Preventing Virtual Reality Motion Sickness in College Students New to VR: Causes, Symptoms, and Solutions

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Abstract

Virtual Reality (VR) motion sickness is one of the largest reported problems that virtual reality users typically experience, which might prevent them from wanting to use the technology beyond the first try or first couple of tries. The current state of research regarding VR motion sickness shows the need for further research to hone in on causation, symptoms, and the general nature of the phenomenon. Our goal is to clarify key concepts, for which the literature currently lacks clarity, by surveying undergraduate college students about their VR experiences, interviewing them to get more detailed understanding, and conducting an experiment which explores the relationship between visual acceleration and motion sickness. The expected results are that sharp acceleration perceived in the virtual environment is a significant cause of VR motion sickness, and that smoothing this acceleration reduces symptoms.

Introduction

Virtual Reality (VR), and its related forms of technology and communication, including Augmented Reality (AR), and the umbrella term Extended Reality (XR), are all rising rapidly in the technology landscape as well as in other fields of study as a tool for job training, education, tourism, and other applications (McGovern et al., 2020).

With the technological innovation that has occurred in the past years to develop virtual experiences such as meeting rooms and games, Munafo et al. (2017) argue that “it is both ironic and frustrating that ‘better’ technology has been associated with more motion sickness,” as virtual technology has been plagued by a range of symptoms in users which include nausea, dizziness, and many others (p. 901). Nausea, headache, raised body temperature and loss of appetite are symptoms that have been experienced by one of this proposal’s authors during and after virtual experiences, with some effects lasting up to a few days, so the need to solve this barrier to adoption is felt personally.

There have been numerous studies on the subject of VR motion sickness dating back to the 1990s (Kolasinski, 1995; Durlach & Mavor, 1995; Prothero 1998). Studies have proliferated especially in the late 2010s and early 2020s, yet there is little consensus or conclusivity regarding nomenclature of individual aspects of the phenomenon (Chang et al., 2020; Chattha et al. 2020; Kim et al. 2018). There is even disagreement about whether the phenomenon should even be considered its own clinical entity, or if it is simply a subclass of “classical” motion sickness (Mazloumi Gavgani et al., 2018, p. 1680).

A framework is needed in order to make progress toward solving the root causes of VR motion sickness. A link has been discovered between vection, or “illusory self-motion” when the physical body is stationary but the user’s virtual body moves in the virtual environment, but the connection is unclear (Keshavarz et al., 2015, p. 472).

Based on the virtual experiences of one of this study’s authors, and introspective reflection on the experiences afterwards, it is suspected that joystick-controlled instantaneous changes in velocity, or infinite accelerations, of the virtual body as it is visually perceived in the virtual environment are a main cause of VR motion sickness, especially in rotation along the vertical axis (turning side to side). Such a hypothesis makes intuitive sense because it is not possible in the physical world. In the physical world, everything must accelerate and decelerate naturally, and instantaneous changes in velocity are not physically or physiologically possible.

The hypothesis explains why snap rotation, where a sideways joystick motion, to the right, for example snaps the user’s virtual body to point 30° to the right is significantly preferable and less motion sickness inducing than smooth rotation, which would involve rotating through the same 30° or other more precise angle at a constant rotational velocity, despite the snap rotation being less realistic, or further separated from how rotation is experienced in the physical world. The snap rotation only involves a change of heading, without simulating the motion to get to that new heading, which the brain seems to be able to process almost as scene change cut, to use a term from the film industry, which is not as disorienting as visually perceived motion through the change in heading at a constant rotational velocity.

The hypothesis also explains why, in a similar way, teleportation, where a user points to where they want to go in the virtual environment with a highlighting selection circle and pulls a trigger to go there, is also significantly preferable and less motion sickness inducing than moving via joystick operation at a constant linear velocity, once again despite teleportation being far less akin to physical motion along a horizontal floor than joystick operated motion at a constant velocity. In the same way, it involves no artificial perceived acceleration, and is perceived as more or less an expected scene change cut to a new viewpoint location.

The most optimal and least motion sickness inducing locomotion seems to be walking in the physical world to walk in the virtual world to a new location, but without large physical activity spaces such as gymnasiums or omnidirectional treadmills, that option is impractical. Using VR while sitting, which some users, previously including one of this study’s authors, are physically limited to, would also preclude physically walking around and physically rotating a full 360°.

The study we propose seeks to clarify key concepts and explore the relationship between visual acceleration in the virtual environment and motion sickness symptoms. The results of the experimental phase could potentially be used to generalize to a larger population than the study's sample population.

Literature Review/Prior Work

In summarizing the early studies of "virtual reality sickness," as Chang et al. (2020) term what is generally referred to throughout this proposal as virtual reality motion sickness, the authors describe how "symptoms were oftentimes speculated to originate from poor performance of the hardware, and it was thought that user's discomfort would be reduced as VR technology matured" with advances like higher resolution and framerates, and wobulation, a 45° shift and alternation in pixel illumination relative to the array which reduces the "screen door effect" of being able to see the small gaps between pixels or seeing projected geometries of multiple pixel arrays superimposed through each other (p. 1660).

However, the advances have not contributed to a significant reduction in the rate of VR motion sickness in users while using VR headset devices, also known as head-mounted displays (HMDs), as of the time of writing this proposal (Chang et al., 2020). In recent years, as HMDs have become more consumer available, as the prices for better quality equipment has steadily decreased, and as demand for devices has increased, there has been more and more focus in the industry on solving the problem of VR motion sickness.

Content-related causes are another primary concern with virtual reality motion sickness and have been studied in depth. Sensory mismatch between visual and vestibular systems when experiencing vection has been identified as a primary cause (Keshavarz et al., 2015). Roll motion and its effects have also been studied (Sumayli & Ye, 2023).

There are other content-related factors that influence a user's physiological properties such as heart rate, blood pressure, and blood sugar level, like the difference between being in a pleasant or neutral VR environment and being in a horror setting with horror sequences such as jump scares (Chattha et al., 2020). Triggering content can prime the user to be more susceptible to stimuli or "sensory mismatches" that usually cause VR motion sickness (Laessoe et al., 2023).

In order to better understand the experienced phenomenon of VR motion sickness, many subjective measures of the experience have been constructed by researchers. In a survey by Chang et al. (2020) of 77 studies, all but one created at least one system of subjective measure of virtual reality, most deriving from the Simulator Sickness Questionnaire (SSQ), and almost half of the studies surveyed used multiple subjective measures, for a total of 117 subjective measurements from the 77 studies.

Kim et al. (2018) have made a more modern, updated Virtual Reality Sickness Questionnaire (VRSQ), as simulator sickness, the term referenced in SSQ, is becoming an outdated, and the

SSQ overall as a measuring tool has begun to become outdated as well, they argue. The VRSQ categorizes VR motion sickness into many different symptomatic subcomponents: “The oculomotor component consists of general discomfort […], fatigue […], eye strain […], and difficulty in focusing […]. The disorientation component consists of headache […], fullness of head […], blurred vision […], dizziness with eyes open […], dizziness with eyes closed […], and vertigo […],” an concerningly uncomfortable set of factors which highlights the urgency of needed solutions for VR motion sickness (Kim et al, 2018, sec. 3.2.2, par. 4).

The prevalence of subjective measurements has more recently brought researchers to also parallelly consider objective measurements of VR motion sickness, with the goal of being able to record physiologically the data that is most correlated with user reports of symptoms. Of the 77 studies reviewed by Chang et al. (2020), with 42 studies collecting 72 different objective measurements, 9 studies of which collected more than one measurement, the most common form of measurement was postural sway, or the apparent loss of balance and the process of regaining it with small movements throughout the body, followed by changes in electrocardiogram (ECG) reading, measurements of the eyes, changes in electrogastrogram (EGG) reading, changes in electroencephalogram (EEG) reading, skin conductivity, breathing measurements, and other physiological data.

While there is general agreement that VR motion sickness is a physiological phenomenon worth studying, there is not unanimous consensus that the phenomenon is clinically divergent from classical motion sickness, with some studies showing no significant difference between the two clinical entities (Mazloumi Gavgani et al., 2018).

Research has also been done into possible correlation between VR motion sickness and sex of the user, with multiple results indicating that there may be a higher rate of occurrence in females than in males (Chattha et al., 2020, and Munafo et al., 2017). These studies are fairly limited in their interpretation of sex and gender, but can be of some informative value in the still early stages of understanding the phenomenon.

Although most Extended Reality motion sickness research and experimentation has been concerned with VR, there have been studies into AR experiences such as those using AR glasses, which can also induce motion sickness (Yu et al., 2019).

There has been some direction for how to solve VR motion sickness using design techniques, such as that from Munafo et al. (2017), who argue that “Our results […] suggest that solutions may be found by addressing aspects of design that influence users' ability to stabilize their own bodies” (p. 901). But the most common theme in the survey of the publications included in this literature review is that more research and experimentation into the subject is needed to more fully understand VR motion sickness. Specifically, clear definitions of causes and symptoms are necessary, and that is one area that we hope to add significant value to the field, by synthesizing language from previous work and coding used by survey and interview participants.

Chang et al. (2020) mention that more experimental evidence is required. Chattha et al. (2020) similarly point out that empirical evidence is lacking in the relationship between physiological and subjective measures of motion sickness in virtual environments. Kim et al. (2018) argue for both further discussion and experimentation to provide deeper understanding of the phenomenon. Laessoe et al. (2023) bring up the idea that individual differences in sensory conflicts should be researched further to better understand their effects. Sumayli & Ye (2023) call for further investigation into the factors that cause variation in experienced virtual reality motion sickness.

The conclusion of Mazloumi Gavgani et al. (2018) even “contradicts previously published results” regarding the clinical designation of the malady, and whether it is the same as or different from classic motion sickness, stating that their findings suggest that there is no clinical difference between the two types of sickness where most other studies have concluded that they are significantly different from one another (1680). Without explicitly stating that further research is needed in the way that most other publications in this literature review do, this contradiction implies that further research is in fact needed in order to settle academic and nomenclatural disputes and to reach more standardized and uniform research approaches and practices in the field regarding virtual reality motion sickness.

With the goal of enhancing clarity of terminology regarding VR motion sickness causes and symptoms in mind, it is expected that alternate potential fixes could emerge from the initial phases of research with participants, and a second goal of the study would naturally emerge to experimentally test the effectiveness of such a fix, and to document how this is measured, for the similar purpose of adding to the existing body of literature how useful and significant the methods used to measure the effectiveness of the fix are, as well as how effective the single potential fix is itself.

Therefore, the proposed study seeks to understand this problem by addressing the following research question: Does one proposed solution involving smoothing of acceleration prevent virtual reality motion sickness symptoms, reduce severity, or delay onset? There are two sub-questions to the main research question: 1) What are the predominant causes of virtual reality motion sickness?; and 2) What are the predominant symptoms of virtual reality motion sickness that can be used to identify when it is occurring?

The research question structure is broad and complex. One way to justify taking in so much information for a single study is that it will require a significant amount of time and effort to contextualize a single solution to VR motion sickness and its effectiveness among participants, in gathering and screening participants for how much experience they have with VR in general and VR motion sickness in particular, finding out more about their experiences, and using consistent language throughout the study. Failing to carefully document these emerging patterns of language and experiences as they are shared by participants would be rather wasteful of the data, especially since there is so much need, according to contemporary authors in the field, for such information to enhance and increase understanding.

While the proposed research is being done, it might as well be done thoroughly and properly, rather than quickly, single-mindedly, and hurriedly, toward the goal of determining the effectiveness of the proposed solution. Maximizing the value of the opportunity to receive and document feedback, both qualitatively and quantitatively, from participants would be the most efficient use of researchers' and participants' time and resources available, considering the entire scope of the research problem. That is why we have selected this particular research question structure, in its breadth and complexity.

Research Design

The proposed study aims to make the most of a mixed methodology research approach, utilizing both positivist and interpretive epistemologies to strengthen one another and the results as whole (Lazar et al., 2017). The justification for this combined approach is that a phenomenon such as motion sickness involves quantifiable, physiological observables as well as subjective, qualitative, and therefore interpreted experiences and perceptions of motion sickness.

This mixed nature of the research problem is possibly one of the most problematic features when it comes to studying the phenomenon. Many studies have been devoted simply to constructing generalizable ratings systems and questionnaires of Virtual Reality motion sickness (Kim et al., 2018). We will use a mixture of experimental and exploratory approaches to gain and share as full of an understanding of the research problem as possible.

One difficulty foreseen in entering into this murky arena is to lose sight of the study and research question through all the different types of reporting and measurements of VR motion sickness. The way to avoid this will be by selecting and sticking to a single method of self-evaluation for VR motion sickness for experimental phases and using language consistent with this framework in earlier phases, while interviewing, and potentially in the language used in the Initial Survey / Recruitment (Phase I) as well.

Furthermore, it will be crucial to maintain meticulous and thorough notes throughout interviews and to diligently and promptly input these notes, transcripts, and survey responses into NVivo to maximize the organizational power of this platform to help identify emerging patterns and themes as they arise in the data.

A survey and interviews are the most appropriate methods of data collection for early phases in order to accomplish the research objective of high-level understanding of the phenomenon of VR motion sickness as a whole, in its causation and symptomatology, because these methods, especially when combined, are excellent tools for gathering diverse perspectives and understanding them in detail (Lazar et al., 2017, ch. 5, 8).

To determine the effectiveness of a potential VR motion sickness fix involving acceleration, we will use experimental data collection methods in Phase III of the research. Experimental data collection methods are most appropriate to achieve some level of generalizability of the findings, which would strengthen and give support to the overall understanding of the research problem (Lazar et al., 2017).

Generating Data

Phase I: Initial Survey / Recruitment

The first step of generating data is sending a survey out to approximately 100-150 potential participants by email using a random selection of undergraduates using email addresses from the University of Washington student directory which provides this information to students, faculty, and staff.

If the response rate is high (near 100%), that would be great for developing emerging patterns regarding occurrence of VR motion sickness in current VR users and inexperience with VR for others, once responses are input into NVivo, but this scale of sample size is not inherently necessary for the sole purpose of Phase I.

It is expected that a relatively small proportion of participants, from the sample population proportion of survey recipients who do respond, will volunteer to participate in the later interview and experimental phases. Having the relatively medium- to large-sized starting survey recipient population size of 100-150 potential participants will ideally ensure that there are enough participants for meaningful data collection in later phases.

Before beginning interviews for Phase II, survey responses would be input into NVivo (see "Analyzing Data," below) and analyzed for emergent response patterns and themes, which could guide later phases of research.

Phase II: In-depth Interviews with Current VR Users

It is expected that from the initial sample population who receive the survey, a relatively small percentage of participants will have ever used virtual reality technologies. Their experience and input on their early or potential experiences of VR motion sickness, or lack thereof, will be highly valuable and informative to draw connections to participant experiences related through prior work, observe changing vocabulary used by current VR users, since the industry is rapidly evolving and there may be changes to perceptions or language commonly used in the couple of years since the majority of the more recent VR-related literature reviewed in this proposal was published (2015-2020, with one more recent outlier from 2023). A handful of participants for Phase II would be considered a successful population sample, and an approximately 30-minute interview should be enough time to gather meaningful data from question answering and discussion.

Through the process of interviewing, with initial questions reviewing participants' survey answers, having analyzed Phase I data by this point to see themes from other respondents who have also experienced VR or VR motion sickness, there would be a set of questions that all participants would be asked, for the sake of having some element of consistency to compare responses, but later in the interview, or throughout, as is conversationally appropriate, at the discretion of the interviewing researcher, other follow-up or original questions or topics could be addressed. With each participant's written and signed consent, interviews would be recorded so that they could be reviewed later for further detail.

It would be possible to have a Meta Quest 2 on hand during interviewing to aid participants pointing out any hardware, software, or UX features that they think might have ever caused VR motion sickness for them, with standard apps available, if they choose to do so, although using a headset to describe their experiences would not be required. It could simply be a useful tool for communication to have present during the interview.

Before beginning Phase III, data from Phase II would be input into NVivo and analyzed for coding and other themes, which may have some overlap with data already collected from Phase I, or may be novel in other aspects.

In the event that no participants are voluntary or available for Phase II, moving on to Phase III would be appropriate and acceptable, since Phase II is not critical for the completeness of the research, although it would help to add thickness to the data where it already might have the "bigness" from survey sample size. Having Thick Data is important to ground Big Data in the stories and experiences of people (Wang, 2013/2016). Therefore, any data collected during this phase could only validate and strengthen the findings of other qualitative and quantitative experimental results.

Phase III: Experimentation

Ideally, approximately 20-30 participants would qualify for our conditions of experimentation by having never used VR before, and would be voluntary and available to participate in this experimental phase.

This sample population would be split into the two following groups of 10-15 participants. For both groups, the following pre-experimental procedures would be used:

The task would have a maximum duration of 20 minutes, since it is generally recommended that new VR users, which all participants would be, should take a break at about that time mark for their own physical and psychological well-being, The task would involve moving to different checkpoints past simple obstructions and obstacles in the virtual environment, and engaging with simple objects, such as picking up a ball or putting it in a basket.

There would be an unlimited number of iterations, so that faster and slower participants would be able to continue being observed for the entire 20 minutes if they were able to. Participants would be informed before beginning experimentation that they can pause or end participation at any point if they feel uncomfortable from VR motion sickness or any other reason (see “Ethical Considerations,” below). With each participant’s written and signed consent, their VR experience would be recorded using a camera to record their physical body and screen capturing software to record their virtual display.

Before putting on the headset, participants would be described a 0–10 rating system of their own level of motion sickness, where 0 corresponds to no discomfort (i.e. nausea, dizziness, feeling suddenly overheated) and 10 corresponds to unbearable level of discomfort from any one of these factors or a combination of them.

Similar subjective scales have been used by other studies (Mazloumi Gavgani et al., 2018; Kim et al., 2018). We have opted for 10 as a maximum level of discomfort as opposed to 9, used by Mazloumi Gavgani et al. (2018), as this is expected to more intuitively correspond to 100% or maximal discomfort in the minds of participants. Using an 11-point scale is expected to help participants be aware of and report more subtle changes than the 4-point Likert scale used by Kim et al. (2018), which could be crucial to seeing significant results develop.

Participants would be asked to evaluate their pre-experimental discomfort level, which would be recorded, and they would be instructed to verbally report any changes to their discomfort level throughout the experiment, which should be recorded along with the time of reporting from the start of the experiment.

While assisting with mounting the Meta Quest 2 headset, researchers would attach forehead skin conductance measuring devices to the participant’s forehead and ensure that there is an active reading by taking and recording a preliminary forehead skin conductance reading.

<u>Group A</u>

This group would experience standard infinite acceleration horizontal planar and rotational locomotion mapping using joysticks, which is the standard locomotion found in most non-VR first person video games and most VR locomotion experiences. They would be physically stationary in a chair in the middle of an open space in the physical world.

<u>Group B</u>

This group would experience the “fix” locomotion mapping, which would be the same as that from Group A, except that it would be smoothly accelerating and decelerating on the horizontal planar and rotational locomotions using joysticks. They would also be stationary in a chair in the middle of an open space in the physical world.

The null hypothesis is that there would be no significant difference between time of motion sickness onset or maximum severity between Group A and Group B.

Phase IV: Post-Experimental In-depth Interviews with First-Time VR Users

This phase would occur immediately after Phase III for any given participant, which is to say that the first participants to enter Phase III will complete phase IV before subsequent participants have been met with to begin their respective participation in Phase III. A 20-minute interview similar to that in Phase II, but slightly abridged, since participants will already have become familiar with the research team through participation in Phase III, should produce meaningful data from question answering and discussion. With each participant's written and signed consent, interviews would be recorded so that they could be reviewed later for further detail.

Once the last participant has completed Phase III and Phase IV, both phases will be considered complete on the level of the entire research study. Collecting data from now-current VR users in this phase could help provide Thick Data if there is little or none available from Phase II (Wang, 2013/2016). Hearing the participants' experiences in their own words, fleshed out and fresh after experiencing their time in VR in Phase III could be very valuable to contextualize, negate, or solidify findings gathered quantitatively during experimentation.

At the end of Phase IV, either as a whole for all participants, or iteratively as each participant or a small group of participants (a day's worth, for example) complete Phase IV, their data from Phases III and IV would be input into Excel and NVivo, respectively, and analyzed for coding and other themes, which may have some overlap with data already collected from Phases I and II, or may be novel in other aspects.

Population Sample

The initial population sampled for the preliminary survey would be University of Washington undergraduate students. The expected age range would be highly centralized between 18 years and 22 years, with some outliers possible, more likely on the older end of the age range. Any respondents under 18 years of age would be screened from further phases so that parent/guardian consent would have to be collected in a separate process from the majority of the participants.

The average age and age range of participants alone could be significant factors that could introduce bias in the results compared with the actual population of new VR users.

The amount of time that such students typically spend on a screen for schoolwork, extracurricular activities, and professional endeavors alone, besides personal time on screens, could be another factor that introduces inherent bias and marks the sample population as notably different from the general population. The interest in virtual reality among those who are sent the initial survey could create a response bias that would skew the observed population toward more technical fields of study, increased rate of participants being gamers, and other introduced biases that could affect the generalizability of the study.

Whether these differences might account for more or less likelihood of experiencing VR motion sickness or intensity of symptoms, and what the magnitude of these differences might be, are all unknown, but still, factors such as daily and weekly regular screen time should be noted at the outset of the study.

In order to reduce the bias that could be caused by varying levels of experience with VR among the initial population, only participants who have never used VR before would be screened and selected for the A/B testing of the potential VR motion sickness fix. That would even the playing field and reduce the range of this independent variable to effectively be a static variable among the tested population.

Because participants who would not qualify for our experimental phase on the basis of their experience with VR could still have important knowledge, insight, and other input, they would have the option to be interviewed in a research phase after the initial survey and before the experimental phase. Gathering and analyzing information from those participants could turn out to be very helpful, or even crucial, in determining the final fix used for comparison in the experimental phase, and for enhancing researchers' understanding of how to talk about and express feelings, symptoms, and potential causes of VR motion sickness.

The potential biases involved in the chosen population sample do not outweigh the convenience for researchers of sampling this population, since we have geographic and scheduling access to the proposed population at a level of convenience that is far beyond any other population sample imaginable for this study, being UW undergraduates ourselves.

It could also be argued that this is an intentional and strategic population sample with a large overlap with market percentage of VR users and especially new VR users, although such an argument would be anecdotal and not supported by market research.

With a sample size of approximately 10-15 participants being ideal for both experimental conditions in the experimental phase (20-30 total experimental participants), and taking into account voluntary participatory rates, the qualifying attribute of having never used VR before, and scheduling availability, it is estimated that surveying 100-150 initial participants in the survey phase would render the desired 20-30 participants for the experimental phase.

It is expected that relatively fewer participants from the survey phase would have experience with VR, would be willing to volunteer for in-depth interviews in the interview phase, and would have the scheduling availability to do so. 5-10 participants for this phase would be considered successful and would ideally render emergent patterns and themes that could be useful for later phases and discussion of results.

Analyzing Data

To analyze the response data gathered in the preliminary survey phase, we would plan to use computer aided qualitative data analysis software (CAQDAS) such as NVivo for descriptive quantitative analysis. We could use similar techniques geared toward qualitative data analysis for interview phases as well. NVivo would allow us to aggregate, code, and analyze the data we collect more thoroughly and completely, and could help produce meaningful patterns and themes regarding how VR users experience and describe VR motion sickness causes and symptoms.

Quantitative data for both the null condition group (Group A) and experimental condition group (Group B) of the experimental phase (Phase III) would include time of onset of motion sickness symptoms, forehead skin conductivity, and participants' numerical evaluations of their own levels of motion sickness before, during, and after the experimental VR experience. To analyze the quantitative data produced during the experimental phase, one of NVivo's features or a Microsoft Excel or Google Sheets spreadsheet to collect the data would be needed to analyze the variance (determine ANOVAs) of the different dependent variables for the two conditions.

If the data from the experimental phase is collected and analyzed properly, it could be used to generalize the results to the larger population of undergraduate students who have not used VR before. It would be more difficult to generalize the results of survey and interview data to the larger population (Lazar et al., 2017).

Ethical Considerations

Comfort of the participants should always be tolerable and the participants should feel that they have the option to opt out of the testing at any point for their physical and psychological well-being. Any self-withdrawals should be noted, and their data for already completed phases of the study should be retained for the purpose of data-tracking but not used in the final study report.

It would be unethical to require participants to power through or ignore symptoms of VR motion sickness in order to complete certain phases of testing, especially since the medium and long term effects of VR motion sickness are largely unknown and deserve an entire subset of longitudinal research studies of their own, which is beyond the scope of this research study.

It would also be unethical to cause participants to feel compelled to disregard their own physical and psychological well-being for the sake of the study, even if this was not in the form of requiring them to continue and push through symptoms. This could take the form of unclear, ambiguous communication between researchers and participants or time constraints from one participant to the next that could cause researchers to cut headset breaks short if breaks are needed by certain participants.

Therefore, it is of utmost importance, in order to treat each participant ethically, to assure that they have a full understanding of their ability to pause, take as long of a break as is needed, or withdraw completely from the study at any time, at their own discretion of their physical and psychological well-being, as miscommunication could be the very cause of unintentional but still unethical treatment if these measures and precautions are not taken.

For participants who consent to their interviews and/or virtual experiences being recorded, they would also be asked if they would prefer for these recordings to be used only within the scope of the study, or if they would allow for recordings to be used for other purposes, such as follow-up studies. If participants opted to change their decisions about any of these matters after their interviews or virtual experiences, their final decisions would be respected, unless they had originally opted out of any recording, in which case they would not have been recorded in the first place. Letting participants have control over their personal data is important for privacy and ethical handling of data (Lazar et al., 2017).

One limitation of the study is that it would likely only involve a select age group from approximately 18 to 22 and only undergraduate university students. The participants would also likely only be from Seattle or the greater Seattle area, since the initial survey would only go out to University of Washington students. These factors might make the study results less generalizable to students from other parts of the country or other parts of the world, and not necessarily generalizable to non-undergraduates or people from older or younger age groups (Lazar et al., 2017).

Discussion

It is anticipated that not all participants will have the same reaction to the proposed VR motion sickness fix. It is possible that it will make some participants have apparently worse experiences than other participants in the null group. Any information toward a conclusion is better than no information gleaned at all.

It is also quite possible that early phases could guide the research toward a more prominent cause of VR motion sickness that would then become the main focus for a potential fix, overriding the planned joystick acceleration fix. This default fix is in place in case no new insights lead research toward another fix, so that at least some meaningful solution could be explored, experimented with, measured, and analyzed.

It is the hope of the study that the locomotion mapping fix (or other fix if another supplants the default) will radically improve users' experience in VR and that it will be landmark in the understanding of how to use UX thinking to remedy VR and other techno-physiological problems, as well as that the patterns found from synthesizing previous work and participant responses will be used almost universally as reference for further research. If this were to be the case, attempting to obtain peer review and publication in at least one journal such as IEEE Transactions on Cybernetics or an HCI journal would be the goal for optimal dissemination.

Conclusion

The major importance of this study will be revealed as more researchers come into the field and more research is done. Subsequent research can use the terminology, frameworks, and findings from this study to inform their practice and how they will conduct their own research. It would hopefully be possible for further research to continue the trend of focusing and refining terminological and higher levels of theoretical understanding of VR motion sickness beyond the general level of clarity found within our review of the current literature, so that the field is more technically delineated.

Ultimately, the sooner that the body of research is able to provide the necessary knowledge and design best practices to VR hardware manufactures and VR software developers to reduce VR motion sickness to nominal levels, the better for all of us. We seem to all be headed toward some level of integration into virtual technology at some point in the future as a society. Motion sickness is a rather unpleasant experience, and those who have to go through it should be… (VIRTUALLY!)… nobody.

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Appendix

Selected Sample Questions for Research Phase I: Initial Survey / Recruitment

*Note: This list does not represent a full set of questions or final question ordering, but provides an idea of the types of questions that might be asked of participants.

- Have you ever used virtual reality (VR) before?
- How many times have you used VR?
- How often do you use VR?
- Have you ever experienced VR motion sickness?
- What specific things in VR do you think cause your motion sickness?
- How often do you play video games (PC or console)?
- What is your age?
- How much time do you estimate you spend using devices with screens such as phones, computers, or TVs per day on average?
- Would you be willing to participate in a 40-minute session consisting of a 20-minute interview and a 20-minute experiment using a VR headset?