5-2024

Exploring the Relationship Between Anxiety and Virtual Reality Sickness

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EXPLORING THE RELATIONSHIP BETWEEN ANXIETY AND VIRTUAL REALITY SICKNESS

A Dissertation

Submitted to the Graduate Faculty of the
University of South Alabama
in partial fulfillment of the
requirements for the degree of

Doctor of Philosophy

in

Instructional Design and Development

by
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May 2024

During this dissertations' writing process, I submitted short excerpts of the abstract, introduction, literature review, and methods for publication in the 2023 proceedings of the Association for the Advancement of Computing in Education's (AACE) Ed Media + Innovate Learning Conference (Copyright by AACE. Reprinted from with permission of AACE [https://aace.org]). AACE's transfer of copyright agreement grants authors the right to reuse any portion of their own work if they include the AACE citation and AACE copyright notice (https://aace.org/copyright/).

ACKNOWLEDGEMENTS

Thank you to the members of my committee, Dr. James Van Haneghan, Dr. Lu Ding, Dr. Gurupreet Khalsa, and Dr. Jack Shelley-Tremblay for guiding me through the dissertation process, teaching me how to test my hypotheses and express my findings, and supplying me with the necessary equipment.

Thank you also to Dr. Joe Gaston for supplying the Oculus headset, Scott Pridgen for helping me access my temporary office, DeAnna Cobb for her meticulous feedback on the manuscript's formatting, and to Ellen Parnham, Lisa Nash, and various faculty and staff of the College of Education and Professional Studies for guiding lost participants to the lab. An additional thank you to Dr. Matt Howard and Elise Van Zandt, whose paper on causes of virtual reality sickness inspired this dissertation. I would also like to thank everyone at the USA Literacy Center for welcoming me into your space during my data collection process and encouraging my efforts. You provided pockets of joy during three very intense weeks.

To my dear friends in the Instructional Design Program, Dr. Yolany Lagos Banks, Dr. Michelle Loo, Dr. Abritty Abullah, and soon-to-be doctors Marwa Alafoo, Tiquera Hall, and Sanju Gharti Chhetri G. C., thank you for letting me share your Ph. D. journey and for sharing mine. In many ways I owe my success in this program to the time you took to help me understand requirements, point me to resources, and reassure me during rough patches. I am also honored to have learned from Dr. Burke Johnson, who gave me my introduction not only to statistical analysis but also to the delights of Molière's comedies. You are an example to follow in ways that far transcend research. Thank you.

My colleagues at Metris Global and the U. S. Coast Guard Aviation Training Center—especially Cindy Grace, who covered the office while I took time off to collect data—also deserve credit for working around my schedule and giving me the space I needed to concentrate on writing. I could not have asked for a more supportive environment in which to transition from my academic career to my professional career.

Most importantly, thank you to my mother. The backlash of any stress I’m under always falls hardest on you. Thank you for standing by me through the ups and downs.

This dissertation also bears the fingerprints of many more people than I could list here, including some I probably didn’t notice and others I wish I hadn’t noticed. My journey at South has spanned two degrees across seven years. In that time, South has taught me much about distinguishing those who want to support your success from those who want to exploit your success. I will carry those lessons with me.

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LIST OF ABBREVIATIONS

ANS	Autonomic nervous system
AR	Augmented reality
BAI	Beck Anxiety Inventory
CSQ	CyberSickness Questionnaire
CV	Confounding variable
DV	Dependent variable
EDA	Electrodermal activity
HARS	Hamilton Anxiety Rating Scale
HDRS	Hamilton Depression Rating Scale
HMD	Head mounted device
HRV	Heart rate variability
IRB	Institutional Review Board
IV	Independent variable
LF/HF	Low frequency/high frequency
MSSQ	Motion Sickness Susceptibility Questionnaire
PSWQ	Penn State Worry Questionnaire
SSQ	Simulator Sickness Questionnaire
STAI	State Trait Anxiety Inventory
STAI-S	State Trait Anxiety Inventory - State
VR	Virtual reality
VRSickQ	Virtual Reality Sickness Questionnaire

VRSympQ	Virtual Reality Symptoms Questionnaire
XR	Extended reality

ABSTRACT

David Wesley Woolverton, Ph. D., University of South Alabama, May 2024. Exploring the Relationship Between Anxiety and Virtual Reality Sickness. Chair of Committee: James P. Van Haneghan, Ph. D.

As virtual reality (VR) becomes more commonly used in education, it is important to understand the technology's weakness and mitigate any potential negative effects on student success. One adverse side-effect of VR use is simulation-induced motion sickness, known in the context of VR as VR sickness. Previous research by Howard and Van Zandt (2021) found that possessing a phobia had a significant positive correlation with VR sickness, but only if the phobia is triggered by the simulation, suggesting that symptoms are actually connected to the anxiety the phobia induces.

This study explored the hypothesized correlation between anxiety and VR sickness, and added to the existing literature by seeking a deeper understanding of a phenomenon closely tied to the success of VR implementation. Sixty-five undergraduate university students used an Oculus Quest to view two 360 YouTube videos: one with low motion intensity and one with high motion intensity. Anxiety and VR sickness were measured before and after each video using a series of questionnaires; balance and heart rate were measured before, during, and after each video using a Wii Balance Board and BIOPAC MP36 system respectively. Statistical analysis comprised a series of three-way mixed ANOVAs testing for correlations between pre- and post-immersion trait anxiety, state anxiety, VR sickness, balance, and heart rate. I also ran two multiple regression models testing the ability of confounding variables (age, gender, ethnicity, technological experience, prior VR experience, and motion sickness susceptibility) along with state and trait anxiety to predict post-immersion VR sickness for each video.

The results showed the effects of state and trait anxiety can replicate the effects VR sickness outside of VR exposure, creating the risk of a false positive with regard to VR sickness. However, genuine VR sickness does also become more severe in the presence of heightened state anxiety. There is reason to suspect this correlation remains in place across levels of motion intensity in VR content and across the general population. The study also offers insight into best practices for implementing VR as an instructional method. Instructors implementing VR should take note of students exhibiting signs of very high anxiety and remain mindful of the possibility that those students could have a harder time completing VR tasks than students with low anxiety.

CHAPTER I

INTRODUCTION

Problem Statement

As virtual reality (VR) becomes more commonly used in education, it becomes more important to understand the technology's weaknesses and mitigate any potential negative effects on student success (Chi et al., 2021). With student/trainee attrition already on the rise in both higher education (Ertem & Gokalp, 2022; Nietzel, 2022) and in industry (Paychex, 2023), any instructional method creating more obstacles than it removes will prove counterproductive to learning and defeat its own purpose. The balance of pros and cons will vary from situation to situation, so potential users should conduct a careful analysis of the implementation context before moving forward with VR (Cunneen, 2021; Sharma et al., 2018), but one cannot properly analyze and address pros and cons if they are not fully understood, as is the case with many aspects of VR (Manzaba & Rodríguez, 2021).

One adverse side-effect of VR use previous research *has* identified is simulation-induced motion sickness, known in the context of VR as VR sickness. Symptoms include nausea, headaches, and dizziness; the recommended response is to stop the simulation immediately (Kim & Ahn, 2021; Meta Quest, 2024). Commercially available VR applications generate VR sickness in between 40% and 70% of users, depending on variations between apps and between users (Lee, 2022). If a learning activity or an assessment required undergoing a VR simulation, having to stop in the middle and risk inability to complete the simulation would slow or halt learner progress until the instructor could implement an alternative instructional strategy (Howard & Van Zandt, 2021; Snelson & Hsu, 2020). Knowledge of factors predicting VR sickness may not empower instructors to avoid its occurrence entirely, but would at least provide worthwhile guidance to direct prevention efforts.

Howard and Van Zandt (2021) found that possessing a phobia relevant to the simulation at hand was one of several factors that had a significant positive correlation with VR sickness, but the correlation disappears if the simulation does not trigger the subject's phobia, seeming to suggest that symptoms are less connected to the phobia itself and more connected to the anxiety the phobia induces. In that case, it would seem to follow logically that other types of anxiety would also positively correlate with VR sickness. This study explored the suggested correlation between anxiety and VR sickness, and the implications of that correlation (or lack thereof) for using VR in education. The relationship has implications for using VR in instruction or in high-stakes assessment insofar as the stress felt by learners because of pressure to succeed could become the very thing hindering their success.

Statement of Purpose

This project aimed to contribute toward a deeper understanding of the degree to which one would expect anxious users to experience a greater severity of VR sickness. The study examined the possibility that anxiety amplifies the effects of VR sickness, and also examined the possibility that anxiety and VR sickness merely have similar effects, meaning anxiety could encourage a false positive when measuring VR sickness. My primary motivation for researching this topic was to promote smoother instructional implementations of VR and, by extension, improved learning. With the use of VR for game-based learning and simulation on the rise, an accurate understanding of VR's advantages and disadvantages will become increasingly important (Chi et al., 2021). This purpose is rooted in the inherently value-bound belief that student well-being and success should form the foundation of all educational decisions, including when, where, and how to implement new technologies such as VR.

Following Bakker's (2018) definitions of common research purposes, this study aligns with the purpose of explaining because it seeks to at least partially explain anxiety's relationship to VR sickness. This study also matches how Keith (2019) defined the purpose of explanation because I had "an interest in cause and effect" (p. 197). I partially intended to parse out, if possible, the extent to which anxiety truly *causes* VR sickness versus merely making VR sickness seem to occur when it does not. As will become apparent in the Conceptual Framework below and the literature review in Chapter II, anxiety and VR sickness are easily confounded, so I had to devote attention to the potential for symptoms measured in this study to have more than one cause. Participants were asked about the order in which they consciously felt both anxiety and VR sickness symptoms, and their perception of the causes of each.

Keith (2019) named an alternative purpose of prediction, in which the researcher is "not necessarily interested in making statements about the effect of one variable on another" because they only want "to be as accurate as possible in predicting some outcome," not to understand how to manipulate the outcome (p. 197). For this study, I intended to go beyond looking at whether or not a set of variables predict each other and examine which caused the other. Keith (2019) noted that explanation typically also includes prediction because explaining a phenomenon brings with it an understanding of the patterns that predict the phenomenon.

This project also aligns with the purpose of advising because the results have implications for promoting student success (Bakker, 2018). If the risk of VR sickness positively correlates to anxiety, and the evidence suggests the correlation creates an undue hindrance to student success, it would be advisable to avoid making students' grades reliant on VR, and to offer more traditional alternatives for students who seem hindered by the use of VR (Howard & Van Zandt, 2021; Snelson & Hsu, 2020).

Conceptual Framework

Howard and Van Zandt's (2021) suggestion that anxiety links phobias with VR sickness agrees with prior studies that have identified a positive correlation between anxiety and various other forms of motion sickness (Faugloire et al., 2007; Hainaut et al., 2011; Stelling et al., 2021). Research connecting anxiety to VR sickness specifically is currently sparse, but the available data do appear to support a correlation (Bouchard et al., 2009; Ling et al., 2011). Bouchard et al. (2021) went so far as to argue that some apparent VR sickness symptoms may be entirely "anxiety-related instead of VR-related, as participants were already experiencing them pre-immersion," (p. 3). Consequently, "anxiety may better explain symptoms such as sweating, discomfort, or fatigue than immersion in VR *per se*" (Bouchard et al., 2021, p. 3). Their work follows output from Ling et al. (2011) and Quintana et al. (2014) advising researchers to treat anxiety as a confounding variable when measuring VR sickness. Symptoms caused by anxiety alone would arguably not constitute VR sickness at all because the symptoms would not arise from factors relating to the simulation. It is worth considering the possibility of a false correlation due to misdiagnosed symptoms and a mistaken assumption that VR sickness occurred when it did not (Quintana et al., 2014).

One theory hypothesizing that a true correlation does (or at least could) exist posits that “those experiencing anxiety may be less capable of resisting influences on their postural stability—such as VR,” a position arguable on the grounds that prior studies revealed an association with postural sway (Howard & Van Zandt, 2021, p. 19). The preceding quote implies anxiety’s impact on motion sickness happens as an extension of anxiety’s impact on postural balance; anxiety weakens balance, and weakened balance reduces resilience against factors that induce motion sickness. This theory is not incompatible with Bouchard et al.’s (2021) theory, but adds the caveat that phenomena with similar outcomes could amplify each other’s effects if they occurred together. Ohno et al. (2004) indicated anxiety does decrease postural stability, and found the correlation was particularly strong with state anxiety (temporary feelings of nervousness), the form of anxiety most likely felt by students nervous about coursework or assessment. The correlation remains present but may slightly diminish in trait anxiety (nervousness as a continuously present feature of one’s personality) depending on the level of anxiety; the subject becoming more nervous than usual amplifies the correlation (Faugloire et al., 2007; Hainaut et al., 2011; Stelling et al., 2021).

Postural instability and motion sickness appear to positively correlate, with instability preceding motion sickness when they concur (Bos, 2011; Merhi et al., 2007). However, previous findings have cautioned against viewing postural instability as the most definitive known cause of motion sickness (Bos, 2011; Previc, 2018). Competing theories exist as to why correlations between motion sickness and postural instability are demonstrably present if postural instability is not the cause of motion sickness. Bos (2011) supported the notion that motion sickness and postural instability both stem from a prior factor which experts do not yet fully understand. Continuing along Bos' (2011) line of reasoning, Previc (2018) proposed "intravestibular imbalance theory," hypothesizing that motion sickness is promoted when "the normal balance of [the semicircular canals and otoliths of the human vestibular system] shifts in the direction of greater canal activity" (p. 130). Previc (2018) did not make postural instability central to his theory, but did mention that one would expect vestibular imbalance to promote postural imbalance, which aligns with findings by Goto et al. (2011). Previc's (2018) conclusion, then, positioned vestibular imbalance as the joint cause of motion sickness and postural imbalance posited by Bos (2011). Previc (2018) touched on the role of anxiety in his framework only in passing, but acknowledged a possible connection.

Hainaut et al. (2011) found that increased anxiety alters "the processing or integration of visual, vestibular and/or somatosensory inputs" (p. 608) in a way that decreases balance control, in which case the vestibular system could also serve as the vehicle through which anxiety impacts motion sickness. Saman et al. (2012) conducted a literature review of existing evidence on the interplay between anxiety and vestibular function, construing the relationship between the two as reciprocal and calling for further research on the complex influences they have on each other. Krishna et al. (2014) corroborated Saman et al.'s (2012) depiction to the point of recommending that medical providers include anti-stress treatments when working with vertigo patients. Bednarczuk et al. (2018) took "the neuro-anatomical and functional overlap between anxiety and vestibular systems” (p. 1522) for granted and focused more on exploring the relationship than proving its existence, suggesting it may have to do with hemispheric dominance in the brain. Goto et al. (2011) further demonstrated that the interplay includes anxiety amplifying the effects of sensory conflict on the vestibular system, which directly connects anxiety’s impact to a factor highly relevant for VR sickness (Balk et al., 2013; Grassini et al., 2021).

Any VR simulation including visual motion without providing a feeling of physical motion (or vice-versa) inevitably creates conflict between what the player sees and what the player feels (Jasper et al., 2020). Kim et al. (2018) divided sensory conflict into three types: “1) what I felt but did not see, 2) what I saw but did not feel, and 3) what I felt but did not match.” (p. 70). Head mounted devices typically create the second type of sensory conflict. For example, a player sitting in a stationary recliner and using a VR helmet to access a flight simulation would see the virtual environment moving at high speeds around them, but would feel themselves remaining motionless. Simulations that deliver matching input to a higher number of senses create less motion sickness (Chang et al., 2020).

Howard and Van Zandt (2021) discussed sensory conflict as a contributor to postural imbalance, whereas Grassini et al. (2021) presented sensory conflict and postural imbalance as distinct competing theoretical causes of motion sickness. The seeming disparity is consistent with the view that postural instability correlates with motion sickness but does not cause motion sickness because both arise from intravestibular disruption (Bos, 2011; Previc, 2018) from factors such as sensory conflict (Hainaut et al., 2011) to which anxiety makes the vestibular system more susceptible (Goto et al., 2011).

In light of the literature reviewed above, this study adopts Previc's (2018) intravestibular imbalance theory as the conceptual foundation for asserting the possibility of a link between anxiety as a construct and VR sickness as a construct.

Research Questions and Hypotheses

I explored the following research questions during this study:

Research question one: Do anxious users experience symptoms similar to but distinct from VR sickness before entering VR?

Hypothesis one: Moderately and highly anxious participants will report VR sickness symptoms before VR immersion whereas participants with low anxiety will not.

Rationale: Understanding the relevant effects of anxiety outside the context of VR is vital to distinguishing true VR sickness from symptoms caused by anxiety alone. The idea that anxiety has similar effects to VR sickness is also central to the theories expressed in the conceptual framework above and borne out by the similarity of symptoms measured by the Hamilton Anxiety Rating Scale (Hamilton, 1959) and VR-centric variants of the Simulator Sickness Questionnaire (Bouchard et al., 2021).

Research question two: Does true VR sickness become more severe in the presence of anxiety?

Hypothesis two: Moderately and highly anxious participants will report higher VR sickness levels compared to participants with low anxiety after VR immersion.

Rationale: Previous research indicated the presence of the hypothesized correlation. Fully understanding this correlation requires more research.

Research question three: Does the level of motion in VR content affect the relationship between anxiety and VR sickness?

Hypothesis three: A low-motion scene will provoke lower VR sickness levels than a high-motion scene, but moderately and highly anxious participants will report higher VR sickness levels compared to participants with low anxiety in both cases.

Rationale: Low-motion VR content creates less sensory conflict than high-motion VR content, weakening one of VR sickness' triggers (Chang et al., 2020; Jasper et al., 2020) but the possibility of VR sickness does not vanish (Oh & Lee, 2021). If anxiety amplifies VR sickness, it should continue to do so in low-motion VR content as well as high-motion content.

Research question four: How do anxiety and VR sickness affect balance and heart rate?

Hypothesis four: Heart rate and balance will change as anxiety and VR sickness change.

Rationale: Balance and heart rate can both reflect changes in anxiety and VR sickness (Hainaut et al., 2011; Held et al., 2021; Nalivaiko et al., 2015; Oh & Lee, 2021). Directly comparing trends in balance and heart rate as caused by anxiety and VR sickness individually can potentially provide insight into the differences in the experience of motion sickness in more anxious and less anxious participants in high and low motion VR.

Research question five: How will participants' experience of VR sickness and anxiety while undergoing the VR activities affect their perception of future instructional VR implementation?

Rationale: This question is more exploratory in nature, as opposed to confirming or refuting any hypotheses. I expected that conversations with the participants about their experiences while participating in the study would naturally involve a discussion of their perceptions of VR use, and that those discussions would yield useful insights for guiding the future use of VR as an instruction method.

Brief Overview of Methodology

I followed a quantitative-driven mixed methods design with quantitative and qualitative data collected and coded concurrently (Johnson & Christensen, 2020). To generate data for analysis, I asked participants to view one high-motion and one low-motion 360 YouTube video using a VR headset, then asked participants to provide information about their experiences. Developing new simulations was not necessary, as suitable content already existed. Quantitative data came from questionnaires, heart rate monitoring, and balance monitoring, and was used to either indicate or contraindicate a correlation between anxiety and VR sickness, plus helping to explore the role of confounding variables.

I collected quantitative data using a demographic questionnaire I developed, the ‘last 10 years’ portion of the Motion Sickness Susceptibility Questionnaire (MSSQ) as revised by Golding (2006), the CyberSickness Questionnaire (CSQ) developed by Stone III (2017), the Beck Anxiety Inventory (BAI) developed by Beck et al. (1988), and the State portion of the State Trait Anxiety Inventory (STAI-S) developed by Spielberger et al. (1983). I provide blank copies of the questionnaires in Appendix A (demographic questionnaire), Appendix B (MSSQ), Appendix C (CSQ), Appendix D (BAI), and

Appendix E (STAI-S). I collected additional data on heart rate, a physiological measure useful for detecting anxiety (Dimitriev et al., 2016) and balance, a more objective indicator of VR sickness (Oh & Lee, 2021). Scores generated with these measures were analyzed using a series of repeated measures ANOVAs and regression models in SPSS.

Qualitative data came from observing the participant's behavior during the simulation, and informal post-immersion debriefs with participants about their experiences. I provide the observation protocol in Appendix F and the debriefing protocol in Appendix G. I coded qualitative data using Microsoft Excel's sorting, analysis, and color-coding functions in to identify and quantify common themes in responses, then applied those themes to discussing perceptions of educational VR use and interpreting the results of quantitative analysis.

Significance of the Study

This study adds to the existing literature surrounding VR by contributing to the understanding of a phenomenon closely tied to the success of VR implementation and user health during simulations, to wit: VR sickness. The study contributes to confirming and further explaining a connection already suspected based on existing research (Howard & Van Zandt, 2021; Stelling et al., 2021). Furthermore, results indicating that some apparent instances of VR sickness may be explained by anxiety alone would indicate a need to consider participants' anxiety level when testing the effects of new simulations or trying to mitigate VR sickness (Ling et al., 2011; Quintana et al., 2014).

By looking at the problem through the lens of education, this study also offers insight into best practices for integrating VR as an instruction and assessment tool.

Specifically, uncovering such a correlation highlights one of the potential hazards that would require consideration during needs assessment and other analysis stages, and would have implications for facilitating learner success in programs that include VR as part of the curriculum. Results indicating the presence of the suspected correlation may suggest students in a state of high anxiety would have a higher risk for VR sickness, which may adversely affect their performance (Howard & Van Zandt, 2021).

With student stress seeing rapid increases in recent years, particularly in higher education, this is an especially important matter to consider (Abrams, 2022; Ertem & Gokalp, 2022; Evans et al., 2018). As early as 2017, Penn State's Center for Collegiate Mental Health declared anxiety one of the two mental health struggles (alongside depression) that most affected college students. The 2021-2022 Healthy Minds Survey National Report (Eisenberg et al., 2022) stated that 37% of college students nationwide tested positive for an anxiety disorder. Eighteen percent had severe anxiety (Eisenberg et al., 2022). Identifying factors which students consistently claim make them feel anxious suggests a path forward for reducing anxiety and creating conditions that better support student flourishing.

Confirming the basic tenet of Previc's (2018) intravestibular imbalance theory (that anxiety creates motion sickness-like symptoms by acting on the semicircular canals and otoliths) was outside the scope of this study. Previous studies had already produced results suggesting that this theory warrants attention and provided corroboration (Bednarczuk et al., 2018; Hainaut et al., 2011; Krishna et al., 2014). In the presence of suggestions that anxiety generates significant symptoms that simulate VR sickness, future research should examine both anxiety's impact on the vestibular system outside the context of VR, and the effect of vestibular disturbance by means other than anxiety on the manifestation of VR sickness.

CHAPTER II

LITERATURE REVIEW

Defining Virtual Reality

While multiple definitions of virtual reality exist, most describe a system of fully immersing users in a three-dimensional computer-generated environment with which the user can interact in a way that replicates the physical world to varying degrees of accuracy (Elmqadden, 2019; Freina & Ott, 2015; Howard, 2018; Rivas et al., 2020). Lee (2004) described a virtual experience as any experience in which "the act of experiencing is mediated by, or is made possible by, human-made technology" that a direct in-person interaction would not require, and/or "experienced objects are artificially created or simulated by technology" (p. 34-5). Conversely, reality refers to "sensory experience of actual objects [...] without using technology" as mediator/facilitator (Lee, 2004, p. 36-7). The apparent oxymoron in the term "virtual reality" refers to the technology's attempt to achieve the experience of interacting with virtual objects as if they were real (Freina & Ott, 2015).

Virtual reality is typically associated with head mounted devices (HMDs) such as the Meta Quest 2 helmet, but other forms of technology can also fall under the category of VR, including surround-screen displays and non-immersive desktop-based simulations (Howard, 2018). It is closely related to augmented reality (AR), which uses much more ubiquitous technology (such as mobile phones) to impose virtual assets on physical environments by projecting digital features onto physical landscapes in a way that allows users to interact with those digital elements as if they were part of the physical environment, creating a much less constrictive experience (Elmqadden, 2019; Fernandez, 2017). Writers discussing VR and AR simultaneously sometimes use “extended reality” (XR) as an umbrella term (Marr, 2021).

Two definitive aspects of VR, as opposed to other mediums, are immersion and presence. While the two concepts are intricately related and easily confused, subtle differences exist between them (Howard, 2018). Wilkinson et al. (2021) made clarifying those distinctions the subject of a mini-review in response to the lack of consistency they perceived in the literature at the time. They concluded that immersion refers to the hardware’s technical ability to deliver realistic sensations, whereas presence refers to the extent to which the user can ignore the technology and become at least partially convinced they are experiencing the simulated scenario for real. Howard (2018) drew the same distinction in his earlier review of hardware and software commonly used to create VR experiences, and also mentioned that immersion is a more objective measure because it deals with the inarguable limitations of the equipment, whereas presence is a more subjective measure because it deals with the user’s personal perception.

Freina and Ott’s (2015) definition of immersion appears to more closely match Wilkinson et al. (2021) and Howard’s (2018) definitions of presence, referring to immersion as “involvement in the play, which causes lack of awareness of time and of the real world, as well as a sense of ‘being’ in the task environment” (p. 1). Freina and Ott (2015) also introduced a more precise concept they called “spatial immersion,” defined as “a perception of being physically present in a non-physical world.” (p, 1), even more closely approaching a description of what the formerly mentioned articles call presence. The emphasis is on the user’s sense of involvement, not the extent to which the hardware facilitates that involvement. Snelson and Hsu (2020) likewise position immersion as a subjective experience of the user. However, Freina and Ott (2015) do provide a separate definition of presence consistent with the other aforementioned authors' definitions, describing a "feeling of being somewhere real when you are in VR" (p. 6). The distinction Freina and Ott make between immersion and presence is much more subtle than the distinction made by Wilkinson et al. and Howard, and de-emphasizes important aspects of the VR experience, making the definitions provided in the previous paragraph arguably more useful for most research purposes.

There is a consensus that immersion is necessary to achieve presence, and increasing immersion generally brings about an increase in presence (Freina & Ott, 2015; Howard, 2018; Wilkinson et al., 2021). Immersion and presence also closely relate to fidelity, the measure of how accurately the simulation replicates the cognitive and sensual experience of the corresponding real-world activity (Howard, 2018). More immersive simulations tend to have more fidelity because increased immersion equates to increased ability to replicate aspects of the activity. Increasing presence also leads to increased fidelity insofar as it allows users to experience more of the cognitive and emotional responses that would accompany real-world performance (Howard, 2018). Augmented reality places significantly less emphasis on immersion, presence, and fidelity because it focuses on overtly using technology to add to the user's experience of the physical environment rather than placing users in a virtual environment and aiming to minimize consciousness of the technology as would VR (Fernandez, 2017).

Summary of VR

Virtual reality describes a system of making users feel as if they can interact with a digitally simulated environment as they would a real environment (Freina & Ott, 2015). Important terms for explaining the process include immersion, presence, and fidelity. Immersion refers to hardware's capability to deliver a realistic experience, presence refers to the user's belief in the reality of the virtual experience, and fidelity refers the accuracy of the simulation compared to reality (Howard, 2018; Wilkinson et al., 2021). Many forms of technology can provide virtual experiences that succeed in all three benchmarks, but head mounted devices (HMDs) tend to receive the most attention, especially in more recent discussions (Howard, 2018).

VR in Education and Training

VR for Learning Activities

Although this form of technology first emerged in the 1960s and underwent a popularity surge in the 1990s, widespread integration of the technology as an instructional method has not yet taken place (Haryana et al., 2022; Mayer et al., 2023). Virtual reality comes with a number of challenges that may hinder implementation, such as the cost of equipment, the limited number of people who can use a single VR headset at once, and the complexities of keeping multiple remote/helmet sets together and avoiding cross-pairing issues (Hawkinson, 2019; Howard, 2018). Potential invasions of user privacy present another concern (Dolan, 2021a, 2021b; Hill, 2018; Venkatadri et al., 2019). Several authors (Cunneen, 2021; Howard & Van Zandt, 2021; Sharma et al.,

2018) have asserted that institutions considering VR implementations should conduct careful needs assessments to ensure that VR is a good fit for their goals and should also prepare to quickly implement effective accommodations for users who experience adverse side effects from participating in VR simulations. Manzaba and Rodríguez (2021) emphasized that making integration of new technologies—including VR—in the classroom effective requires much training, and the impact of many new technologies is still not widely known.

Nonetheless, VR can lead to significantly increased learning in a number of contexts, including nursing courses (Samosorn et al., 2020), driving classes (İçten, 2021), educational heritage sites (Aso et al., 2021), and workplace behavior training (Blunden, 2017). Analysts also generally seem to agree that the benefits of VR outweigh the likely risks in certain situations (Hawkinson, 2019; Howard & Van Zandt, 2021; Marr, 2021; Sharma et al., 2018). Virtual reality is primarily suited to cases in which physical training would be excessively expensive or dangerous because it allows instructors to recreate complex and/or potentially life-threatening scenarios without setting up copious amounts of physical equipment or exposing users to real-world consequences (Howard & Gutworth, 2020; Makransky et al., 2019; Nenn, 2021).

Virtual reality also enables physically impossible experiences. One notable example comes from a biology course using VR to let students go inside microscopic cells to observe the cellular structure from within, giving them a perspective of the cell's various components that microscopes cannot provide (Evans, 2018; Smith, 2019). Another example is allowing learners to psychologically inhabit a body of a gender other than their own and safely perform the roles of that gender in realistic social settings

(Slater et al., 2010). Designers have successfully used VR gender swap simulations to help transgender users explore their preferred gender identity (Kane, 2021) and give men firsthand experience of workplace misogyny from a woman's perspective (Blunden, 2017).

When used for the kinds of learning activities suggested above, VR facilitates high levels of engagement, comprehension, retention, and transfer (Makransky et al., 2019; Makransky & Lilleholt, 2018). Rowe et al. (2022) also found that VR led to better performance compared to physical simulations. Chi et al. (2021) concluded that VR is useful as a learning tool because it "reaches young students on an experiential level, which students prefer" and provides "genuine experience" (p. 107). Furthermore, VR promotes a constructivist experience by allowing students to learn by doing, leading to higher self-efficacy. They also added that VR overcomes motivational challenges faced by other teaching methods because the "entertainment value and novelty" of VR has an attention-grabbing effect "even in subjects normally dull or meaningless to students" (Chi et al., 2021, p. 107). However, Kim and Ahn (2021) found that students who were intrinsically motivated to continue their education did achieve better learning outcomes than students whose motivation came from the simulation.

Ibañez-Etxeberria et al. (2021) agreed with Chi et al. (2021) that the most notable advantage of VR is increased motivation, but their findings contrasted with Chi et al.'s insofar as they suggest VR promotes "the exchange of experiences among users" and "cooperation and collaboration among agents" (p. 16) whereas Chi et al. argued the lack of interaction with other learners within the virtual environment runs the risk of hindering learners' socialization process. Ibañez-Etxeberria et al. (2021) may have arrived at a more positive conclusion because they included AR in their study; Chi et al. (2021) focused solely on immersive VR. Advancements in VR may also increase social interaction within the virtual environment in a way that makes Ibañez-Etxeberria et al.'s findings more accurate than Chi et al.'s (2021).

Augmented reality also received coverage by Aso et al. (2021), who reported that both practicing and trainee teachers viewed AR as useful because it provides a more holistic learning experience and promotes active discovery. It is worth noting, though, that teachers with intrinsic motivation to facilitate better learning achieve better results when using AR compared to teachers who use AR only because they deem it the cheapest option (Aso et al., 2021). Users with more technical knowledge also tend to have higher expectations for AR apps because they are aware of AR's potential. User-friendliness and technological non-invasiveness both influence user satisfaction; input from subject matter experts and appearances by live actors are both necessary to make the experience as accurate and humanized as possible (Aso et al., 2021).

Adhikari et al. (2021) developed a serious game intended to educate nursing students on the treatment of sepsis and provide them with a form of practice by asking them to complete a virtual simulation. Adhikari et al. (2021) measured the game's impact both through a comparison of pre-test and post-test scores, and through self-reports on student perceptions of how completing the game impacted their self-efficacy and comprehension levels. Quantitative data revealed a statistically significant rise in test scores post-intervention; qualitative data revealed that students perceived the game as extremely useful in giving them a chance to apply their knowledge in a practical situation. These results indicate that virtual simulations of this type can effectively supplement nursing education. However, Adhikari et al. (2021) also made a point of arguing that, although VR can adequately supplement other forms of education, it should not fully replace more traditional methods. Kim and Ahn (2021) reinforced that assertion by finding that VR is most effective as a teaching strategy when used in conjunction with more traditional methods such as in-class lectures, assigned readings, and desktop-based videos.

Instructors can also increase VR's effectiveness by implementing orientation to ease learners into the VR experience. Orientation serves to overcome several implementation issues by decreasing both distractions and discomfort for users (Howard & Lee, 2019; Kim & Ahn, 2021). Orientation can especially help increase learners' familiarity with the equipment, reducing the cognitive load on users by allowing them to focus on the simulation itself rather than on the equipment necessary to interact with the simulation (Kim & Ahn, 2021). The high number of elements in virtual environments that attract attention away from instructional content, referred to as seductive details, further contribute to the importance of orientation (Howard & Lee, 2019). Some examples are background motion and excessive freedom to explore the environment. Orientation ensures users know what information is most relevant to the simulation's learning outcomes and can focus their attention accordingly (Howard & Lee, 2019). Ideally, educational VR content should include a minimum of seductive details (Kim & Ahn, 2021), but this may be difficult to achieve when using premade, commercially available content developed without input from instructors.

VR for Performance Assessments

When used as an assessment tool, the most logical application of VR is for performance assessment, meaning assessments that require the learner to perform actions and/or create products (Messick, 1994). Performance assessment offers increased transfer from the learning context to the performance context by providing evidence that learners can apply their knowledge in practical situations (Messick, 1994). While it is possible to conduct traditional question and answer assessments in VR (Woolverton, 2023), the medium is much better suited to replicating more complex activities like interacting with patients or implementing lab safety protocols.

An unfortunate downside of performance assessment is that, especially when utilizing physical simulations, it often quickly becomes time-consuming, expensive, and sometimes dangerous because of the equipment and personnel involved, limiting the number of times students can repeat a simulation within short timeframes (Bandalos, 2017). While VR can also become expensive depending on the number of devices required and the price of the software necessary to simulate the desired scenario (Baniasadi et al., 2020), it can take less space and hardware than physical simulations, depending on the scenario in question (Rowe et al., 2022). Using VR for performance assessment also avoids the need to hire and schedule sessions with live actors, increasing the number of opportunities students have to retake the assessment and lowering the pressure students feel to perform perfectly the first time (Huckabee, 2016).

As stated above, one of VR's greatest strengths is its ability to faithfully replicate situations without subjecting students to the consequences those situations would bring about in the real world. Huckabee (2016) observed that, in a virtual environment, the consequences of performing an action incorrectly are not as dire as in the physical environment. She provided the example of a learner using VR to practice assembling a piece of machinery, assembling it incorrectly, and having the machine collapse with pieces falling through the floor. Such an event occurring in reality would very likely involve personal injury and would certainly have large financial implications for the institution. In VR, the student has the opportunity to immediately receive feedback and make another attempt based on what they learned from the mistake (Huckabee, 2016). Makransky et al. (2019) list several contexts where the dangers of physical training and assessment are even more apparent, such flying airplanes, fighting fires, and working in a construction site. Removing the risk of dangerous physical consequences also increases the range of safely simulatable scenarios, thus expanding the number of fields that can utilize performance assessment (Howard & Gutworth, 2020; Makransky et al., 2019).

Virtual reality also shares performance assessment’s concern with comprehensiveness and fidelity, both of which are important for ensuring the validity of performance assessments (Messick, 1994; Van Haneghan, 2009). Both VR games and performance assessments are more successful when the simulation accurately replicates (fidelity) and includes all aspects (comprehensiveness) of the real-world situation within the bounds of safety (Lee, 2004; Messick, 1994). From an assessment standpoint, the complexity created by fidelity can make scoring difficult and introduce subjectivity, which can lead to inconsistent scoring. That effect can be mitigated by implementing rubrics based on the aspects of the simulation most important in the performance context (Messick, 1994). Video games offer the opportunity for programmers to build point systems into the game that automatically score players according to rubrics defined by subject matter experts and trainers, ensuring the rubric is applied consistently in all situations (Gee, 2013; Hertel & Millis, 2002).

Learner Perceptions

Huckabee (2016) described her own first encounter with VR instruction as more engaging than other forms of instruction she had previously undergone not only because the novelty of the experience appealed to her, but also because wearing the headset and holding the controllers denied her the ability to focus on distractions like checking emails. Novelty is a recurring theme in the current literature on student perceptions of VR (Chi et al., 2021; Ferdig & Kosko, 2020; Lege & Bonner, 2020). Students appear to find VR interesting because they perceive playing VR games as a new experience that arouses their curiosity. Since VR is a form of gameplay, it also stands to reason that students would find the experience more enjoyable compared to other forms of instruction (Chi et al., 2021; Kim & Ahn, 2021; Snelson & Hsu, 2020).

Novelty can also become a distraction in its own right because students could focus more on exploring the gameworld or admiring the visuals than on what they are supposed to learn (Howard & Lee, 2019; Lege & Bonner, 2020; Snelson & Hsu, 2020). Although the mechanics of VR blind the user to distractions in the physical environment (Huckabee, 2016), the virtual environment may itself include distractions in the form of seductive details (Howard & Lee, 2019). Trying to distinguish between seductive details and instructional content while avoiding distractions can greatly increase the cognitive load for students unfamiliar with VR who have not yet learned what to look for (Lege & Bonner, 2020). Subjects interviewed by Matome and Jantjies (2019) and by Lege and Bonner (2020) reported having limited knowledge of VR. That lack of familiarity will continue until the technology becomes more ubiquitous. Because gaps exist in students' familiarity with VR, students may perceive a need for increased orientation before the simulation and scaffolding during the simulation.

Chi et al. (2021) reported concerns about equitable access to the internet and to VR devices off campus if they are not supplied by the institution. Matome and Jonjties' (2019) work underlined the same concern. Combined, these findings about training and infrastructure suggest learners sense a need for institutions and individual instructors who want to implement VR to commit to the implementation by providing adequate resources and training, and that students want to see that kind of commitment in practice.

Students who have received instruction through VR generally seem to believe the implementation has value. Makransky et al. (2019) asked participants to learn from an assigned reading, a desktop-based VR simulation, or an immersive VR simulation. Their results indicated that students who learned through immersive VR not only enjoyed the experience more but also had greater self-efficacy afterwards, suggesting students believed VR left them more prepared to enter the performance context than other forms of learning. Learners in Adhikari et al.'s (2021) study agreed, responding that VR simulation made them more confident in their skills because it gave them a chance to learn and immediately apply that learning in a practical scenario. Likewise, Matome and Jantjies (2019) wrote that students placed more value on VR instruction than traditional instruction because they perceived VR as offering more practical experience than the theory-centric instruction they received from more traditional methods. Based on these studies, students have reasons apart from enjoyment and curiosity to view VR positively;

they believe VR is inherently able to offer a fuller learning experience that better prepares them to achieve their goals.

Pack et al. (2020) implemented VR for teaching English as a second language and achieved mixed results, with some learner feedback contrasting the above studies. While some participants did agree that VR helped them focus and motivated them more because of its novelty, others said they did not feel VR was a good fit for the content. Content would be expected to play a significant role in students' perception of VR's suitability, since the medium is demonstrably better suited to some contexts than others (Sharma et al., 2018). Some participants also said they perceived VR as impersonal and preferred in-person interactions with classmates (Pack et al., 2020). This perspective provides an interesting contrast with responses from a small percentage of Matome and Janjties' (2019) students, who expressed a perception that VR could lead to more personal interactions between themselves and their peers, though they did not describe how.

Domingo and Bradley (2018) directly mentioned the possibility of hosting virtual meetings with user avatars, virtual representations of players that mimic players' movements and usually offer customizability to give users freedom of visual self-expression. While large-scale virtual meetings between avatars in VR are technologically possible, utilizing that capability in the classroom only has value if most or every student has access to a VR helmet and sufficient internet access. Again, the matter of equitable access deserves careful attention (Matome & Jonjties, 2019).

According to Baniasadi et al. (2020), learners' perception of VR may depend on their perceptions of technology overall. Learners who accept new technology in the classroom more easily will have a more positive attitude about VR. Domingo and

Bradley (2018) provided evidence corroborating that claim by soliciting opinions from education students who participated in VR learning. Students who held a negative opinion of VR before the simulation retained their negative viewpoint after the simulation and reported an unsatisfactory experience; students who viewed VR positively before the simulation said they enjoyed the experience (Domingo & Bradley, 2018). Increased technological familiarity may help overcome hesitancy for those with reservations (Baniasadi et al., 2020). At least one of Pack et al.'s (2020) learners mentioned having concerns because of unanswered questions about how VR would affect the user's eye health. The need to answer user questions and build technological familiarity further reinforces the importance of orientation when using VR (Howard & Lee, 2019).

Summary of Instructional VR

Using VR for education and training has pros and cons, especially when using HMDs. The limited number of learners who can use a VR headset at once (one) requires either buying a large number of headsets, which can become expensive, or creatively scheduling time for multiple learners to use a shared device in turns, which can become time consuming (Hawkinson, 2019). Also, the occurrence of VR sickness may hinder some learner's progress (Howard & Van Zandt, 2021), and the novelty of the medium can create distractions (Lege & Bonner, 2020). The benefits of VR for learning make it worth exploring responses to those obstacles.

Managed correctly, VR's novelty becomes a driving force for learner engagement and motivation (Chi et al., 2021). Teaching through VR increases comprehension and transfer by enabling students to apply knowledge and practice skills in an approximation of the performance context, which also increases self-efficacy (Adhikari et al., 2021).

Both as a learning activity and as an assessment, VR can facilitate dangerous or physically impossible experiences safely and on demand, widening the range of domains that can be taught and/or assessed authentically (Huckabee, 2016; Makransky et al., 2019).

Learners generally see value in receiving instruction through VR, mainly because it addresses the need for more practical guidance than traditional methods can sometimes offer (Matome & Jantjies, 2019). However, learners also perceive a need to answer outstanding questions about implementation (Pack et al., 2020) and address concerns about equitable access (Chi et al., 2021). Individual learners' perspective on VR use may largely depend on their perspective on technology more broadly (Baniasadi et al., 2020). Having thus summarized the concept of VR's potential as an instructional tool, the I will now shift the focus to the aspect of implantation with which the current study is most concerned: the likelihood, causes, and effects of VR sickness.

VR Sickness

Definition and Causes

Virtual reality sickness is a name commonly used in the existing literature to refer to the occurrence of symptoms similar to motion sickness as a side-effect of VR gameplay (Balk et al., 2013; Sharma et al., 2018). Although cybersickness has the subtle distinction of arising from any screen-based sensory conflict rather than solely from VR as does VR sickness, cybersickness and VR sickness have the same effects (Gavgani et al., 2018) and the term "cybersickness" is often used in place of the term "VR sickness"

(Brown & Powell, 2021; Stone III, 2013). Symptoms can include headaches, eyestrain, nausea, dizziness, and vomiting, among others (Howard & Lee, 2019; Kim & Ahn, 2021). Garcia-Agundez et al. (2019) list anxiety as one of general cybersickness' indicators, but the most common measures do not treat anxiety as a VR sickness symptom.

Unfortunately, VR sickness affects women disproportionately more than men (Howard & Van Zandt, 2021; MacArthur et al., 2021), with women experiencing symptoms "four times as often as men" (Jasper et al., 2020, p. 3). MacArthur et al. (2021) called for further research on how gender identity and gender affirming care complicate the relationship, having found few studies that mention the distinction at all and even fewer that draw practical conclusions about the distinction. Studies speculating on why gender plays a role in VR sickness tend to point to physical characteristics that gender affirming care could complicate, though gender affirming care is seldom mentioned (Howard & Van Zandt, 2021; Jasper et al., 2020). Kane (2021) and Reyes and Fisher (2022) explored VR as a tool for administering gender affirming care but did not discuss VR sickness as part of their findings. Presumably VR sickness did not arise in enough participants (necessarily mostly transgender, gender fluid, or gender nonconforming) to impede the studies, otherwise the authors would have mentioned the concern.

Howard and Van Zandt (2021) noted that relatively little research has currently been done on causes of VR sickness and potential methods for avoiding its occurrence. Sensory conflict in the form of mismatch between what the user seers and what the user feels likely plays a large role (Kim et al., 2018), especially in VR delivered through HMDs, which cannot deliver sensual stimuli that match the visuals the user receives

(Jasper et al., 2020). Virtual reality sickness also relates to vection, an illusion of self-movement when large amounts of the visual field move (Oh & Lee, 2021; Widdowson et al., 2019).

The disparity between motion and perception of motion appears to create an intravestibular disruption (Previc, 2018) that leads to postural instability and feelings of motion sickness (Bos, 2011). Virtual reality sickness is considered a specific type of motion sickness, similar to but distinct from other forms of motion sickness (Kim et al., 2018). Users who experience VR sickness to an extreme degree should exit the VR environment immediately (Meta Quest, 2024). In educational settings, VR sickness could present a barrier to implementation if any students experience symptoms to such a degree that they consistently cannot participate in learning or assessment activities (Snelson & Hsu, 2020).

One proposed solution for overcoming this issue is to avoid VR itself and offer an alternative instruction method that allows learners to achieve the same learning outcomes without having to participate in immersive simulations (Howard & Van Zandt, 2021; Snelson & Hsu, 2020). If offering alternative instruction methods is not a viable option, research suggests adopters can mitigate the effects of VR sickness through increased technological experience, which they can achieve through conducting orientation to help users prepare for the experience before beginning simulations (Howard & Lee, 2019; Howard & Van Zandt, 2021; Kim & Ahn, 2021).

Summary of VR Sickness Definition and Causes.

Virtual reality sickness refers to a distinct form of motion sickness caused by exposure to VR (Balk et al., 2013). Symptoms include but are not limited to headaches, nausea, dizziness, and vomiting (Kim & Ahn, 2021). Understanding the causes of VR sickness requires more research (Howard & Van Zandt, 2021; MacArthur et al., 2021). Users experiencing symptoms should not remain in the VR environment (Meta Quest, 2024). Intravestibular disruption provoked by sensory conflict appears to contribute to symptoms (Jasper et al., 2020; Kim et al., 2018; Previc, 2018).

Measurements

Most studies on VR sickness, especially those conducted prior to 2018, have relied on Kennedy et al.'s (1993) Simulator Sickness Questionnaire (SSQ) as an instrument for measuring the severity of symptoms for the purpose of finding correlations with other variables. The SSQ is intended for administration following a simulation to measure sickness during or after its occurrence; it cannot predict susceptibility to motion sickness before symptoms begin. Participants are presented with a list of 16 symptoms and asked to rate the severity of the symptom on a four-level scale of "none" to "severe." Those ratings are then translated to numerical scores with "none" equating to 0 and "severe" equating to 3. Symptoms are sorted into three categories: nausea, oculomotor, and disorientation. The questionnaire provides formulas for creating individual scores for each category as well as an overall score including all three. Some symptoms are sorted into more than one category and therefore weighted higher in the final overall score.

Several authors have chosen to revise the SSQ because of its failure to account for the differences between head-mounted VR devices and other forms of simulation, and its inclusion of seemingly irrelevant symptoms, such as burping (Ames et al., 2005; Bouchard et al., 2007; Kim et al., 2018; Stone III, 2017). Sevinc and Ilker (2020) agree that because Kennedy et al. (1993) did not concern themselves with VR's distinctions from other simulations and the distinctions between VR sickness and other forms of motion sickness, their questionnaire lacks content validity when used for VR, meaning it is not “representative of the entire domain the test was intended to assess” (Schultz et al., 2014, p. 83). Most authors who have critically examined the SSQ have also agreed that its unequal weighting creates scoring problems (Ames et al., 2005; Balk et al., 2013; Bouchard et al., 2021; Sevinc & Ilker, 2020). Items counted as part of multiple categories are essentially scored twice (Kennedy et al., 1993). Bouchard et al. (2021) point out that items significantly contributing to multiple factors can be problematic in classical factor analysis, though cross-loading items can sometimes be categorized according to the most relevant factor or dropped altogether (Schultz et al., 2014).

One of the most recently developed and commonly used variations is Kim et al.’s (2018) Virtual Reality Sickness Questionnaire (VRSickQ). Cieślik et al. (2020) stated that Kim et al. attempted to resolve both of the SSQ’s weaknesses by simply removing the nausea component from the SSQ, but that description is not strictly accurate. While the VRSickQ does not include a nausea component, only six out of the seven individual symptoms Kim et al. (2018) removed were part of the nausea component; one (dizziness with eyes open) was part of the disorientation component. Kim et al. also left in one item from the nausea component, general discomfort, but this item was also part of the oculomotor component (Kennedy et al., 1993). Excluding a nausea component seems counter-intuitive considering VR sickness is largely defined by feeling nauseous (Ames et al., 2005; Bouchard et al., 2021). Kim et al.’s (2018) defense for their deletions was that the items associated with the SSQ’s nausea component “contributed less to motion sickness than the oculomotor and disorientation components” (p. 170)—mainly because they seldom occurred—and also that some items had high covariance with others that were not deleted. They imply that assessing the smaller set of items would lead to roughly the same result as measuring the larger set of items.

In contrast, Bouchard et al. (2007) conducted a factor analysis with varimax rotation and determined that if any component deserved elimination from the SSQ, it was the disorientation component. Bouchard et al. (2007) made that claim not because they believed any of the items in the disorientation component are irrelevant to VR sickness, but because variables loaded on only two factors, and the authors judged "nausea" and "oculomotor" to describe the groupings better than disorientation. Grassini et al. (2021) and Balk et al. (2013) demonstrated that the symptoms Kim et al. (2018) deleted do positively correlate with inability to complete a VR simulation, and Bouchard et al. (2007) demonstrated that the deleted items correlate as highly as items left in, so ignoring them creates risk of ignoring contributing variables. For this reason, Bouchard et al. (2007) chose to retain all symptoms in their version of the SSQ and only adapt the scoring procedure to count each item only once and include only two categories.

The VRSickQ has one notable advantage over Bouchard et al.'s (2007) revised SSQ: brevity. The VRSickQ includes nine items compared to the revised SSQ's 16, making completion time quicker and reducing the demands on participant motivation. The other most notable SSQ variant, Ames et al.'s (2005) Virtual Reality Symptoms Questionnaire (VRSympQ) contains 13 items. However, brevity alone does not necessarily make an instrument the best fit for every situation, especially when that instrument's strengths are shared by other variations. Stone III's (2017) CyberSickness Questionnaire (CSQ) also has only nine items and uses only two factors, but includes a different subset of symptoms (notably retaining nausea, and dizziness with eyes open and closed) and categorizes them according to different factors (dizziness and difficulty focusing) than are used in any other variant of the SSQ, which nearly all title their components some combination of nausea, oculomotor, and disorientation. Similarly, Ames et al. (2005) include boredom and drowsiness as symptoms, inclusions exclusive to their variant. The suitability of each SSQ variant for a specific study will depend on that study's research questions and the extent to which a questionnaire's unique combination of symptoms and categories aligns with those research questions.

Bouchard et al. (2021) found that several symptoms listed in the original SSQ and retained in the 2007 variant correlated highly enough with increased anxiety to warrant concerns that data obtained using the SSQ and measuring VR sickness might be confounded by anxiety, with some symptoms previously assumed to stem from VR exposure actually potentially having no relation to the simulation (caused solely by anxiety). The possibility that some symptoms have more than one plausible source and researchers do not always control for alternative causes may explain why authors attempting to alter the SSQ have arrived at such varying conclusions regarding which symptoms warrant inclusion and which warrant exclusion, and how to categorize symptoms (Ames et al., 2005; Bouchard et al., 2007; Stone III, 2017).

Comparing measures of VR sickness and simulator sickness with measures of anxiety does reveal some overlap in the symptoms used to document cases of each. The Hamilton Anxiety Rating Scale is a paper questionnaire intended for use by a clinician to document a patient's anxiety symptoms (Hamilton, 1959). The physiological symptoms listed among its items mirror several items in the SSQ (although with slightly different wording). Some of the overlapping symptoms are difficulty focusing, sweating, fatigue, blurred vision, nausea, discomfort, and stomach awareness (Hamilton, 1959; Kennedy et al., 1993).

The overlap of items between questionnaires measuring anxiety and motion sickness underlines the complexity of identifying causes of symptoms participants experience (Pot-Kolder et al., 2018) and may outright confirm that anxiety and motion sickness can and do mimic each other. For precisely that reason Bouchard et al. (2021) mentioned suboptimal discrimination between mid-simulation anxiety symptoms and motion sickness symptoms as one of the weaknesses of prior studies. Even if two questionnaires claim to measure different constructs, it would hardly be surprising that scores of those questionnaires would correlate if the questionnaires included the same items. Indeed, it would be more surprising if scores did *not* correlate. Using questionnaires that measure the two constructs according to different symptoms can help with discrimination but would still run the risk of misunderstanding the causes of those symptoms unless participants were closely questioned about their experience and their reaction to that experience.

Between Ames et al.’s (2005) VRSympQ, Bouchard et al.’s (2007) revised SSQ, Kim et al.’s (2018) VRSickQ, and Stone III’s (2007) CSQ, the CSQ has the least overlap with the Hamilton Anxiety Rating Scale and physiological symptoms of anxiety (see Appendix H) while retaining the advantage of brevity compared to Ames et al.’s (2005) questionnaire and including factors that at face value are more intuitive for measuring VR sickness compared to the factors Kim et al.’s questionnaire includes, as mentioned above.

Sevinc and Ilker (2020) demonstrated that the CSQ measures VR sickness more accurately than the SSQ and has at least as much content validity as the VRSickQ.

The CSQ's greatest disadvantage is its "complicated scoring system based on item weights" (Sevinc & Ilker, 2020, p. 10) and the fact "there is not a 'total score' for the CSQ as there is for the SSQ" (Stone III, 2017, p. 87). Rather, scores are calculated for the CSQ's two categories individually; no method for synthesizing them into a unified score is provided, only general speculation on how the two scores could relate to each other. Stone III (2017) acknowledged that "Scoring of the CSQ requires accepting a compromise" of his study (p. 86) and "There is clearly further work to be done to refine the CSQ" (p. 87).

The VRSickQ includes the same number of items (nine) and categories (two) and even has the same distribution of items into categories (one group of five items and one group of four items) as the CSQ, but whereas both questionnaires generate scores for each category individually, the VRSickQ generates those scores in such a way that they can be synthesized into a total score very simply by averaging (Kim et al., 2018; Stone III, 2017). Kim et al.'s (2018) scoring method adapts the method used by the original SSQ (Kennedy et al., 1993), a convention Ames et al. (2005) and Bouchard et al. (2007) also followed.

Data on VR sickness' presence and severity can also come from measures not dependent on participants' self-perception, such as center of gravity, or center of pressure, which provide insight on balance and postural sway. The center of gravity shifting off baseline would indicate a loss of balance (Widdowson et al., 2019). If VR sickness relates to postural instability as supposed by the present study's conceptual framework, then changes in balance should reflect changes in VR sickness level (Widdowson et al., 2019). Oh and Lee (2021) successfully used sway velocity and length as a measure of cybersickness; greater sway equated to greater cybersickness. Arcioni et al. (2019) supported the claim that postural instability could predict the negative effects a user would feel from VR, though Widdowson et al. (2019) did not find sufficient evidence to conclude that baseline postural control reliably predicted VR sickness severity. Researchers can collect data on balance using commercially available balance boards or higher-grade force boards. Studies on the validity and reliability of the Nintendo Wii Balance Board in particular have found that it sufficiently measures and records center of gravity for use as an indicator of postural sway and balance, providing a cheaper and quicker alternative to force boards (Bartlett et al., 2014; Clark et al., 2010), especially when coupled with software intentionally designed with research in mind (Goble et al., 2014; Rohof et al., 2020).

Summary of VR Sickness Measurements.

Researchers can measure VR sickness through self-report questionnaires (Bouchard et al., 2007; Stone III, 2017) and through physiological measures such as balance (Chardonnet et al., 2020). Most self-report instruments are variations of Kennedy et al.’s (1993) Simulator Sickness Questionnaire (SSQ), which focuses on motion sickness caused by types of simulation other than VR. Authors attempting to adapt the SSQ for VR sickness have arrived at different understandings of what symptom lists, category labels, and scoring procedures provide the best method for measuring VR sickness (Ames et al., 2005; Bouchard et al., 2007; Kim et al., 2018; Stone III, 2017). Authors focusing on the use of balance boards agree that commercially available examples such as the Nintendo Wii Balance Board provide reliable data (Bartlett et al., 2014; Clark et al., 2010). Shifting off-center can reflect an increase in VR sickness (Oh & Lee, 2021).

Anxiety

Definitions

Ormrod (2016) defined anxiety as “a feeling of uneasiness and apprehension about a situation, typically one with an uncertain outcome” (p. 448). Dimitriev et al. (2016) defined anxiety similarly as “a negative emotional response to threatening circumstances” (p. 2). However, arousal in response to a perceived threat does not always equate to anxiety, since arousal may take the form of an enjoyable thrill rather than discomforting fear or panic (Staab et al., 2013). Neither does fear always equate to anxiety; someone may have a constant fear of spiders but only become anxious when they actually see a spider (Staab et al., 2013). Anxiety includes not only mental functions such as “troubling thoughts and beliefs about one’s ability to deal with the situation” but also bodily manifestations such as “muscular tension [...] increased heart rate, and perspiration, as well as such behavioral responses as restlessness and pacing” (Ormrod, 2016, p. 448). While a certain amount of anxiety is unavoidable and even a healthy sign of stable drive for self-preservation, it can rise to levels constituting or contributing to psychological and physical disorders (El-Gabalawy et al., 2014; Malakcioglu, 2022).

A distinction exists between trait anxiety, which persists as a consistent component of a person’s personality, and state anxiety, temporarily heightened anxiety in response to a specific, passing situation (Hainaut et al., 2011; Ormrod, 2016; Spielberger et al., 1983; Stelling et al., 2021). Trait and state anxiety can also both be broken down into facilitating anxiety, which improves performance, and debilitating anxiety, which deteriorates performance (Moyer, 2008). Anxiety that induces VR sickness would constitute debilitating anxiety because it would create conditions that reduce the subject's ability to continue the simulation.

It is also common to label anxiety according to its source. A well-known example is performance anxiety, anxiety directly tied to giving a performance in front of an audience. When anxiety arises from some part of a person's academic pursuits, it is typically referred to as academic anxiety (Pizzie & Kraemer, 2019; Rasool et al., 2022; Tobias, 1979). Academic anxiety can arise from, among other things, engaging subjects the learner considers difficult, interactions with instructors the learner finds intimidating, or excessive pressure to succeed (Pizzie & Kraemer, 2019; Rasool et al., 2022). Anxiety arising from certain subjects could be titled after the subject that creates the discomfort, such as math anxiety, writing anxiety, or science anxiety (Pizzie & Kraemer, 2019). Those forms of anxiety still qualify as academic anxiety if academic anxiety is treated as an umbrella term covering multiple more specific anxiety types.

When anxiety is tied to any form of assessment, it becomes test anxiety (Brady et al., 2018; Tobias, 1979). Liebert and Morris (1967) put forward the idea that test anxiety also has both a cognitive component, which they label "worry," and an emotional component labeled "emotionality." Under this paradigm, worry would refer to students' *thoughts* about their potential performance, and emotionality would refer to their *feelings* about their potential performance. Emotionality can also bring with it the physiological responses brought on by strong emotion (Brady et al., 2018). Brady et al. (2018) asserted that only worry truly hurts performance on assessments and the physiological side effects of emotionality may actually help test performance if students learn to view their anxiety in a positive light and not to worry. Their finding builds on Liebert and Morris's (1967) findings that worry negatively affected test performance but emotionality had little or no impact. One should note, though, that the worry/emotionality dichotomy is not without flaws. According to Brady et al., 2018), "worry is an inadequate term," but "there has not been consensus in the literature on a better alternative" (p. 396). There is some consensus that viewing test anxiety according to only two factors is probably insufficient, with anxiety comprising at least "four components: cognitive, affective, motivational and physiological" (Roos et al., 2022, p. 74). For better or worse, this complexity is "often neglected in empirical analyses, presumably for practical reasons," so "anxiety is usually analyzed as a relatively undifferentiated and one-dimensional construct" (Roos et al., 2022, p. 74).

Cassady et al., (2019) pointed out that while "it makes logical sense that the notion of 'academic anxiety' is a broader construct that would be hierarchically superordinate to test anxiety, there is limited empirical work to validate this representation" (p. 1). Test anxiety's presence does typically promote academic anxiety because students tend to base their perception of a subject's difficulty on their success or failure with assessments in that subject (Mensah et al., 2023). Unsurprisingly, both academic and test anxiety are more prevalent in perfectionist students and less prevalent in students with higher self-efficacy (Dobos et al., 2021; Kayani et al., 2020; Mensah et al., 2023).

Alternatively, students may feel anxious in an academic setting for reasons related not to academia itself, but to other issues created, highlighted, or exacerbated by academic pursuits, including but not limited to: poor work/life balance (Evans et al., 2018; Fang, 2021), socioeconomic inequality (Montero-Hernandez et al., 2019), immigration issues (Cadenas & Nienhusser, 2021), gender dysphoria (Kane, 2021), and ongoing concerns about COVID-19 (McMurtrie, 2020). Anxiety arising from any of those sources would not strictly qualify as academic anxiety because it would arise from factors outside of academia, but disentangling any form of anxiety from any other form of anxiety in the highly likely event that occurrences overlapped would present challenges. All the aforementioned anxieties could also qualify as either state or trait anxiety depending on how consistently the subject feels anxious about the matter at hand. For research purposes, subjects would have to undergo close questioning about their anxiety's sources and duration to identify what form of anxiety they experience.

Summary of Anxiety Definitions.

Anxiety broadly refers to uneasy feelings about situations perceived as threatening, especially when one cannot certainly predict the outcome (Dimitriev et al., 2016; Ormrod, 2016). Small to moderate levels of anxiety can be healthy and facilitate improved performance in some contexts, but anxiety becomes debilitating when highly present in most day-to-day situations (El-Gabalawy et al., 2014; Moyer, 2008). It can take the form of trait anxiety or state anxiety, depending on if the person feels anxious consistently as part of their personality or only feels anxiety in temporary situations (Spielberger et al., 1983). Anxiety is a complex phenomenon, and likely involves cognitive, affective, motivational and physiological components, though not all of those are frequently discussed in the literature (Roos et al., 2022).

Current Trends

General anxiety has steadily increased among college students for decades, a trend that shows no indication of slowing in the foreseeable future (Abrams, 2022; Eisenberg et al., 2022). It is common in conversation among college students to remark that the average college student’s anxiety level is greater than that of the average psychiatric hospital patient. This belief appears to originate with a distortion of a statement made by Twenge (2000) that the “average American child in the 1980s reported more anxiety than child psychiatric patients in the 1950s” (p. 1007). Nonetheless, in my own personal experience, the distorted version of the statement that compares current college students to current psychiatric hospital patients is consistently treated as plausible and unsurprising when mentioned in conversation, suggesting widespread perception that a serious problem exists in this area.

Genuine research does bear out that perception (Zsido et al., 2020). Eisenberg et al.’s (2022) statistic that 37% of college students in the United States experienced anxiety in 2022 was up three percent from 2020 (Eisenberg et al., 2020) and up six percent from 2019 (Eisenberg et al., 2019). The problem of steadily rising anxiety is limited neither to the to the United States or to higher education, though. Zsido et al. (2020) emphasized that “anxiety is becoming the most common mental disorder worldwide” (p. 5) despite anxiety disorders likely going underdiagnosed; Malakcioglu (2022) concurred.

Comparatively recent developments in education that may have contributed to anxiety’s widespread increase include but are not limited to: “growth of high stakes testing coupled with an audit culture in many Western school systems, characterized by performance and accountability pressures, publicized test scores, and high target standards” (Zeidner, 2014, p. 265). Non-scholastic reasons why anxiety would currently increase among younger populations in particular include: the growing gap between the rising cost of living and workload coupled with stagnant wages (Bethune, 2022; Fang, 2021), uncertainty about how artificial intelligence will affect job security (The Harris Poll, 2023), increasing consciousness that climate change will have lasting harmful effects without perception of a productive response (Hickman et al., 2021), and, especially in the United States, a rapid decline in civil liberties for women, the LGBTQIA+ community, and racial and ethnic minorities (Bethune, 2022).

Racial and ethnic minority groups will naturally exhibit greater anxiety than the majority because they face greater societal challenges and receive less mental health support (Kattari et al., 2020; University of Southern California, 2018). Transgender, gender fluid, and gender nonconforming people are more likely to experience anxiety than cisgender people (Herman & O’Neill, 2022; Kattari et al., 2020; Pattison et al., 2021). Women are also significantly more likely to experience anxiety than men (Bethune, 2022; Zsido et al., 2020), mirroring a documented pattern that occurs in VR sickness (Jasper et al., 2020; MacArthur et al., 2021).

El-Gabalawy et al. (2014) warned that increased anxiety is associated with increased risk of physical disease later in life. An upswing in anxiety among the general population brings with it the risk for a downturn in public physical health. The connection between anxiety and the vestibular system plays a role in some of those health issues. For one thing, anxiety disorders concur with vestibular disorders more prevalently than with general health disorders (Eckhardt-Henn et al., 2003; Ruckenstein et al., 2001). For another, the outcomes of surgery and other medical treatments on the vestibular system worsen in the presence of anxiety (Boleas-Aguirre et al., 2007).

Anxiety from fear of falling (experienced by around one third of older adults) also heightens fall risk in older adults (Staab et al., 2013) partially by causing them to engage in stiffening strategies that actually disrupt balance adaptations and make them more likely to fall (Hadjistavropoulos et al., 2011; Young & Williams, 2015). The effect becomes less noticeable in younger adults, but that population does still exhibit increases in sway when presented with a stressor that reduces balance confidence, such rising height on a small platform (Young & Williams; 2015). Virtual simulations of the height stressor can produce the same results vis-à-vis increased sway as its physical counterpart (Staab et al., 2013).

Anxiety's rise has implications for student success as well, especially in higher education. Anxiety is typically debilitating in an educational context insofar as anxiety diminishes students' ability to focus and to retain information (Mensah et al., 2023; Pizzie & Kraemer, 2019; Zeidner, 2014; Zheng et al., 2023). Poor performance, in turn, increases anxiety, perpetuating a cycle (Dobos et al., 2021). In fact, Jiménez-Mijangos et al. (2022) cited anxiety as among the most prevalent reasons for student attrition. Mensah et al. (2023) found that students' perception of a course's usefulness to their future careers inversely correlated with anxiety. As participants became more anxious, their perception of a course's usefulness decreased. Zeidner (2014) wrote that the "loss to society of the full contribution of potentially capable students through anxiety-related distress [...] constitutes an important problem" (p. 265).

Little research currently suggests that the prospect of entering VR may cause anxiety in and of itself. On the contrary, many sources tout VR as a method for overcoming anxiety in multiple areas, especially for medical purposes and social situations (Diemer et al., 2016; Garone, 2019; Kissel et al., 2021; Sharma et al., 2018). Anxiety would more likely arise from aspects of the simulation. Slater et al. (2010), who hoped their simulation would give players a sense of body-ownership over their virtual avatar, considered their simulation successful precisely because it triggered feelings of discomfort consistent with a perception that physical attacks on the player's avatar happened to the player as well. Elements of VR environments can also trigger phobias as strongly as elements of the physical environment, hence VR is sometimes used for desensitization therapy (Diemer et al., 2016) and research on threat responses (Staab et al., 2013).

As with any form of instruction, the topic of the VR experience could also make participants anxious. Instructional VR content about climate change provides a good example. As noted above, the realities of climate change contribute to the rise of general anxiety among younger demographics (Hickman et al., 2021). In many people, the topic inspires dread of increased natural disasters and disease, a sense of helplessness because average individuals have so little control over climate change's causes, and feelings of anger because those in power have not responded more strongly to the problem (Hickman et al., 2021). Conversely, students who, for any reason, do not believe in climate change may resent having to undergo instruction on a topic they consider silly at best and invasive at worst (Weintrobe, 2021). In either case, the student's anxiety would arise not from fear of failing to learn about the topic, or about having to use VR as a learning tool, but from negative aspects of the topic itself.

That does not mean instructors should avoid teaching about climate change or other disconcerting topics. Students often *must* engage in difficult topics in order to function more successfully outside of the classroom, and including healthy debate on relevant social topics engages and motivates learners (Bransford et al., 2000). Even so, current trends in anxiety among college students do indicate a need for increased mental health support, and for consideration of what factors constitute necessary stressors that promote learning, such as challenging material and interactions outside students' comfort zones, compared to what factors constitute undue hurdles that place students at an unproductive disadvantage, such as unnecessarily high workload and unclear communication about necessary processes (Abrams, 2022; Evans et al., 2018).

Universities that have begun to increase mental health support through steps like instituting more comprehensive counseling programs and cultivating a culture of self-care that prioritizes work/life balance have seen positive results (Abrams, 2022). Corporations outside of higher education can also benefit from a similar approach. Trends in anxiety among working professionals show the same patterns as those among college students, and corporations that actively work to create better conditions for their workers see benefits in the form of better engagement and employee loyalty (Kutscher, 2022).

Summary of Current Anxiety Trends.

In recent years, anxiety has risen throughout the general population, and that trend shows no signs of reversing in the near future (Bethune, 2022; Eisenberg et al., 2022; Kattari et al., 2020; Zsido et al., 2020). The increase has occurred as a product of recent uptakes in the number and seriousness of day-to-day stressors, especially for college students and minorities in the US (Bethune, 2022; Fang, 2021; Hickman et al., 2021; Weintrobe, 2021). If the trend continues, it will begin to have repercussions for public health, academia, and the global economy (El-Gabalawy et al., 2014; Zeidner, 2014). Increasing mental health support and reducing the number of unnecessary stressors encountered in ordinary activities can have productive outcomes (Abrams, 2022; Kutscher, 2022).

Measurements

Anxiety can be reliably measured using self-report questionnaires or measures of physiological symptoms. Colleting self-reports is less complicated than measuring physiological symptoms, but may prove fallible because of faults in the design of questionnaires or in participants' self-perception and willingness to respond (Beck et al., 1988; Fioravanti-Bastosa et al., 2011). In contrast, physiological measures are often perceived as more objective and less biased, though they are still frequently subject to confounding variables (Farnsworth, 2019; Roos et al., 2022). Some specifics of measuring anxiety through self-reports and physiological symptoms are discussed below.

Self-Reporting.

In their study examining the overlap between SSQ items and anxiety symptoms, Bouchard et al. (2021) relied on the State Trait Anxiety Inventory (STAI) developed by Spielberger et al. (1983). Although the STAI ranks among the most common measures of both state and trait anxiety and is regarded as valid and reliable (Fioravanti-Bastosa et al., 2011; Zsido et al., 2020), Beck et al. (1988) argued the STAI lacks discriminant validity with depression and thus runs the risk of measuring depression symptoms as anxiety symptoms. Fioravanti-Bastosa et al. (2011) agreed with Beck et al. (1988). In contrast, Zsido et al. (2020) pointed to a body of literature that reinforces the STAI's utility. Zsido et al. (2020) did not refer to the STAI's ability (or lack thereof) to discriminate between anxiety and depression, which was the basis of Beck et al.'s (1988) critique and was one of Fioravanti-Bastosa et al.'s (2011) concerns.

Zsido et al. (2020) focused instead on the STAI's length, pointing out the preferability of shorter questionnaires (Johnson & Christensen, 2020), and developed and validated a shorter version of the STAI. Zsido et al.'s (2020) shortened STAI-S asks participants only to rate the extent to which they feel upset, frightened, nervous, jittery, or confused (Zsido et al., 2020). In an earlier study, Davey et al. (2007) claimed to have reduced the questionnaire further still by showing that "a single question with a five-point Likert Scale response" predicted STAI score sufficiently to be used as a measure of anxiety (p.356). However, Davey et al.'s (2007) study is one of nine that Zsido et al. (2020) rightly cited as using a too homogeneous sample to ensure transferability.

Fioravanti-Bastosa et al. (2011) also expressed concerns about the STAI's length, and likewise developed a shorter version of the STAI. An important difference between the two is that Fioravanti-Bastosa et al.'s (2011) version includes items measuring both the presence and absence of anxiety in an effort to preserve the psychometric properties of the original STAI, whereas Zsido et al.'s (2020) version includes only items measuring the presence of anxiety in an effort to avoid reliability concerns arising from reverse-scored items (Johnson & Christensen, 2020). Fioravanti-Bastosa et al. (2011) directly mentioned their shortened STAI did not include items relating to depression, but also called for future research to compare their questionnaire to depression questionnaires as confirmation. Zsido et al. (2020) do not appear to have prioritized their version’s discriminant validity as it relates to depression because it received little attention in their article, but they did provide a table showing that their abbreviation had only slightly improved discriminant validity in this regard compared to the original STAI.

Beck et al. (1988) also argued that another popular measure of anxiety, the Hamilton Anxiety Rating Scale (HARS), suffered from inability to discriminate between anxiety and depression because it shared overlapping items with the Hamilton Depression Rating Scale (HDRS) and thus would be expected to measure depression as well as anxiety (Beck et al., 1988; Hamilton, 1959, 1960). In fact, the HDRS includes a section intentionally measuring anxiety, apparently treating anxiety as a potential symptom of depression. As I noted in the section on measuring VR sickness above, the HARS also lacked discriminant validity as it relates to simulator sickness and VR sickness, as its items overlapped with items in the SSQ and several of its variants.

Considering it preferable to design a questionnaire with discriminant validity in mind at the outset rather than adjust existing questionnaires, Beck et al. (1988) responded to the perceived weakness of the aforementioned anxiety measures by designing the Beck Anxiety Inventory (BAI). To check the BAI's discriminant validity, Beck et al. (1988) compared BAI scores to scores of the HARS and the HDRS. Beck Anxiety Inventory scores moderately correlated with HARS scores and mildly correlated with HDRS scores, meaning the BAI has discriminant validity between anxiety and depression because its results correlate better with other measures of anxiety and correlate less with measures of depression (Johnson & Christensen, 2020).

Beck et al. (1988) also conducted a factor analysis with Varimax rotation including items from their own Beck Depression Inventory to create a depression factor and see if any items from the BAI loaded on the depression factor. Only one, “terrified,” did so, and only secondarily. All others loaded on two factors which Beck et al. (1988) chose to label as “somatic symptoms” and “subjective anxiety and panic.” The somatic symptoms factor includes primarily physiological manifestations that accompany anxiety with one exception: “scared.” The subjective anxiety factor includes primarily emotional manifestations with two exceptions: “difficulty breathing” and “indigestion.” These factors are not important for scoring the BAI according to the instructions left by the original authors. Scoring happens by summing the Likert ratings of the 21 symptoms measured by the questionnaire.

Because the BAI does not include cognitive manifestations, clinical practitioners sometimes pair it with the Penn State Worry Questionnaire (BetterHelp Editorial Team, 2023). The Penn State Worry Questionnaire (PSWQ) was developed by Meyer et al. (1990) and contains 16 items focused solely on worry. It is interesting that the BAI’s factor structure and the occasional pairing of the questionnaire with the PSWQ suggests a similar pattern to that suggested by the four component (cognitive, affective, motivational, and physiological) structure Roos et al. (2022) described. Liebert and Morris’ (1967) theory of anxiety’s components is typically only discussed in relation to test anxiety, but could have implications for other types of anxiety as well. Although Beck et al. (1988) did not have VR sickness in mind when they designed their questionnaire, the BAI also shares fewer items with the SSQ and its variants compared to the HARS (see Appendix H). The same can be said for Spielberger et al.’s (1983) STAI, which measures participants' emotional responses rather than physiological symptoms that could arise from factors other than anxiety.

<u>Physiological Measures.</u>

Reliance on participants' self-perception can sometimes create its own problems because self-reporting depends on memory, understanding, and willingness to report, all of which are fallible to varying degrees in individual subjects (Johnson & Christensen, 2020; Roos et al., 2022). Interest in electronic measures of physiological anxiety responses arises from a perception that such responses are autonomic, not consciously controlled by the participant, and therefore less biased and more objective than self-reports (Farnsworth, 2019; Roos et al., 2022). McLeod et al. (1986) found no correlation between self-reports of anxiety level and physiological measures, but did discover a pattern that self-reports and physiological measures agreed about when the participant's symptoms increased or decreased, just not the extent to which they increased or decreased. Roos et al. (2022) found the correlation changed depending on the subject's dominant emotion during measurement.

Descriptions of the physiological factors associated with anxiety are consistent in the literature. Dimitriev et al. (2016), Hamilton (1959), Held et al. (2021), Kissel et al., (2021). Owens and Beidel (2015), Pot-Kolder et al. (2018), and Roos et al. (2022) among others agree regarding useful physiological symptoms, and most describe similar methods of measuring them. Of those symptoms, electrodermal activity (EDA), heart rate, and heart rate variability (HRV) receive the most attention. All three can be easily measured with small sensors placed on the body that do not hinder movement or the completion of other tasks (Dimitriev et al., 2016; Gavgani et al., 2017; Held et al., 2021; Reyero-Lobo & Pérez, 2022; Roos et al., 2022; Stone III, 2017).

Electrodermal activity (EDA) is the skin's electrical conductivity from sweat, and reflects responses of the autonomic nervous system (ANS), specifically the sympathetic branch (Roos et al., 2022). Heart rate variability (HRV) refers to changes in the amount of time between heartbeats; heart rate simply refers to the number of beats per minute (Held et al., 2021). Heart rate variability is a result of the oscillation between parasympathetic activity slowing heart rate and sympathetic activity increasing heart rate (Setiowati et al., 2020). Increasing heart rate tends to lower HRV because increasing the number of heart beats per minute reduces the amount of time available for variation between beats (Held et al., 2021; Sajadieh et al., 2004).

Chalmers et al.'s (2014) meta-analysis confirmed an association between clinical anxiety disorders and reduced HRV. Dimitriev et al. (2016) focused on state anxiety, and reported a similar decrease in HRV as state anxiety rose. Held et al. (2021) also reported that confronting their participants with a stressor increased the participants' heart rate and lowered their HRV; the amount of change from baseline did not significantly differ in participants with anxiety disorders compared to healthy participants.

Changes in heart rate, HRV, and EDA can also have other causes which could make interpreting results delicate in the context of the current study (Reyero-Lobo & Pérez, 2022; Stone III, 2017). Farnsworth (2019), writing of EDA, mentioned that any strong emotion would create changes a sensor could pick up, as most emotions can solicit an ANS response, so EDA measures the intensity but not the type of emotion. Furthermore, since EDA varies according to sweat production, it could also be impacted by factors that promote sweating outside of an ANS response, such as physical activity (Valli et al., 2019). It is also common knowledge that physical activity would increase heart rate. Stone III (2017) attempted to track EDA with a wristband as a way to measure VR sickness, but encountered firmware issues with the equipment that encumbered accurate data recording. Gavgani et al. (2017) found that skin conductance measured with forehead sweat correlated with self-reported nausea caused by VR immersion, but argued VR-induced nausea only moderately impacted HRV.

Setiowati et al. (2020) reported a negative correlation between nausea and low/high frequency ratio (LF/HF), an HRV metric that captures whether sympathetic or parasympathetic activity is primarily controlling heart rate. Reyero-Lobo and Pérez (2022) agreed that LF/HF showed a more significant correlation with cybersickness than other HRV metrics. Nalivaiko et al. (2015) reported increased heart rate in participants experiencing more severe nausea. None of the aforementioned studies concerned anxiety, so the authors did not compare HRV or heart rate's response to VR sickness to its response to anxiety. However, Reyero-Lobo and Pérez (2022) did caution against assuming VR sickness caused HRV fluctuations in the presence of other stressors.

Summary of Anxiety Measurements.

Clinical observation and self-report instruments exist to capture a wide range of anxiety symptoms and sources. Spielberger et al.'s (1983) State Trait Anxiety Inventory (STAI), Beck et al.'s (1988) Beck Anxiety Index (BAI), and the Hamilton's (1959) Hamilton Anxiety Rating Scale (HARS) are commonly used examples. Beck et al. (1988) designed the BAI with the purpose of building a questionnaire with more discriminant validity between anxiety and depression compared to the HARS. Physiological measures can provide a more objective representation of an individual’s symptoms (McLeod et al., 1986; Roos et al., 2022). Electrodermal activity (EDA), heart rate, and heart rate variability (HRV) have proven accurate indicators; increases in EDA and heart rate, and decreases in HRV reflect increases in anxiety (Dimitriev et al., 2016; Held et al., 2021; Roos et al., 2022).

Applying Literature Review to Research Design

The current literature heavily suggests a relationship exists between anxiety and VR sickness, but leaves many opportunities open for confirming and exploring that relationship more directly. Potential manifestations of the relationship include the correlation between VR sickness and triggered phobias observed by Howard and Van Zandt (2021), the pre-immersion presence of VR sickness symptoms in anxious participants observed by Bouchard et al. (2009), and the overlap between anxiety and VR sickness’ indicators (Bouchard et al., 2021; Hamilton, 1959). Recent increases in general anxiety (Eisenberg et al., 2022) and in instructional VR implementation (Chi et al., 2021) make understanding any potential correlation between them important for student success. My purpose for this study is to contribute to that understanding.

Anxiety’s impact on VR sickness may stem from anxiety’s impact on the vestibular system. Hainaut et al. (2011) wrote that anxiety weakens participants’ balance by altering the integration of visual and vestibular information, increasing susceptibility to sensory conflict. Goto et al. (2011) reinforced the assertion that anxiety makes the vestibular system more susceptible to sensory conflict. Sensory conflict is a high risk for users of head-mounted VR devices because the helmet alone cannot stimulate their physical senses in a way that matches the visual input provided by the helmet if the simulation involves a large amount of motion or contact between the user and virtual objects (Jasper et al., 2020). Previc (2018) argued that disruptions to the vestibular system would promote motion sickness, of which VR sickness is a form. Under this theory, anxiety would promote VR sickness by extension through promoting intravestibular imbalance. However, the same mechanism could enable anxiety to generate symptoms consistent with VR sickness on its own (Bouchard et al., 2021). Because anxiety involves physical manifestations of its own as well as cognitive and emotional manifestations (Ormrod, 2016), it could impact physical responses to other stimuli, including VR.

Anxiety is associated with behaviors that lead to or reflect poor balance (Young & Williams; 2015). Balance shifting off center also connects to changes in VR sickness levels (Chardonnet et al., 2020). Anxiety, VR sickness, and their relationships to balance likely involve disruptions to the vestibular system's normal functioning (Goto et al., 2011; Previc, 2018). If anxiety and VR sickness occur simultaneously, it makes sense to expect similarities between variance in balance and variance in anxiety.

My first research question responds to Bouchard et al.'s (2021) call for research directly investigating the extent to which heightened anxiety might create a false positive in tests of VR sickness. Certainly, the two phenomena have a similar ability to increase heart rate and lower HRV (Dimitriev et al., 2016; Reyero-Lobo & Pérez, 2022). Howard and Van Zandt (2021) suggested that, rather than replacing VR exposure as the cause of symptoms, anxiety might make VR sickness cases more extreme by reducing users' resistance. It stands to reason that layering symptom triggers would exacerbate symptoms. Just as VR sickness symptoms get worse the longer VR sick users continue playing the simulation (Meta Quest, 2024), one would expect immersion in a high-motion environment to increase any similar symptoms felt by the player before they entered VR. My second research question focuses on assessing the accuracy of this assumption.

Much may depend on the level of motion in the VR content (Oh & Lee, 2021). Oh and Lee (2021) used a research design similar to mine and found that an immersive VR game featuring a moving background led to increases in postural sway and cybersickness compared to a fixed background game. Virtual reality sickness occurs less frequently in low-motion content because low-motion content creates less sensory conflict (Chang et al., 2020; Jasper et al., 2020), but VR sickness can still occur (Oh & Lee, 2021). If VR sickness rises with anxiety, that trend should hold true even with low-motion content. Research question three responds to that possibility. Research question four refers back to my statement that anxiety and VR sickness both relate to changes in balance, and also acknowledges that researchers have connected both anxiety and symptoms of VR sickness to heart rate (Held et al., 2021; Nalivaiko et al., 2015). My current project will contribute to parsing how the impacts of anxiety and VR sickness on heart rate and balance trends differ.

In the presence of significant correlations between anxiety and VR sickness, one would also expect groups more susceptible to anxiety to have higher susceptibility to VR sickness. This hypothesis seems to hold true regarding differences between men and women’s susceptibility to anxiety and VR sickness (Jasper et al., 2020; Zsido et al., 2020). MacArthur et al. (2021) rightly insisted that the current dearth of research exploring the effect of gender affirming care and gender identity on the relationship between gender and VR sickness needs addressing, for which reason I treated gender identity as a separate variable from gender assigned at birth in the current study.

Findings from this research will have practical implications for efforts to take advantage of VR's educational potential. Students interviewed for previous studies indicated a belief that pursuing the goal of facilitating smoother classroom VR implementation has value. Learners seem to perceive VR as offering more practical instruction because VR content is generally more experiential than more traditional teaching methods (Adhikari et al., 2021; Matome & Jantjies, 2019). However, learners also realize that important questions about user health and equitable access to the technology still need answers (Matome & Jonjties, 2019; Pack et al., 2020). In research question five, I make the connection between my current study and educational VR explicit by asking participants (undergraduate students) how their experiences of the VR content they viewed during the intervention impact their perception of potential future VR instruction.

Summary of Literature Review's Implications

The literature on VR sickness, anxiety, and combinations of them has many interesting gaps presenting opportunities to contribute fresh academic output. Nonetheless, previous research offers a basis for forming general hypotheses, and the research questions and hypotheses listed in this report arose out of the existing literature. As such, this study will add to existing knowledge of VR sickness and anxiety's relationship by providing new evidence that aspires to make implied correlations explicit and probe untapped aspects of the constructs under investigation.

Summary of Literature Review

In this chapter, I defined virtual reality, virtual reality sickness, and anxiety. For the purposes of my study, VR is an immersive medium for viewing digital content, VR sickness is the manifestation of motion sickness symptoms as a result of using VR, and anxiety is apprehensiveness that could potentially exacerbate VR sickness if anxiety occurs at the time of VR immersion (Freina & Ott, 2015; Howard & Van Zandt, 2021; Ormrod, 2016). The rise of instructional VR has coincided with the rise of anxiety such that both are highly relevant to current learners, and any relationship between the two constructs has large implications for promoting rather than hindering learner success through VR (Abrams, 2022; Kavanagh et al., 2017).

Similarities between how certain aspects of anxiety and VR sickness manifest and the instruments used to measure them raises enough questions to warrant investigating their connection (Bouchard et al., 2009; Bouchard et al., 2021; Dimitriev et al., 2016; Hamilton, 1959; Howard & Van Zandt, 2021; Reyero-Lobo & Pérez, 2022). Both can lead to feelings of physical discomfort including nausea (Bouchard et al., 2021; Hamilton, 1959), and both have a connection to vestibular function and balance (Bednarczuk et al., 2018; Goto et al., 2011; Previc, 2018; Widdowson et al., 2019). Chapter II of my report culminated in an explanation of how the literature leads to the specific research questions, hypotheses, and methods used for this study, which I describe further in Chapter III.

CHAPTER III

METHODOLOGY

Research Questions and Hypotheses

I explored the following research questions during this study:

Research question one: Do anxious users experience symptoms similar to but distinct from VR sickness before entering VR?

Hypothesis one: Moderately and highly anxious participants will report VR sickness symptoms before VR immersion whereas participants with low anxiety will not.

Rationale: Understanding the relevant effects of anxiety outside the context of VR is vital to distinguishing true VR sickness from symptoms caused by anxiety alone. The idea that anxiety has similar effects to VR sickness is also central to the theories expressed in the conceptual framework above and borne out by the similarity of symptoms measured by the Hamilton Anxiety Rating Scale (Hamilton, 1959) and VR-centric variants of the Simulator Sickness Questionnaire (Bouchard et al., 2021).

Research question two: Does true VR sickness become more severe in the presence of anxiety?

Hypothesis two: Moderately and highly anxious participants will report higher VR sickness levels compared to participants with low anxiety after VR immersion.

Rationale: Previous research indicated the presence of the hypothesized correlation. Fully understanding this correlation requires more research.

Research question three: Does the level of motion in VR content affect the relationship between anxiety and VR sickness?

Hypothesis three: A low-motion scene will provoke lower VR sickness levels than a high-motion scene, but moderately and highly anxious participants will report higher VR sickness levels compared to participants with low anxiety in both cases.

Rationale: Low-motion VR content creates less sensory conflict than high-motion VR content, weakening one of VR sickness' triggers (Chang et al., 2020; Jasper et al., 2020) but the possibility of VR sickness does not vanish (Oh & Lee, 2021). If anxiety amplifies VR sickness, it should continue to do so in low-motion VR content as well as high-motion content.

Research question four: How do anxiety and VR sickness affect balance and heart rate?

Hypothesis four: Heart rate and balance will change as anxiety and VR sickness change.

Rationale: Balance and heart rate can both reflect changes in anxiety and VR sickness (Hainaut et al., 2011; Held et al., 2021; Nalivaiko et al., 2015; Oh & Lee, 2021). Directly comparing trends in balance and heart rate as caused by anxiety and VR sickness individually can potentially provide insight into the differences in the experience of motion sickness in more anxious and less anxious participants in high and low motion VR.

Research question five: How will participants' experience of VR sickness and anxiety while undergoing the VR activities affect their perception of future instructional VR implementation?

Rationale: This question is more exploratory in nature, as opposed to confirming or refuting any hypotheses. I expected that conversations with the participants about their experiences while participating in the study would naturally involve a discussion of their perceptions of VR use, and that those discussions would yield useful insights for guiding the future use of VR as an instruction method.

Variables

The between-subjects independent variables (IVs) are: BAI score (trait anxiety) and STAI-S score (state anxiety). Each measure can generate three levels of scores. For the BAI, a score of 0-21 is low, a score of 22-35 is moderate, and a score above 36 is high (Beck et al., 1988). For the STAI-S, a score of 20-37 is low, a score of 38-44 is moderate, and a score of 45-80 is high (Spielberger et al., 1983). In one set of statistical tests focused on balance and heart rate trends in VR sick participants compared to non-VR sick participants, post-immersion CSQ score will also serve as a between-subjects IV with two groups (VR sick or not). It was not possible to give every participant every level of these variables.

The within-subjects IVs are VR immersion and motion intensity. VR immersion has two levels: pre-immersion and post-immersion. Motion intensity also has two levels: high-motion and low-motion. Every participant received every level of these variables.

The dependent variables (DVs) are: pre- and post-immersion CSQ scores, balance, and heart rate.

Confounding variables (CVs) based on a meta-analysis conducted by Howard and Van Zandt (2021) with added guidance from MacArthur et al. (2021) include:

- Age
- Gender identity.

- Gender assigned at birth.
- Presence or absence of gender affirming care.
- Ethnicity.
- Technological experience prior to study.
- VR experience prior to study.
- MSSQ score.

Howard and Van Zandt (2021) also identified real-world experience with the simulation's subject matter as a factor that impacts VR sickness, but it seemed unlikely that any participants would have real-world experience with the content of the VR videos used in this study (coral reefs), and indeed only a very small number of participants gave any indication they might have such experience.

Research Design

The study followed a quantitative-driven mixed methods design (Johnson & Christensen, 2020). Measuring the statistical significance and effect size of the correlation between anxiety and VR sickness fell under the purview of quantitative methods, while qualitative data aided in the interpretation of the study's results by enabling participants to offer input regarding the practical significance of any findings (Johnson & Christensen, 2020). For the intervention, I took a repeated measures approach in which participants underwent one VR experience that did not create any perception of motion from the viewer and one VR experience that created a perception of the viewer constantly moving. Counterbalancing was accomplished by changing the order in which participants received each simulation (Johnson & Christensen, 2020).

Institutional Review Board

I submitted all instrumentation to the University of South Alabama's Institutional Review Board (IRB) along with a description of the intervention and the consent form asked participants to complete (see Appendix I). Implementations and data collection began only after the IRB granted approval for the project (See Appendix J).

Participants

The participants were 65 undergraduate university students. Ages ranged primarily from 18-29, with one outlier who was 53 years of age. The most common ages were 19 (40%), 18 (30%) and 20 (14%). Forty-five participants (69%) were assigned female at birth and 20 (31%) were assigned male at birth. Only one participant expressed a gender identity other than cisgender (nonbinary), and another selected "Prefer not to say." No participants said they had received or were receiving gender affirming care. The most common ethnicities were white (62%), black (25%), and mixed race of various descriptions (11% cumulatively). Participants received extra credit in relevant courses as an incentive for participating in the study.

VR Content Used in This Study

The VR experience consisted of viewing two immersive 360 YouTube videos. Both videos centered around damage to coral reefs as a result of climate change and the larger implications of that damage for the rest of the environment. Neither video included a virtual avatar representing the participant. The videos also did not require physical activity from the viewer, so viewing the videos did not unduly influence participants' heart rate, and the need for participants to remain standing on the balance board did not create a problem.

In one video, published by the Wildlife Conservation Society (2021), the viewer both saw and felt themselves standing still, minimizing sensory conflict (Kim et al., 2018). In the other video, published by the channel AirPano VR (2022), the camera constantly moved, sometimes at distorting angles, but there was a motionless logo imposed on one corner of the virtual environment, on which the user could focus to orient themselves. Sensory conflict was maximized in the AirPano VR (2022) video; viewers saw themselves moving through the environment, but their other senses did not replicate that motion (Kim et al., 2018). Having participants undergo VR immersion at two differing levels of motion intensity made it possible to reliably test the effect of motion intensity on other variables in the study. The high-motion video lasted eight minutes and 17 seconds; the low-motion video lasted five minutes and 44 seconds.

I identified potential videos to use in the study by searching different combinations of "educational 360 videos" and different topics on YouTube. I chose immersive 360 YouTube videos as the VR content used in the study instead of video games because they were easily accessible, offered a wider variety of educational content, and ensured that I could administer a high-motion experience and a low-motion experience in the subject area. Keeping both videos related to the same subject matter avoided having to account for the subject of the simulation as a confounding variable.

I selected the videos mentioned above because they were high quality, met the requirements of the study, and had educational value for all students regardless of discipline. By taking viewers under the ocean in diverse locations such as Tanzania

(Wildlife Conservation Society, 2021) and the Philippines (AirPano VR, 2022), these videos also showcased one of VR’s most valuable advantages for education: the ability to give students some level of access to otherwise totally inaccessible environments (Freina & Ott, 2015).

The topic of climate change and its potential effects had the potential to cause distress for some participants (Hickman et al., 2021; Van Sistine, 2022). Scenes placing the viewer underwater also had the potential to trigger hydrophobia. Participants would not have been pressured to complete the VR experience if they experienced extreme psychological discomfort.

Data Collection

Instrumentation

The first questionnaire administered in this study was one I developed that requested the participant’s name, age, gender identity, gender assigned at birth, ethnicity, technological experience level, and level of familiarity with VR. This information was used to test the effect of confounding variables during data analysis. The selection of information requested was based on findings from previous research (Howard & Van Zandt, 2021; MacArthur et al., 2021).

Each participant was asked to complete the ‘last 10 years’ portion of Golding’s (2006) revision of the MSSQ. The MSSQ measures the subject’s resistance to motion sickness (Golding, 2006), a datapoint required to control for a confounding variable since motion sickness susceptibility in general logically equates to greater VR sickness susceptibility and is a confirmed predictor of VR sickness (Chang et al., 2020). A higher score equated to greater likelihood that the participant would experience severe VR sickness.

Participants' trait anxiety was determined using the BAI, a clinical anxiety measure also sometimes used for research, measuring the prevalence of symptoms the participant experienced over the month prior to completing the questionnaire. Because the BAI is more geared towards trait anxiety than state anxiety, I considered it necessary to use another measure to capture the participant's state anxiety at the time they underwent the simulations. Therefore, I asked each participant to rate their state anxiety level using the STAI-S developed by Spielberger et al. (1983).

I measured VR sickness symptoms using a version of the CSQ modified to create a single VR sickness score. The CSQ adapts Kennedy et al.'s (1993) Simulator Sickness Questionnaire (SSQ) to measure the severity of a selection of symptoms related specifically to VR-induced simulation sickness, as opposed to simulator sickness more generally, which the original SSQ measures. Higher scores equate to greater severity of the symptoms each measures.

I chose to use the CSQ's items over using the VRSickQ for this study because the CSQ's items overlapped less with items included in common measures of anxiety (Beck et al., 1988; Hamilton, 1959), which was important for discriminating between symptoms of anxiety and symptoms of VR sickness (Johnson & Christensen, 2020). However, because the CSQ does not result in a single overall VR sickness score according to the scoring process its original author outlined (Stone III, 2017), I scored responses according to the method used for Kim et al.'s (2018) Virtual Reality Sickness

Questionnaire (VRSickQ) to generate a single score for analysis. Both questionnaires are SSQ variants that use nine items and sort them according to two factors, so the same scoring principles can generate a score between zero and 100 for both questionnaires, with responses closer to zero signifying lower VR sickness and a response closer to 100 signifying higher VR sickness.

The decision makes sense following a formative measurement model, which builds on the notion that latent constructs rise from their indicators, and expert judgement constitutes a valid basis for scale adjustment because experts are qualified to judge the indicators' contributions to the construct (Riebel & Lichtenberg, 2023). In this case, adjusting the CSQ would be justified by the example set by most other SSQ variants, which consistently follow the same scoring process as the original, adjusted for the number of symptoms and factors included (Ames et al., 2005; Bouchard et al., 2007; Kennedy et al., 1993; Kim et al., 2018).

During the session, I recorded each participant's heart rate using a BIOPAC MP36 system, with sensors attached to the left wrist and both ankles. The sensors did not inhibit participants' ability to complete a VR activity, but may have been noticeable enough to mildly impact learner's behavior (Reyero-Lobo & Pérez, 2022). The sensors were changed between sessions. The placing of the sensors left the palms and forehead free for the VR equipment. Heart rate is simply the number of heart beats per minute (Held et al., 2021); a usable score can be generated by counting the number of beats in a one-minute interval. A range of 60-100 is considered normal in adults (Laskowski, 2022).

I recorded balance using a Nintendo Wii Fit balance board (WBB) linked to CU BrainBloX software (Cooper et al., 2014), which records length of sway and center of pressure (Neuromechanics Laboratory, 2017). The balance board rose less than an inch off the ground and was stable, presenting a negligible fall risk (J. Shelley-Tremblay, personal communication, August 31, 2023).

Procedures

Names and contact information were used solely for scheduling lab sessions and interviews; that information was removed from the data before analysis and does not appear in the report. To match questionnaires, heart rate data, balance data, observation data, and interview data to the correct participant without the use of names, each participant received a participant identification number based on the order in which they participated. The sequence of numbers started with 1 and progressed linearly. That number appeared on all data collected from the corresponding participant.

Virtual reality sessions were scheduled via Calendly and the University of South Alabama Psychology Department's Subject Pool Database. Participants received an email providing directions to the lab and a short orientation video (Woolverton, 2024) showing them how the headset works and how to access the video used for the project. Participants were asked to wear flat shoes to their VR sessions to avoid balance issues with high-heels.

Upon arrival in the lab, I asked participants to provide demographic information using my own questionnaire, rate their motion sickness susceptibility using the MSSQ, their trait anxiety using the BAI, their state anxiety level using the STAI-S, and their baseline VR sickness symptoms using the CSQ. Although Young et al. (2006) cautioned that administering the SSQ pre-simulation could result in response bias towards feeling symptoms, I argue it was worth the risk in this case to adhere to Bouchard et al.'s (2021) assertion that clarifying the impacts of VR immersion and anxiety on self-reported symptoms would require researchers to measure "anxiety without immersing people in VR and assess the relationship between anxiety and the symptoms of unwanted negative side effects measured by the SSQ" (p. 3). Young et al. (2006) and Bouchard et al. (2021) do not address the CSQ directly, but their comments about the SSQ seem applicable to the CSQ since that instrument is a variant of the SSQ using a subset of the same items.

When the participants had completed all the pre-immersion questionnaires, I asked them to attach the electrodes for the heart rate monitor and step onto the balance board. They then put on the VR helmet to view the first video. The helmet was already turned on and ready for the participant to hit play on the first video. I asked them to remain still for one minute to establish baseline readings. Heart rate and balance monitoring continued the whole time the video was playing. To counterbalance order effects that could impact the outcome of the study (Johnson & Christensen, 2020), participants viewed the two videos in different orders. At the time of the intervention, I noted the order in which each participant received each video.

I remained in the room while participants viewed the VR content to supervise the activity and observe participants as they underwent each simulation so I could make notes about their behavior. Participants were not pressured to complete the VR experience if they exhibited excessive side-effects. When extreme symptoms occurred, participants had space to sit down and rest, and were allowed to do so before completing any additional questionnaires or answering any additional questions. Only one participant who experienced very extreme symptoms required longer than five minutes before continuing.

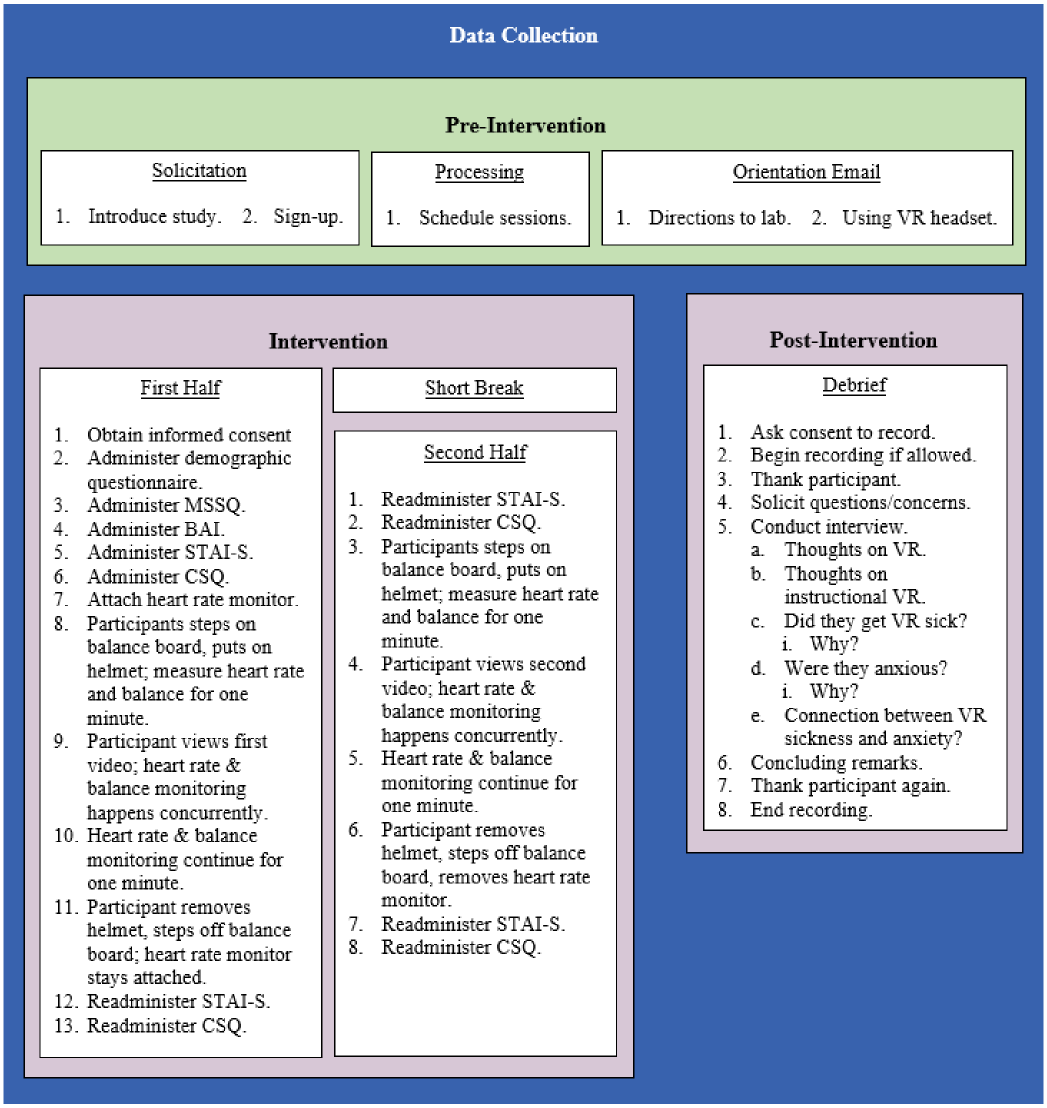
After the first video ended, I asked participants to continue monitoring their heart rate and balance for an additional minute with no activity, and step off the balance board after one minute. They kept the heart rate monitor attached to ease the transition into the second VR activity, but monitoring did not take place between immersions. I readministered the STAI-S and CSQ at this time to measure the increase or decrease in symptoms directly attributable to the VR activity. Participants were given a short rest between VR activities to allow their heart rate and balance levels to return to baseline and let any VR sickness symptoms subside (Ohio State University, 2020). During this interval, I sat up the second video and cleaned the helmet.

After a few minutes, I readministered the CSQ and STAI-S to generate a pre-immersion VR sickness score for the second VR activity and ensure that I had accurate data on the participant's state anxiety at the time of their second VR immersion. Participants stepped back onto the balance board, put the helmet back on, and resumed heart rate and balance monitoring for one minute. The process for observing participants and measuring their heart rate and balance during and after the video was repeated from the first activity. The STAI-S and CSQ were readministered for the final time after the second video ended and the heart rate monitor was disconnected.

After the second VR activity, I conducted short, informal debriefings with willing participants to ask for further information about their perception of their experience. Those who reported symptoms on CSQs were questioned about the relationship they perceived between anxiety, the simulation, and their symptoms. Participants who expressed any form of anxiety were questioned about its causes and normality in their life. All participants were questioned about their reaction to the VR content used in this study and their perception of future educational VR use. Debriefings were audio recorded and transcribed unless the participant denied consent to record, in which case I took handwritten notes. The VR headset was cleaned and the heart rate electrodes were replaced between sessions. Figure 1 provides an infographic of the data collection process.

Figure 1

Infographic Outlining Data Collection Process for Woolverton Dissertation



Data Collection

Pre-Intervention

Solicitation

1. Introduce study.
2. Sign-up.

Processing

1. Schedule sessions.

Orientation Email

1. Directions to lab.
2. Using VR headset.

Intervention

First Half

1. Obtain informed consent
2. Administer demographic questionnaire.
3. Administer MSSQ.
4. Administer BAI.
5. Administer STAI-S.
6. Administer CSQ.
7. Attach heart rate monitor.
8. Participants steps on balance board, puts on helmet; measure heart rate and balance for one minute.
9. Participant views first video; heart rate & balance monitoring happens concurrently.
10. Heart rate & balance monitoring continue for one minute.
11. Participant removes helmet, steps off balance board; heart rate monitor stays attached.
12. Readminister STAI-S.
13. Readminister CSQ.

Short Break

Second Half

1. Readminister STAI-S.
2. Readminister CSQ.
3. Participants steps on balance board, puts on helmet; measure heart rate and balance for one minute.
4. Participant views second video; heart rate & balance monitoring happens concurrently.
5. Heart rate & balance monitoring continue for one minute.
6. Participant removes helmet, steps off balance board, removes heart rate monitor.
7. Readminister STAI-S.
8. Readminister CSQ.

Post-Intervention

Debrief

1. Ask consent to record.
2. Begin recording if allowed.
3. Thank participant.
4. Solicit questions/concerns.
5. Conduct interview.
    a. Thoughts on VR.
    b. Thoughts on instructional VR.
    c. Did they get VR sick?
        i. Why?
    d. Were they anxious?
        i. Why?
    e. Connection between VR sickness and anxiety?
6. Concluding remarks.
7. Thank participant again.
8. End recording.

Data Analysis

Observation and debriefing data were coded first in a series of Excel spreadsheets to identify recurring themes on opinions of educational VR, anxiety sources, and VR sickness sources. Findings supplied the answer to research question five. I analyzed quantitative data using SPSS.

Research question one asks whether or not anxious users experience symptoms similar to but distinct from VR sickness before entering VR. The criteria for answering this question in the affirmative was:

1. Moderately and highly anxious participants exhibited signs of VR sickness (elevated CSQ score and low balance score) before VR immersion began whereas participants with low anxiety did not.
2. Participants' individual CSQ and balance scores did not change following VR immersion.

Research question two asks whether or not true VR sickness becomes more severe when anxiety is present. The criteria for answering this question in the affirmative was:

1. Participants' individual CSQ scores increased and balance scores decreased following VR immersion.
2. Moderately and highly anxious participants achieved higher CSQ scores and lower balance scores compared to participants with low anxiety.

Research question three asks whether or not the level of motion in VR content affects the relationship between anxiety and VR sickness. The criteria for answering this question in the affirmative was:

1. Moderately or highly anxious participants still achieved higher CSQ scores and lower balance scores compared to participants with low anxiety even though all participants showed less change between pre- and post-CSQ scores and balance scores from the low-motion video compared to the high-motion video.

Research question four asks how anxiety and VR sickness affect balance and heart rate. The answer to this question came from examining graphs depicting trends in heart rate and balance among participants who reported VR sickness and those who did not, and among moderately and highly anxious participants compared to participants with low anxiety.

Howell (2012) described methods for analyzing forms of repeated measures that involve a blend of within-subjects and between-subjects variables. His descriptions formed the template for my statistical approach. Statistical significance and effect size was judged based on pairwise comparisons with the alpha level set at .05. I conducted post hoc tests using LSD. I ran nine three-way mixed ANOVAs. The first six included CSQ scores, balance scores, and heart rate scores as the within-subject dependent variables respectively. Three of those ANOVAs used BAI score as the between-subjects independent variable; another three used STAI-S scores as the between-subjects independent variable. Within-subjects independent variables were (1) immersion and (2) motion intensity. The additional three ANOVAs used post-immersion CSQ scores as between-subjects independent variables and anxiety, balance, and heart rate as dependent variables respectively. I also ran a series of one-way ANOVAs using only data from before the first video, to test the relationship between anxiety and VR sickness measures in the total confirmed absence of effects from VR, as well as running a series of two-repeated measures ANOVAs that are described in more detail in Chapter IV for the purpose of depicting trends in balance and heart rate based on specific timestamps in each of the videos.

Before running the analysis, I adjusted the settings in SPSS to generate line graphs showing the trends in how CSQ pre and post scores, balance scores, and heart rate scores differed between subjects based on BAI level and STAI-S level, and in how balance and heart rate scores differed based on CSQ post scores. These graphs included confidence intervals, and were the primary evidence used to describe the effect of the different forms of anxiety on VR sickness symptoms. In each case, I focused on discerning whether any linear or quadratic trends emerged, and whether trends in highly anxious participants differed significantly from trends in participants with moderate and low anxiety, as well as whether the trends differed in high-motion content compared to low-motion content or based on viewing order.

To test the impact of confounding variables, I conducted two multiple regression analyses. One used data from the low-motion video; the other used data from the high-motion video. Both treated post-immersion CSQ scores from each video as the dependent variable and included viewing order as an independent variable alongside the variables listed as confounding in the Variables sections above. The purpose was to identify differences between the models of which variables most predict VR sickness for the high-motion video and the model for the low-motion video. Differences were determined by comparing the regression equations and the regressions coefficients resulting from each multiple regression. The number of possible outcomes analysis could have revealed makes listing them all here impractical, but examples included:

- Prior VR experience predicting VR sickness to a greater extent for the high-motion video.
- Viewing order only predicting VR sickness for the low-motion video.

Some confounding variables were left out of the analysis because they would obviously not have yielded useful results. For example, all but two participants reported that their gender assigned at birth matched their gender identity, and no participants reported receiving gender affirming care, so only gender assigned at birth received attention during analysis.

Assumptions of Statistical Tests

Mixed Model ANOVA.

The assumptions of the mixed model ANOVA—which also include the assumptions for two-way and repeated measure ANOVAs)—as defined by Howell (2012; 2016) are as follows:

- Correct model specification: The correct variables are included in the study and the correct statistical analysis was selected to analyze them.
- Valid and reliable measurement: The data collection tools accurately and consistently measure what they aim to measure.
- Independence: Participants are independently drawn from the population.
- Normality: The means are normally distributed (bell-shaped). This assumption will be checked by examining a histogram generated in SPSS.
- Homoscedasticity of the between-subjects variables: The variance between groups is equal. This assumption will be checked by examining the Levene's test generated in SPSS; a non-significant result will mean the assumption was met.
- Sphericity of the within-subjects variables: This assumption will be checked by examining the Mauchly's test results generated in SPSS.

Multiple Regression.

The assumptions of multiple regression as defined by Keith (2019) are as follows:

- Linearity: The dependent variable is a linear function of the independent variables.
- Valid and reliable measurement: The data collection tools accurately and consistently measure what they aim to measure.
- Independence: Participants are independently drawn from the population.
- Normality: The means are normally distributed (bell-shaped). This assumption will be checked by examining a histogram generated in SPSS.
- Homoscedasticity: The variance between groups is equal. This assumption will be checked by examining the Levene’s test generated in SPSS; a non-significant result will mean the assumption was met.
- Proper conception of variables: Variables treated as causes must be causes; variables treated as effects must be effects.

CHAPTER IV

RESULTS

<u>Introductory Observations</u>

VR Sickness

Out of 256 CSQs completed by 65 participants, 43 participants (66% of participants) reported symptoms on 129 CSQs (50.39% of CSQs). Sixty-three percent of those 43 participants scored higher on the CSQ's difficulty focusing component, 26% scored higher on the dizziness component, and the remaining 11% had roughly equal dizziness and difficulty focusing scores. The post-second video CSQ had the highest total number of symptoms reported (*n* = 97), but the post-first video CSQ had the highest average intensity of symptoms (M = 1.85). The pre-first video CSQ had the lowest total number of symptoms reported (*n* = 39), but the pre-second video CSQ had the lowest average intensity of symptoms (M = 1.11).

The most common symptoms reported were eyestrain (*n* = 72) and difficulty focusing (*n* = 69), followed in order by dizziness with eyes open (*n* = 28), headache (*n* = 35), blurred vision (*n* = 23), dizziness with eyes closed (*n* = 22), nausea (*n* = 15), fullness of the head (*n* = 16), and vertigo (*n* =4). The symptoms with the highest average intensity when they did occur were nausea (M = 1.4), dizziness with eyes open (M = 1.28), and difficulty focusing (M = 1.27).

Only one participant ended his session without undergoing the second VR activity due to extreme harmful side-effects. This participant reported that he started feeling hot and lost his vision during the one minute of heart rate and balance monitoring post-immersion, and collapsed almost as soon as he had taken off the VR headset. He recovered quickly after taking some time to rest and had returned to normal in around 12 minutes, but it seemed unwise to have him undergo immersion a second time. He had only viewed the low-motion video. The participant had played VR games before with no ill effects, and claimed unawareness of any medical problem that should have caused him to pass out from VR exposure. In fact, he said he had enjoyed the experience until then, and would enter VR again given the chance. Upon reflection, he believed the episode had something to do with having to stand still for the balance measurement, but had no theories as to why. He also mentioned that the underwater environment of the video reminded of his time serving on Navy submarines, but stated he had never experienced issues similar to this during his service.

Another participant completed both videos but had to skip the one minute of heart rate and balance monitoring following the second video because of nausea. She likewise felt better in around five minutes after accepting plain crackers and ginger ale to settle her stomach. No other participants were hindered from fully completing their session by harmful physical side-effects. Only one other participant asked for crackers and ginger ale to help ease nausea at the end of the session.

Discomfort from standing still for the balance measurement was an issue for 24 participants (38%). One participant (*not* the participant who collapsed) who expressed distaste for the VR activity overall did so solely because standing still made him highly uncomfortable. Another participant pointed out hypermobility as a factor that could influence anxiety and balance in VR, especially in a lab setting, suggesting the construct may require more attention in future research.

One participant said he generally gets very motion sick when he does VR, but did not feel motion sick while viewing the videos in this study. He said he generally played for much longer periods (30 minutes to one hour) and the level of sensory conflict in the games he plays is more extreme. Among participants who did experience VR sickness, instances of the camera zooming in and out on the reefs or cutting to large drop offs were mentioned as moments when symptoms became most apparent.

Anxiety

State Anxiety.

The most commonly reported reason for elevated state anxiety among participants was fear of the unknown (*n* = 10) around the lab's location, the researcher's personality, and what the study would entail. Anxiety arising from this source dissipated as participants found the lab, talked with the researcher, and became familiar with the study's purpose and procedures. Other recuring sources of anxiety were time constraints (*n* = 5), overwhelming to-do lists (*n* = 5), academic anxiety (*n* = 5), and fear of failure (*n* = 3). Trying to stand still for the balance measurement also caused anxiety in four participants because it made them fear falling, caused them to worry about distorting the results of the study, or went against their natural inclination to move. Thirty-one participants (51%) reported lower than maximum self-confidence on at least one STAI-S.

Sixteen participants mentioned that they found the videos used for the study calming (25%) compared to five (8%) who mentioned feeling uneasy about some aspect of the videos. Specific aspects of the videos they found calming were the ocean imagery (*n* = 7), the smooth music (*n* = 6), and the monotone voices of the narrators (four occurrences).

The only aspect of the videos mentioned by multiple participants as anxiety inducing was the mention of corals dying due to climate change (*n* = 4). However, most participants who reported feeling discomfort about the subject matter said the music and visuals were sufficiently calming or distracting to counteract the anxiety they felt. Two participants mentioned they always feel uncomfortable around the ocean or in close proximity to sea creatures, and one participant mentioned that the music reminded of her boyfriend who had recently enlisted in the military.

Trait Anxiety.

Thirty-six participants (55%) self-identified in post-session debriefs as generally calm; sixteen (25%) self-identified as generally anxious, with four indicating they regularly felt high anxiety. One participant gave a non-committal answer. The remaining 12 were not asked about their normal anxiety level for various reasons. These numbers differ from the results of the BAI, on which 59 participants (91%) were identified as having low trait anxiety, six participants (9%) were identified as having moderate trait anxiety, and no participants were identified as having high trait anxiety. This discrepancy may indicate a weakness in either the questionnaire or participants' self-perception.

Among generally calm participants who articulated a reason for their lack of anxiety, the most cited reason was that they simply saw no need to worry (*n* = 8). Other responses indicated that some participants were naturally calm without awareness of the reason or stopped themselves from overthinking through deliberate effort. Among participants who reported trait anxiety, the most common triggers were academic anxiety and test anxiety (*n* = 5), social anxiety (*n* = 3), and fear of the unknown (*n* = 3).

Temporal Order of Anxiety and VR Sickness Symptoms

Only 18 participants (28%) reported awareness of any relationship between their anxiety level and symptoms consistent with VR sickness.

- Three said anxiety and nausea caused each other.
- Four participants said anxiety caused nausea, but nausea did not cause anxiety.
- One participant said only extreme anxiety caused nausea, but nausea did not cause anxiety.
- Four participants said only extreme anxiety caused nausea and nausea also caused anxiety.
- Three participants said nausea caused anxiety, but anxiety did not cause nausea.
- One participant said only extreme nausea caused anxiety, but anxiety did not cause nausea.
- One participant said anxiety only caused eyestrain and only throwing up caused anxiety.
- One participant said anxiety only caused lightheadedness and no other VR sickness symptoms caused anxiety.

The participant who collapsed after viewing the first video confirmed his high STAI-S score following the episode arose because of his concern about the symptoms he felt, so the symptoms were not caused by anxiety. The only other participant who got nauseous enough to stop the activity early denied she usually felt nausea because of anxiety but said she generally felt anxious if she felt herself getting nauseous. It is worth noting that her STAI-S scores were among the highest, though she only felt strong VR sickness after the second video. These results present the relationship between anxiety and VR sickness as reciprocal and do not clarify which could more accurately be said to consistently cause the other.

Confounding Variables

Two multiple regression models were conducted to see if any of the confounding variables significantly predicted post-immersion CSQ scores for the high-motion or low-motion video. The regression model for the low-motion video was statistically nonsignificant ($F[9, 53] = .678$, $p = .752$, $R^2 = .103$); the regression model for the high-motion video was also statistically nonsignificant ($F[9, 54] = 1.157$, $p = .341$, $R^2 = .162$). None of the confounding variables predicted a statistically significant amount of variance in post-immersion CSQ scores for either video. The regression coefficients for the low-motion video are provided in Appendix K; the regression coefficients for the high-motion video are provided in Appendix L.

Research Questions

Research Question One

Do anxious users experience symptoms similar to but distinct from VR sickness before entering VR?

Twenty-two participants (34%) reported CSQ symptoms before ever entering VR. Difficulty focusing occurred the most ($n = 14$; M = 1.36), followed by eyestrain ($n = 12$; M = 1), and headache ($n = 5$; M = 1). Thirteen of those participants stated their symptoms were either a normal part of their life or arose from things like not sleeping, spending too much time looking at computers, or side-effects of medications; they were not conscious of anxiety playing a role.

State Anxiety.

To test the effect of state anxiety on CSQ outside of VR, I ran a one-way ANOVA in SPSS using STAI-S score as the independent variable and only CSQ scores from before the first VR activity as the dependent variable. All of the assumptions of the model were met. The ANOVA was statistically significant ($F[1, 125] = 18.375$, $p < .001$, $\eta p^2 = .128$). Participants reporting moderate state anxiety had higher average CSQ scores than participants reporting low state anxiety. The exact means and standard deviations for both groups are reported in Table 1.

Table 1

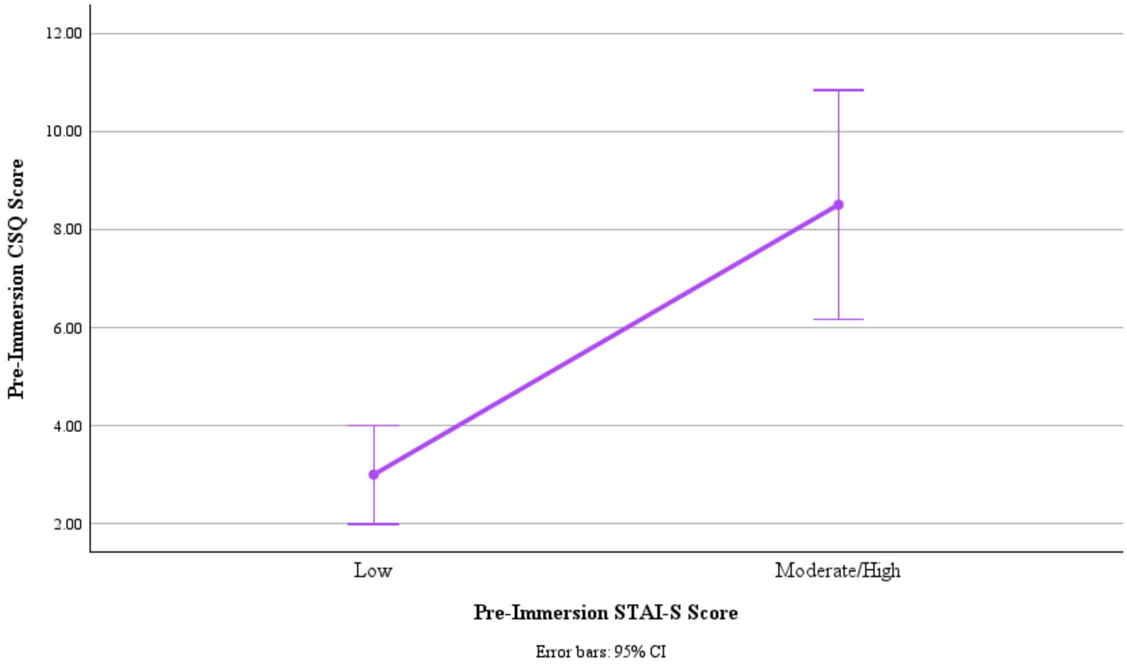
Means and Standard Deviations of CyberSickness Questionnaire (CSQ) Scores for State Trait Anxiety Inventory – State (STAI-S) Groups

STAIS-S Group	Mean	Standard Deviation
Low	2.99	5.06
Moderate/High	8.50	6.31
Total	3.87	5.62

Figure 2 illustrates the difference between the groups in the form of a line graph.

Figure 2

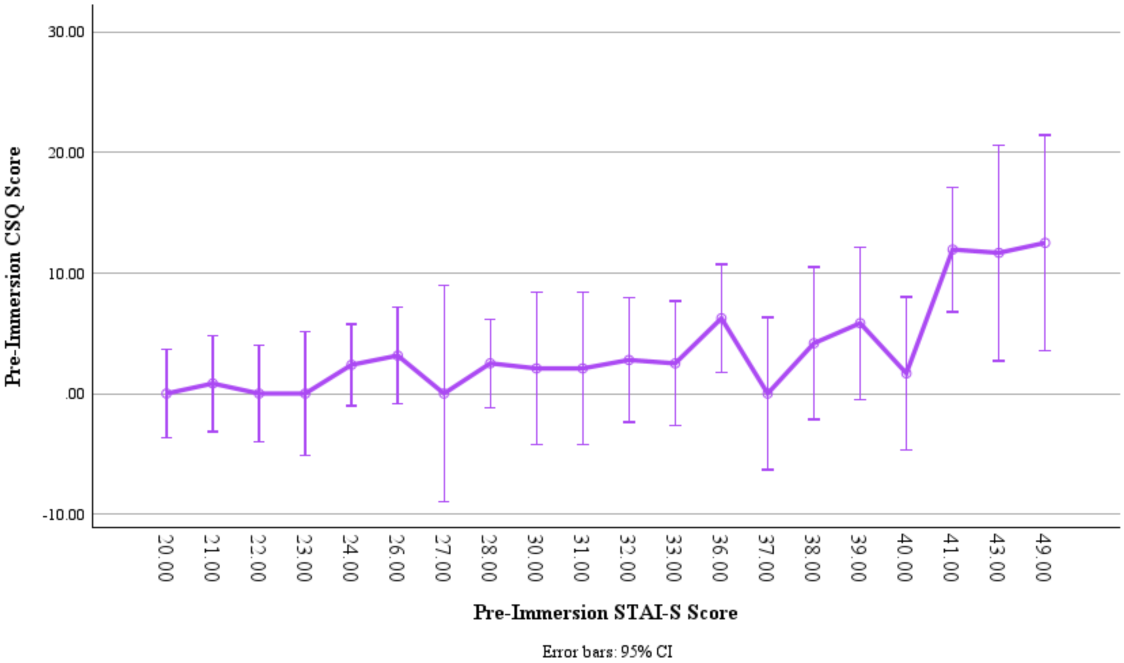
Effect of on State Trait Anxiety Inventory - State (STAI-S) Score on Pre-Immersion CyberSickness Questionnaire (CSQ) Score



To generate a line graph showing the trend that emerged in raw pre-immersion CSQ scores based on raw STAI-S score, I ran a two-way ANOVA in SPSS using pre-immersion CSQ score as the dependent variable and pre-immersion STAI-S score as the independent variable. The ANOVA was statistically significant (F[25, 100] = 1.76, p = .026, ηp^2 = .306). The trend was quadratic, so it is not possible to conclude that pre-immersion CSQ score consistently rises or falls as STAI-S score rises and falls, only that CSQ scores are more likely to be higher at higher levels of the STAI-S. Figure 3 shows trends in pre-immersion CSQ score based on STAI-S score.

Figure 3

Trend in Pre-Immersion CyberSickness Questionnaire (CSQ) Score Based on State Trait Anxiety Inventory - State (STAI-S) Score



I also ran a one-way ANOVA with pre-immersion STAI-S score as the independent variable and X axis balance pre score as the dependent variable. The ANOVA was nonsignificant (*F*[1, 118] = .150, *p* = .699, ηp^2 = .001), as was a repetition of the same ANOVA using Y axis balance pre score as the dependent variable (*F*[1, 118] = .762, *p* = .384, ηp^2 = .006]. The means and standard deviations of balance on the X axis for both STAI-S groups are reported in Table 2.

Table 2

Means and Standard Deviations of X Axis Balance for State Trait Anxiety Inventory – State (STAI-S) Groups

STAI-S Group	Mean	Standard Deviation
Low	0.55	0.66
Moderate/High	0.49	0.41
Total	0.54	0.63

The means and standard deviations of balance on the Y axis for both STAI-S groups are reported in Table 3.

Table 3

Means and Standard Deviations of Y Axis Balance for State Trait Anxiety Inventory – State (STAI-S) Groups

STAI-S Group	Mean	Standard Deviation
Low STAI-S	0.88	0.38
Moderate/High	0.80	0.35
Total	0.87	0.37

I ran a correlation analysis to examine the correlation between heart rate and CSQ score pre-immersion, which was nonsignificant (r = .07, p = .60). I also ran a correlation analysis to examine the correlation between heart rate and X axis balance pre-immersion, which was also nonsignificant (r = -.05, p = .72). Lastly, I ran a correlation analysis to examine the correlation between heart rate and Y axis balance pre-immersion, which was also nonsignificant ($r = -.17$, $p = .20$). These results indicate that heart rate was unrelated to balance and VR sickness pre-immersion.

Trait Anxiety.

To test the effect of trait anxiety on CSQ outside of VR, I ran a one-way ANOVA in SPSS using BAI score as the independent variable and only CSQ scores from before the first VR activity (the only point at which effects from VR could be totally ruled out) as the dependent variable. All of the assumptions of the model were met. The ANOVA was statistically significant ($F[1, 125] = 10.12$, $p < .002$, $\eta p^2 = .075$). Participants reporting moderate trait anxiety had higher average CSQ scores than participants reporting low trait anxiety. The exact means and standard deviations for both groups are reported in Table 4.

Table 4

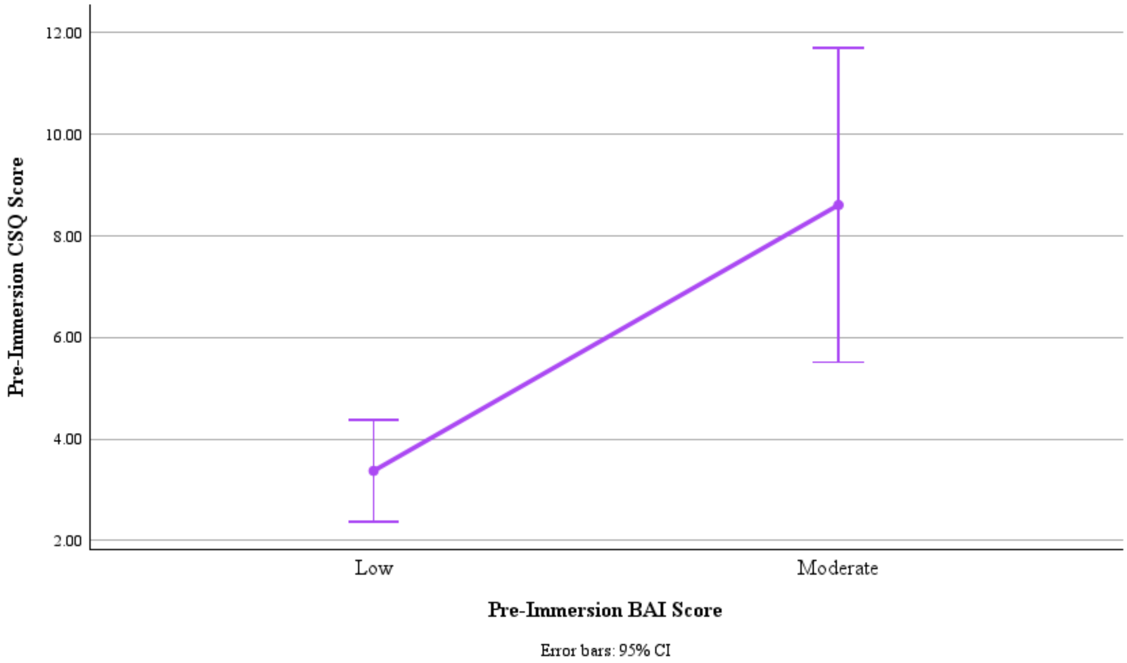
Means and Standard Deviations of CyberSickness Questionnaire (CSQ) Scores for Beck Anxiety Inventory (BAI) Groups

BAI Group	Mean	Standard Deviation
Low	3.37	5.22
Moderate	8.60	7.23
Total	3.87	5.62

Figure 4 illustrates the difference between the groups in the form of a line graph.

Figure 4

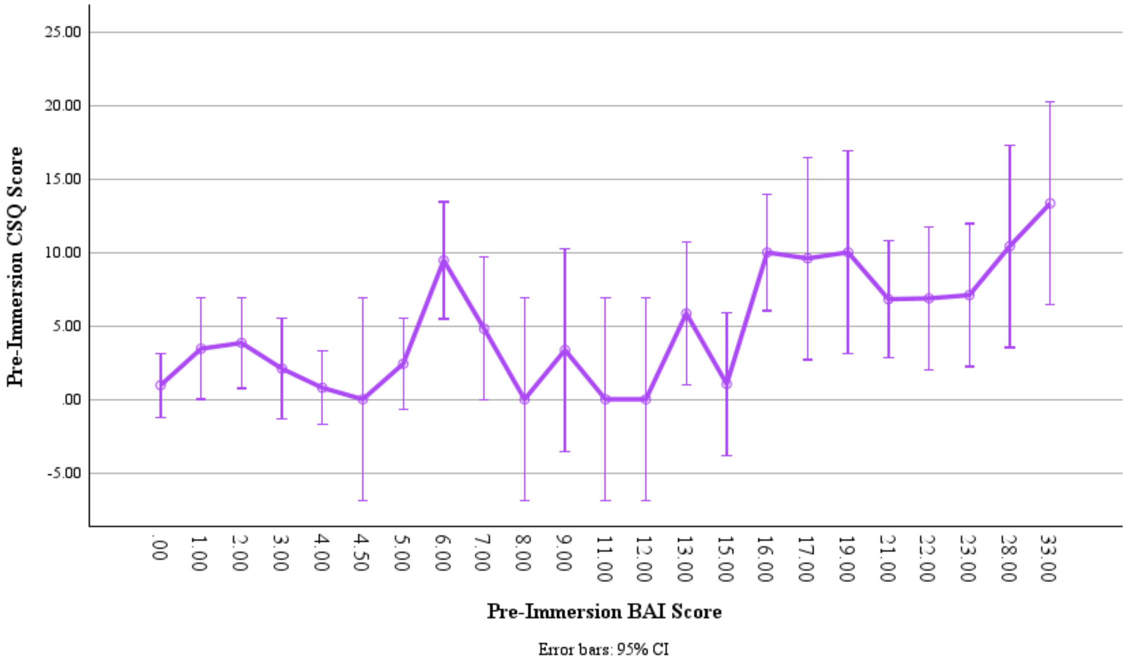
Effect of Beck Anxiety Inventory (BTAI) Score on Pre-Immersion CyberSickness Questionnaire (CSQ) Score



To generate a line graph illustrating the correlation between BAI score and CSQ pre-immersion more precisely, I repeated the ANOVA using raw BAI scores (the previous ANOVA treated the different levels of BAI score as groups). The ANOVA was statistically significant ($F[22, 104] = 2.79$, $p < .001$, $\eta p^2 = .371$). The trend was quadratic, so it is not possible to conclude that pre-immersion CSQ score consistently rises or falls as BAI score rises and falls, only that CSQ scores are more likely to be higher at higher levels of the BAI. Figure 5 shows trends in pre-immersion CSQ score based on BAI score.

Figure 5

Trend in Pre-Immersion CyberSickness Questionnaire (CSQ) Score Based on Beck Anxiety Inventory (BAI) Score



I also ran a one-way ANOVA with pre-immersion BAI score as the independent variable and X axis balance pre score as the dependent variable. The ANOVA was nonsignificant (F[1, 119] = .000, p = .983, $\eta p^2 = .000$), as was a repetition of the same ANOVA using Y axis balance pre score as the dependent variable (F[1, 119] = 1.579, p = .211, $\eta p^2 = .013$). The means and standard deviations of balance on the X axis for both BAI groups are reported in Table 5.

Table 5

Means and Standard Deviations of X Axis Balance for Beck Anxiety Inventory (BAI) Groups

BAI Group	Mean	Standard Deviation
Low	0.54	0.64
Moderate	0.53	0.43
Total	0.54	0.63

The means and standard deviations of balance on the Y axis for both BAI groups are reported in Table 6.

Table 6

Means and Standard Deviations of Y Axis Balance for Beck Anxiety Inventory (BAI) Groups

BAI Group	Mean	Standard Deviation
Low	0.85	0.36
Moderate	1.00	0.42
Total	0.87	0.37

Summary of Results for Research Question One.

Hypothesis one: Moderately and highly anxious participants will report VR sickness symptoms before VR immersion whereas participants with low anxiety will not.

Hypothesis one was confirmed with regard to trait and state anxiety and CSQ scores but not heart rate or balance. Participants scoring moderate and high on trait and state anxiety questionnaires were more likely to report CSQ symptoms before immersion, but were not more likely to have low balance before immersion.

Research Question Two

Does true VR sickness become more severe in the presence of anxiety?

To confirm that VR sickness did occur, I ran a two-way repeated measures ANOVA using CSQ score as the within-subjects dependent variable, and immersion motion intensity as the within-subjects independent variables. All assumptions of the model were met. Participants' CSQ scores were significantly higher after immersion than before immersion ($F[1, 125] = 17.922$, $p < .001$, $\eta p^2 = .125$). The exact means and standard deviations are presented in Table 7. The interaction between immersion and motion intensity was statistically nonsignificant ($F[1, 125] = .001$, $p = .976$, $\eta p^2 = .000$).

I also ran a two-way repeated measures ANOVA using balance along the X axis as the within-subjects dependent variable, and immersion motion intensity as the within-subjects independent variables. All assumptions of the model were met. The change based on immersion was statistically significant ($F[2, 238] = 11.370$, $p < .001$, $\eta p^2 = .087$). The exact means and standard deviations are presented in Table 7. The interaction between immersion and motion intensity was statistically nonsignificant ($F[2, 238] = .427$, $p = .653$, $\eta p^2 = .004$).

I ran an additional two-way repeated measures ANOVA using balance along the Y axis as the within-subjects dependent variable, and immersion motion intensity as the within-subjects independent variables. All assumptions of the model were met. The change based on immersion was statistically significant ($F[2, 238] = 17.259$, $p < .001$, $\eta p^2 = .127$). The exact means and standard deviations are presented in Table 7. The interaction between immersion and motion intensity was statistically nonsignificant (*F*[2, 238] = .900, *p* = .408, $\eta p^2 = .008$).

For both types of balance, scores were high before the videos began, decreased during the videos, and increased after the videos ended but did not return to pre-video levels (see Table 7). The means indicate the extent to which participants swayed along the X and Y axis, so a lower mean equates to higher balance; a higher mean equates to lower balance. The X axis represents left to right; the Y axis represents forwards and backwards.

Table 7

Means and Standard Deviations of CyberSickness Questionnaire (CSQ) and Balance Scores Before, During, and After Virtual Reality Videos

Measurement	Mean	Standard Deviation
CSQ Score Pre	3.87	5.62
CSQ Score Post	6.35	7.91
X Axis Balance Pre	0.54	0.63
X Axis Balance During	0.98	1.08
X Axis Balance Post	0.77	0.97
Y Axis Balance Pre	0.87	0.37
Y Axis Balance During	1.11	0.50
Y Axis Balance Post	0.97	0.44

These results suggest immersion in VR did play a role in increasing VR sickness indicators for both the low-motion and high-motion video, so the presence of genuine VR sickness can be inferred.

State Anxiety.

I ran a three-way mixed ANOVA including CSQ score as the within-subjects dependent variable, STAI-S score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and STAI-S score was significant (*F*[1, 123] = .13.303, p < .001, ηp^2 = .098). The interaction between immersion and motion intensity was nonsignificant, (*F*[1, 123] =.514, *p* = .475, ηp^2 = .004), as was the interaction between immersion, motion intensity, and STAI-S score (*F*[1, 123] = .858, *p* = .356, ηp^2 = .007). Table 8 presents the means and standard deviations of CSQ scores for each STAI-S group at each level of immersion.

Table 8

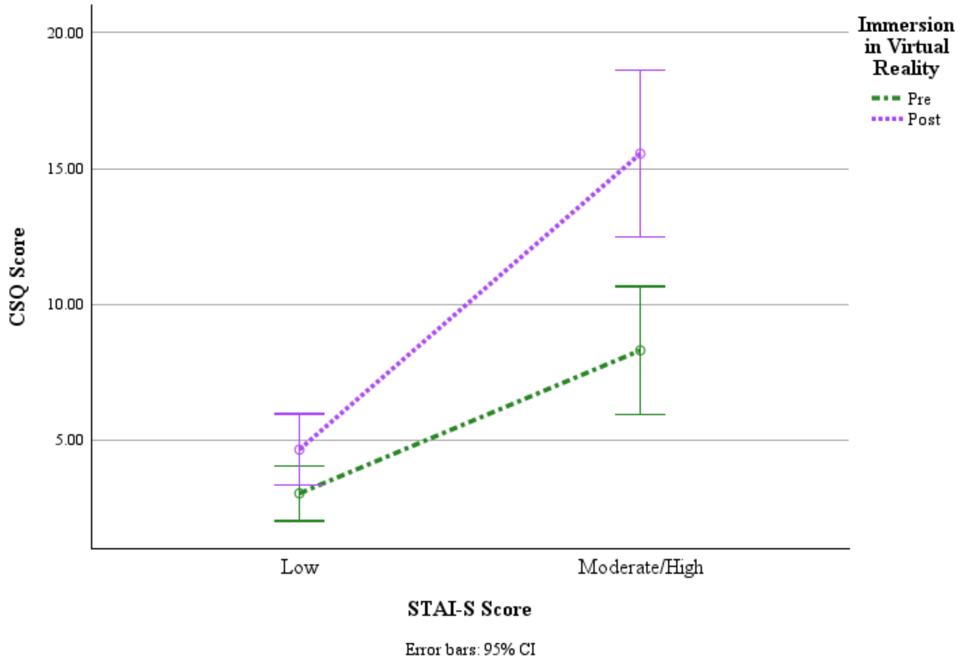
Means and Standard Deviations of CyberSickness Questionnaire (CSQ) Score Based on State Trait Anxiety Inventory - State (STAI-S) Score and Motion Intensity Before and After Virtual Reality (VR) Videos

Immersion in VR	STAI-S Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	3.61	4.95
		High	2.44	4.44
		Total	3.03	4.72
	Moderate/High	Low	7.87	5.14
		High	8.72	9.64
		Total	8.34	7.76
	Total	Low	4.22	5.16
		High	3.52	6.06
		Total	3.87	5.62
Post	Low	Low	5.06	6.92
		High	4.21	4.69
		Total	4.64	5.91
	Moderate/High	Low	16.39	11.70
		High	14.67	10.48
		Total	15.46	10.78
	Total	Low	6.67	8.63
		High	6.02	7.18
		Total	6.35	7.91

Figure 6 shows a line plot generated in SPSS illustrating the difference in CSQ scores based on STAI-S level. Examination of the interaction plot and pairwise comparisons showed participants in the moderate range of STAI-S scores experienced significantly ($p < .001$) higher VR sickness scores post immersion compared to participants with low STAI-S scores post immersion.

Figure 6

Effect of State Trait Anxiety Inventory - State (STAI-S) Score on CyberSickness Questionnaire (CSQ) Score Pre- and Post-Immersion



I also ran a three-way mixed ANOVA including balance on the Y axis as the within-subject dependent variable, STAI=S score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and STAI-S score was statistically significant ($F[2, 234] = 3.979$, $p = .020$, $\eta p^2 = .033$). The interaction between immersion and motion intensity was nonsignificant ($F[2, 234] = 1.007$, $p = .367$, $\eta p^2 = .009$), as was the interaction between immersion, motion intensity, and STAI-S score (*F*[2, 234] = .237, *p* = .790, ηp^2 = .002). Table 9 presents the means and standard deviations of Y axis balance for each STAI-S group at each level of immersion.

Table 9

Means and Standard Deviations of Y Axis Balance Based on State Trait Anxiety Inventory - State (STAI-S) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	STAI-S Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	0.90	0.38
		High	0.86	0.37
		Total	0.87	0.37
	Moderate/High	Low	0.79	0.28
		High	0.81	0.41
		Total	0.80	0.34
	Total	Low	0.88	0.37
		High	0.85	0.38
		Total	0.87	0.37
During	Low	Low	1.13	0.52
		High	1.17	0.75
		Total	1.08	0.47
	Moderate/High	Low	1.39	0.59
		High	1.17	0.75
		Total	1.28	0.67
	Total	Low	1.17	0.53
		High	1.05	0.47
		Total	1.11	0.50

Table 9 (Continued)

Means and Standard Deviations of Y Axis Balance Based on State Trait Anxiety Inventory - State (STAI-S) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	STAI-S Group	Motion Intensity	Mean	Standard Deviation
Post	Low	Low	0.99	0.50
		High	0.97	0.41
		Total	0.98	0.45
	Moderate/High	Low	0.89	0.38
		High	0.87	0.34
		Total	0.88	0.35
	Total	Low	0.97	0.41
		High	0.96	0.40
		Total	0.97	0.44

Examination of the pairwise comparisons and interaction plot revealed that Y axis balance levels actually did not differ significantly between the low and moderate/high groups before ($p = .432$), during ($p = .129$), or after ($p = .371$) the videos. However, the trend in Y axis balance differed between the two groups such that, although both groups exhibited weakened balance during the videos, participants in the moderate/high range of STAI-S returned to baseline after the videos whereas participants in the low range did not. For the moderate and high group STAI-S group, balance before the video did not differ significantly from balance after the video ($p = .490$), but balance during the video was higher than before the video ($p < .001$) and after ($p < .001$). For participants in the low group, balance after the video was significantly higher than balance before the video

(p = .027), and balance during the video was significantly higher than both before (p < .001) and after (p = .022). Figure 12 under the section detailing the results for research question four illustrates the relationship as a line graph.

I ran an additional three-way mixed ANOVA in SPSS, including balance on the X axis as the within-subject dependent variable, STAI-S score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and STAI-S score was nonsignificant (F[2, 234] = 1.404, p = .248, ηp^2 = .012). The interaction between immersion and motion intensity was also nonsignificant (F[2, 234) = 1.481, p = .230, ηp^2 = .013), as was the interaction between immersion, motion intensity, and BAI score (F[2, 234] = 1.250, p = .287, ηp^2 = .011). Table 10 presents the means and standard deviations of X axis balance for each STAI-S group at each level of immersion.

Table 10

Means and Standard Deviations of X Axis Balance Based on State Trait Anxiety Inventory - State (STAI-S) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	STAI-S Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	0.51	0.69
		High	0.51	0.46
		Total	0.51	0.59
	Moderate/High	Low	0.81	1.13
		High	0.60	0.35
		Total	0/54	0.63
	Total	Low	0.56	0.77
		High	0.52	0.45
		Total	0.54	0.63
During	Low	Low	0.98	1.12
		High	0.89	0.92
		Total	0.94	1.02
	Moderate/High	Low	1.63	1.89
		High	0.80	0.40
		Total	1.21	1.39
	Total	Low	1.08	1.26
		High	0.88	0.86
		Total	0.98	1.08

Table 10 (Continued)

Means and Standard Deviations of X Axis Balance Based on State Trait Anxiety Inventory - State (STAI-S) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	STAI-S Group	Motion Intensity	Mean	Standard Deviation
Post	Low	Low	0.83	0.98
		High	0.76	1.10
		Total	0.79	1.04
	Moderate/High	Low	0.67	0.56
		High	0.65	0.33
		Total	0.66	0.44
	Total	Low	0.80	0.93
		High	0.74	1.04
		Total	0.77	0.97

I also ran a three-way mixed ANOVA including CSQ score as the within-subject dependent variable, heart rate as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and heart rate was nonsignificant (F[60, 42] = 1.223, p = .245, ηp^2 = .631). The interaction between immersion and motion intensity was also nonsignificant, (F[1, 43] = .547, p = .464, ηp^2 = .013), as was the interaction between immersion, motion intensity, and heart rate (F[18, 43] = 1.447, p = .159, ηp^2 = .377).

I also ran a three-way mixed ANOVA including balance on the Y axis as the within-subject dependent variable, heart rate as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and heart rate was nonsignificant ($F[1, 115] = 1.393$, $p = .240$, $\eta p^2 = .013$). The interaction between immersion and motion intensity was also nonsignificant ($F[1, 115] = 2.004$, $p = .160$, $\eta p^2 = .017$), as was the interaction between immersion, motion intensity, and heart rate ($F[1, 115] = .163$, $p = .687$, $\eta p^2 = .001$). I ran an additional three-way mixed ANOVA including balance on the X axis as the within-subject dependent variable, heart rate as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and heart rate was nonsignificant ($F[1, 115] = 1.200$, $p = .276$, $\eta p^2 = .010$). The interaction between immersion and motion intensity was also nonsignificant ($F[1, 115] = .581$, $p = .447$, $\eta p^2 = .005$), as was the interaction between immersion, motion intensity, and heart rate ($F[1, 115] = .023$, p = .879, $\eta p^2 = .000$).

Trait Anxiety.

I ran a three-way mixed ANOVA in SPSS, including CSQ score as the within-subject dependent variable, BAI score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and BAI score was significant ($F[1, 123] = 4.754$, $p = .031$, $\eta p^2 = .036$). The interaction between immersion and motion intensity was nonsignificant ($F[1, 123] = 4.754$, $p = .128$, $\eta p^2 = .019$), as was the interaction between immersion, motion intensity, and BAI score (*F*[1, 123] = 3.494, *p* = .064, $\eta p^2 = 0.28$). Table 11 presents the means and standard deviations of CSQ scores for each BAI group at each level of immersion.

Table 11

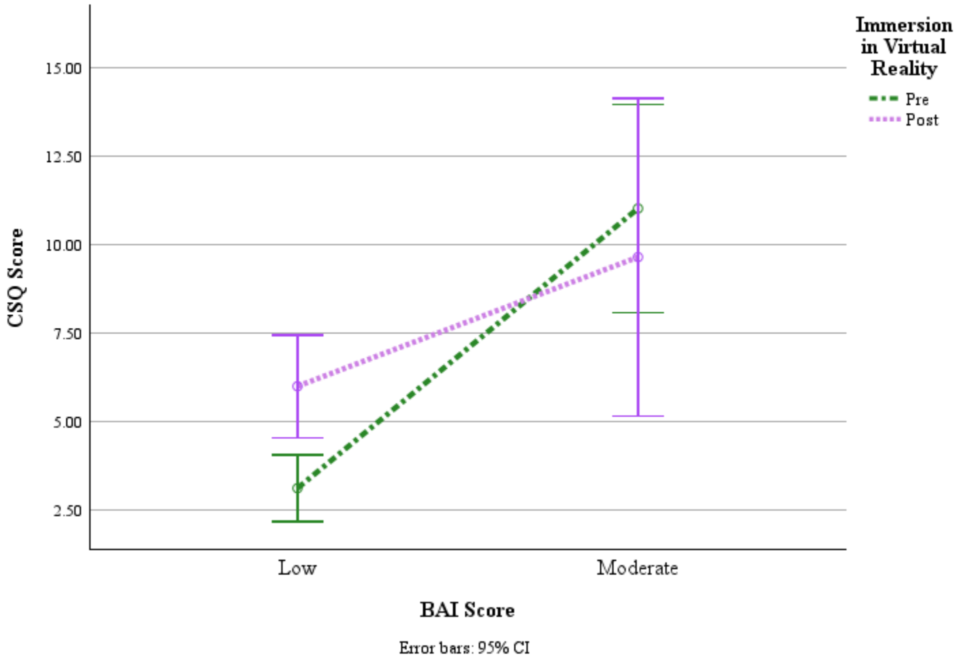
Means and Standard Deviations of CyberSickness Questionnaire (CSQ)Score Based on Beck Anxiety Inventory (BAI) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	BAI Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	3.23	4.06
		High	2.99	5.81
		Total	3.11	4.99
	Moderate/High	Low	13.46	5.75
		High	8.61	6.56
		Total	11.03	6.40
	Total	Low	4.22	5.16
		High	3.87	6.06
		Total	3.87	5.62
Post	Low	Low	6.47	8,87
		High	5.55	7.29
		Total	6.00	8.09
	Moderate/High	Low	8.76	6.07
		High	10.56	4.04
		Total	9.66	5.01
	Total	Low	6.69	8.63
		High	6.02	7.18
		Total	6.35	7.91

Figure 7 shows a line plot generated in SPSS illustrating the difference in CSQ scores based on BAI level. Examination of the pairwise comparisons revealed that trait anxiety only had an effect pre-immersion. The difference in post-immersion CSQ scores between participants with low and moderate trait anxiety was nonsignificant (*p* = .131).

Figure 7

Effect of Beck Anxiety Inventory (BAI) Score on CyberSickness Questionnaire (CSQ) Score Pre- and Post-Immersion



I also ran a three-way mixed ANOVA including balance on the Y axis as the within-subject dependent variable, BAI score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and BAI score was nonsignificant (*F*[2, .234] =

1.564, $p = .211$, $\eta p^2 = .013$). The interaction between immersion and motion intensity was also nonsignificant ($F[2, 234] = .161$, $p = .851$, $\eta p^2 = .001$), as was the interaction between immersion, motion intensity, and BAI score ($F[2, 234] = .828$, $p = .365$, $\eta p^2 = .007$). Table 12 presents the means and standard deviations of Y axis balance for each BAI group at each level of immersion.

Table 12

Means and Standard Deviations of Y Axis Balance Based on Beck Anxiety Inventory (BAI) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	BAI Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	0.87	0.35
		High	0.84	0.38
		Total	0.85	0.36
	Moderate	Low	1.01	0.60
		High	0.96	0.35
		Total	0.99	0.46
	Total	Low	0.88	0.37
		High	0.85	0.37
		Total	0/87	0.37

Table 12 (Continued)

Means and Standard Deviations of Y Axis Balance Based on Beck Anxiety Inventory (BAI) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	BAI Group	Motion Intensity	Mean	Standard Deviation
During	Low	Low	1.17	0.52
		High	10.02	0.42
		Total	1.09	0.48
	Moderate	Low	1.23	0.66
		High	1.44	0.81
		Total	1.33	0.70
	Total	Low	1.17	0.53
		High	1.05	0.47
		Total	1.11	0.50
Post	Low	Low	0.98	0.50
		High	0.95	0.39
		Total	0.97	0.53
	Moderate	Low	0.89	0.27
		High	0.99	0.53
		Total	0.94	0.40
	Total	Low	0.97	0.48
		High	0.96	0.40
		Total	0.97	0.44

I ran an additional three-way mixed ANOVA including balance on the X axis as the within-subject dependent variable, BAI score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. Post hoc tests were conducted using LSD. All assumptions of the model were met. The interaction between immersion and BAI score was nonsignificant (*F*[2, 234] = 2.626, *p* = .075, ηp^2 = .022). The interaction between immersion and motion intensity was also nonsignificant (*F*[2, .234] = .138, *p* = .765, ηp^2 = .002), as was the interaction between immersion, motion intensity, and BAI score (*F*[2, 234] = .407, *p* = .666, ηp^2 = .003). Table 13 presents the means and standard deviations of X axis balance for each BAI group at each level of immersion.

Table 13

Means and Standard Deviations of X Axis Balance Based on Beck Anxiety Inventory (BAI) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	BAI Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	0.55	0.79
		High	0.53	0.46
		Total	0.54	0.64
	Moderate	Low	0.59	0.59
		High	0.45	0.18
		Total	0.52	0.42
	Total	Low	0.56	0.77
		High	0.52	0.45
		Total	0.54	0.63

Table 13 (Continued)

Means and Standard Deviations of X Axis Balance Based on Beck Anxiety Inventory (BAI) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	BAI Group	Motion Intensity	Mean	Standard Deviation
During	Low	Low	1.03	1.21
		High	0.81	0,65
		Total	0.92	0.97
	Moderate	Low	1.63	1.88
		High	1.70	2.06
		Total	1.66	1.86
	Total	Low	1.08	1.26
		High	0.88	0.86
		Total	0.98	1.08
Post	Low	Low	0.79	0.90
		High	0.69	1.01
		Total	0.74	0.96
	Moderate	Low	0.94	1.29
		High	1.30	1.07
		Total	1.12	1.14
	Total	Low	0.80	0.93
		High	0.74	1.02
		Total	0.77	0.97

Summary of Results for Research Question Two.

Hypothesis two: Moderately and highly anxious participants will report higher VR sickness levels compared to participants with low anxiety after VR immersion.

Hypothesis two was confirmed regarding the CSQ and state anxiety but not trait anxiety. Moderate and high STAI-S score corresponded to higher post-immersion CSQ scores compared to low STAI-S score; no such relationship was found between CSQ score and BAI score. Hypothesis two was not confirmed with regard to heart rate.

Hypothesis two was not confirmed with regard to state or trait anxiety and balance. No significant relationship was found between STAI-S score and balance on the X axis. Patterns in Y axis balance did appear to differ insofar as participants reporting moderate/high state anxiety returned to baseline balance following the videos whereas participants reporting low state anxiety did not. However, there was no significant difference between state anxiety groups in Y axis balance scores at each level of immersion. No significant relationship was found between trait anxiety and balance.

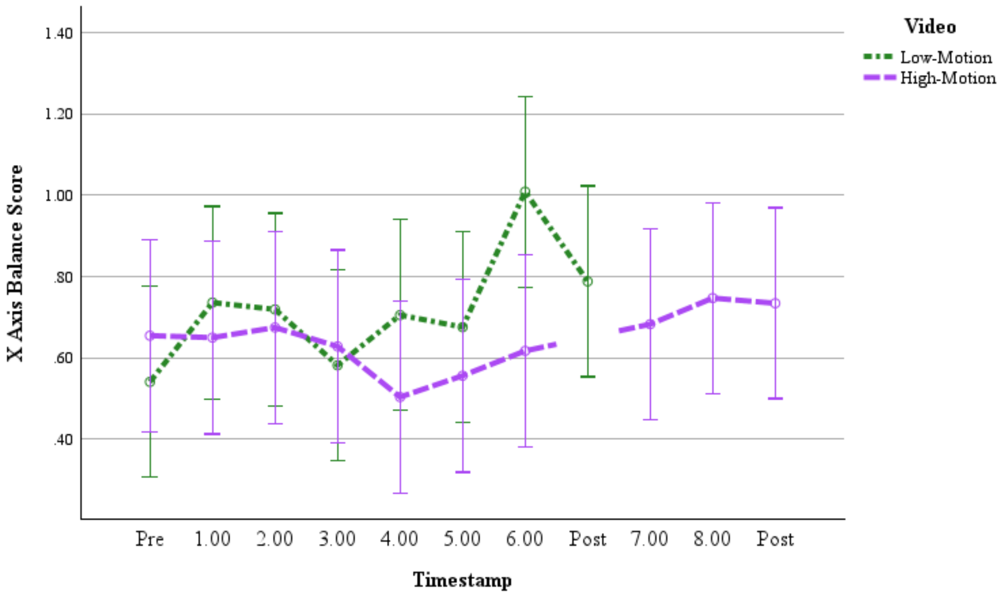
Research Question Three

Does the level of motion in VR content affect the relationship between anxiety and VR sickness?

Sixteen participants (25%) said they noticed feeling more destabilized by the high-motion video (regardless of viewing order) because of the higher level of sensory conflict compared to the low-motion video. Figure 8 shows trends in balance along the X axis for both videos in the form of a line graph generated in SPSS by running a two-way ANOVA using X axis balance as the dependent variable and timestamp and timestamp as the independent variables. A higher score equates to lower balance. The simple main effect of timestamp was nonsignificant ($F[10, 1089] = .751$, $p = .129$, $\eta p^2 = .002$), so it is not possible to point to specific moments in the videos that had particularly strong effects. The interaction between timestamp and video was also nonsignificant ($F[6, 1089] = .853$, $p = .453$, $\eta p^2 = .005$).

Figure 8

Trends in X Axis Balance Before, During, and After Virtual Reality Videos



Note. Because the low-motion video was shorter than the high-motion video, the line representing the low-motion video in the graph is shorter than the line representing the high-motion video. Also for this reason, there are two Post markers in the graph, and the line representing the high-motion video splits to visually depict that the first Post marker is not applicable to the high-motion video.

Table 14 presents the means and standard deviations of balance scores along the X axis at each timestamp for both videos.

Table 14

Means and Standard Deviations of X Axis Balance Before, During, and After Virtual Reality Videos

Timestamp	Video	Mean	Standard Deviation
Pre	Low-Motion	0.54	0.75
	High-Motion	0.65	1.03
	Total	0.59	0.90
1:00	Low-Motion	0.74	1.03
	High-Motion	0.65	1.03
	Total	0.69	1.03
2:00	Low-Motion	0.71	0.97
	High-Motion	0.67	0.99
	Total	0.69	0.98
3:00	Low-Motion	0.58	0.65
	High-Motion	0.63	0.91
	Total	0.60	0.79
4:00	Low-Motion	0.70	1.12
	High-Motion	0.50	0.46
	Total	0.60	0.79
5:00	Low-Motion	0.68	0.94
	High-Motion	0.56	0.63
	Total	0.62	0.80
6:00	Low-Motion	1.00	1.58
	High-Motion	0.62	0.55
	Total	0.81	1.20
7:00	Low-Motion		
	High-Motion	0.68	0.88
	Total	0.68	0.88

Table 14 (Continued)

Means and Standard Deviations of X Axis Balance Before, During, and After Virtual Reality Videos

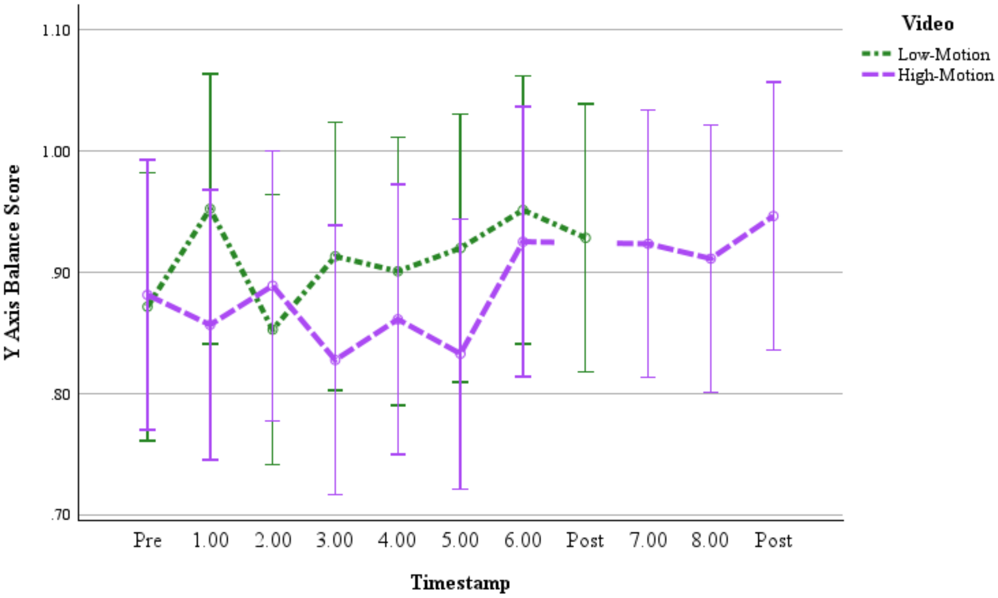
Timestamp	Video	Mean	Standard Deviation
8:00	Low-Motion		
	High-Motion	0.75	0.93
	Total	0.75	0.93
Post	Low-Motion	0.78	0.92
	High-Motion	0.73	0.99
	Total		
Total	Low-Motion	0.72	1.03
	High-Motion	0.64	0.86
	Total	0.68	0.94

Note. Because the low-motion video was shorter than the high-motion video, some timestamps are not applicable to the low-motion video and are left blank in the table.

Figure 9 shows trends in balance along the Y axis for both videos in the form of a line graph generated in SPSS by running a one-way ANOVA using Y axis balance as the dependent variable and timestamp as the independent variable. A higher score equates to lower balance. The simple main effect of timestamp was nonsignificant (F[10, 1089] = .496, p = .893, ηp^2 = .005), so it is not possible to point to specific moments in the videos that had particularly strong effects. The interaction between timestamp and video was also nonsignificant, (F[6, 1089] = .412, p = .871, ηp^2 = .002).

Figure 9

Trends in Y Axis Balance Before, During, and After Virtual Reality Videos



Note. Because the low-motion video was shorter than the high-motion video, the line representing the low-motion video in the graph is shorter than the line representing the high-motion video. Also for this reason, there are two Post markers in the graph, and the line representing the high-motion video splits to visually depict that the first Post marker is not applicable to the high-motion video.

Table 15 presents the means and standard deviations of balance scores along the Y axis at each timestamp for both videos.

Table 15

Means and Standard Deviations of Y Axis Balance Before, During, and After Virtual Reality Videos

Timestamp	Video	Mean	Standard Deviation
Pre	Low-Motion	0.87	0.37
	High-Motion	0.88	0.44
	Total	0.88	0.40
1:00	Low-Motion	0.95	0.62
	High-Motion	0.86	0.44
	Total	0.90	0.54
2:00	Low-Motion	0.85	0.37
	High-Motion	0.89	0.55
	Total	0.87	0.47
3:00	Low-Motion	0.91	0.40
	High-Motion	0.83	0.35
	Total	0.87	0.38
4:00	Low-Motion	0.90	0.46
	High-Motion	0.86	0.43
	Total	0.88	0.44
5:00	Low-Motion	0.92	0.40
	High-Motion	0.83	0.42
	Total	0.88	0.41
6:00	Low-Motion	0.95	0.51
	High-Motion	0.93	0.46
	Total	0.94	0.49
7:00	Low-Motion		
	High-Motion	0.92	0.41
	Total	0.92	0.41

Table 15 (Continued)

Means and Standard Deviations of Y Axis Balance Before, During, and After Virtual Reality Videos

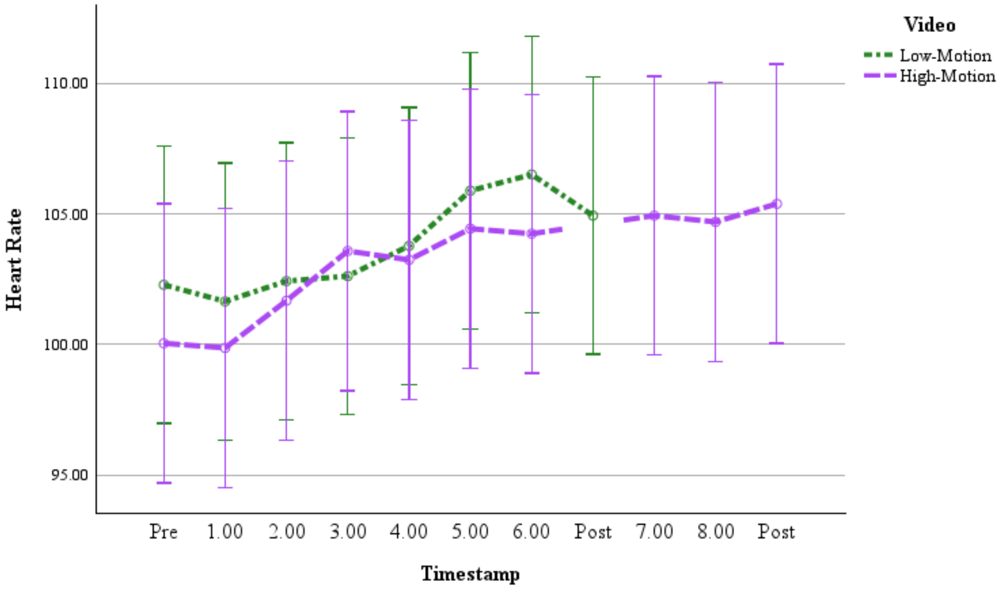
Timestamp	Video	Mean	Standard Deviation
8:00	Low-Motion		
	High-Motion	0.91	0.41
	Total	0.91	0.41
Post	Low-Motion	0.93	0.45
	High-Motion	0.95	0.40
	Total	0.94	0.43
Total	Low-Motion	0.91	0.45
	High-Motion	0.89	0.43
	Total	0.89	0.44

Note. Because the low-motion video was shorter than the high-motion video, some timestamps are not applicable to the low-motion video and are left blank in the table.

Figure 10 shows trends in heart rate for both videos in the form of a line graph generated in SPSS by running a one-way ANOVA using heart rate as the dependent variable and timestamp as the independent variable. A higher score equates to higher heart rate. The simple main effect of timestamp was nonsignificant (*F*[10, 1106] = .751, *p* = .677, ηp^2 = .007), so it is not possible to point to specific moments in the videos that had particularly strong effects. The interaction between timestamp and video was also nonsignificant (*F*[6, 1106] = .090, *p* = .997, ηp^2 = .000).

Figure 10

Trends in Heart Rate Before, During, and After Virtual Reality Videos



Note. Because the low-motion video was shorter than the high-motion video, the line representing the low-motion video in the graph is shorter than the line representing the high-motion video. Also for this reason, there are two Post markers in the graph, and the line representing the high-motion video splits to visually depict that the first Post marker is not applicable to the high-motion video.

Table 16 presents the means and standard deviations of heart rate at each timestamp for both videos.

Table 16

Means and Standard Deviations of Heart Rate Before, During, and After Virtual Reality Videos

Timestamp	Video	Mean	Standard Deviation
Pre	Low-Motion	102.29	22.30
	High-Motion	100.05	22.22
	Total	101.18	22.20
1:00	Low-Motion	101.65	23.20
	High-Motion	99.87	22.33
	Total	100.77	22.70
2:00	Low-Motion	102.43	19.82
	High-Motion	101.68	22.31
	Total	102.06	21.01
3:00	Low-Motion	102.62	20.25
	High-Motion	103.58	21.08
	Total	103.09	20.59
4:00	Low-Motion	103.78	21.35
	High-Motion	103.24	20.74
	Total	103.51	20.97
5:00	Low-Motion	105.89	19.53
	High-Motion	104.44	21.62
	Total	105.17	20.52
6:00	Low-Motion	106.51	21.46
	High-Motion	104.44	21.62
	Total	105.17	21.41
7:00	Low-Motion		
	High-Motion	104.94	21.74
	Total	104.94	21.74

Table 16 (Continued)

Means and Standard Deviations of Heart Rate Before, During, and After Virtual Reality Videos

Timestamp	Video	Mean	Standard Deviation
8:00	Low-Motion		
	High-Motion	104.69	20.39
	Total	104.69	20.39
Post	Low-Motion	104.94	21.14
	High-Motion	105.39	22.63
	Total	105.05	22.15
Total	Low-Motion	103.76	21.09
	High-Motion	103.21	21.59
	Total	103.46	21.36

Note. Because the low-motion video was shorter than the high-motion video, some timestamps are not applicable to the low-motion video and are left blank in the table.

Fifteen participants (35% of VR sick participants) said they first became conscious of CSQ symptoms starting during the high-motion video (regardless of viewing order) compared to nine (21%) who said their symptoms started during the low-motion video (regardless of viewing order). One participant mentioned the low-motion video caused more eyestrain because there was more information posted around at different angles and they were trying to see everything without turning their head. Another mentioned they found the high-motion video more soothing because it featured calmer music and less narration.

In the high-motion video (AirPano VR; 2022), Five participants mentioned a scene at timestamp 2:23 in which the camera gets very close to one particular fish. This scene made participants feel unsettled and destabilized because the fish appeared abruptly and created a sense that the viewer was about to collide with the fish. A similar shot of a turtle at timestamp 4:30 had the same effect. In the low-motion video (Wildlife Conservation Society, 2021), participants pointed to two moments as sources of headaches and eyestrain regardless of viewing order: the scene at timestamp 0:46 in which the scenery transitions from underwater to dry land, and the end credits beginning at 5:35. Both scenes featured very bright lights which contrasted with the subdued lighting of the rest of the video. None of these examples relate to motion intensity.

The series of three-way mixed ANOVAs I described in the section detailing the results for research question two above also yielded information applicable to research question three, and I refer the reader to the section on research question two for full descriptions of the exact statistical tests run, including the tables of means and standard deviations.

In the three-way mixed ANOVA that featured CSQ score as the within-subjects dependent variable and STAI-S score as the between-subjects independent variable, the interaction between immersion and motion intensity ($F[1, 123] = .514$, $p = .475$, $\eta p^2 = .004$), and the interaction between immersion, motion intensity, and STAI-S score ($F[1, 123] = .858$, $p = .356$, $\eta p^2 = .007$) were statistically nonsignificant. Likewise, in the three-way mixed ANOVA that featured CSQ score as the within-subjects dependent variable and BAI score as the between-subjects independent variable, the interaction between immersion and motion intensity ($F[1, 123] = 4.754$, $p = .128$, $\eta p^2 = .019$), and the interaction between immersion, motion intensity, and BAI score (*F*[1, 123] = 3.494, *p* = .064, ηp^2 = 0.28) were statistically nonsignificant. In the three-way mixed ANOVA that featured CSQ score as the within-subjects dependent variable and heart rate as the between-subjects independent variable, the interaction between immersion and motion intensity (*F*[1, 43] = .547, *p* = .464, ηp^2 = .013), and the interaction between immersion, motion intensity, and heart rate (*F*[18, 43] = 1.447, *p* = .159, ηp^2 = .377) were also statistically nonsignificant.

In the three-way mixed ANOVA that featured X axis balance as the within-subjects dependent variable and STAI-S score as the between-subjects independent variable, the interaction between immersion and motion intensity (*F*[2, 234) = 1.481, *p* = .230, ηp^2 = .013), and the interaction between immersion, motion intensity, and STAI-S score (*F*[2, 234] = 1.250, *p* = .287, ηp^2 = .011) were statistically nonsignificant. Likewise, in the three-way mixed ANOVA that featured X axis balance as the within-subjects dependent variable and BAI score as the between-subjects independent variable, the interaction between immersion and motion intensity (*F*[2, .234] = .138, *p* = .765, ηp^2 = .002), and the interaction between immersion, motion intensity, and BAI score (*F*[2, 234] = .407, *p* = .666, ηp^2 = .003) were statistically nonsignificant. In the three-way mixed ANOVA that featured X axis balance as the within-subjects dependent variable and heart rate as the between-subjects independent variable, the interaction between immersion and motion intensity (*F*[1, 115] = .581, *p* = .447, ηp^2 = .005), and the interaction between immersion, motion intensity, and heart rate (*F*[1, 115] = .023, p = .879, ηp^2 = .000) were also statistically nonsignificant.

In the three-way mixed ANOVA that featured Y axis balance as the within-subjects dependent variable and STAI-S score as the between-subjects independent variable, the interaction between immersion and motion intensity (*F*[2, 234] = .1.007, *p* = .367, ηp^2 = .009), and the interaction between immersion, motion intensity, and STAI-S score (*F*[2, 234] = .237, *p* = .790, ηp^2 = .002) were statistically nonsignificant. Likewise, in the three-way mixed ANOVA that featured Y axis balance as the within-subjects dependent variable and BAI score as the between-subjects independent variable, the interaction between immersion and motion intensity (*F*[2, 234] = .161, *p* = .851, ηp^2 = .001), and the interaction between immersion, motion intensity, and BAI score (*F*[2, 234] = .828, *p* = .365, ηp^2 = .007) were statistically nonsignificant. In the three-way mixed ANOVA that featured Y axis balance as the within-subjects dependent variable and heart rate as the between-subjects independent variable, the interaction between immersion and motion intensity (*F*[1, 115] = 2.004, *p* = .160, ηp^2 = .017), and the interaction between immersion, motion intensity, and heart rate (*F*[1, 115] = .163, *p* = .687, ηp^2 = .001) were also statistically nonsignificant.

Summary of Results for Research Question Three.

Hypothesis three: A low-motion scene will provoke lower VR sickness levels than a high-motion scene, but moderately and highly anxious participants will report higher VR sickness levels compared to participants with low anxiety in both cases.

Hypothesis three was partially confirmed. Motion intensity did not affect the relationship between anxiety and VR sickness, but it also did not affect the level of VR sickness participants experienced.

Research Question Four

How do anxiety and VR sickness affect balance and heart rate?

<u>State Anxiety.</u>

I ran a three-way mixed ANOVA including heart rate as the within-subject dependent variable, STAI-S score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. All the assumptions of the model were met. The trends were linear for both groups. Although participants reporting higher state anxiety appear to exhibit higher heart rates, the interaction between immersion and STAI-S score was statistically nonsignificant (F[2, 242], $p = .063$, ηp2 = .001). Table 17 presents the means and standard deviations of heart rate for each STAI-S group at each level of immersion.

Table 17

Means and Standard Deviations of Heart Rate Based on State Trait Anxiety Inventory - State (STAI-S) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	STAI-S Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	99.51	20.83
		High	102.67	25.44
		Total	101.11	23.21
	Moderate/High	Low	106.20	29.56
		High	97.50	16.73
		Total	101.23	23.21
	Total	Low	100.61	22.33
		High	101.84	24.21
		Total	101.23	23.21
During	Low	Low	100.67	17.06
		High	103.59	21.18
		Total	102.15	19.22
	Moderate/High	Low	110.80	27.56
		High	98.20	13.71
		Total	104.50	22.15
	Total	Low	102.33	19.26
		High	102.73	20.17
		Total	102.53	19.64

Table 17 (Continued)

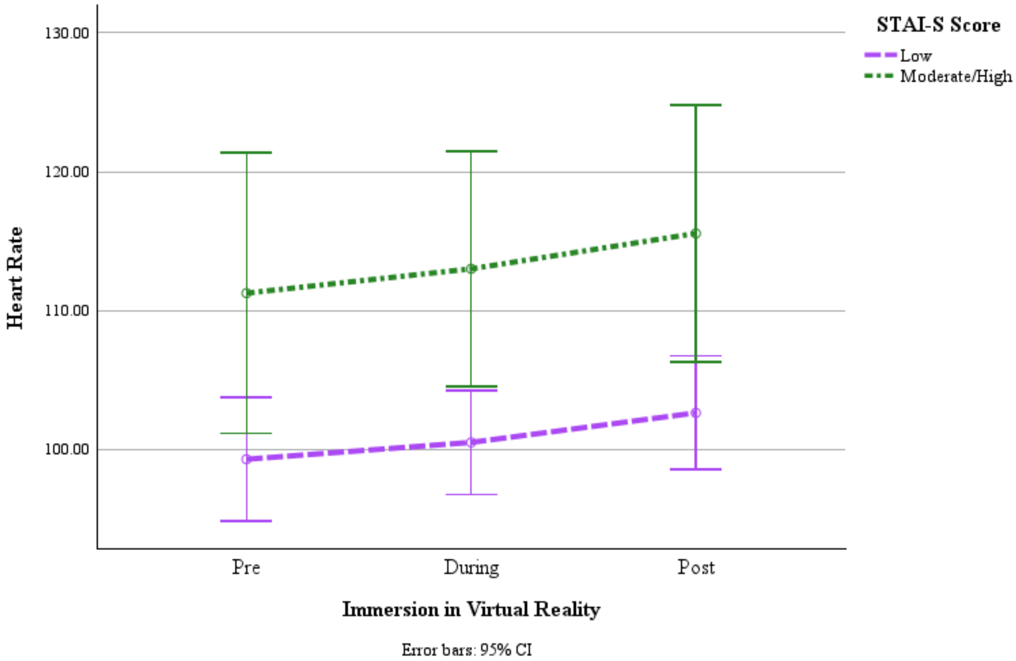
Means and Standard Deviations of Heart Rate Based on State Trait Anxiety Inventory - State (STAI-S) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	STAI-S Group	Motion Intensity	Mean	Standard Deviation
Post	Low	Low	101.59	18.46
		High	105.46	23.49
		Total	103.54	21.14
	Moderate/High	Low	118.10	25.67
		High	103.50	16.17
		Total	110.80	21.14
	Total	Low	104.30	20.51
		High	105.15	22.37
		Total	104.72	21.39

Figure 11 shows that the trends in heart rate are similar across STAI-S groups.

Figure 11

Trends in Heart Rate Based on State Trait Anxiety Inventory - State (STAI-S) Score



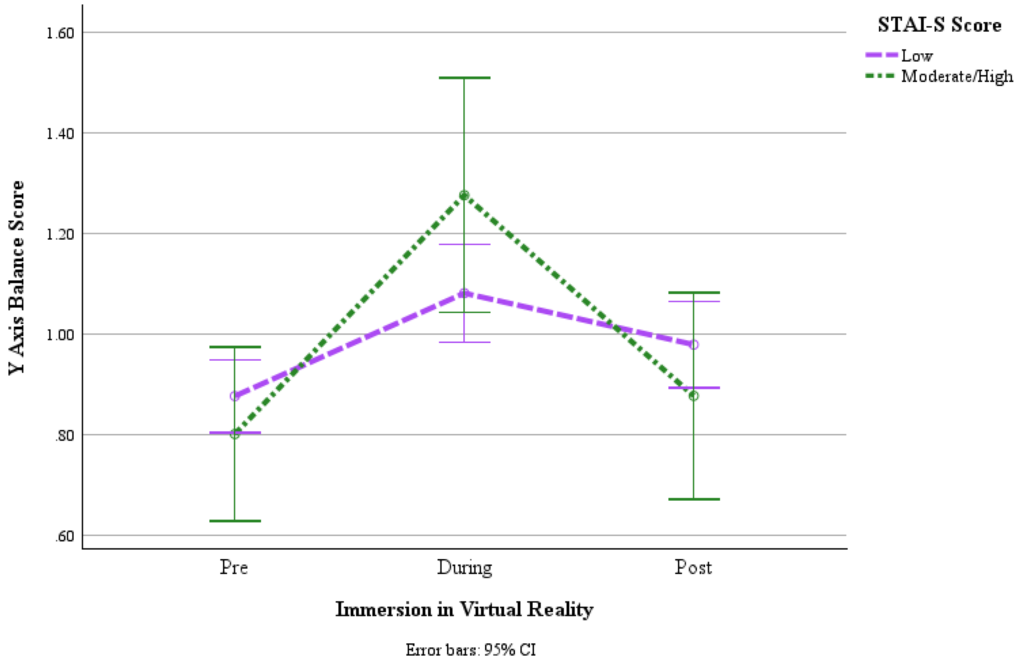
Four participants directly mentioned their heart rate may have been up at the time of the session because they had just come from working out or because a high heart rate was a normal for them. Another mentioned he felt his heart beat faster when the video first started because he did not expect to feel so immersed in the ocean. These comments highlight the possibility that changes in heart rate were affected by other factors not accounted for in the design of the study (Held et al., 2021).

I have already mentioned in the section detailing the results for research question two that STAI-S score did not impact balance on the X axis, but the trends in Y axis balance differed between STAI-S groups such that participants with a moderate/high STAI-S score returned to baseline balance after the video whereas participants with a low

STAI-S score did not. I refer the reader to the section on research question two for a full description of the analysis run, including means and standard deviations. However, the trends match insofar as balance declined during the videos and rose to some extent after the videos for both groups. Figure 12 presents the trend in Y axis balance in the form of a line graph. It can be seen that the trends are similar.

Figure 12

Trends in Y Axis Balance Based on State Trait Anxiety Inventory - State (STAI-S) Score



Trait Anxiety.

I ran a three-way mixed ANOVA including heart rate as the within-subject dependent variable, BAI score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. All the assumptions of the model were met. While trends in heart rate appear to vary based on BAI score such that the trend is quadradic for the moderate group and linear for the low group, the interaction between immersion and BAI score was statistically nonsignificant (*F*[2, 242] = .453, *p* = .636, ηp2 = .004). Table 18 presents the means and standard deviations of heart rate for each BAI group at each level of immersion.

Table 18

Means and Standard Deviations of Heart Rate Based on Beck Anxiety Inventory (BAI) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	BAI Group	Motion Intensity	Mean	Standard Deviation
Pre	Low	Low	99.87	22.79
		High	101.48	25.06
		Total	100.68	23.87
	Moderate	Low	107.33	17.76
		High	105.17	14.99
		Total	106.25	15.71
	Total	Low	100.61	22.33
		High	101.84	24.21
		Total	101.23	23.21

Table 18 (Continued)

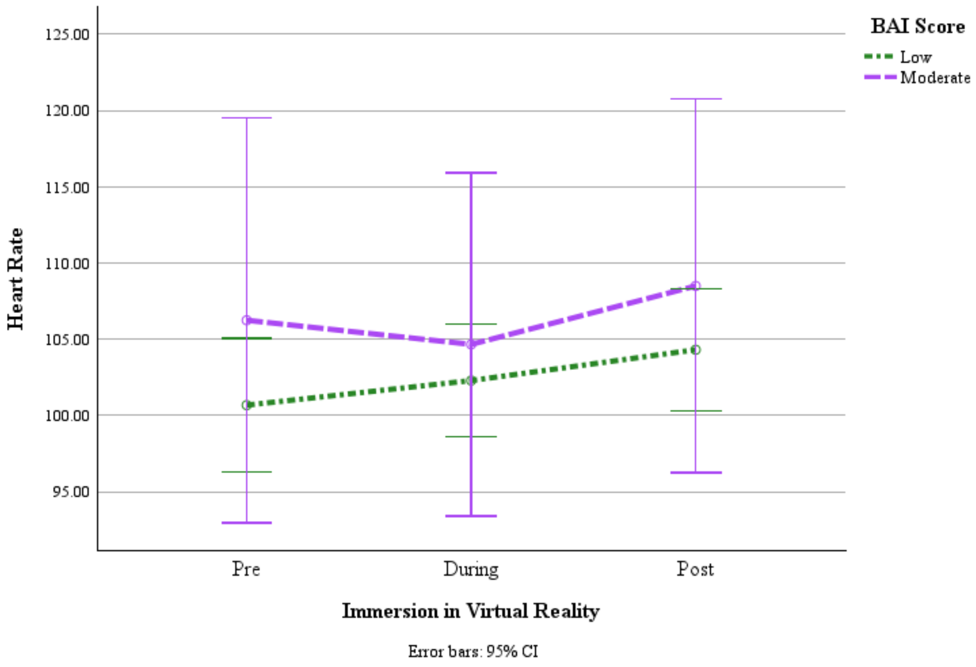
Means and Standard Deviations of Heart Rate Based on Beck Anxiety Inventory (BAI) Score and Motion Intensity Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	BAI Group	Motion Intensity	Mean	Standard Deviation
During	Low	Low	102.05	19.97
		High	102.54	20.92
		Total	102.30	20.37
	Moderate	Low	104.83	11.55
		High	104.50	12.01
		Total	104.67	11.24
	Total	Low	102.33	19.26
		High	102.73	20.17
		Total	102.53	19.64
Post	Low	Low	103.87	21.34
		High	104.75	23.13
		Total	104.32	22.17
	Moderate	Low	108.17	10.53
		High	108.83	14.20
		Total	108.50	11.93
	Total	Low	104.29	22.37
		High	105.15	22.37
		Total	104.72	21.39

Figure 13 presents the trend in heart rate based on BAI score as a line graph. The graph depicts similar trends for each group.

Figure 13

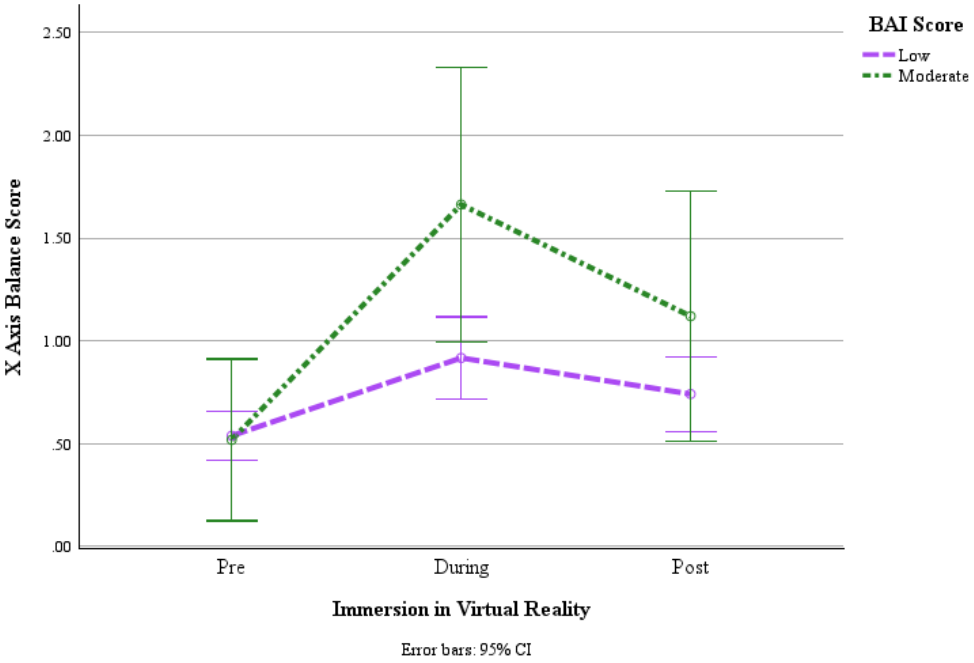
Trends in Heart Rate Based on Beck Anxiety Inventory (BAI) Score



I have already mentioned in the section detailing the results for research question two that no statistically significant relationship interaction between BAI score and balance on either axis. I refer the reader to the section on research question two for a full description of the analysis run, including means and standard deviations. While trends in X axis balance appear to vary based on BAI score such that the trend is quadradic for the moderate group and linear for the low group, the interaction between immersion and BAI score was statistically nonsignificant ($F[2, 234] = 2.626$, $p = .075$, $\eta p^2 = .022$). The trend remained quadratic for both groups. Figure 14 presents the trend in X axis balance based on BAI score as a line graph.

Figure 14

Trends in X Axis Balance Based on Beck Anxiety Inventory (BAI) Score



VR Sickness.

I ran a three-way mixed ANOVA including heart rate as the within-subject dependent variable, post-immersion CSQ score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. All the assumptions of the model were met. The interaction between immersion and CSQ score was statistically nonsignificant ($F[2, 246] = .091$, $p = .913$, ηp2 = .001). For both participants with low CSQ scores and participants with moderate and high CSQ scores, the trends show a linear progression for lower average heart rate before starting the VR activity to elevated heart rates during and after the VR activity. Table 19 presents the means and standard deviations of heart rate for each CSQ group at each level of immersion.

Table 19

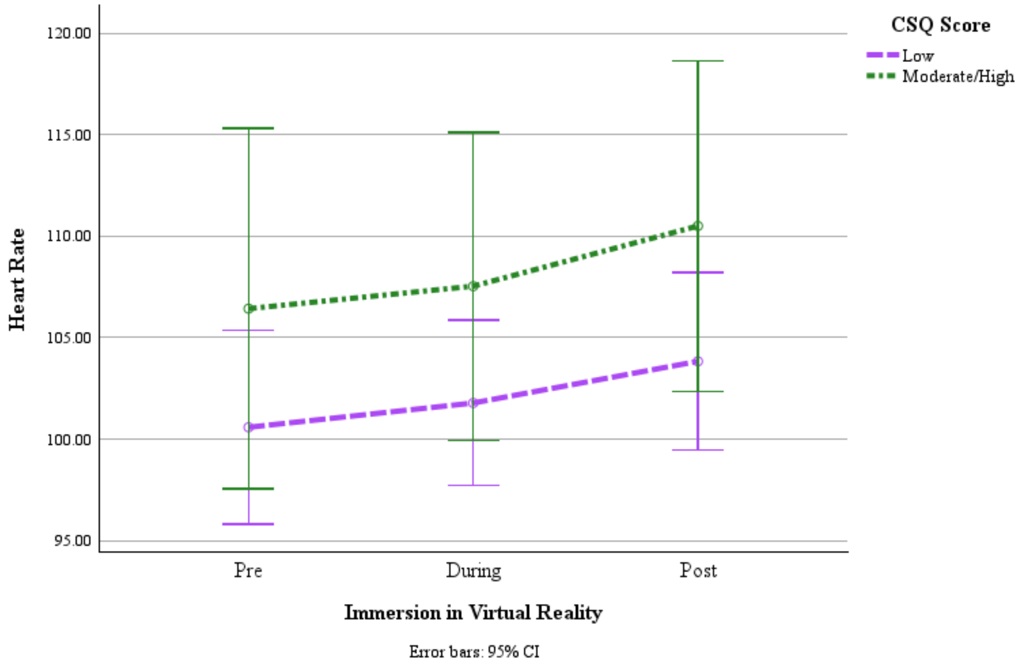
Means and Standard Deviations of Heart Rate Based on CyberSickness Questionaire (CSQ) Score Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	CSQ Group	Mean	Standard Deviation
Pre	Low	100.59	24.11
	Moderate/High	106.43	22.33
	Total	101.89	23.76
During	Low	101.78	20.15
	Moderate/High	107.54	20.70
	Total	103.07	20.34
Post	Low	103.84	21.55
	Moderate/High	110.50	22.38
	Total	105.33	21.83

Figure 15 depicts similar trends in heart rate in participants who had moderate/high VR sickness following immersion and those who had low motion sickness. The difference between the trends was nonsignificant.

Figure 15

Trends in Heart Rate Based on CyberSickness Questionnaire (CSQ) Score



I also ran a three-way mixed ANOVA including X axis balance as the within-subject dependent variable, post-immersion CSQ score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. All the assumptions of the model were met. The interaction between immersion and CSQ score was statistically nonsignificant (*F*[2, 240] = .049, *p* = .952, ηp2 = .000). For both participants with low CSQ scores and participants with moderate and high CSQ scores, the trends show that balance was high before the videos began, decreased during the videos, and increased after the videos ended but did not return to pre-video levels. Table 20 presents the means and standard deviations of X axis balance for each CSQ group at each level of immersion.

Table 20

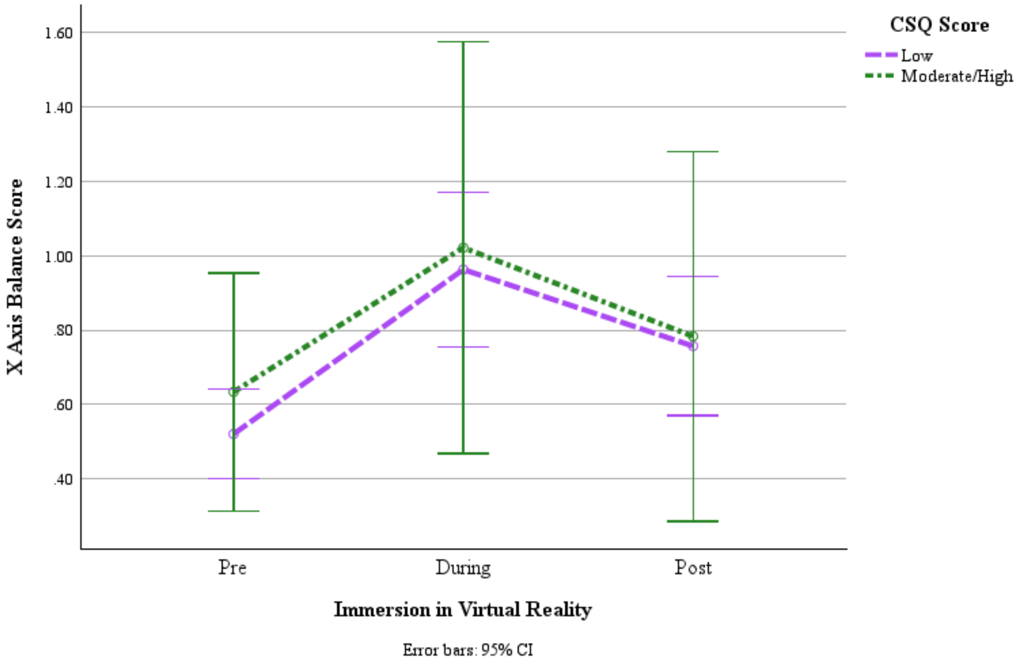
Means and Standard Deviations of X Axis Balance Based on CyberSickness Questionaire (CSQ) Score Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	CSQ Group	Mean	Standard Deviation
Pre	Low	0.52	0.64
	Moderate/High	0.63	0.48
	Total	0.53	0.63
During	Low	0.96	1.14
	Moderate/High	1.02	0.54
	Total	0.97	1.08
Post	Low	0.76	1.03
	Moderate/High	0.78	0.33
	Total	0.76	0.97

Figure 16 presents these results in the form of a line graph. It can clearly be seen that the trends are similar regardless of group.

Figure 16

Trends in X Axis Balance Based on CyberSickness Questionnaire (CSQ) Score



I also ran a three-way mixed ANOVA including Y axis balance as the within-subject dependent variable, post-immersion CSQ score as the between-subjects independent variable, and immersion and motion intensity as the within-subjects independent variables. All the assumptions of the model were met. The interaction between immersion and CSQ score was statistically significant (*F*[2, 240] = 3.575, *p* = .030, ηp2 = .029). Participants in the moderate and high group had lower balance (M = 1.43; SD = .647) during the videos compared to participants in the low group (M = 1.06; SD = .458), but not before or after the videos. The trend remained quadratic for both groups. Table 21 presents the means and standard deviations of Y axis balance for each CSQ group at each level of immersion.

Table 21

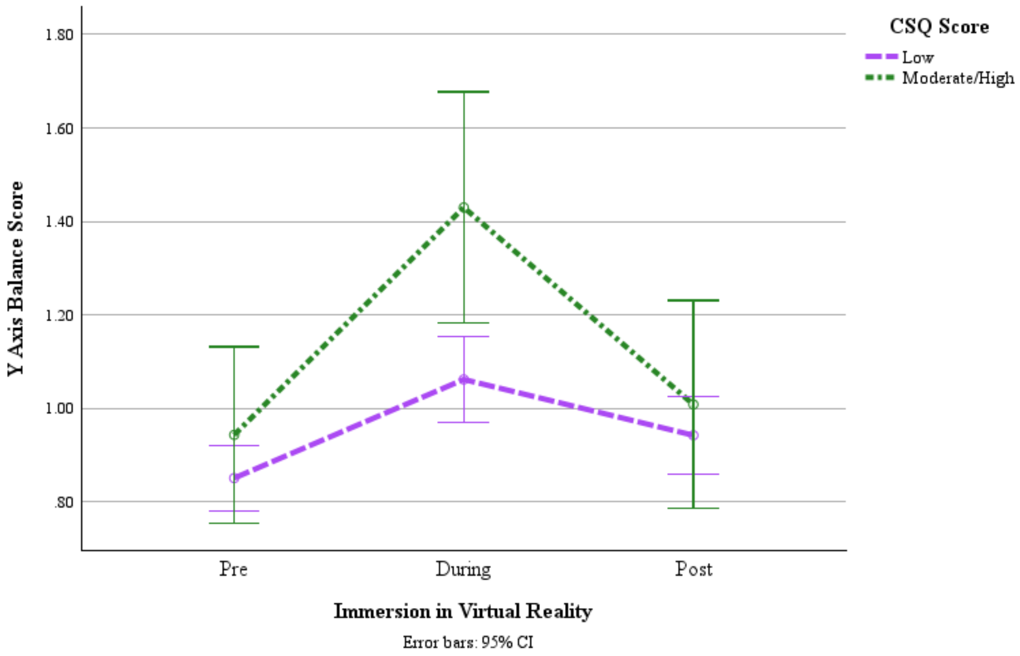
Means and Standard Deviations of Y Axis Balance Based on CyberSickness Questionaire (CSQ) Score Before, During, and After Virtual Reality (VR) Videos

Immersion in VR	CSQ Group	Mean	Standard Deviation
Pre	Low	0.85	0.36
	Moderate/High	0.94	0.45
	Total	0.86	0.37
During	Low	1.06	0.46
	Moderate/High	1.43	0.65
	Total	1.11	0.49
Post	Low	0.94	0.44
	Moderate/High	1.01	0.37
	Total	0.95	0.44

Figure 17 presents these results in the form of a line graph. The graph illustrates the interaction between CSQ and immersion. There is a difference between the moderate/high group and the low group during the videos but not before or after.

Figure 17

Trends in Y Axis Balance Based on CyberSickness Questionnaire (CSQ) Score



Summary of Results for Research Question Four.

Hypothesis four: Heart rate and balance will change as anxiety and VR sickness change.

Hypothesis four was not confirmed with regard to heart rate. Trends did not change based on VR sickness, trait anxiety, or state anxiety.

Hypothesis four was confirmed with regard to balance and state anxiety but not trait anxiety. Changes in STAI-S score did not affect trends in X axis balance, but the trend differed along the Y axis. Changes in BAI score did significantly impact trends in balance along either axis.

Hypothesis four was confirmed with regard to VR sickness and balance. Participants who achieved moderate or high CSQ scores had lower balance along the Y axis during the videos.

Research Question Five

How will participants' experience of VR sickness and anxiety while undergoing the VR activities affect their perception of future instructional VR implementation?

Fifty-two respondents (80%) had favorable reactions to VR, 11 respondents (17%) had mixed or neutral reactions, and two respondents (3%) had unfavorable reactions. Recurring positive remarks indicated participants found the VR activity cool (*n* = 33), immersive (*n* = 14), calming (*n* = 7), and fun (*n* = 6). Respondents also called the experience “different”, “interesting,” and “informative”. Sixteen respondents (25%) attributed their excitement about the activity to the newness of the experience. Twelve respondents (17%) connected their enjoyment to the ocean-themed content rather than to VR itself. Recurring negative remarks came from participants who found the immersive experience “weird” or “unsettling” (*n* = 3), considered the content to be of poor quality in some regard (*n* = 3), or felt themselves losing their balance during the session (*n* = 2). No participants who wore glasses expressed that they had a hard time wearing the helmet over their glasses, though a few mentioned they believed their glasses distorted the images they saw in VR.

Of the participants who were asked about their opinions on future educational VR implementation, 39 (64%) expressed favorable opinions, 17 (28%) expressed mixed or neutral opinions, and five (8%) expressed unfavorable opinions. These results roughly align with the distribution of reactions to the VR activity used in this study. Respondents who expressed favorable opinions said they believed using VR would provide more hands-on learning (*n* = 10), increase focus (*n* = 9), provide more helpful visuals (*n* = 7), increase motivation (*n* = 6), be more engaging (*n* = 6), and provide more practical experience (*n* = 4). Respondents who expressed unfavorable opinions cited physical side-effects such as eyestrain, headache, and nausea (*n* = 5), risk of negative transfer (*n* = 3), and distractions posed by overwhelming visuals (*n* = 2). Interestingly, the participant who briefly passed out during his session said he would still be excited to engage in VR activities as part of his education. He connected his discomfort to having to stand still for so long, a condition that would not apply to most instructional VR use cases.

Fifteen participants (23%) said the overwhelming visuals in the videos distracted from the narration to the point that they did not retain any information from either video; only five participants (8%) directly confirmed that sensory overload did not hinder their retention of the information. However, of the 15 who admitted to feeling distracted, six said they believed they could have focused more on the narration by applying slightly more effort if they had thought they would be quizzed on the videos after viewing.

Nine participants also expressed awareness that the suitability of VR depends on a number of variables such as the subject of the class, the length and type of VR content used, and the individual characteristics of the learner. Five participants argued that VR would best serve fields such as teaching and nursing where students would benefit from experiencing simulated scenarios before entering real practice, and three said they would like to see VR used as a supplement alongside more traditional methods. Another three who said they did not feel familiar enough with VR to have confidence about using it for a grade said they would feel more prepared if their instructor provided orientation before the activity. Participants who viewed the orientation video prepared for this study said it made them feel more prepared for the session and were able to operate the helmet without further guidance. Three participants who had negative experiences of VR during their session stressed a need for alternative options for completing any assignments that involve VR.

Summary of Results

Although 66% of participants reported VR sickness symptoms, 63 out of 65 participants were able to fully complete the session, and only one had to stop without receiving any exposure to the second video. Eyestrain and difficulty focusing emerged as the symptoms most likely to occur, but nausea and dizziness emerged as the symptoms that had the highest severity when they did occur. Responses from participants depicted anxiety’s relationship with VR sickness as reciprocal, and did not offer insight into which might more consistently cause the other. Reasons for heightened state anxiety among participants were fear of the unknown, overwhelming to-do lists, academic anxiety, and fear of failure. Some of those same triggers were also mentioned as causes of trait anxiety.

Participants scoring moderate and high on trait and state anxiety questionnaires were more likely to report VR sickness before immersion, but were not more likely to have low balance before immersion. Heart rate did not correlate with any measure of VR sickness. Scores on self-reports of VR sickness increased following immersion, and participants could point to moments in the videos that caused their symptoms, which indicates genuine VR sickness did occur and that not all CSQ symptoms reported were false positives. Aspects of the video that triggered symptoms were fast camera motions, abrupt transitions from dark scenes to bright scenes, and overly close perceived proximity to objects in the virtual environment.

Self-reports of state anxiety correlated with self-reports of VR sickness symptoms after immersion, but self-reports of trait anxiety did not. Trait anxiety did not impact balance. Lower state anxiety interfered with the return to balance along the Y axis after the videos; participants with moderate and high state anxiety returned to baseline. Heart rate did not correlate with balance in either direction or self-reports of VR sickness symptoms. Trends in heart rate also did not vary according to self-reports of state or trait anxiety. Self-reports of VR sickness correlated with decreased forward-and-backward balance during the videos.

Favorable reactions to the VR experience and the prospect of future instructional VR implementations outweighed neutral and negative reactions. Participants believed VR had potential to offer more hands-on learning that would keep them more focused and provide more helpful visual input compared to traditional teaching methods. However, feedback from participants also reinforced the need to use VR responsibly by providing orientation, choosing content that minimizes sensory overload, keeping VR assignments short and infrequent, and providing alternative completion methods for learners who feel unduly hindered by VR use. Participants also reinforced that VR is best used as a supplemental tool in fields where active performance of practical tasks plays a large role.

The results were not complicated by gender, ethnicity, prior technological experience, prior VR experience, motion sickness susceptibility, viewing order, or the intensity of motion in each video. No participants had undergone gender affirming care, and only two reported a gender identity that differed from their gender assigned at birth, so it was not possible to explore the effects of these potential confounding variables.

I discuss the implications of the results documented in this chapter for future research and practice in Chapter V.

CHAPTER V

DISCUSSION

Research Questions

Research Question One

Do anxious users experience symptoms similar to but distinct from VR sickness before entering VR?

The results of this study indicate that elevated state and trait anxiety as measured by self-report questionnaires do correlate with symptoms that mimic VR sickness as measured by self-report questionnaires pre-immersion. These results indicate that anxiety does deserve attention as a confounding variable when VR sickness is measured using self-report questionnaires, consistent with findings by Bouchard et al. (2021) and Quintana et al. (2014).

Neither form of anxiety correlated with changes in pre-immersion balance, indicating that the mechanism by which anxiety mimics VR sickness pre-immersion may not relate to balance or sway. This would appear to disagree with intravestibular imbalance theory (Previc, 2018), which provided the theoretical framework for this study’s assertion that anxiety and VR sickness could correlate. However, it may mean that examining postural balance can help distinguish the actual occurrence of VR sickness from false positives. Future research should examine other potential links between anxiety and common symptoms of VR sickness.

Heart rate also did not correlate with self-reports of VR sickness symptoms or changes in balance. This outcome may suggest that heart rate may not be as reliable a predictor of VR sickness pre-immersion as self-reports of anxiety. This outcome also concurs with findings by Gavgani et al. (2017) and Reyero-Lobo and Pérez (2022), who presented evidence against treating heart rate as a strong indicator of VR sickness. This seems counter-intuitive if heart rate is a reliable measure of anxiety (Dimitriev et al., 2016). However, Held et al. (2021) did note that studying heart rate directly following exposure to stressors has met with mixed results in the past. The possibility exists that other factors not accounted for in this study explain more of the variance in heart rate between participants than anxiety (Held et al., 2021). If so, future research aiming to apply heart rate as a measure of anxiety in the context of VR should account for confounding variables in a way this study did not.

Research Question Two

Does true VR sickness become more severe in the presence of anxiety?

Self-reports of trait anxiety did not correlate with self-reports of VR sickness post-immersion, but self-reports of state anxiety did. This outcome suggests state anxiety correlates with VR sickness *per se*, though trait anxiety may not. The indication that participants becoming more than usually anxious promotes VR sickness bolsters prior claims made by Bouchard et al. (2021), Ling et al. (2011), and Quintana et al. (2014).

Interestingly, low state anxiety seems to have reduced the ability to return to baseline balance post-immersion more than moderate or high state anxiety, much at odds with the findings of Goto et al. (2011), Krishna et al. (2014), and Ohno et al. (2004). Although this result may complicate the literature on the possibility of a link between anxiety and balance in the context of VR immersion, it does affirm the assertions of previous authors (Faugloire et al., 2007; Hainaut et al., 2011; Oh & Lee, 2021) that the possibility deserves attention from future research to clarify the relationship.

Changes in trait anxiety did not bring about significant changes in balance. Previous research suggested trait anxiety would have an impact but would have less of an effect that state anxiety (Faugloire et al., 2007; Hainaut et al., 2011; Stelling et al., 2021). Since pairwise comparisons appeared to show statistically significant changes even though the overall interaction between trait anxiety and immersions effects on balance was nonsignificant, it is possible that trait anxiety played a small role but did not have enough of an impact to affect the results, which would be more consistent with expectations based on existing literature.

Heart rate also did not correlate with self-reports of VR sickness symptoms or changes in balance. Comments made about this development under the discussion of research question one remain applicable here.

The design of this study did not make space for statistically analyzing the possibility that someone’s awareness of becoming VR sick could make them more anxious, potentially initiating a cycle in which each construct continually causes the other to increase in intensity. Nonetheless, data from post-intervention debriefings suggest a strong possibility VR sickness and anxiety promote each other roughly equally, similar to the reciprocity that characterizes anxiety’s relationship with balance (Krishna et al., 2014; Saman et al., 2012). Based on the results of this study, it is not possible to speak of anxiety more commonly *causing* VR sickness or vice-versa because the temporal order cannot be confidently placed; it is only possible to speak of an apparent correlation. Ergo, the study did not add new information to the existing literature in this regard.

Research Question Three

Does the level of motion in VR content affect the relationship between anxiety and VR sickness?

The results indicate that the two videos used in the study generated similar outcomes regardless of motion intensity and viewing order. This suggests the conclusions arrived at for research questions one, two, and four are applicable to a variety of VR videos and not confined to only videos with low motion intensity or high motion intensity. However, based on the work of Chang et al. (2020) and Jasper et al. (2020), I expected the high-motion video to provoke VR sickness more strongly than the low-motion video. Possibly the levels of motion in the videos chosen for this project (AirPano VR, 2022; Wildlife Conservation Society, 2021) did not differ greatly enough to have significant impact, in which case researchers studying this topic in the future should implement VR experiences with a greater level of variance between motion levels.

Research Question Four

How do anxiety and VR sickness affect balance and heart rate?

Neither anxiety or VR sickness appear to have affected trends in heart rate for the participants in this study. This outcome was more expected with regard to VR sickness (Gavgani et al., 2017; Reyero-Lobo & Pérez, 2022) than with regard to anxiety (Dimitriev et al., 2016; Gavgani et al., 2017). Again, confounding variables not adequately accounted for may have played a role (Held et al., 2021).

I have already referred to balance's relationship with state and trait anxiety and the implications of that relationship in the section discussing the results for research question two. Self-reports of VR sickness only correlated with decreased balance during the videos, when participants who reported higher VR sickness levels also exhibited decreased balance along the Y axis. This aligns with Widdowson et al.'s (2019) assertion that insufficient evident exists to claim that baseline postural control predicts VR sickness, as opposed to Arcioni et al.'s (2019) claim that postural instability does predict VR sickness. However, this finding does offer some support for Oh and Lee's (2021) finding that sway velocity and length may effectively capture one aspect of cybersickness during immersion.

It is interesting that VR sickness' relationship to balance appears more similar to trait anxiety's relationship to balance than state anxiety's, considering state anxiety correlated with VR sickness post-immersion when trait anxiety did not. Nonetheless, the similarity may prevent balance data from helping to distinguish anxiety's effects and the effects of VR sickness in instances where anxiety and VR sickness occur simultaneously.

Research Question Five

How will participants' experience of VR sickness and anxiety while undergoing the VR activities affect their perception of future instructional VR implementation?

Reactions from participants were consistent with conclusions of previous research summarized in the "Learner Perceptions" section of the literature review in Chapter II. Participants who noticed stronger side-effects from the VR content used in this study did generally express more apprehension about completing VR assignments in the future whereas participants who had unambiguously positive experiences showed only excitement, but the overall takeaway from participant feedback was that VR's usefulness depends on how instructors harness its potential. Some general guidelines are listed in the "Practical Significance" section below.

Practical Significance

Since 97% of participants successfully completed the session and 98% successfully finished viewing both videos, the risk of large numbers of students having difficulty completing VR learning activities or assessments would likely prove small, provided sound multimedia design principles (Clark & Mayer, 2014) are adhered to. Previous conversations between myself and an instructor who assigns VR activities in an undergraduate cellular biology course also support that prediction (Woolverton, 2022), as do descriptions of successful interventions by previous authors (Chi et al., 2021; Kane, 2021; Reyes and Fisher, 2022; Rowe et al., 2022).

In the context of VR, successful multimedia design would involve limiting sensory input to what is required for achieving the learning objectives (Kim & Ahn, 2021) and ensuring that any visual cues draw learners' attention to the material they need to comprehend and retain (Clark & Meyer, 2014). Ideal VR content minimizes the amount of visual motion for the sake of minimizing sensory conflict and the risk for certain aspects of VR sickness (Chang et al., 2020), and gives learners control over their movement in the environment provided they possess the expertise required and have sufficient guidance to make their exploration of the environment productive (Clark & Meyer, 2014). Virtual reality activities should also only be as long as required to achieve the learning objectives, which will vary depending on the course's field of study and the activity's learning objectives (Clark & Mayer, 2014; Meta Quest, 2024).

Instructors implementing VR should take note of students exhibiting signs of very high anxiety and remain mindful of the possibility that those students could have a harder time completing VR tasks than students with low anxiety. Occurrences of this issue will likely be infrequent enough to make implementing alternate completion methods feasible. Also, working to reduce anxiety in learners may help to reduce the likelihood of VR sickness. Methods for doing this within the purview of instructors include assessing the amount and difficulty of tasks given to learners, the amount of applied pressure to succeed in those tasks, and increasing the amount of scaffolding offered for learners within reasonable levels that still allow students to sufficiently grapple with course content to promote learning (Abrams, 2022; Zeidner, 2014).

Pre-implementation orientation familiarizing learners with VR and what they are expected to use it for facilitates learner success not only by making learners more effective VR users but also by reducing anxiety brought on by fear of the unknown and fear of failure (Howard & Lee, 2019; Kim & Ahn, 2021). The work of making VR implementation effective is worth it, especially for more practice-based fields such as nursing, for the sake of building engagement and providing more hands-on instruction (Adhikari et al., 2021). Learners are interested in seeing this instructional method implemented more widely and would willingly make the most of any opportunities granted them to learn through VR.

Threats to Validity

The sample size was small for the number of variables involved in this study. The sample was also homogenous in that the participants were all undergraduate university students under the age of 30 (with one outlier above the age of 30). The results may not be applicable to the wider population. Furthermore, individuals who know they are highly susceptible to motion sickness, highly anxious, disinterested in VR, or have hydrophobia may have chosen not to participate in the study. Responses given during the debriefing about the usefulness of VR for education may have been biased towards favorability if only users interested in VR took part. As with all qualitative data, the possibility of reviewer bias towards confirming hypotheses also posed a risk (Johnson & Christensen, 2020).

The number of participants who experienced high trait or state anxiety or high VR sickness is also very low. Future research should make stronger attempts to induce greater anxiety and VR sickness to see what trends emerge at higher levels of each construct. Based on the results of this study, I would expect that the effects described in this report would become more consistent and noticeable at higher levels of trait and state anxiety.

Since the VR experience occurred in a lab setting, and only involved viewing videos, the results may lack transferability to other contexts (such as in-class VR use) or other types of VR experience (such as VR gameplay). Future research could explore scenarios not covered by this study. Because VR sickness and anxiety share symptoms (Bouchard et al., 2021; Hamilton, 1959), misdiagnosis could easily have occurred. The list of confounding variables controlled for may also fail to cover all possibilities.

The total number of tasks and questionnaire items I asked participants to complete was high, which could have created fatigue and lead to participants rushing and misreporting their symptoms (Johnson & Christensen, 2020). On the BAI, some participants may also have reported symptoms that did not directly relate to anxiety. Out of 13 participants who reported exclusively or almost exclusively physiological symptoms on the BAI, only three were directly confirmed to have reported only symptoms that directly stemmed from anxiety; one was directly confirmed to have reported symptoms known to stem from factors other than anxiety.

On the CSQ, participants may have had different understandings of some symptoms. Of the participants who selected difficulty focusing as a symptom at any point, three confirmed they interpreted the symptom as referring to their ability to keep their vision focused on a single point. Six confirmed they interpreted the symptom as referring to mental concentration. One participant confirmed she accounted for both possible interpretations. Given that the SSQ, on which the CSQ is based, includes both difficulty focusing (ocular) and difficulty concentrating (mental) as symptoms (Kennedy et al., 1993), participants who based their difficulty focusing score on mental concentration did so incorrectly.

Additionally, 10 participants reported that some of the CSQ symptoms they selected were caused by factors outside the VR experience, such as sinus trouble, health problems, and focus on maintaining balance. Symptoms caused by those factors would constitute false positives in the context of VR sickness because they would have no connection to VR exposure. Other participants who mainly felt eyestrain and headaches said those symptoms arose from having the screen so close to their eyes (*n* = 3) or from the adjustment back to the normal lighting and vision of reality after removing the headset (*n* = 4). These could qualify as VR sickness because they arise from factors inherently tied to VR exposure.

Recommendations for Future Research

Researchers attempting to study the relationship between anxiety and VR sickness in the future should attempt to induce higher levels of each than were achieved in this study. Virtual reality content in particular should feature more extreme motion and perhaps go on for longer, and should feature less soothing visuals and music than did the videos used in this study. Based on the trends that resulted from this implementation, the relationship between anxiety and VR sickness is likely more apparent and consistent at higher levels. If heart rate is included in the analysis of any future studies, researchers should account for variables other than anxiety and VR sickness that may influence heart rate levels. Future research should also explore potential links between anxiety and common symptoms of VR sickness that do not relate to balance.

Although fulfilling the next recommendation would be highly ambitious, anxiety should be treated more fully than it has been by this study and other studies in the past. This study did not break anxiety down further than state and trait anxiety. If, as Roos et al. (2022) argue, anxiety has four components (cognitive, affective, motivational and physiological), and those components can have different outcomes as Brady et al. (2018) argue, it may turn out that only certain components of anxiety correlate with VR sickness. Accounting for this possibility is especially important if what creates the correlation between anxiety and VR sickness is the overlap in physiological symptoms between them

(Hamilton, 1959; Kennedy et al., 1993). Additionally, VR sickness is itself a multi-component construct, though different questionnaires have different names for these components and disagree on what symptoms each component includes (Ames et al., 2005; Bouchard et al., 2007; Kim et al., 2018; Stone III, 2017). Perhaps only certain components of anxiety correlate with certain components of VR sickness, and identifying these combinations could help identify the reasons for the correlation. It would be worthwhile to conduct tests using multiple anxiety and VR sickness questionnaires that emphasize different combinations of symptoms and components.

Other important aspects to examine are hypermobility and sensory sensitivity. Hypermobility refers to having an increased range of movement in some or all of a person's joints, which, in many members of the population, can cause adverse symptoms that make them more likely to report high VR sickness levels (National Health Service, 2024). Sensory sensitivity refers to how sensitive a person is to sensory input such as light, sound, and movement, and high sensitivity to such stimuli can greatly increase symptoms used to measure VR sickness (Fulvio et al., 2021). Both of these conditions could be confounding variables for VR sickness. In my personal experience outside of this dissertation, participants with very high sensitivity to more than one type of sensory input have difficulty remaining in VR for longer than a few moments at a time, while participants with more mild sensory sensitivity do better after taking some time to adjust to immersion. In the present study, a few participants mentioned that sensitivity to light caused eyestrain, which elevated their CSQ scores, but this was the only type of sensory sensitivity reported, and the issue did not prevent participants from completing both VR activities.

Future research should also pay more attention to gender affirming care as a potential complication of the relationship between VR sickness and gender (MacArthur et al., 2021), as research on that aspect of the problem is currently lacking and the present study proved unable to contribute any information. Additionally, studies should be conducted examining anxiety's correlation with VR sickness in the context of a variety of VR activities in a variety of contexts. Researchers should study the correlation in the context of both passive viewing of media and active gameplay. For education and training, it will be especially important to study the correlation using an in-class VR activity and as part of an implemented training program.

Conclusion

I focused this study on a potential connection between heightened anxiety and greater risk for adverse side-effects from immersion in virtual reality, known as VR sickness. The results show the effects of both state and trait anxiety can replicate the effects VR sickness outside of VR exposure, creating the risk of a false positive with regard to VR sickness if researchers do not account for anxiety's impact. However, genuine VR sickness symptoms (meaning symptoms directly attributable to VR) do also become more severe in the presence of heightened state anxiety. There is reason to suspect this correlation remains in place across levels of motion intensity in VR content and across the general population. The role of balance in this relationship deserves more attention.

My motivation for conducting this study was to promote improved implementation of more effective teaching strategies, to wit: instructional VR. Virtual reality has much to offer for education and training, and understanding potential side-effects and how to mitigate them allows instructional VR to reach its full potential. The link between VR sickness and anxiety will likely only become important for instructional VR in extreme circumstances. Nonetheless, instructors using VR should remain mindful of VR sickness as a possibility, and awareness of anxiety's role makes instructors that much more equipped to notice and address potential risk factors. Applied thusly, this research can help inform best practices and lead to smoother instructional VR use.

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APPENDICES

Appendix A: Demographic Questionnaire

Please answer each of the following questions.

1. What is your age?

2. What is your current gender identity? (Circle any that apply).
    - Cisgender female
    - Cisgender male
    - Transgender female
    - Transgender male
    - Intersex
    - Nonbinary
    - Gender fluid
    - Prefer not to say
    - Other (write in):

3. What is your gender assigned at birth? (Circle one).
    - Female
    - Male
    - Intersex
    - Prefer not to say

4. Have you undergone gender affirming care? (Circle all that apply).
    - Yes, hormone replacement therapy
    - Yes, surgical operation(s)
    - No
    - Prefer not to say
    - Other (write in)

5. What is your ethnicity? (Circle any that apply).
    - Native American
    - Hispanic/Latinx
    - Black
    - Middle Eastern
    - Asian
    - Pacific Islander
    - White

6. How would you rate your current level of technological experience? (Circle one).

   1. Not experienced at all
   2
   3
   4
   5. Highly experienced

7. How would you rate your current level of experience VR? (Circle one).

   1. Not experienced at all
   2
   3
   4
   5. Highly experienced

Appendix B: Motion Sickness Susceptibility Questionnaire (Short Form)

This questionnaire is designed to find out how susceptible to motion sickness you are, and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting.
Your Experience over the LAST 10 YEARS (approximately), for each of the following types of transport or entertainment please indicate:
Over the LAST 10 YEARS, how often you **Felt Sick or Nauseated** (tick boxes):

	Not Applicable - Never Travelled	**Never Felt Sick**	**Rarely Felt Sick**	**Sometimes Felt Sick**	**Frequently Felt Sick**
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					

Appendix C: CyberSickness Questionnaire (Modified)

Please circle how much each symptom below is affecting you right now.

	0	1	2	3
Dizziness				
1. Headache	None	Mild	Moderate	Severe
2. Nausea	None	Mild	Moderate	Severe
3. Dizziness with eyes open	None	Mild	Moderate	Severe
4. Dizziness with eyes closed	None	Mild	Moderate	Severe
5. Vertigo	None	Mild	Moderate	Severe
Difficulty Focusing				
6. Eyestrain	None	Mild	Moderate	Severe
7. Difficulty focusing	None	Mild	Moderate	Severe
8. Fullness of head	None	Mild	Moderate	Severe
9. Blurred vision	None	Mild	Moderate	Severe

A = Sum of questions 1-5: __________

C = A/15 x 100: __________

B = Sum of questions 6-9: __________

D = B/12 x 100: __________

Total Score = (C + D)/ 2: __________

Appendix D: Beck Anxiety Inventory

Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by checking the corresponding space in the columns next to each symptom.

	Not At All	**Mildly but it didn't bother me much**	**Moderately - it wasn't pleasant at times**	**Severely – it bothered me a lot**
Numbness or tingling				
Feeling hot				
Wobbliness in legs				
Unable to relax				
Fear of worst happening				
Dizzy or lightheaded				
Heart pounding/racing				
Unsteady				
Terrified or afraid				
Nervous				
Feeling of choking				
Hands trembling				
Shaky / unsteady				
Fear of losing control				
Difficulty in breathing				
Fear of dying				
Scared				
Indigestion				
Faint / lightheaded				
Face flushed				
Hot/cold sweats				

Appendix E: State Trait Anxiety Inventory (State Portion)

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the number at the end of the statement that indicates HOW YOU FEEL RIGHT NOW. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best. Thank you.

	Not at all	Somewhat	Moderately	Very Much
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I feel tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel uncomfortable	1	2	3	4
11. I feel self confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I feel jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I feel relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

Appendix F: Observation Protocol

Participant:

Viewing order:

Notes on participant’s anxiety
Notes on participant’s VR sickness
Other Notes

Appendix G: Debriefing Protocol

This is a semi-structured protocol insofar as it includes prewritten questions intended to be asked of most participants, but also assumes that some responses will provoke unique follow-up questions about each participant's experience.

Do you mind if I ask you a few questions and record your responses?

Firstly, do you have any questions for me?

What did you think of the VR experience?

Considering the VR experience you just had, how would you feel if one of your teachers mentioned using VR for class in the future?

If they indicate motion sickness. You indicated you felt VR sickness during the simulation. When did you start to feel sick?

- What do you think made you feel sick?
  - *Base follow-up questions on their responses. Investigate anything that suggests they were sick because of something outside the simulation.*
- Were you already feeling sick before the simulation?
  - *If yes*, do you normally experience those symptoms when you feel anxious?
  - *If no*,did you notice that any parts of the video made you feel sicker?

You indicated that you felt anxious before, during, or after (delete as applicable) the simulation. Can you tell me what you felt anxious about?

- How regularly do you feel anxious about that?

Does feeling anxious usually also make you feel sick?

Did your anxiety increase or decrease during the simulation?

- When?
- Why?

Depending on whether their anxiety fluctuated during the sim, did you notice that your motion sickness increased or decreased when you felt more anxious compared to when you felt more relaxed?

- OR did feeling motion sick also make you feel more anxious?
- Do you think you'd become less likely to feel VR sick as you gained more experience with VR?

Appendix H: Overlap in Items on Anxiety and VR Sickness Scales

Table 22

Overlap in Items on Anxiety and Virtual Reality Sickness Scales

	SSQ	VRSympQ	VRSickQ	CSQ	HARS	BAI
General discomfort	x	x	x		x	
Fatigue	x	x	x		x	
Headache	x	x	x	x	x	
Eyestrain	x	x	x	x		
Difficulty focusing	x	x	x	x	x	
Fullness of head	x		x	x		
Blurred vision	x	x	x	x	x	
Vertigo	x		x	x		
Dizziness (eyes closed)	x		x	x		
Dizziness (eyes open)	x			x		
Dizziness (general)		x				x
Increased salivation	x					
Sweating	x				x	x
Nausea	x	x		x	x	
Difficulty concentrating	x	x				
Stomach awareness	x					
Burping	x					
Boredom		x				
Drowsiness		x				
Tired eyes		x				
Sore/aching eyes		x				
Numbness or tingling						x
Feeling hot						x
Wobbliness in legs						x
Heart pounding or racing						x
Unsteady						x

Table 22 (Continued)

Overlap in Items on Anxiety and Virtual Reality Sickness Scales

	SSQ	VRSympQ	VRSickQ	CSQ	HARS	BAI
Hands trembling						x
Shaky/unsteady						x
Scared						x
Faint						x
Face flushed						x
Unable to relax						x
Fear of the worst happening						x
Terrified						x
Nervous						x
Feelings of choking						x
Fear of losing control						x
Difficulty breathing						x
Fear of dying						x
Indigestion or abdominal discomfort						x

Appendix I: Informed Consent Form

Informed Consent: Social, Behavioral and Educational Research

Title of Project: Exploring the Relationship Between Anxiety and VR Sickness

Principal Investigator: David Wesley Woolverton, dww1721@jagmail.southalabama.edu, 251-463-3501

Advisor: Dr. James Van Haneghan, jvanhane@southalabama.edu

Purpose: This study's goal is to support instructional use of virtual reality (VR) by helping identify best practices.

Procedures: You will be asked to schedule one 60–90-minute lab visit to view two immersive 360 YouTube videos about coral reefs on an Oculus VR helmet, with a short break in between. While viewing each video, you will be asked to stand on a small platform that uses sensors to measure your balance. You will also be asked to wear small sensors on your wrist and ankles that measure your heart rate. You will be standing throughout both videos, but otherwise will not engage in physical activity. Before and after each video, you will be asked to complete a few short questionnaires about your background and comfort levels. At the end of your session, you will be asked to participate in a short, optional interview about your experience.

Risks:

Multiple people will use the same headset and controllers. All equipment will be thoroughly cleaned between sessions. *If you are sick on the day of your scheduled session, please reschedule or withdraw from the study.*

Users with epilepsy or who have a history of seizures should not participate in this study because the monitors are so close to the eyes and sometimes flash.

Users prone to dissociation (being unable to tell the difference between reality and fiction) or who have been advised by a medical/psychiatric professional that may experience dissociation *should not participate in this study.*

If you are pregnant or elderly, it is not recommended for you to participate in VR activities.

Symptoms similar to motion sickness, referred to as VR sickness, may occur for some users. Symptoms you may experience include: headache, eyestrain, fullness of the head, blurred vision, vertigo, dizziness, and nausea. *If you become uncomfortable while viewing either video, you are encouraged to stop the video, remove the VR helmet, and let the researchers know.* You will be given time to rest until you feel better before completing post-simulation questionnaires, and will not be asked to continue the VR activity unless you want to.

In case you lose balance while wearing the VR helmet, a small table or other support surface will be available for you to lean on.

The VR used in this study makes it appear as if you are underwater, which *could trigger hydrophobia. If you become uncomfortable during your session, you are encouraged to stop the video, remove the headset, and let the researchers know.*

Potential Benefits: You may not directly benefit from your participation, but the information gained by doing this research may help other students in the future by improving the implementation of more effective teaching strategies.

Confidentiality: Your name and email address are the only identifying data collected at any stage of the project. Your name and email address will only be used to schedule your lab visits, and will be deleted from all records related to this study as soon as the researchers no longer have a reason to contact you. You will be assigned a unique participant identification number that will replace your name on all data records. All data will be stored in a locked desk drawer in a locked office in the College of Education or on Google Drive, which is part of the University of South Alabama's (USA) secure network, on folders only accessible by the Principal Investigator (a doctoral student at USA) and two USA professors assisting with data analysis. All records will be destroyed after the study ends around April 15th, 2024. No identifying information will be published or shared with anyone other than the researchers.

Costs: The only cost associated with participation in this study is the time commitment.

Incentive: The Principal Investigator will work with the instructor who reached out to you about participating in this study to make participation one extra credit opportunity among others in that instructor's course. The amount of extra credit given will be at the instructor's discretion.

Voluntary Participation: Your participation in this research study is completely voluntary. You do not have to participate. You may quit at any time without any penalties, and will still get course credit if you withdraw without completing the session.

Audio / Video Taping: Audio/video taping will only happen during the post-intervention interview. No audio/taping will happen while you are in VR.

Contacts and Questions: For questions about your rights as a research participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Institutional Review Board at 251-460-6308 or email irb@southalabama.edu

By signing below, you state that:

You have read, or have had read to you, and understand the purpose and procedures of this research.

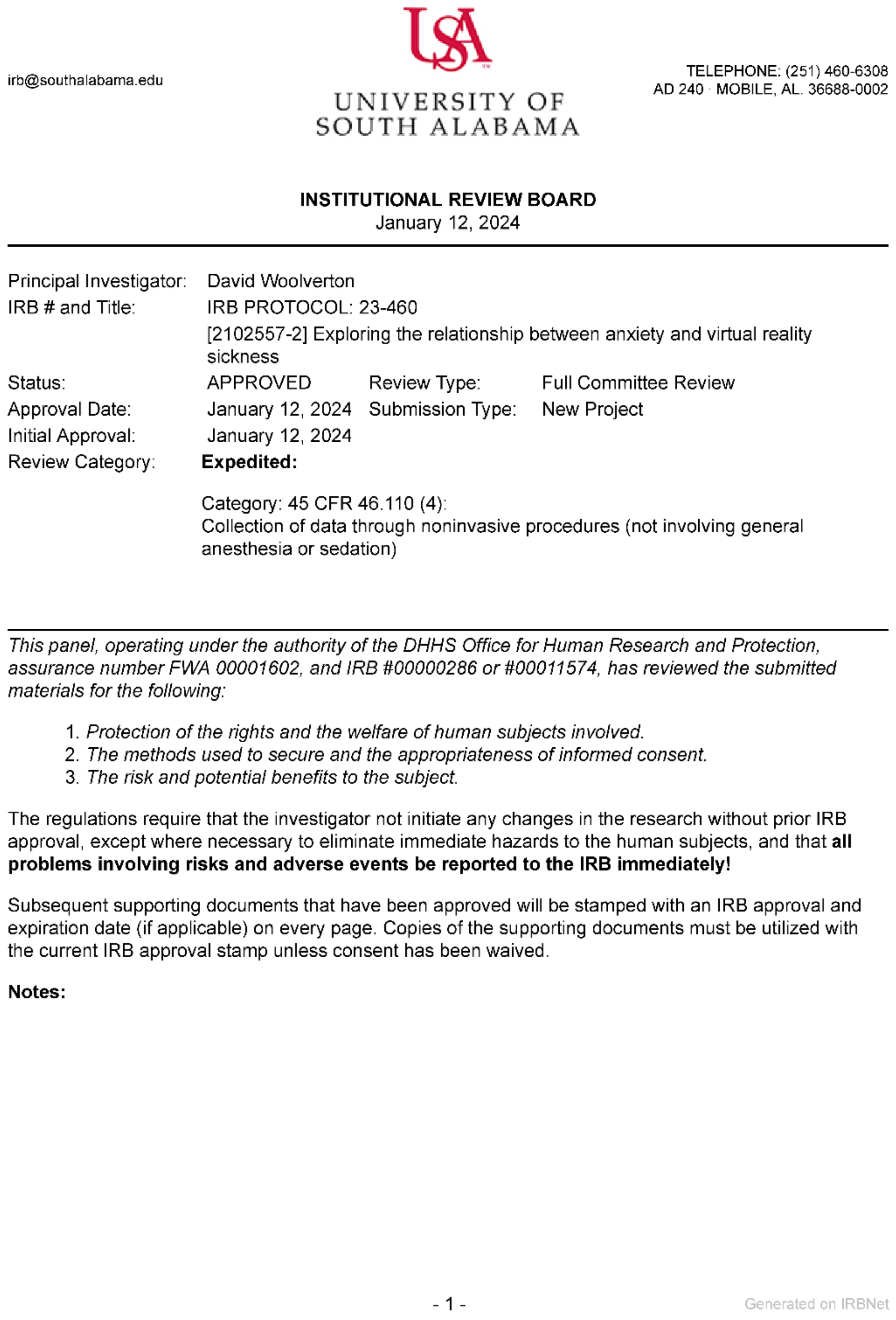
You have had an opportunity to ask questions which have been answered to your satisfaction.

You voluntarily agree to participate in this research as described.
You do not experience dissociative episodes or symptoms of epilepsy or another neurological disorder, are not pregnant, and are not above the age of 30.
You agree to inform the investigator at the session if you prefer not to have your post-session interview audio recorded. Notes about your responses will be handwritten.

Participant Name (printed)/ Signature of Participant Date

Signature of Person Obtaining Informed Consent Date

Appendix J: Institutional Review Board Approval



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INSTITUTIONAL REVIEW BOARD
January 12, 2024

Principal Investigator:	David Woolverton		
IRB # and Title:	IRB PROTOCOL: 23-460 [2102557-2] Exploring the relationship between anxiety and virtual reality sickness		
Status:	APPROVED	Review Type:	Full Committee Review
Approval Date:	January 12, 2024	Submission Type:	New Project
Initial Approval:	January 12, 2024		
Review Category:	**Expedited:** Category: 45 CFR 46.110 (4): Collection of data through noninvasive procedures (not involving general anesthesia or sedation)		

This panel, operating under the authority of the DHHS Office for Human Research and Protection, assurance number FWA 00001602, and IRB #00000286 or #00011574, has reviewed the submitted materials for the following:

1. *Protection of the rights and the welfare of human subjects involved.*
2. *The methods used to secure and the appropriateness of informed consent.*
3. *The risk and potential benefits to the subject.*

The regulations require that the investigator not initiate any changes in the research without prior IRB approval, except where necessary to eliminate immediate hazards to the human subjects, and that **all problems involving risks and adverse events be reported to the IRB immediately!**

Subsequent supporting documents that have been approved will be stamped with an IRB approval and expiration date (if applicable) on every page. Copies of the supporting documents must be utilized with the current IRB approval stamp unless consent has been waived.

Notes:

Appendix K: Regression Coefficients Table Showing Confounding Variables' Ability to Predict Virtual Reality Sickness from Low-Motion Immersive Video

Table 23

Regression Coefficients Table Showing Confounding Variables' Ability to Predict Virtual Reality Sickness from Low-Motion Immersive Video

	Unstandardized Coefficients		Standardized Coefficients		
Model	Unstandardized B	Standard Error	Beta	t	Significance
Constant	-.81	11.61		-.07	.95
Viewing Order	1.25	2.33	.07	.536	.59
Age	.05	.26	.03	.20	.85
Gender	-2.51	2.73	-.14	-.92	.36
Ethnicity	.76	.67	.153	1.13	.26
Technological Experience	-1.11	1.80	-.10	-.62	.54
Prior Virtual Reality Experience	2.20	1.27	.287	1.73	.09
Motion Sickness Susceptibility	-1.04	3.67	-.04	-.28	.78
Trait Anxiety	2.24	3.91	.08	.57	.57
State Anxiety	3.67	3.17	.16	1.16	.25

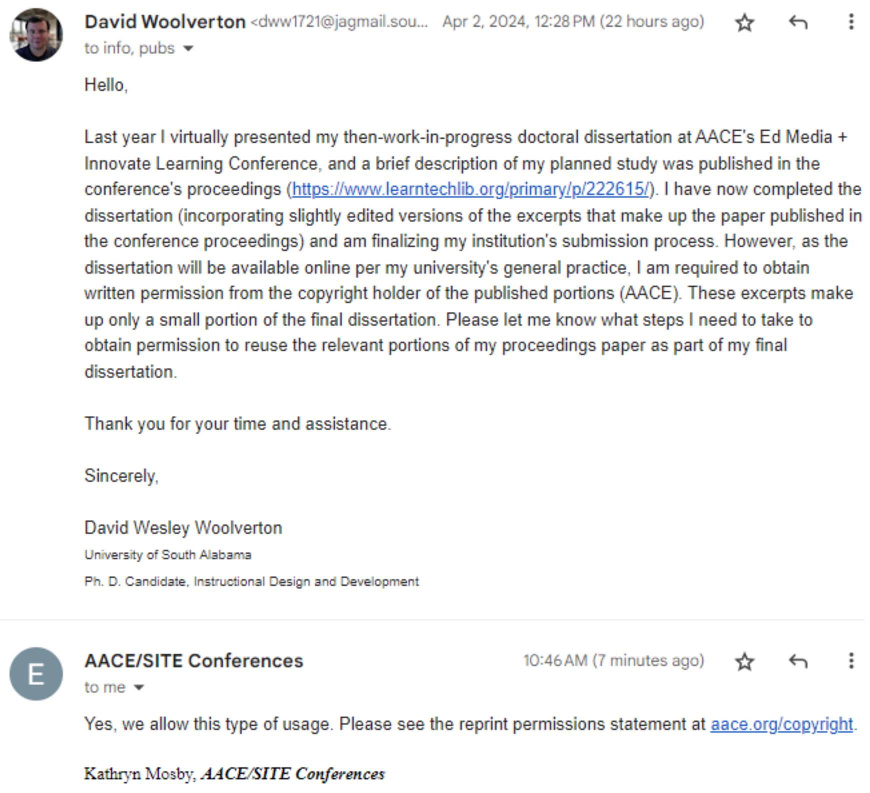
Appendix L: Regression Coefficients Table Showing Confounding Variables' Ability to Predict Virtual Reality Sickness from High-Motion Immersive Video

Table 24

Regression Coefficients Table Showing Confounding Variables' Ability to Predict Virtual Reality Sickness from High-Motion Immersive Video

	Unstandardized Coefficients		Standardized Coefficients		
Model	Unstandardized B	Standard Error	Beta	t	Significance
Constant	3.95	7.84		.50	.62
Viewing Order	-1.78	1.88	-.13	-.95	.35
Age	.02	.21	.01	.10	.92
Gender	-2.45	2.28	-.16	-1.08	.27
Ethnicity	.05	.53	.01	.10	.92
Technological Experience	-1.10	1.43	-.12	-.77	.44
Prior Virtual Reality Experience	1.15	.98	.18	1.181	.24
Motion Sickness Susceptibility	2.46	3.07	.11	.80	.43
Trait Anxiety	.65	1.53	.06	.43	.67
State Anxiety	4.80	2.66	.25	1.81	.08

Appendix M: Screenshot of Emails Providing Permission to Reprint Previously Published Portions of this Dissertation



David Woolverton <dww1721@jagmail.sou... Apr 2, 2024, 12:28 PM (22 hours ago)

to info, pubs

Hello,

Last year I virtually presented my then-work-in-progress doctoral dissertation at AACE's Ed Media + Innovate Learning Conference, and a brief description of my planned study was published in the conference's proceedings (https://www.learntechlib.org/primary/p/222615/). I have now completed the dissertation (incorporating slightly edited versions of the excerpts that make up the paper published in the conference proceedings) and am finalizing my institution's submission process. However, as the dissertation will be available online per my university's general practice, I am required to obtain written permission from the copyright holder of the published portions (AACE). These excerpts make up only a small portion of the final dissertation. Please let me know what steps I need to take to obtain permission to reuse the relevant portions of my proceedings paper as part of my final dissertation.

Thank you for your time and assistance.

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University of South Alabama
Ph. D. Candidate, Instructional Design and Development

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Awards and Honors:

Dr. Chandru Hiremath Memorial IDD Ph. D. Student of the Year, 2024, University of South Alabama
Stokes Center Graduate Creative Nonfiction Award, 2019, University of South Alabama
English Department Endowed Graduate Essay Award, 2018, University of South Alabama
Ignacio Ellacuria, S. J. Award, 2017, Spring Hill College
President’s Scholar in Writing, 2017, Spring Hill College

Publications:

Woolverton, D. W. (2023). Exploring the correlation between anxiety and virtual reality sickness. In: T. Bastiaens (Ed.). *Proceedings of EdMedia + Innovate Learning*. Association for the Advancement of Computing in Education. https://www.learntechlib.org/primary/p/222615/
Woolverton, D. (2019). Memento mori. *Oracle Fine Arts Review*, *27*(1), 96.
Woolverton, D. (2019). The wandering star. *Oracle Fine Arts Review*, *27*(1), 56.
Nolan, B., Patterson, A., & Woolverton, D. W. (Eds.). (2019). *The Mobile canon*. Stokes Center for Creative Writing.