV, this method of mitigation can circumvent the possible sex-sensitive effects of intense FoV limitation on 3D spatial navigation [3]. Given the noticeable effects on simulator sickness, the method works well as an alternative to vignetting that avoids tampering with user FoV, while retaining effectiveness. However, nasum virtualis is hindering in its commercial aspect, given that developers need to purchase a license in order to use the method [15]. This presents a barrier for many smaller parties attempting to work with or experiment in VR, who may not yet be willing to commit fully to the space financially.

2.3 Virtual Trails

Trails have shown to be effective navigational guides in other virtual environments [14], with effective applications in VR [16]. In virtual environments, drawing trails for users has in the past proven an effective navigational guide, marking off areas that users had already traversed. The technique, however, benefits most from clarity of trails: overlapping trail noise has a tendency to instead confuse users [14].

The navigational effects of leading bread-crumb trails were initially shown to be effective in VR environments in the study "Improving Patient Education and the Transition Process Using Virtual Reality" [16]. However, as yet no one has assessed the effectiveness of predictive trails as they relate to motion sickness mitigation. Given their usefulness as a navigational measure, and the potential visual focus effect of a trail cast in front of a user, as opposed to behind them, the idea of predictive trails blossomed.

3 Approach

3.1 Equipment

All development and testing took place on a single desktop computer, running on an Intel Core i5-4430, Nvidia GTX 970 4GB, and 8GB DDR3 1600Mhz RAM. The headset used was an Oculus Rift CV1, along with two Oculus sensors. Both the Oculus Touch controllers and the Xbox One controller were used to test smooth locomotion for within the system. While the Oculus Touch controllers can be used to also test in a standing capacity, the project was targeted towards a seated experience.

The project was implemented in the form of a Unity program, built for use with an Oculus Rift, where user navigation can be conducted with either Oculus Touch controllers (using the analogue sticks) or an XInput gamepad (such as an Xbox 360 or Xbox One controller). Environments are navigated by using the analogue sticks to dictate the direction one's avatar moves in VR, which provides data to generate the navigational trails. The Oculus SDK was used to build and test the predictive trail program, thus limiting compatibility to Oculus-related hardware in the program's current form.

3.2 Module Details

The predictive trails use Unity's in-built A* navigational meshes to maximize compatibility with other Unity programs. These navigational meshes can be used to plot out 'navigable' terrains (terrains accessible by the player/user) in a given 3D environment, and can dynamically account for impassable obstacles in a user's path. Predictive trails are constructed by casting a ray in the vection direction, and recording where it hits along a ring attached to the player avatar. From these coordinates, the module finds the nearest point on the nearest navigation mesh, and plots a path from the player avatar's location to this valid navigation mesh location. Trails can be configured to be opaque or transparent, and can cast shadows as an in-world object. Initial testing (only involving myself) was conducted only with opaque trails.

3.3 Basis and Contribution

The mitigation method I've developed builds off previous explorations of VR accessibility, primarily de-emphasizing peripheral focus without using FoV restrictions [13][16][17], while attempting to implement some of the navigational benefits of trails previously investigated outside of the VR environment [14]. The predictive trail aims to not only establish the navigable spaces for a given user, but also offers a centering object for the user's central vision which has been shown to assist in distracting users from the movement occurring in their peripheral vision [17]. In completing the task of removing attention from the periphery without resorting to FoV restriction, predictive trails aim to make a broadly more inclusive form of simulator sickness mitigation that also provides navigational aid. The component eschewing FoV restrictions targets the sex-bias in solutions for navigational and mitigation issues that have appeared in the past [3]. In particular, in VR environments demanding constant vection, dynamic FoV limitations would begin to resemble permanent FoV restrictions, which have had sex-biased effects on navigational ability [3]. In addition, the option to combine predictive trails and vignetting exists for users who would prefer to use both, rather than just one.

Additionally, the module was built with the explicit intention of being openly distributed. While currently limited to use with Oculus virtual reality devices, the program is otherwise easy to export/import, and uses assets and components that are either original to it, built into Unity, or openly accessible (like the Oculus SDK) by other developers. This was done to maximize compatibility with other development pipelines. The predictive trail module is available at the following link:

https://github.com/TheStarTiger/vr-navigation-trails

4 Proposed User Study

The project aims to help us better understand how to increase navigational accessibility and aid motion sickness mitigation in the VR space through the use of predictive trails. I have created several VR scenarios to measure the influence of predictive trails on motion sickness and the player's ability to navigate. The trails are implemented as a visible, guiding line in the direction that the user is currently traveling, illuminating what parts of the digital environment are navigable. In addition to applications in VR accessibility, particularly for users who would benefit less from FoV restriction, this method can be easily packed into a shareable module, and used as either a developer aid, or a learning tool for students learning the Unity environment.

Testing of these accessibility measures' ability to mitigate motion sickness/assist navigation will be conducted by navigating a single environment twice (once from a statue landmark to a set of staircases, the other from the staircases to the statue) through which participants should navigate from one end to the other, with the assistance of in-map 'breadcrumbs'. The environment is constructed to test a variety of basic navigational hurdles, such as turning around corners, and ascending/descending staircases. The environment has been constructed with a 'maze-like' segment, in which users' turning skills are tested. Each maze-like will, however, be strictly linear, holding no options for users to navigate down branching paths. There are two different options for the maze-like (as illustrated below), with one built to be more complex/with sharper turns (maze-like 1) and another built with smoother, simpler turns (maze-like 2). The difference in maze-likes was implemented to test as to whether differences in turn difficulty would have differing effects on the efficacy of the predictive trail's navigational aid properties. Additionally, it would allow additional variation in a given participant's session. Participants will navigate both the forward and backward version of the environment in a single session, where maze-like 1

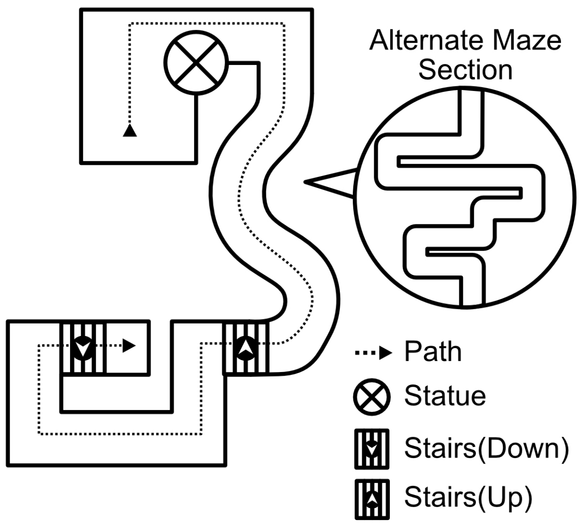

Figure 1: Map of testing environment in forwards configuration

and 2 are assigned randomly to either the forward or backward version.

Each testing experience will last around 30 minutes, in which participants will be seated in a Bowdoin College classroom and instructed on how to use a desktop VR system (Xbox One controller and an Oculus Rift headset) to navigate through two versions of a virtual environment. The experiment will conclude once the participant has either finished navigating both environments, or they indicate they wish to discontinue the experiment before it is completed. After the participants complete the experiment, they will be asked to complete a questionnaire (Figs. 4 and 5). This questionnaire includes the Virtual Reality Sickness Questionnaire (VRSQ) [8], along with supplemental questions asking participants about their experience in virtual environments. This would be used to analyze the user experience and compare relative levels of sickness across experience levels. Participants will be informed in the debriefing whether they were a member of a control group. Control groups will have been told, like the experiment groups, that one of the environments they will navigate will have accessibility measures activated. However, control groups will navigate both environments without the predictive trails activated.

In addition to the data gathered on how long it takes each participant to reach each 'breadcrumb' in a given environment, the headset will also be measuring the head-sway of each participant, and estimating levels of cybersickness using the modified formula for head dispersion (D_{head}) determined in Kim et al.'s study, "An effective FoV restriction approach to mitigate VR sickness on mobile devices" [9].

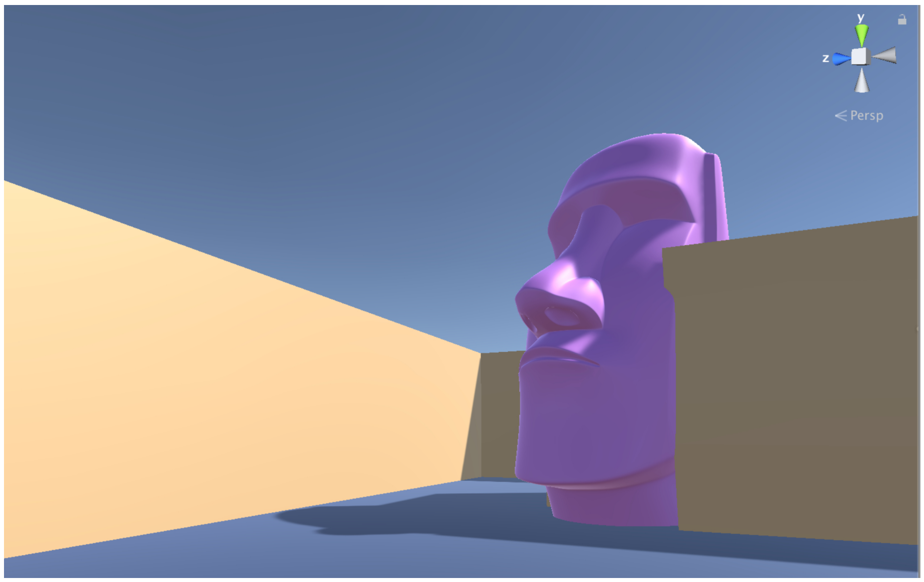

Figure 2: A screenshot of the statue section of the test environment

$$D_{head} = \frac{\sqrt{\sum(\theta_{roll}(k) - \bar{\theta}_{roll})^2 + \sum(\theta_{pitch}(k) - \bar{\theta}_{pitch})^2}}{n}$$

Figure 3: Equation for head dispersion as measured by an IMU in a VR headset

In this case, each $\theta(k)$ represents the change in degrees in radians of rotation for the head pitch or roll at a given time, $\bar{\theta}$ represents time. As shown in the study, the head dispersion tightly correlates with the participant's center of gravity area, which is linked to a participant's body sway. The relationship can be used in this case to estimate a quantitative analysis of each participant's experience of motion sickness in combination with the qualitative assessment of the modified VRSQ (see appendix).

Due to the unfortunate effects of the COVID-19 pandemic, I was unable to complete extensive testing as initially planned. IRB approval for the above testing was, however, granted, and the relevant supporting documentation (summarised in the appendices) was going to be used for the study. Some initial testing was run on me, the principal investigator, but testing equipment was unavailable for more rigorous recording after lock-down measures were enforced for the pandemic. In my time with the device, however, I noticed some light improvements to my experience navigating environments, compared to navigating with no measures whatsoever. The program itself has been uploaded to Github for use/testing (a link is available in the Approach section).

5 Discussion

5.1 Results

As user testing was unfortunately unable to take place on a larger scale, much of the perceptions of the system as it stands stem from my own experience with it. As an experienced user of VR, and someone closely related to the creation of both the system and its testing environment, I noticed some minor improvements in my experience with locomotion. However, the difference was largely indistinguishable for me from vignetting, with both serving better than either one individually. I, however, am a poor participant for testing, given that the target audience is largely people new to VR, new to 3D digital environments, or both.

The predictive trail solution offers an intuitive companion to other existing methods, such as vignetting, and has a grounding in other VR navigation methods' visual languages (many solutions for teleportation provide a visual aiming guide from one's controller to the point that they wish to move to). It additionally builds upon prior work into distraction from peripheral movement, while avoiding PoV restriction. As the system is currently built, it's easy to share and integrate for a large portion of Unity users. A limitation on it as it exists would be possible performance hits, given that dynamic path-finding is required for the routine to work. In addition, non-traditional 3D environments or applications might struggle to find ways to implement the module in an immersive way.

While natural locomotion serves as the easiest solution to vection-related sickness, as it mitigates the dissonance that causes most cases of motion sickness, it's not an option afforded to everyone, whether due to a lack of space, or medical conditions that would make natural locomotion either difficult or un-

Mitigation Method	FoV Restriction	Licensing	Navigational Impact
Vignetting	Yes	Open Source	Neutral/Negative
Nasum Virtualis	No	Commercial	Neutral
Predictive Trails	No	Open Source	Positive

Table 1: A comparison of the properties of the mitigation methods discussed

comfortable. Other software-based forms of mitigation often incorporate FoV restriction (these methods are compared in Table 1), a method known to be disproportionately less effective for women [3]. It is key that inclusive accessibility measures are built, especially in an emerging interactive space that's still seeking a foothold in the mainstream. Failure to account for these populations would do nothing but hinder the potential of VR as both accessible learning experience, and digital escape.

5.2 Further Work

Further work on this particular mitigation method would focus around possibly developing an independent, more optimized path-finding routine. Given my lack of access to the exact construction of Unity's built-in pathfinding solution, a solution baked into the module would have uses in both testing the computational time of the system. This in particular would be important for further investigations, given the already computationally stressful nature of most VR applications, and the fact that dynamic pathfinding can increase in complexity with more moving obstacles and AI actors. While no noticeable performance problems occurred during testing (the system maintained a consistent 90 frames-per-second), a stress test after testing equipment is available again would be helpful in surveying the limits of predictive trails' computational footprint. In addition, a scratch-built system would assist in circumventing future changes in Unity's pathfinding system, and making cross-version compatibility more manageable.

Another point of investigation would be to determine whether the effects of varying the opacity and physicality (casting shadows or not) of trails would be helpful in further fleshing out the uses of this method in VR environments. Given the mitigation method laid out does feature prominently in a user's vision, incorporating presence testing would be helpful in weighing the value of physicality and opacity.

When it comes to testing, aiming for an IRB certification that allows for testing of a standing version of the technology would also be critical in surveying the full extent of the mitigation method's effectiveness across sexes. As shown in previous studies [12], standing VR experiences have shown a disproportionately higher likelihood of triggering simulator sickness in women, as opposed to the more even effects of sitting VR.

Additionally, despite the more inclusive implications of this mitigation method, it does face context restrictions. As a mitigation method based in pathfinding, it would be inappropriate for applications like search or object location tasks.

Additionally, scenarios lacking traditional navigational environments/lacking in easily definable navigation meshes may require module adjustments, and additional testing. A case of such a need may be in applications where users have free omni-directional movement, such as simulations of zero gravity.

As VR becomes more widespread, it's pertinent that experiences built for the platform can cater as inclusively as possible for the broad spread of comfort levels people have with not only VR, but traversing digital environments in general.

References

[1] Tunneling Demo | Google VR.

[2] VR Tunnelling Pro: VR Tunnelling Pro.

[3] Majed Al Zayer, Isayas B. Adhanom, Paul MacNeilage, and Eelke Folmer. The effect of field-of-view restriction on sex bias in vr sickness and spatial navigation performance. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI '19, page 1–12, New York, NY, USA, 2019. Association for Computing Machinery.

[4] Paul DiZio and James R. Lackner. Circumventing side effects of immersive virtual environments. In Michael J. Smith, Gavriel Salvendy, and Richard J. Koubek, editors, *HCI (2)*, pages 893–896. Elsevier, 1997.

[5] A. S. Fernandes and S. K. Feiner. Combating vr sickness through subtle dynamic field-of-view modification. In *2016 IEEE Symposium on 3D User Interfaces (3DUI)*, pages 201–210, 2016.

[6] Per-Anders Fransson, Mitesh Patel, Hanna Jensen, Michèle Lundberg, Fredrik Tjernström, Måns Magnusson, and Eva Hansson. Postural instability in an immersive virtual reality adapts with repetition and includes directional and gender specific effects. *Scientific Reports*, 9, 12 2019.

[7] S. IWARSSON and A. STÅHL. Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships. *Disability and Rehabilitation*, 25(2):57–66, 2003. PMID: 12554380.

[8] Hyun K Kim, Jaehyun Park, Yeongcheol Choi, and Mungyeong Choe. Virtual reality sickness questionnaire (vrsq): Motion sickness measurement index in a virtual reality environment. *Applied ergonomics*, 69:66–73, 2018.

[9] Sehoon Kim, Seungheon Lee, Nupur Kala, Jaesung Lee, and Wonhee Choe. An effective FoV restriction approach to mitigate VR sickness on mobile devices. *Journal of the Society for Information Display*, 26(6):376–384, 2018.

[10] James Jeng-Weei Lin, Henry B. L. Duh, Habib Abi-Rached, Donald E. Parker, and Thomas A. Furness Iii. Effects of Field of View on Presence, Enjoyment, Memory, and Simulator Sickness in a Virtual Environment. In *Proceedings of the IEEE Virtual Reality Conference 2002*, VR '02, page 164, USA, March 2002. IEEE Computer Society.

[11] Gerard Llorach, Alun Evans, and Josep Blat. Simulator sickness and presence using HMDs: comparing use of a game controller and a position estimation system. In *Proceedings of the 20th ACM Symposium on Virtual Reality Software and Technology*, VRST '14, pages 137–140, Edinburgh, Scotland, November 2014. Association for Computing Machinery.

[12] Justin Munafo, Meg Diedrick, and Thomas A. Stoffregen. The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects. *Exp Brain Res*, 235(3):889–901, 2017.

[13] G. Nie, H. B. Duh, Y. Liu, and Y. Wang. Analysis on Mitigation of Visually Induced Motion Sickness by Applying Dynamical Blurring on a User's Retina. *IEEE Transactions on Visualization and Computer Graphics*, pages 1–1, 2019.

[14] Roy A Ruddle. The effect of trails on first-time and subsequent navigation in a virtual environment. In *IEEE Proceedings. VR 2005. Virtual Reality, 2005.*, pages 115–122. IEEE, 2005.

[15] Purdue News Service. Purdue startup commercializing virtual reality sickness solutions, helps move virtual reality mainstream. Library Catalog: www.purdue.edu.

[16] Tamara Vagg, Sabin Tabirca, Cathy Shortt, Claire Fleming, and Barry Plant. Improving patient education and the transition process using virtual reality. In *The International Scientific Conference eLearning and Software for Education*, volume 1, pages 523–526. "Carol I" National Defence University, 2019.

[17] David Matthew Whittinghill, Bradley Ziegler, T Case, and B Moore. Nasum virtualis: A simple technique for reducing simulator sickness. In *Games Developers Conference (GDC)*, page 74, 2015.

9/29/2019 Post-Session Questionnaire

Post-Session Questionnaire

The following survey is completely anonymous, and will be used to help improve accessibility measures to mitigate both navigational and motion-sickness issues in virtual reality. Thank you in advance for your honest responses!

1. **Have you had any prior experience with navigating 3D virtual environments (simulators, video games, etc.)?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No

2. **If so, how frequently?**
   Mark only one oval.

	1	2	3	4	
Rarely	◯	◯	◯	◯	Very Often

3. **Have you had any prior experience with virtual reality?**
   Mark only one oval.
   - ◯ Yes
   - ◯ No

4. **If so, how frequently?**
   Mark only one oval.

	1	2	3	4	
Rarely	◯	◯	◯	◯	Very Often

5. **Rate how strongly you experienced the following sensations during your session:**
   Check all that apply.

	Strongly Agree	Agree	Disagree	Strongly Disagree
General discomfort	☐	☐	☐	☐
Fatigue	☐	☐	☐	☐
Eyestrain	☐	☐	☐	☐
Difficulty focusing	☐	☐	☐	☐
Headache	☐	☐	☐	☐
Fullness of head	☐	☐	☐	☐
Blurred vision	☐	☐	☐	☐
Dizzy (eyes closed)	☐	☐	☐	☐
Vertigo	☐	☐	☐	☐

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Figure 4: Appendix 1A: Modified VRSQ for proposed test

9/29/2019 Post-Session Questionnaire

6. **Feel free to add any additional thoughts about your experience below:**

Powered by
Google Forms

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Figure 5: Appendix 1B: Modified VRSQ for proposed test