ADVANCING DISASTER PREPAREDNESS: THE ROLE OF VIRTUAL REALITY AND PSYCHOLOGICAL OWNERSHIP IN RISK COMMUNICATION

by

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(Under the Direction of Sun Joo (Grace) Ahn)

ABSTRACT

High-risk, low-frequency events like hurricanes and storm surges often feel intangible to individuals, leading to optimism bias. Survivors frequently report feelings of grief after losing possessions to natural disasters. Although such experiences can increase attachment to belongings and a desire to protect them in the future, many people struggle to fully comprehend the true risk of storm surges without firsthand experience. Research shows that virtual reality (VR) technology can make these risks more tangible by immersing users in realistic simulations of disasters and the aftermath, such as hurricanes and storm surge events. It also allows users to actively practice risk prevention strategies, helping them prepare for future disasters. VR features enable users to customize a virtual space to their personal taste, tailoring the experience to each individual. This interaction with virtual objects can foster psychological ownership over the space, potentially simulating the emotional impact of losing personal possessions and prompting responses similar to those of natural disaster survivors. Building on prior research, this dissertation examines how allowing users to customize a virtual coastal home cultivates psychological ownership, and how that ownership influences their psychophysiological processing of storm surge risk, emotional responses, risk and efficacy perceptions, and behavioral intentions. Guided by foundational risk communication frameworks, this work illustrates the potential of VR to enhance storm surge risk communication by providing users with a safe, customized, and immersive experience.

INDEX WORDS: Virtual Reality, Psychological Ownership, Risk Communication Cognitive Processing, Disaster management

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DEDICATION

This dissertation is first and foremost dedicated to my best friends, Dr. Ronnie Fulton and Dr. Barley Bean. The strength I drew from their companionship and love sustained me through every challenge and made even the hardest days a little easier. I'd also like to dedicate this work to the two greatest surprises in my life, my extraordinary siblings Isabella and Tanner. Your presence in my life has brought me unmeasured joy and invaluable perspective. I cannot wait to watch you both soar.

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TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Effective risk communication is a crucial step in ensuring public safety. Communication efforts must convey clear information about potential risks to reduce public uncertainty and equip individuals with the knowledge needed to protect themselves and their property. When a natural disaster occurs, individuals often have limited time to respond, as timely action is crucial to ensure their safety. Federal agencies such as the National Oceanic and Atmospheric Administration (NOAA) and the Federal Emergency Management Agency (FEMA) have dedicated substantial resources to ensure that coastal communities understand how to stay safe during hurricane season, including a hurricane preparedness tour that visited six coastal cities along the East Coast ahead of the 2024 hurricane season (NOAA, 2025). Despite these persistent efforts to inform and prepare at-risk communities, many individuals remain disengaged or desensitized, resulting in inadequate preparation in the face of approaching storms (Cole & Fellows, 2008).

This desensitization, combined with the infrequent yet high-risk nature of natural disasters, leads individuals to perceive these threats as intangible and distant, causing them to underestimate both the *severity* of the risk and their own *susceptibility* to it (Lee & Lee, 2018; Meyer, 2006; Witte, 1992). When risk is not made salient and risk perceptions are diminished, individuals are significantly less likely to attune to vital safety information or engage in *risk prevention strategies* to protect their lives and property (Griffin et al., 1999; 2013; Witte, 1996). Communicating these risks pose significant challenges for emergency managers and communication practitioners, as they must find new strategies to effectively communicate the risks of hurricanes and storm surges.

Storm surges are rapid, abnormal rises in sea level caused by hurricanes, often leading to catastrophic flooding in both coastal and inland areas. These surges are formed as the swirling winds push water from the ocean toward the shore where they combine with normal tides and can increase the water level by up to 30 feet (NOAA, n.d.). Once they reach land, these storm surges can travel for over 20 miles, flooding everything in their path (National Hurricane Center, n.d.). Vulnerability to storm surges, as well as their frequency and intensity, have increased dramatically over the past few decades due to urbanization and population growth in coastal regions worldwide (World Health Organization [WHO], 2025)

Emerging research highlights the potential of virtual reality (VR) to be a powerful tool for enhancing awareness of severe weather risks (Frank et al., 2025; Mol et al., 2022). Immersive mediated environments via VR provide users with an experience rich in sensorimotor cues to replicate the threats posed by natural disasters, enabling users to learn about related risks and mitigations through simulated experiences without the dangers of real-world exposure. These VR experiences have increased risk perceptions, heightened emotional engagement, and ultimately motivated users to adopt precautionary behaviors (Ahn, 2015; Ahn et al., 2022; Frank et al., 2025; J. Lee et al., 2023). In the context of storm surge preparedness, VR enables users to visualize and rehearse mitigation strategies, enhancing their sense of self-efficacy and facilitating real-world behavioral change (Frank et al., 2028; Plechatá et al., 2022; Wienrich et al., 2021)

Additionally, integrating customizable elements into VR environments may further enhance user engagement and preparedness by fostering a sense of *psychological ownership* over the virtual space (Frank et al., 2025; Y. Lee & and Chen, 2011; Mol et al., 2022). Eliciting feelings of ownership over the virtual space could help address the concerns of coastal leaders that the virtual storm surge simulation may not be impactful to users if it is not contextualized to their community (Frank et al., 2025). These leaders worried that even if the VR experience was immersive and accurately simulated a catastrophic storm surge flood, users may still perceive a disconnect between their property and the virtual home depicted in the experience. This disconnect could potentially weaken the desired effects that the VR experience may have on users' risk perceptions and mitigation intentions (Evans et al., 2024; Raja & Carrico, 2021). As it is difficult to develop a VR experience that is reflective to each user's community, the ability to personalize and control features within the virtual environment, such as customizing the decor and furniture in a virtual home, can lead users to develop psychological ownership over the virtual space, deepening their emotional attachment and enhancing the perceived relevance of the risks presented (Lyman & Scott, 2009; Shu & Peck, 2011). Importantly, enhancing personal relevance is an effective way to increase users' risk perceptions and motivate them to engage in protective behaviors (Griffin et al., 1999; 2013; Witte, 1996). Further, feelings of ownership have been shown to prompt individuals to be more attentive to risk communication messages and to engage in risk prevention behaviors to protect their possessions from future hazards (Freedy et al., 1992; Koles & Nagy, 2021).

The present study explores how VR can serve as an effective tool to communicate the risks of storm surges by leveraging its unique capabilities to immerse users in a highly realistic, personalized storm surge scenario that allows them to gain near first-hand experience of a catastrophic storm surge flood, as well as the opportunity to practice implementing FEMA recommended risk prevention tactics in a controlled environment. To do so, this study integrates two theoretical frameworks, the Extended Parallel Process Model (Witte, 1992) and the Risk Information Seeking and Processing model (Griffin et al., 1999; 2013), to investigate how allowing users to interactively customize their virtual home ahead of a virtual storm surge may influence their reported *negative affect* after virtual the home is destroyed, as well as users' storm surge *risk perceptions* and *risk prevention intentions*. Additionally, the how certain psychological mechanisms such as psychological ownership, *spatial presence*—the feeling of being there in VR instead of the physical environment (Wirth et al., 2007)— *perceived self-efficacy*, shape users' emotional response and behavioral intentions are examined.

Finally, the study considers psychophysiological responses related to *cognitive resource allocation* and physiological *arousal* that occur as users process the VR-based risk information. These measures allow for a real-time examination of user responses, providing insights into the underlying mechanisms that occur as users are processing the VR experience (Potter & Bolls, 2012). Coupling user's physiological and self-report responses enables this study to provide a more nuanced understanding of how users cognitively and emotionally process the virtual storm surge experience.

The present study aims to fill a gap in the literature by offering a systematic and methodologically rigorous investigation into the influence of virtual psychological ownership in a risk communication context. By grounding this experiment in risk communication theory, findings can provide insights into how cultivating virtual psychological ownership may influence the information processing pathways outlined in the Extended Parallel Process Model (Witte, 1992) and the Risk Information Seeking and Processing model (Griffin et al., 1999; 2013). Moreover, the use of psychophysiological measures can provide further insights into these processing pathways by exploring the underlying mechanisms that occur in real time as users process the VR experience. Additionally, this study can offer guidance to VR developers and emergency managers on the best practices for developing and implementing VR technology in public risk communication and disaster preparedness efforts.

CHAPTER 2

IMPLEMENTING VIRTUAL ENVIRONMENTS IN RISK COMMUNICATION

VR and other immersive virtual environments used in risk communication and disaster preparedness efforts are often created using computer-generated imagery to closely replicate an environment or event in the physical world (Bakhtiari et al., 2023; Zhu & Li, 2021). VR engages a variety of users' senses that allow them to feel present in the mediated environment instead of the physical world (Biocca, 1997; Blascovich et al., 2002). This layered sensory experience provides a realistic simulation of events or interactions, which has been shown to elicit attitudinal and behavioral changes in the real-world (Ahn, 2015; Ahn et al., 2013; Blascovich et al., 2002). The success of VR to effectively communicate risks lies these immersive qualities, which allow users to feel present while they safely experience a simulated disaster scenario (Lee et al., 2023; Mol et al., 2022). Virtual exposure to the disastrous and sometimes fatal consequences of being unprepared to a risk can make the risk more salient and tangible to the user. Moreover, VR has the unique capability to provide users with the opportunity to practice preparing and responding to risks, such as natural disasters, in conditions that mimic a risk scenario in the physical world (Bakhtiari et al., 2023; Fujimi & Fujimura, 2020; Fusco & Zhu, 2023).

Immersion

Colloquially, immersion often refers to a state of intense attention or personal investment that can result in a loss of self-awareness (Balzer, 2011). In this view, immersion is a subjective psychological state one might enter when playing an engaging video game (Bowman, 2018). However, in the discussion of VR, *immersion* refers to the extent to which the technology provides users with comprehensive and realistic reproductions of the physical world (Lombard & Ditton, 1997a; Slater & Wilbur, 1997; Wirth et al., 2007). More specifically, immersion is an objective measure of technological fidelity, which refers to the degree to which virtual environments accurately resemble a desired physical environment or interaction (Biocca, 1997; Lombard, 1995; Wirth et al., 2007). Fidelity has two dimensions relevant to immersion: display fidelity and interaction fidelity (Ahn et al., 2022; Biocca, 1997).

The extent to which an immersive technology has the capacity to create layered and vivid sensory experiences for users in VR that closely resemble the physical environment is referred to as *display fidelity* (Biocca, 1997). Virtual environments with high display fidelity can simultaneously engage users' visual, auditory, and tactile senses, providing a sensory experience that closely mimics the physical environment (Ahn et al., 2022; Biocca, 1997; Lombard & Ditton, 1997b; Wirth et al., 2007). VR offers a more immersive user experience than traditional media—radio or television—due to its ability to provide this layered sensory experience to users (Biocca, 1997; Blascovich et al., 2002; Lombard & Ditton, 1997). Further, experiencing VR in a Head-Mounted Display (HMD) can suppress stimuli from the immediate physical environment, aiding immersion by gradually minimizing the effects of outside stimuli on the user's senses and replacing them with sensory cues from the virtual environment (Biocca, 1997).

Interaction fidelity is focused on the capacity of VR to provide realistic sensorimotor information to the user, which encourages or discourages their ability to realistically interact with the environment (Ahn et al., 2022; Lombard & Ditton, 1997; Wirth et al., 2007). When interaction fidelity is high, objects in a virtual home would respond to a virtual flood the same way they would in the physical world (Biocca, 1997). For example, when VR has high interaction fidelity, water would enter the home through open or shattered windows, and the furniture would shift and float as the water rises. Importantly, VR experiences with high fidelity have been shown to make users feel psychologically present in the virtual environment (Biocca, 1997; Wirth et al., 2007). When users feel spatially present in VR, they perceive themselves as being located in the virtual environment and believe their actions can have a meaningful impact on the environment (Lombard & Ditton, 1997; Wirth et al., 2007). Through this suspension of belief, users can gain meaningful, near first-hand experience that can significantly shape their behavioral intentions in the real world (Ahn, 2015; Ahn et al., 2013; Biocca, 1997; J. Lee et al., 2023; Wirth et al., 2007).

Presence

In the most general sense, *presence* is a 'perceptual illusion' that occurs when users engage with a mediated environment but do not perceive it to be mediation (Lombard & Ditton, 1997). Instead, users continue to engage with the media as if it is their real, physical environment (Biocca, 1997; Lombard & Ditton, 1997). In VR specifically, presence can be described as a psychological state that refers to the subjective experience of "being there" and occurs as users continuously process, respond to, and engage with the virtual environment (Biocca, 1997; Blascovich et al., 2002; Lombard & Ditton, 1997; Wirth et al., 2007).

Presence experiences are influenced by certain qualities of the VR technological features and user traits (Lombard & Ditton, 1997). Features that impact fidelity such as, the *realism* and *interactivity* of a virtual environment, are consistently discussed as significant drivers of presence (Lombard, 1995; Lombard & Ditton, 1997; Wirth et al., 2007). While both social realism (plausibility of the media representation) and perceptual realism (fidelity of the media) are drivers of presence (Biocca, 1997; Lombard & Ditton, 1997), it is the perceptual realism of VR that impacts users' presence the most (Lombard & Ditton, 1997; Slater & Wilbur, 1997; Wirth et al., 2007). Constructing a virtual environment with high fidelity ensures that users can feel present, regardless of whether it is depicting fictional or unreal scenes (Lombard & Ditton, 1997). For example, users may find it implausible that they are experiencing a storm surge inside a lab that hours away from the coast. However, if the virtual environment provides an accurate depiction of the storm surge, users are still able to suspend their belief and feel present in the virtual environment.

Additionally, VR experiences that appropriately respond to users' actions can increase presence (Lombard & Ditton, 1997; Wirth et al., 2007). For example, head-tracking features in VR should respond to users turning their heads in HMD by changing the view. Interactivity refers to the degree that a virtual environment responds in real-time to a user's input (Lombard & Ditton, 1997). A highly interactive VR that allows users to influence the environment and provide responses matching users' actions increases users' sense that they are located in the virtual world (Lombard & Ditton, 1997).

Due to the immersive qualities of VR, it is quite effective at eliciting a sense of presence in users (Ahn, 2015; Ahn et al., 2022; J. Lee et al., 2023; Mol et al., 2022; Wirth et al., 2007). However, individuals can experience presence while engaging in various media, including reading a book or watching a movie (Biocca, 1997; Lombard, 1995; Lombard & Ditton, 1997). When non-or lower-immersive media elicit a sense of presence, individuals may need to compensate for the lack of sensory input by exerting more effort in cognitive processes, such as recalling relevant memories (Biocca, 1997). Due to this increased effort, individuals' motivation to engage with the medium is crucial for eliciting a sense of presence (Blascovich et al., 2002). Presence experiences in highly immersive media, such as VR, may be less affected by users' motivations and more affected by users' characteristics and complexity of the environment (Biocca, 1997; Sacau et al., 2007; Wirth et al., 2007). For instance, users with VR experience often develop greater levels of presence than novice users due to their familiarity with navigating virtual worlds (Brade et al., 2017; Sacau et al., 2007) In complex virtual environments, users' cognitive and spatial abilities may affect how present they feel in an environment (Hecht & Reiner, 2007; Westerman & Cribbin, 1998; Wirth et al., 1997). Overall, users who are more familiar with the technology feel less anxious engaging with novel media and have greater capacity to cognitively encode new spaces are likely to feel more present in a virtual environment (Lombard & Ditton, 1997; Sacau et al, 2007).

Although the precise conceptual definition of presence is still being debated in the scholarship (Klein & Ahn, 2024), past literature generally recognizes the following three dimensions comprising presence: self-presence, social presence, and spatial presence (Biocca, 1997; Lombard & Ditton, 1997; Slater & Wilbur, 1997; Wirth et al., 2007). Each dimension focuses on specific psychological processes that affect users as they experience VR (Lombard & Ditton, 1997). Broadly, *self-presence* refers to how connected users feel to their virtual body and identity (Biocca, 1997; Ratan & Hasler, 2009). This dimension of presence focuses on a user's self-perception within a virtual environment (Biocca, 1997). In VR, users are often depicted through avatars or virtual humans, which offer a digital representation of themselves within the environment (Ahn et al., 2013; K. L. Nowak & Fox, 2018). As users feel in control of these avatars, they begin to perceive that they have a body in VR, referred to as *embodiment* (Ahn et al., 2022; Biocca, 1997; K. L. Nowak & Fox, 2018). When embodied, a user's understanding of their physical body can be influenced by how their avatar maps onto their physical body (Biocca, 1997; K. L. Nowak & Fox, 2018; Williams, 2010). The second dimension of presence is *social presence*, which describes the feeling of "we are here together" when multiple users simultaneously occupy a virtual environment (Biocca, 1997; Blascovich et al., 2002). Perceptions of social presence are directly related to users' beliefs that they can discern the intellect, intent, and impressions of others (Lombard & Ditton, 1997).

The third dimension of presence describes a phenomenon that occurs when users do not recognize that their physical space is being mediated by technology (Wirth et al., 2007). *Spatial presence* is the feeling of "being there" in VR instead of the physical world (Biocca, 1997; Lombard & Ditton, 1997; Wirth et al., 2007). Spatial presence includes two sub-dimensions: 1) self-location and 2) ability to act. Self-location is central to this dimension of presence and refers to the feeling of being physically located in the spatial environment depicted by a medium (Wirth et al., 2007). The ability to act refers to the user's action possibilities available to them in the virtual environment (Lombard & Ditton, 1997; Wirth et al., 2007).

Users experience spatial presence by building a spatial situational model from both spatial cues and relevant personal spatial memories (Lombard & Ditton, 1997; Wirth et al., 2007). Once users build this spatial situational model, they continuously reconcile incongruences in their ego reference frame–a first person mental model of the surrounding environment—between the virtual and the physical environment (With et al., 2007). Ultimately, spatial presence occurs when users accept the virtual environment as their primary ego reference frame (Lombard & Ditton, 1997; Wirth et al., 2007). This results in users perceiving their location, action possibilities, and mental frame of reference as being tied to the virtual environment (Lombard & Ditton, 1997; Wirth et al., 2007). While all dimensions of presence help explain how individuals respond to VR, the present study is interested in how individual users respond to a storm surge event destroying the virtual space (e.g., a virtual home) around them. Therefore, only spatial presence will be examined.

Prior research has confirmed that the communication effects and outcomes of spatial presence are important considerations for researchers aiming to use virtual environments in a risk communication context (Lee et al., 2023; Mol et al., 2022; Zhu & Li, 2021). When users perceive that they are located in a virtual environment (self-location component of spatial presence) and believe that their actions can impact the environment (action possibility component of spatial presence), they can actively learn how to respond to risk. The capability of VR in delivering experiential learning allows users to encounter a risky scenario, such as natural disasters and extreme weather events, and experience a visceral simulation of the event without suffering, sometimes fatal, consequences that they would in the physical world.

Implementing VR in Disaster Management

VR technologies are increasingly being integrated into disaster management scenarios to enhance individuals' understanding of (1) the risks posed by the disaster and (2) the recommended response when the disaster strikes (Bakhtiari et al., 2023; Macchione et al., 2019; Wang et al., 2019). VR has been implemented to achieve all five of the core objectives of disaster management: prevention, mitigation, preparation, response, and recovery (Bakhtiari et al., 2023). Prevention focuses on *avoiding* the occurrence of disasters. Often, VR is involved in prevention through efforts to increase public awareness and to visualize key geographical areas, aiding communities in strategically planning the use of land and strengthening key infrastructure (Macchione et al., 2019; Wang et al., 2019). Mitigation involves controlling or reducing the adverse effects of disasters (Bakhtiari et al., 2023). VR uses mitigation efforts to test and optimize disaster control strategies (Zhu & Li, 2021). Preparation centers around increasing individuals' and communities' capability to respond appropriately to a disaster before the disaster occurs (Bakhtiari et al., 2023). VR provides interactive forecasts of natural disasters, increasing users' understanding of how they can best prepare for them (Zhu & Li, 2021). Response describes actions aimed at protecting property, reducing loss, alleviating suffering, and saving lives following the disaster (Bakhtiari et al., 2023; Mol et al., 2022). VR can aid disaster response by providing real-time visualizations of disasters—for example, visualizing the path of a flood or wildfire—and increasing a user's ability to perform recommended responses for a given disaster (Haynes et al., 2018). Recovery includes any behaviors performed to return a community to normal conditions (Bakhtiari et al., 2023). VR is used in recovery actions by providing visual disaster assessments and construction projects to rebuild or restore damaged areas (Wang et al., 2019).

Although VR has been successfully used in efforts toward all phases of the disaster management objectives, the technology is overwhelmingly employed to aid preparedness and response efforts (Hoehler, 2021; Meijers et al., 2023; Oyshi et al., 2022; Zhu & Li, 2021). A recent meta-analysis focusing on the use of VR specifically in urban flood management reported that more than 30% of the studies focused on preparation, and 20% focused on flood response (Bakhtiari et al., 2023). Emergency managers and scholars have devoted significant attention and resources to incorporating VR in preparedness and response efforts due to the ability of the technology to provide users with a realistic experience of responding to and preparing for a disaster. However, the disproportionate focus on these objectives may also be driven by concerns for the public's well-being (Bakhtiari et al., 2023; Sledge & Thomas, 2019). Failure to adequately *prepare* communities for an impending or potential disaster (versus responding to a disaster that has already taken place) has resulted in dire consequences, including devastating loss of life and property (FEMA, 2024). In addition to significantly increasing survival rates, being prepared when disaster strikes can help reduce the financial impact and aid in recovery (FEMA, 2024).

Furthermore, public perceptions that their community is ill-prepared when disaster strikes can erode trust in the community leaders and institutions they rely on to stay safe (Paton, 2007). In the fall of 2024, municipal, state, and federal governments faced severe criticism for failing to adequately prepare for Hurricanes Helene and Milton, which tore through much of the southeastern United States (Brugal & Freedman, n.d.; Chan et al., 2024). Similarly, officials in Los Angeles, California, received similar complaints alleging that the city's infrastructure was ill-equipped to combat the Eaton and Palisades fires that broke out in late January of 2025 (Tarasov, 2025). Thus, investing resources in VR development to increase preparedness makes fiscal sense (Bakhtiari et al., 2023; Zhu & Li, 2021).

VR technology can uniquely aid in preparedness efforts (Bakhtiari et al., 2023; Mol et al., 2022) by enhancing threat and safety assessments and providing a realistic environment for safety training (Fusco & Zhu, 2023; Zhu & Li, 2021). VR enables realistic, interactive visualizations of disasters, allowing for accurate assessment of a given area's risk for future disaster events (Liu et al., 2019). For example, VR can help emergency managers identify areas at risk of flooding, enabling them to properly prepare the infrastructure for future floods (Oyshi et al., 2022). VR technology can also aid safety training by providing immersive experiences that increase users' situational awareness of a given threat (Fujimi & Fujimura, 2020).VR-based safety training can also facilitate decision-making by allowing users to explore the efficacy of various risk prevention strategies (Bakhtiari et al., 2023; Mol et al., 2022).

By eliciting spatial presence, VR allows users to practice decision-making and emergency response strategies in a controlled, risk-free setting. This experiential learning can increase users' familiarity with emergency procedures, improve situational awareness, and strengthen their confidence in managing real-world crises (Nguyen et al., 2019). For instance, users can practice enacting risk mitigation strategies and following evacuation routes under simulated stress, all of which can enhance their readiness for actual disaster scenarios (Bakhtiari et al., 2023; Bonanno et al., 2010; Meijers et al., 2023; Williams, 2010). *Virtual time travel* (Ahn, 2021) can also be utilized to alter the timing and sequence of events in the virtual environment. In virtual disaster simulations, virtual time travel can allow users to experience the negative, sometimes fatal, consequences of being inadequately prepared for a storm surge, as well as enabling users to travel back in time to properly prepare before the storm reaches landfall (Frank et al., 2025; Lee et al., 2023). Moreover, VR can personalize risk communication by adapting scenarios to users' specific geographic locations or unique vulnerabilities, making the experience more relevant and impactful (Frank et al., 2025; Liu et al., 2019). Incorporating a VR experience in disaster preparedness training also reduces the need to replicate disaster scenarios in the physical world (e.g., fire fighter training), which lowers cost and increases the accessibility for community members to gain near first-hand experience responding to an impending storm.

The psychological and physiological effects associated with exposing users to virtual disaster scenarios have several effects on disaster preparedness training. Overall, research indicates that virtual simulations of natural environments can elicit psychological and physiological effects similar to those associated with real-world experiences (Browning et al., 2021; Higuera-Trujillo et al., 2017; Oyshi et al., 2022; Yu et al., 2018; Zhu & Li, 2021). Users report psychological responses to the virtual simulations, including increased risk perceptions and negative affect (Meijers et al., 2023; Mol et al., 2022). Physiological responses to these simulations were associated with increased stress responses, such as sympathetic nerve activation and increased heart rate (Czarnek et al., 2020; Oyshi et al., 2022). Importantly, these psychological mechanisms were often mediated by spatial presence (Meijers et al., 2023; Zhu & Li, 2021).

These findings suggest that when users feel spatially present in a virtual disaster scenario simulation, their psychological and physiological responses mimic real-world responses. Specifically, research indicates that exposing individuals to virtual simulations of disaster scenarios was related to physiological stress markers (Zhu & Li, 2021). Additionally, researchers focusing on flooding have found that exposing individuals to a virtual flood simulation increased risk perceptions (Oyshi et al., 2022) and risk prevention behaviors (Mol et al., 2022). Thus, VR can allow individuals to encounter these risks in a safe environment (e.g., hurricanes or wildfires) without having to experience the dire consequences in the physical world (Meijers et al., 2023).

Lessons from Previous Work

Recent studies have examined how users respond to experiencing a storm surge in VR (Frank et al., 2025,). The present study leverages insights gained from these earlier efforts to refine the virtual storm surge experience employed in previous studies and to investigate how these enhancements impact users' risk perceptions and intentions to engage in preparedness behaviors.

A qualitative study conducted in early spring of 2022 explored how community leaders in coastal communities responded to a prototype of the virtual storm surge experience. In this approximately six-minute VR experience, users experienced a virtual storm surge that flooded their new coastal home before they traveled back in time and implemented two storm surge risk prevention strategies, purchasing flood insurance and elevating the home. The storm surge returned following these basic preparations, and although their house was properly elevated, debris from their neighbors' unelevated homes shattered their windows, causing their virtual home to flood once again, placing users in danger. The experience concluded with a brief audio message urging users to follow evacuation orders to stay safe during hurricanes and storm surges, because even preparedness behaviors may not provide adequate protection when the storm surge is severe enough to warrant evacuation. Overall, the community leaders enjoyed the VR experience and believed it would help make the risk of storm surge more tangible and salient to coastal residents. These leaders indicated that the VR experience elicited a strong fear response, which they attributed to the high level of presence they felt in VR (Frank et al., 2025). However, many also suggested that the VR experience would be more impactful if tailored and personalized to each coastal resident.

Following this initial prototype testing, the VR experience was modified and improved. The modifications primarily focused on increasing the display and interaction fidelity and incorporating three additional risk prevention strategies: packing an evacuation kit, boarding up windows, and evacuating ahead of the storm. A follow-up lab study was conducted with college students to examine how interactively practicing these risk mitigation tactics in VR would affect their engagement with the topic of storm surge and their intentions to perform the risk mitigation tactics in the physical world. Overall, we found that participants who practiced risk prevention strategies in VR reported higher levels of spatial presence than those who viewed a video detailing the same strategies (Frank et al., in preparation). Heightened spatial presence was associated with an increase in users' confidence in their ability to implement these risk prevention strategies in real life and a greater level of hope that societal changes would help reduce the risk of storm surges. The users' heightened confidence was loosely associated with an increase in their behavioral intentions, and their hope increased their willingness to engage with the topic of storm surges in their daily lives (Frank et al., 2024).

The present study builds on these previous findings by incorporating customizable elements into the existing VR experience to examine the effects of users developing psychological ownership (a concept discussed in the following section) over the virtual home and how this sense of ownership influences their perceptions and behavioral intentions. Exploring the impact of psychological ownership builds on previous findings in which coastal community members and opinion leaders emphasized the need for a more personalized experience to enhance the overall impact of the VR intervention on user (Frank et al., 2025). These leaders' insights align with previous risk communication research which indicates that tailored messaging enhances the effectiveness the message

(Fusco & Zhu, 2023; Griffin et al., 2013). Additionally, the study incorporated physiological measures to complement users' self-report responses to better understand the underlying mechanisms that occur as users process and respond to the VR experience.

CHAPTER 3

VIRTUAL PSYCHOLOGICAL OWNERSHIP AND RISK

Psychological ownership refers to a perception in which an individual feels that something or place belongs to them (Pierce et al., 2001; Van Dyne & Pierce, 2004). Put simply, psychological ownership can be described as the 'mine' feeling individuals may feel for their possessions (Pierce et al., 2001). Psychological ownership does not always equal legal ownership, and it is primarily driven by one's perception and largely acknowledged by that individual or social group (Van Dyne & Pierce, 2004). In the physical world, individuals may develop feelings of ownership of physical objects that they legally own (e.g., a smartphone), rent (e.g., an apartment), or even objects that are not legally owned (e.g., a seat in a classroom).

Understanding the perception of ownership over these targets of ownership in the physical world is largely intuitive. An individual either visibly has possession of, or access to, the target and, therefore, can offer tangible evidence of why they feel that they own that item. In the virtual world, legal or psychological ownership is not as easy to comprehend. Users may spend hours in a world-building game such as The Sims or Second Life, carefully constructing a virtual life for their personalized avatar, favorite car, and dream home; however, they have no legal ownership of these items. Users' creations on these and other virtual platforms are legally considered the intellectual property of the platform itself and not the user who created them (Electronic Arts, 2025). Despite users' inability to legally own these virtual objects, research shows that users readily and frequently develop strong feelings of ownership over their virtual belongings (Van Dyne & Pierce, 2004; Watkins et al., 2016; Zhou et al., 2018).

Motivations and Antecedents of Psychological Ownership

Consumer psychology and sociobiological research provide support for the concept of psychological ownership in both physical and virtual worlds (Belk, 2013; Peck & Luangrath, 2023; Shu & Peck, 2011; Watkins et al., 2016). This body of research suggests that psychological ownership may be an innate or learned behavior that engages individuals' emotional processes at a higher level than their cognitive processes (Belk, 1988; Peck & Luangrath, 2023). Individuals engage these processes and develop PO to fulfill various sociobiological needs such as 1) efficacy, 2) belonging, 3) autonomy, 4) identity expression and extension, 5) responsibility, and 6) territoriality (Avey et al., 2009; Olckers, 2013; Pierce et al., 2001; Van Dyne & Pierce, 2004). Efficacy refers to the individual's need to feel that they can effectively interact with their environment (Bandura, 1982; White, 1959). Efficacy describes an individual's need to wield or control the target of ownership and determine who else can access the target (Peck & Luangrath, 2023; Pierce et al., 2001). For example, users report feeling increased ownership over objects in virtual spaces that have high interaction fidelity and allow them to manipulate the object for their desired use (Krauss & Wienrich, 2025; Watkins et al., 2016; Yuan et al., 2021).

Belongingness describes the need for individuals to feel secure and comfortable (Pierce & Peck, 2018). Individuals will develop a sense of ownership of familiar environments (e.g., their customized Sims home) to meet this need for security (Watkins et al., 2016; Zhang & Xu, 2019). Beyond security needs, individuals are also motivated to engage in psychological ownership to fulfill a need for stimulation (Pierce & Jussila, 2011). Thus, individuals are motivated to develop a sense of ownership over objects that interest them and with which they enjoy interacting (e.g., personalized avatars). Autonomy is a key dimension of psychological ownership, particularly in how it relates to individuals' sense of control, independence, and personal investment in a given object, space, or experience (Olckers, 2013; Pierce & Jussila, 2011). In the context of psychological ownership, autonomy describes the degree to which individuals feel they have control over their interactions with and decisions regarding an object or environment, such as a virtual home or other customizable spaces. Importantly, when individuals feel that they can make autonomous decisions and exert control over a target of ownership, they are more likely to exert effort in maintaining the target (Hensen, 2015; Mayhew et al., 2007).

Additionally, individuals engage in psychological ownership to help define, maintain, and express their identity (Pierce et al., 2003). Consumer behavior research has shown that an individual's possessions often reflect their identity, and the products and services they purchase help them extend and maintain their sense of self (Belk, 1988, 2013). Users are also motivated to extend and express their identities in virtual spaces, much like they do in the physical world. Thus, users are willing to expend resources (e.g., time, money) to extend their sense of self and gain status, belonging, and comfort, even in virtual environments. These core motivations help to shape how individuals interact with objects in the virtual and physical worlds (Belk, 2013; Zhang & Xu, 2019).

The final dimensions of psychological ownership, territoriality, and responsibility describe how individuals may feel protective over their possessions (Olckers, 2013). Responsibility specifically describes how individuals hold themselves accountable for protecting and maintaining the target of ownership (Avey et al., 2009; Olckers, 2013). Notably, feelings of responsibility can motivate individuals to employ mitigation tactics to safeguard their possessions from harm (Freedy et al., 1992; Olckers, 2013). For example, climate change messaging that emphasized individual responsibility to combat climate change led to increased intentions to engage in pro-environmental behavior (Gagrčin et al., 2022; Hensen, 2015). Notably, territoriality can also lead individuals to put more effort into protecting their possessions from risks (Freedy et al., 1992; Lyman & Scott, 2009).

In addition to sociobiological motivations that prompt individuals to develop a sense of ownership over virtual and physical objects, there are antecedents or routes that individuals follow as they develop a sense of ownership over objects. There are three key antecedents to the development of psychological ownership: 1) control, 2) investment of self, and 3) cultivation of intimate knowledge (Pierce et al., 2001; Van Dyne & Pierce, 2004). The control antecedent is not only related to how an object may be used but also to managing how others access the object (Pierce et al., 2001; Pierce & Peck, 2018). For example, a social media user may develop psychological ownership over their profile by exerting control over the type of content they post or by controlling who has access to the content.

Investment of self describes a process where an individual develops psychological ownership after expending resources (e.g., time, money, effort) to create, personalize, or maintain a place or object (Belk, 1988; Pierce & Jussila, 2011). Thus, when a social media user takes the time and effort to develop their profile, they are more likely to feel a sense of ownership over it. The final route to psychological ownership occurs when individuals cultivate intimate knowledge of the target of ownership (Pierce & Peck, 2018;

Van Dyne & Pierce, 2004). This cultivation takes time and requires that an individual become familiar with and gain a deeper understanding of the target. For instance, an avid user of *The Sims* game may feel a greater sense of ownership over their virtual life when they have spent time familiarizing themselves with the ins and outs of the gaming platform (Belk, 2013; Watkins et al., 2016).

As it is unlikely that participants will have sufficient time to cultivate knowledge of the virtual home within the short 10-minute VR experience, the present study focuses on providing individuals with ample 1) control and 2) opportunities to invest themselves in the virtual home to elicit feelings of ownership. Additionally, recent evidence suggests that these two antecedents of psychological ownership commonly extend to augmented and virtual environments (Carrozzi et al., 2019). For instance, researchers found that users' psychological ownership was heightened when they were able to customize a virtual product (e.g., a vehicle) by changing its size, color, and placement within the virtual space (Carrozzi et al., 2019; Song et al., 2019). Customization of virtual objects is effective at eliciting feelings of ownership as it allows users to extend their identities and provides them with a sense of control over the virtual space (Carrozzi et al., 2019; Watkins et al., 2016; Yuan et al., 2021). Related to the sociobiological motivation of efficacy, the sense of power users gain as they exert control over virtual objects increases the likelihood that they will develop psychological ownership (Pierce & Peck, 2018). Research supports the control antecedent, showing that users' PO over objects increases when they can touch and manipulate objects in both physical and virtual environments (Brengman et al., 2019; Peck & Shu, 2018; Song et al., 2019). These innate motivations and antecedents to psychological ownership provided a theoretical rationale for creating the virtual environment used in the present study. Various technical features were developed to give users high control over the virtual environment, enabling them to extend their identities into the virtual environment by investing time and effort into customizing a virtual home according to their distinct preferences.

Consequences of Psychological Ownership and Loss of Possessions

Majority of the existing research that empirically examines effects of PO is found in organizational management and consumer behavior research (Brengman et al., 2019; Olckers, 2013; Pierce & Peck, 2018). For instance, consumer psychology suggests that there are both positive and negative consequences when individuals develop PO over physical and virtual products (Hulland et al., 2015). When individuals feel a sense of ownership over a brand or product, they tend to remain more loyal and engaged with the brand (Chang et al., 2012). Individuals also report feeling happier or more satisfied when they purchase products from a brand that they feel a sense of ownership over (Jussila et al., 2015). However, psychological ownership can cause individuals to feel disappointed, frustrated, or angry when a product or a feature of the product is altered or removed (Chang et al., 2012; Jussila et al., 2015; Watkins et al., 2016). While not directly situated in a risk communication context, this body of literature provides a framework that begins to elucidate how individuals may respond when the target of their ownership is altered or destroyed in the physical and virtual worlds.

As previously discussed, individuals readily develop a sense of ownership over virtual, intangible objects such as their social media profiles (Karahanna et al., 2015). For instance, TikTok, a popular social media platform, allows users to view and post short-form videos on a centralized “For You Page” (TikTok, n.d.). As the name suggests, every user’s TikTok algorithm provides their own For You Page full of content that the algorithm predicts they will enjoy. Many long-term and avid TikTok users report feeling as though they have built or fine-tuned their For You Page by engaging with content that aligns with their interests (Hatton, 2021). Through this process of curating desirable content, users develop a sense of ownership over their For You Page and often express disappointment and frustration when they feel that the algorithm has changed the content placed on the page without their consent (Gerbaudo, 2024; Koç, 2023).

Our understanding of the motivations and antecedents that drive individuals to engage in psychological ownership helps to explain these users' responses to changes, or at least perceived changes, made to the TikTok algorithm. First, users were likely motivated by their need for efficacy and identity extension to develop psychological ownership over their For You Page. Second, TikTok gave users a sense of control by enabling them to adjust their For You Page by engaging with desirable content (i.e., liking, sharing, or reposting) and disengaging from undesirable content (i.e., selecting "not interested" or reporting). As the algorithm responds to their activity, users spend more time and effort trying to create a perfectly curated feed. Thus, when they perceived that the platform changed their For You Page, the users felt disappointed that they no longer felt a sense of control over their feed and that their investment in the For You Page no longer allowed them to extend, express or maintain their sense of self (Carrozzi et al., 2019b; Koç, 2023; Pierce et al., 2001; Watkins et al., 2016).

This sense of disappointment, frustration, and even loss is reflected in disaster management studies that examine disasters in the physical world, studying how individuals respond to the destruction of their possessions (Norris et al., 1999). Survivors of natural disasters reported experiencing acute psychological stress and a deep sense of grief for their lost possessions (DeLorme et al., 2004). In interviews, these survivors spoke about their destroyed homes and belongings as if they were a lost loved one (Sayre, 1994). These individuals also reported a greater emotional attachment to their recovered possessions (Sneath et al., 2009). Furthermore, most survivors were intent on rebuilding and/or preserving their possessions, and through these actions, they rebuilt and preserved their sense of self (DeLorme et al., 2004).

Survivors of Hurricane Katrina, the deadly category three storm that decimated the city of New Orleans and much of the Louisiana coast (Sneath et al., 2009), reported that the sense of loss they experienced for both their possessions and self-identity drove their heightened consumption behaviors in the months that followed the storm (DeLorme et al., 2004; Sayre, 1994; Sneath et al., 2009). These findings indicated that losing possessions can elicit prolonged negative affect, threaten individuals' sense of self, and increase the value individuals place on their remaining possessions (DeLorme et al., 2004; Norris et al., 1999). Taken together, these examples of the consequences of psychological ownership in both virtual and physical worlds show that individuals can experience a variety of negative emotions when their possessions are destroyed (DeLorme et al., 2004; Koç, 2023; Norris et al., 1999; Sneath et al., 2009).

Pilot Study Overview

In the fall of 2024, a pilot study (N= 45) was conducted to explore the feasibility of eliciting users to develop psychological ownership over virtual objects and a virtual home following a single, relatively brief exposure. In the study, half of the users could interactively customize their homes to their personal taste. The other half of users were given pre-set homes and simply watched the objects float into place without the ability to customize the space to their preferences. After the virtual home was decorated, all users experienced a storm surge flood that damaged the virtual home and the furniture inside.

Findings from the pilot study suggested that when users interactively customized a virtual home, they developed greater feelings of ownership over it than users who experienced a virtual home with pre-set furnishings (Frank et al., in preparation). Moreover, users who customized their virtual home reported storm surges to pose a greater risk (Witte, 1996) relative to users in the control group. Additionally, it was found that users' ability to customize a virtual home was indirectly related to the user's self-reported negative affect (i.e., feeling distressed, sad, guilty, regretful, lonely, afraid, worried, scared, disappointed, upset, angry, frustrated, disgusted) when a storm surge destroyed the virtual home and the objects in it. The users' reported feelings of ownership mediated this indirect effect—users' risk perceptions of storm surges were controlled for analysis. These initial findings are encouraging, as they suggested that both the customization task and users' psychological ownership of the virtual home were positively associated with heightened negative affect and elevated risk perceptions. Importantly, risk communication theories emphasize that increasing negative emotional responses and risk perceptions are critical first steps in motivating individuals to engage in adaptive, protective behaviors (Griffin et al., 2013; Witte, 1996).

The present study builds on the initial pilot testing by examining how the customization task and users' psychological ownership of the virtual home influence how they process and respond to an additional VR experience designed to increase their confidence in implementing storm surge risk prevention strategies in the physical world. This second VR experience will allow users to actively practice implementing risk prevention strategies to protect themselves and their virtual home from future storms. Additionally, psychophysiological measures, discussed in a subsequent chapter, will be incorporated to investigate the underlying mechanisms that occur as users process the VR experience. These additions will allow for examination of how PO affects users' cognitive and emotional responses to the virtual storm surge, as well as how it influences their subsequent perceptions and behavioral intentions regarding storm surge risks. intentions to engage in storm surge risk prevention strategies in the physical world. Given the findings of the pilot study the following effect is predicted:

H1: Users in the customization present condition will report greater psychological ownership over the virtual home than users in the customization absent condition.

CHAPTER 4

THEORETICAL APPROACHES TO RISK COMMUNICATION

The persistent nature of risks elicits fear but simultaneously promotes complacency (Wachinger et al., 2013). Risk is engrained in an individual's existence; therefore, risk and responses it elicits are complex and subjective. Broadly, risk is defined as the possibility and probability of loss or injury of something valuable (Griffin et al., 1999; Kaplan & Garrick, 1981; Witte, 1992). The central objective of risk communication is to increase an individual's awareness and understanding of a hazard (McComas, 2006; Rowan, 1991). Therefore, the theoretical approaches frequently focus on how individuals 1) process risk information and 2) develop their perceptions of risk (Griffin et al., 1999, 2013; Witte, 1992, 1996). Two such approaches to risk communication include the Model of Risk Information Seeking and Processing (Griffin et al., 1999) and the Extended Parallel Process Model (Witte, 1992).

The Model of Risk Information Seeking and Processing (RISP) and the Extended Parallel Process Model (EPPM) frameworks were initially developed to study the communication of health risks (Griffin et al., 1999; Witte, 1992). Since their inception, both frameworks have been utilized to examine a range of risks. The RISP model has been applied to the environmental context to study risks associated with climate change and natural disasters (Maibach et al., 2023; Rodríguez et al., 2018; Yang et al., 2014). While the EPPM is still widely applied in a health context, such as vaccine communication (Pang & Ma, 2023), it has also been applied in environmental contexts (Marchand & Diallo, 2020) and to study the communication of cybersecurity risks (Boss et al., 2015). The types of risks or hazards that communication scholars have employed these frameworks vary in subject matter, severity, frequency, recommended responses, and at-risk populations (Marchand & Diallo, 2020; Pang & Ma, 2023; Witte, 1996). However, this body of knowledge is unified by the psychological and physiological processes examined, as well as the common goal to increase individuals' understanding, awareness, and risk prevention behaviors (Griffin et al., 1999, 2008; Pang & Ma, 2023; Witte, 1994, 1996). It is necessary to review each framework before detailing how they will be integrated in the present study.

The Model of Risk Information Seeking and Processing

The model of RISP outlines a process that details how certain characteristics of an individual and the hazard affect how individuals engage with and process risk information (Griffin et al., 1999, 2013). Specifically, RISP argues that information-seeking and processing behaviors are driven by 1) risk perceptions, 2) negative affect, 3) perceived capacity to gather information, 4) social norms, and 5) existing knowledge of the specific risk. RISP was developed by integrating two foundational information processing theories—the Heuristic-Systematic Model (HSM) and the Elaboration Likelihood Model (ELM)—with the Theory of Planned Behavior (TPB).

The ELM posits that the processing of persuasive information occurs either through low elaboration (peripheral route) or high elaboration (central route). Central processing is associated with the development of more stable attitudes than the peripheral route (Petty & Cacioppo, 1986). The HSM is a dual-processing theory similar to the ELM. The HSM contends that individuals process persuasive information both systematically (centrally) and heuristically (peripherally). Heuristic processing is viewed as limited and requires fewer cognitive resources, meaning individuals rely on snap judgments when they take in information (Bohner et al., 1994; Chaiken, 1993). Conversely, systematic processing requires increased cognitive effort and is characterized by a critical, analytical treatment of information (Chaiken, 1993). While the ELM and HSM focus on information processing, the TPB describes the complex process of changing behavior. The framework argues that a person's behavior is determined by their existing attitudes and behavioral intentions (Ajzen, 1991). Specifically, the TPB states that an individual's behavioral intention is determined by their 1) attitude toward the behavior, 2) perceived social pressure to perform the behavior (i.e., social norms), and 3) belief in their capacity to perform the behavior (Ajzen, 1991; Griffin et al., 1999).

RISP builds on these foundational theories to identify factors that influence individuals' motivation to seek out and actively process risk information to manage uncertainty (Griffin et al., 1999). It explains how the desire to acquire accurate information and uphold their existing beliefs drives risk-information-seeking behaviors. The model argues that an individual's risk perceptions are positively associated with reported negative affect. When one's risk perceptions and negative affect are heightened, they are motivated to engage in information-seeking behaviors to manage their feelings of uncertainty and to learn how to mitigate the potential harm the hazard poses (Clair et al., 2021; Griffin et al., 2013).

The model builds upon previous research to provide a nuanced conceptualization of risk and risk perceptions (Griffin et al., 2013). In line with previous work, RISP views *risk* as the probability and possibility of a hazard occurring (Griffin et al., 1999). It argues that individuals respond to risks both cognitively and affectively (Griffin et al., 1999, 2008, 2013). First, RISP posits that *risk perceptions* involve a cognitive assessment influenced by two main factors: 1) the perceived severity of the risk and 2) the individual's sense of susceptibility to potential harm. Second, the model argues that an individual's cognitive risk perceptions will be associated with their affective perception of risks, such as negative affect (e.g., worry, dread, and fear). RISP asserts that both cognitive and affective risk appraisals will drive individuals to engage in information-seeking behaviors to manage their uncertainty (Clair et al., 2021; Griffin et al., 2008, 2013).

The Extended Parallel Process Model

The EPPM builds on foundational motivational processing theories—the Protection Motivation Theory and the Parallel Process Model—in an attempt to explain how individuals process fear appeals (Witte, 1992, 1996). The parallel process model posits that adaptive, risk-prevention behaviors occur when individuals engage in cognitive processes (Leventhal, 1979). This cognitive process occurs when individuals are motivated to control the danger of a threat by engaging in adaptive behaviors to mitigate harm from a threat (Leventhal, 1979; Witte, 1996). Alternatively, when emotional processes are engaged, individuals act to control their fear of the threat by engaging in maladaptive behaviors such as avoidance (Leventhal, 1979). Critical to the development of the EPPM, the parallel process model distinguishes between the effects of emotional and cognitive processes (Witte, 1992).

The Protection Motivation Theory enhanced our understanding of how people process risk information by identifying message components that encourage adaptive behaviors over fear-induced maladaptive behaviors (Rogers, 1983). These components include 1) perceived susceptibility linked to threat probability, 2) perceived severity associated with threat significance, 3) perceived response efficacy regarding the effectiveness of the recommended behavior, and 4) perceived self-efficacy related to an individual's ability to perform the recommended behavior.

The EPPM expanded on the Parallel Process Model and the Protection Motivation Theory theories by incorporating the cognitive and emotional processes outlined in the Parallel Process model, along with the assumptions regarding the roles of threat and efficacy perceptions detailed in the Protection Motivation Theory (Witte, 1992, 1994, 1996). Notably, the conceptualization of threat/risk and threat/risk perceptions in the EPPM aligns well with the RISP model, as both explore the roles of severity and susceptibility (Griffin et al., 1999, 2008, 2013). The EPPM argues that successful risk messages must elicit threat perceptions that are sufficient to motivate individuals to process the information, but that are not excessive enough to elicit a fear control response (Witte, 1992). The ability of VR to make users feel present in a risk scenario offers a unique opportunity to increase the salience of a threat while users are in a safe, controlled environment. Significantly, research shows that VR can sufficiently increase the salience of a threat and motivate users to engage in adaptive risk prevention behaviors (Lee et al., 202; Mol et al., 2022).

Parallel to the threat related appraisals, the model outlines two dimensions of perceived efficacy: self-efficacy and response efficacy. Self-efficacy refers to the extent to which an individual perceives themselves as capable of performing a behavior (Bandura, 1982; Witte, 1992). Response efficacy refers to the perceived effectiveness of a behavior to mitigate a threat adequately (Witte, 1996). Specifically, the EPPM posits that when an individual's self and response efficacy perceptions are high, they engage in cognitive processes that promote risk prevention behaviors (danger control). Conversely, when perceived efficacy is low, individuals are more likely to respond emotionally, focusing on managing their fear rather than addressing the risk (fear control). This distinction highlights how efficacy perceptions directly influence whether individuals adopt adaptive or maladaptive behaviors in response to perceived threats (Witte, 1992, 1994).

Furthermore, previous research has demonstrated that an individual’s level of issue involvement can impact their efficacy perceptions. Specifically, when individuals perceive the issue (e.g., storm surges) as relevant and important, they are more likely to devote cognitive resources to process the information presented, which can also boost their sense of efficacy (Griffin et al., 2013; J. Lee et al., 2023; Petty & Cacioppo, 1986). Enhanced efficacy can result from a deeper understanding of the recommended actions and a stronger belief in their effectiveness (Witte, 1996). As individuals process risk information more thoroughly, they become more confident in their ability to carry out protective measures, which, in turn, increases their likelihood of adopting adaptive behaviors (Griffin et al., 2008; Witte, 1994). This process highlights how engaging and interactive communication strategies can strengthen efficacy perceptions and increase an individual's risk mitigation intentions.

Applying RISP and EPPM to Risk Communication with Virtual Reality

Integrating the RISP and EPPM models provides a more comprehensive framework for understanding how individuals process and respond to risk information presented in the VR experience. The RISP framework explains how users’ cognitive and emotional processes influence their information-seeking and processing behaviors, while the EPPM focuses on how perceptions of threat and efficacy shape users’ behavioral intentions (Griffin et al., 1999; Witte, 1992). Notably, RISP also considers the influence of a broader range of negative emotions beyond fear on how individuals engage with risk information. Together, these models support a more complete examination of the pathway from information processing to behavior change.

Both the EPPM and RISP models argue that individuals are motivated by their cognitive and emotional risk appraisals to engage in adaptive behaviors (Griffin et al., 2013). Therefore, employing VR to communicate the risk of storm surges may be advantageous due to its unique affordances (Ahn, 2015; Lee et al., 2023;Nowak et al., 2020) that elicit spatial presence, allowing users to gain near first-hand experience of a storm surge event (Lombard & Ditton, 1997; Wirth et al., 2007). Additionally, previous research indicates that VR can increase users' reported risk perceptions and negative affect (Frank et al., in preparation; Lee et al., 2023; Mol et al., 2022), which the RISP argues are precursors to users seeking out additional information about the risk including harm prevention strategies (Griffin et al., 2013).

Furthermore, the frameworks emphasizes the importance of enhancing an individual's perception that a risk is severe and that they are susceptible to the harm it poses to prompt them to engage in risk prevention strategies (Griffin et al., 1999, 2013). Previous research exploring the use of immersive technologies in disaster management has found that virtual simulations are effective at increasing users' risk perceptions by making the risk more salient and tangible for users (Bakhtiari et al., 2023; J. Lee et al., 2023; Mol et al., 2022). This effectiveness comes from users' ability to interact with concrete virtual representations of elements that may be intangible in the physical world, make real-time decisions, and experience simulated consequences. The interactivity, realism, and customizable experience that VR technology provides enhance users' emotional involvement and cognitive processing, thereby making the risk feel more severe and increasing perceived susceptibility to the consequences (Frank et al., 2025;

Griffin et al., 1999; J. Lee et al., 2023; Mol et al., 2022; Witte, 1992). Based on this rationale and guided by previous research, the present study examines how users' ability to interactively customize their virtual home leads individuals to report increased risk perceptions. Thus, the following is predicted:

H2: Users in the customization present condition will report greater risk perceptions of storm surges than those in the customization absent condition.

Central to the EPPM and RISP models is the idea that emotional and cognitive appraisals of risk shape how people process and respond to risk information(Griffin et al., 1999, 2013). To build on the pilot study discussed in the previous chapter, the current study will examine whether spatial presence mediates the relationship between experimental conditions (i.e., customization present vs. customization absent) and negative affect, suggesting that users who feel more present in the VR experience may also report heightened emotional responses to the virtual storm surge. Additionally, drawing from the emphasis RISP places on individual-level factors, such as relevant hazard experience and political ideology, influencing risk processing (Griffin et al., 2008, 2013), the present study will explore whether user's psychological ownership of the virtual home moderates the relationship between reported spatial presence and negative affect. This moderating effect may reveal how a sense of ownership over the virtual home strengthens users' affective responses to the destruction of their virtual possessions during the storm surge sequence. The following research question is posed (see Figure 1):

RQ1: How will users' psychological ownership of the virtual home affect the relationship between their feelings of spatial presence and their reported negative affect?

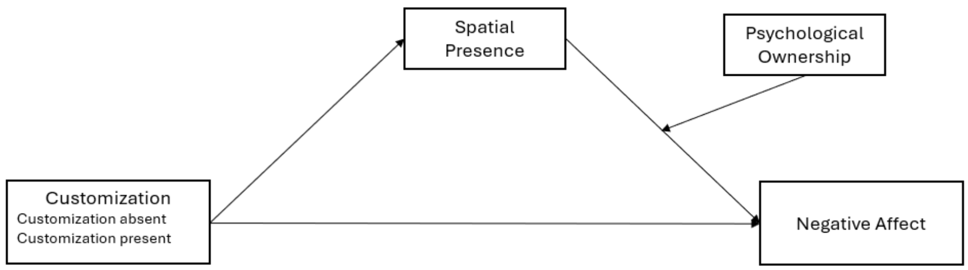

Figure 1. Conceptual Model for RQ1

Both frameworks also posit that individuals' intentions to engage in adaptive behaviors are significantly influenced by their perceived efficacy in performing those behaviors. When perceived efficacy is high, individuals take action (e.g., seek out information or engage in risk prevention behaviors) to reduce their risk. As a result, risk messages are most persuasive when they effectively communicate both the urgency of the threat and the feasibility of overcoming it through attainable behavior changes (Marchand & Diallo, 2020; Witte, 1996). VR presents unique opportunities to apply these frameworks by immersing users in realistic scenarios, eliciting feelings of spatial presence, and allowing them to actively practice risk prevention strategies. By leveraging VR's ability to provide engaging and interactive efficacy information, the virtual storm surge experience is expected to prompt individuals to actively process the information, strengthen efficacy perceptions, and increase individuals' intentions to engage in risk prevention strategies, aligning with the core principles of the RISP and EPPM models (Frank et al., 2025; Mol et al., 2022; Witte, 1994).

Additionally, previous research indicates that psychological ownership can increase an individual's intentions to protect, guard, and maintain the target of ownership (Pierce et al., 2001; Van Dyne & Pierce, 2004). Therefore, the extent to which an individual feels as though they own the virtual home is likely to impact their intentions to engage in mitigation behaviors. Therefore, the present study will draw on the EPPM and RISP models to examine how spatial presence affects users' perceived efficacy in reducing their risk of harm from a storm surge. Further analyses will be conducted to determine how these efficacy perceptions, with psychological ownership included as a moderator, affect individuals' intentions to engage in storm surge risk prevention strategies in the physical world. Thus, the following hypothesis and research question are posed (see Figure 2):

H3: Spatial presence and perceived self-efficacy will sequentially mediate the relationship between experimental conditions and users' mitigation intentions.

RQ2: How will psychological ownership affect users' perceived efficacy and their hurricane risk mitigation intentions?

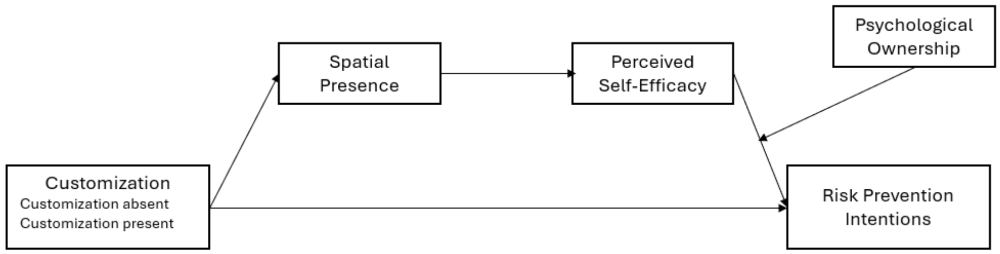

Figure 2. Conceptual Model for H3 and RQ2.

CHAPTER 5

PYSCHOPHYSIOLOGICAL RESPONSES TO RISK COMMUNICATION

In addition to using self-report measures to examine the cognitive and affective responses outlined in the RISP and EPPM, the present study will collect psychophysiological data to examine the underlying mechanisms that occur when individuals process risk (e.g., virtual storm surge). Incorporating these measures will help to provide insights into the real-time responses to the virtual storm surge and allow for a more nuanced examination of the cognitive and affective processes the frameworks predict when individuals are exposed to risk information (Griffin et al., 2013; Potter & Bolls, 2012; Witte, 1992). These physiological measures may help unlock the "black box" of the brain, enabling a deeper understanding of how individuals develop cognitive risk perceptions and the emotional responses these perceptions elicit (Griffin et al., 1999; Witte, 1992). Before making formal predictions, it is necessary to review the core tenets of psychophysiological research the present study aims to apply.

Motivational Systems and The Defense Cascade

Media psychophysiologists posit that there are two motivational systems, appetitive and aversive systems (Cacioppo et al., 2016; P. J. Lang & Bradley, 2013; Potter & Bolls, 2012). These systems are automatically activated when individuals process motivationally relevant stimuli and affect how we cognitively process information (Lang & Bradley, 2013). Activation of these motivational systems can occur independently of one another, reciprocally (where one is active and the other is not), or coactively, where both systems are activated simultaneously (Fisher & Weber, 2020; Potter & Bolls, 2012; Sparks & Lang, 2015).

The appetitive (or approach) system is activated in response to desirable stimuli that afford opportunities, such as food or social belonging (Lang, 1990). Appetitive system activation occurs in a steady and controlled manner, associated with exploratory behaviors such as scouting for food or investigating features in a video game (Lang, 2006; Lee & Eden, 2023). At our baseline, humans' appetitive system is more active because it is an evolutionary advantage to be motivated to search out resources in the surrounding environment (Lang & Bradley, 2013). The natural increase in appetitive activity is referred to as the *positivity offset* (Cacioppo et al., 2016; Lang, 2006; Lee & Eden, 2023). Conversely, the aversive (or avoidance) system activates more rapidly in response to dangerous or threatening stimuli and is associated with protective behaviors such as fight or flight (Lang, 2006, 2014). The quick onset of aversive system activation is referred to as *negativity bias* (Cacioppo et al., 2016; Lang, 2006; P. J. Lang & Bradley, 2013).

The way these systems activate has significant effects on how individuals process information in their environment. Informational processing can be divided into three sub-processes: encoding, storage, and retrieval. These sub-processes occur automatically and simultaneously as individuals respond to various stimuli in their environment (Lang, 2006). The primary function of the appetitive system is to allocate resources to gather information from the environment (encoding). Notably, the increased resources allocated to encoding information during appetitive system activation also allow individuals to better maintain (store) the information over time (Fisher & Weber, 2020; Lang, 2006, 2014). In contrast, the primary goal of the aversive system is to guard against danger

(Kozlowska et al., 2015; P. J. Lang & Bradley, 2013; Potter & Bolls, 2012), which means that activation of this system is characterized by decreased resources allocated to processing information in the surrounding environment (Clayton et al., 2018; Lang, 2006). The behavioral response to aversive system activation, such as declines in information processing and heightened fear responses, is known as the Defense Cascade (Bradley et al., 2001; Kozlowska et al., 2015; Lang, 2006; Lang & Bradley, 2013).

The Defensive Cascade describes the process of how organisms respond to risks or threats in their environment (Kozlowska et al., 2014). The model predicts that information processing decreases as an external threat increases. When a threat is first detected, the aversive system is activated, and the organism begins to show signs of physiological arousal. The organism stops encoding and storing neutral environmental information and orients its attention to encoding and storing information about the threat (Clayton et al., 2018; Lang, 2006; Lang & Bradley, 2013). During this time, the organism assesses the threat (encoding) and begins to allocate resources to recounting previous experiences (retrieval) to determine its best course of action. As the risk of danger becomes more imminent, a tipping point is reached where resources are diverted from informational processing to a behavioral response to guard against the threat —i.e., fight, flight, or freeze—(Clayton et al., 2018; Kozlowska et al., 2015; Lang, 2006).

Implementing Psychophysiological Measures in Risk Communication

Collecting physiological data takes time and requires that researchers be precise and reliable (Cacioppo et al., 2000; Potter & Bolls, 2012). Furthermore, to interpret this data, one must have a deep understanding of the physiological mechanisms that isolate key relationships and response patterns (Potter & Bolls, 2012). However, these physiological measures are advantageous as they can be coupled with self-report measures to provide a fuller examination of how individuals process risk and efficacy information in the virtual storm surge experience (Cacioppo et al., 2000; Potter & Bolls, 2012; Witte, 1992). Understanding how interactive virtual environments affect users' cognitive and emotional responses is essential for evaluating the effectiveness of immersive risk communication tools.

The Defense Cascade, prompted by aversive stimuli, is evolutionarily advantageous as it drives animals and humans to respond appropriately to danger (Kozlowska et al., 2015). However, risk communication that elicits too much fear may be rendered ineffective as individuals may focus on retrieving information to protect themselves from the perceived threat instead of encoding and storing important risk prevention information embedded in the message (Clayton et al., 2018; Kozlowska et al., 2015; Lang & Bradley, 2013). Notably, a previous study employing a similar virtual storm surge sequence found that although individuals reported enjoying the virtual storm surge, they also reported feeling frightened and uneasy as the flood submerged them and their virtual home (Frank et al., 2025).

Given these self-reported mixed emotions, individuals are likely to experience coactivation of the appetitive and aversive motivational systems (Lang, 2006, 2009). Moreover, the present study utilized a modified, customizable VR experience specifically designed to elicit feelings of ownership over the virtual home. The pilot study also showed that the VR experience heightened users' risk perceptions and overall negative affect in response to the storm surge destroying their homes (Frank et al., in preparation). The EPPM and RISP models describe fear and negative affect precursors to individuals engaging in adaptive behaviors (Witte, 1992; Griffin et al., 2013). However, as outlined in the Defense Cascade, eliciting excessive fear and arousal can cause individuals to reject (fight response) or avoid (flight response) the message, leading them to fail to encode and store the relevant risk information the VR experience sought to provide (Clayton et al., 2018; Lang & Bradley, 2013; Witte, 1992).

These initial findings, which describe individuals' emotional and cognitive responses, along with the arguments presented in the EPPM and RISP models, are supported by the negativity bias (Cacioppo et al., 2000; Clayton et al., 2018; Lang, 2006). Thus, employing psychophysiological measures can help us uncover 1) how users respond to the VR experience in real-time, 2) the intensity of motivational system activation, measured through physiological arousal, and 3) how individuals allocate cognitive resources to encode and store information during the VR experience.

Cognitive resource allocation and physiological arousal will be measured through activation of the autonomic nervous system , which is involved in the processing of fear appeals (Clayton et al., 2018; Kozlowska et al., 2015; Lang & Bradley, 2013) and risk information (Barreda-Ángeles et al., 2021; González Javier et al., 2021; Schmälzle & Grall, 2020). The autonomic nervous system is a branch of the peripheral nervous system and comprises two sub-branches: the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system originates from a cluster of ganglia neurons in the spinal cord and is responsible for fight-or-flight responses (Potter & Bolls, 2012). Due to the sympathetic nervous system activating fight-or-flight responses, it is strongly linked to increased arousal via the activation of the aversive motivational system described in the defensive cascade (Kozlowska et al., 2015; Lang, 2006). The parasympathetic nervous system consists of neurons that begin in the brain and lower spine and send signals directly to the organs, bypassing the ganglia of the sympathetic nervous system. The parasympathetic nervous system is responsible for the "rest and repair" response and is associated with appetitive system activation, which leads to increased resources allocated to encoding and storing information (Clayton et al., 2018; Potter & Bolls, 2012).

More specifically, cognitive resource allocation is measured through *heart rate deceleration* that is indicative of resources being used to encode and store information as users engage in the virtual environment (Bradley et al., 2001; Clayton et al., 2019; Fisher & Weber, 2020; A. Lang, 2014). Interestingly, although it may be counterintuitive, previous research has found that changes in heart rate are indirectly associated with self-reported fear (Ordoñana et al., 2009). These findings align with our understanding of the connection between heart rate deceleration and the processing of aversive stimuli and the defense cascade, which suggests that when individuals perceive a threat, they allocate increased cognitive resources to respond to it (Clayton et al., 2019; Lang, 2014). Increased cognitive resource allocation during exposure to fear eliciting risk communication is supported by the assumptions that the EPPM and RISP models make regarding information processing (Griffin et al., 1999/2013; Witte, 1992). This psychophysiological response suggests that the message elicited a sufficient levels of perceived risk to prompt the active, systematic processing of the message predicted in the two models (Griffin et al., 1999; Kozlowska et al., 2015; Witte, 1992). This evidence shows that a VR experience can elicit a strong fear response (Frank et al., 2025) without harming an individual's ability to encode and store essential risk information.

Physiological arousal is measured through increased *skin conductance level.* which is analyzed by examining the conductance of the eccrine sweat glands. Scholars agree that this is associated with physiological arousal and self-reported fear (Cacioppo et al., 2000; Potter & Bolls, 2012), which is commonly referred to as electrodermal activity.

The qualitative study (Frank et al., 2025) suggested that the virtual storm surge experience has the potential to activate both the aversive and appetitive motivational systems (coactivation). Coactivation can enhance engagement and learning, but excessive activation of the aversive system may lead to defensive responses, potentially hindering the processing of important risk information (Clayton et al., 2019; Kozlowska et al., 2015; Lang, 2006). Given that 1) Frank et al., (2025) did not investigate whether the virtual storm surge elicited excessive aversive system activation nor how the VR experience affected how users processed the risk information, 2) the pilot study that showed customization of the virtual home was associated with increased risk perceptions (Frank et al., in preparation), and 3) the framework provided by the EPPM, RISP, and the defensive cascade; the following research question and hypothesis are proposed:

RQ3: How does the users' ability to customize their virtual home (customization present) in a virtual environment influence their cognitive resource allocation, as measured by heart rate deceleration over time, compared to those who did not customize their virtual home (customization absent)?

H4: Users in customization present condition will exhibit increased skin conductance levels, indicating heightened physiological arousal, during the storm surge experience compared to those in the customization absent condition.

CHAPTER 6

METHODS

This experiment will build on the initial pilot test by incorporating users' self-efficacy appraisal to accompany the risk information provided in the virtual storm surge sequence, examining how users' ability to customize their virtual coastal home affects their sense of spatial presence and overall risk perceptions of storm surges. Additional downstream effects on negative affect, perceived efficacy, and intentions to engage in risk prevention behaviors will be explored. Further analyses will investigate how users' reported psychological ownership of the virtual home serves as a core psychological mechanism that moderates their affective responses and intentions to engage in mitigation behaviors. Finally, psychophysiological measures will be employed to gain a deeper understanding of the underlying mechanisms, that occur when users experience the destruction of their virtual property in a storm surge and interactively practice implementing storm surge risk mitigation tactics in VR. Assessing cognitive resource allocation will provide insights into how users are attuning to the virtual storm surge sequence and physiological arousal indicates the intensity of users' emotional response to the experience.

Experimental Design and Participants

A two-condition (Customization present or absentbetween-subjects experiment was conducted in a controlled laboratory setting. All participants experienced the virtual storm surge experience presented in a head-mounted display (HMD; Meta Quest 3) using hand controllers. Participants were recruited using flyers and e-mail listservs that targeted undergraduate and graduate students, faculty, and staff of large university in the southeastern United States, as well as individuals that reside in the surrounding community. Eligible student participants received research credit for their participation. Data collection took place from April to June of 2025.

Stimuli

The virtual storm surge experience provided risk information and designed to be public-facing and distributed to coastal communities as part of a NOAA-funded research and outreach project. While the public-facing version of the VR experience contains a storm surge flood experience, users' ability to interact with the environment was limited to provide a more user-friendly experience for those unfamiliar with VR technology. Over the course of 15 months, the public-facing VR experience underwent significant modifications to create the two experimental conditions. The customization present condition was transformed into a highly flexible environment that allowed users to interact with and personalize the virtual home. The preset condition still had limited interactivity but allowed users to visually see the virtual home being unpacked and set up before the storm surge made landfall. Both the public-facing VR experience and the experience used in the present study were created using Unity 3D (unity). Designing and implementing modifications to the VR experience took place over the course of 15 months and was completed in August 2024.

The virtual storm surge experience is set in a scene where a user begins by entering their newly purchased coastal home ahead of an impending storm surge that they are unaware of. The experience takes place in the living room, which begins empty and undecorated. A narrator informs users in the customization present condition, “It’s time to make the home your own. Move around your living room and use your controller to point at the furniture and decorations to select pieces that fit your personal style." Next, a tutorial attached to the user's right controller teaches them how to personalize their space. The tutorial guides users through using a menu interface (attached to the left-hand controller) to place furniture, grab and move furniture pieces around the room, customize the colors of objects, and delete unwanted objects from the space. After completing the tutorial, users were given four minutes to finish personalizing their space.

In the customization absent condition, users completed a shorter tutorial that taught them how to teleport and change their view using the thumbstick on the right-hand controller. After users familiarized themselves with the controls, they passively watched for four minutes as the preset furniture was automatically placed around their living room (Figure 3). The duration of the decoration process for both conditions was purposefully kept constant to ensure the time spent in the virtual environment was controlled across both groups. After four minutes had passed, users in both conditions were alerted to the impending storm by a narrator: "Now take a look around your home. The furniture was heavy, and it took a lot of effort to set things up, but now it's your own space. You can envision hosting get-togethers and parties with friends and family here. While you were busy moving in, it looks like the rain and wind have picked up outside."

Figure 3. Image of the Customization process inside the virtual home.

As the storm surge began, the sky grew dark, and the sounds of wind and rain alerted participants that the storm was coming. The virtual home loses electricity, and users' right-hand controllers served as flashlights, allowing them to watch as the storm raged. Users soon heard their windows crash, and their home quickly flooded with water, damaging everything inside and leaving them trapped, unable to find higher ground. The water soon recedes, and participants were given a brief moment to survey the damage (Figure 4). The entire virtual storm surge experience lasted approximately seven minutes.

After users viewed their damaged home, they briefly responded to survey questions designed to assess how spatially present they felt in the virtual environment, the extent to which they felt ownership over the virtual home, their affective responses, and their risk perception of storm surges. Following this survey, users in both conditions completed the same VR-based efficacy experience. All users practiced enacting hurricane

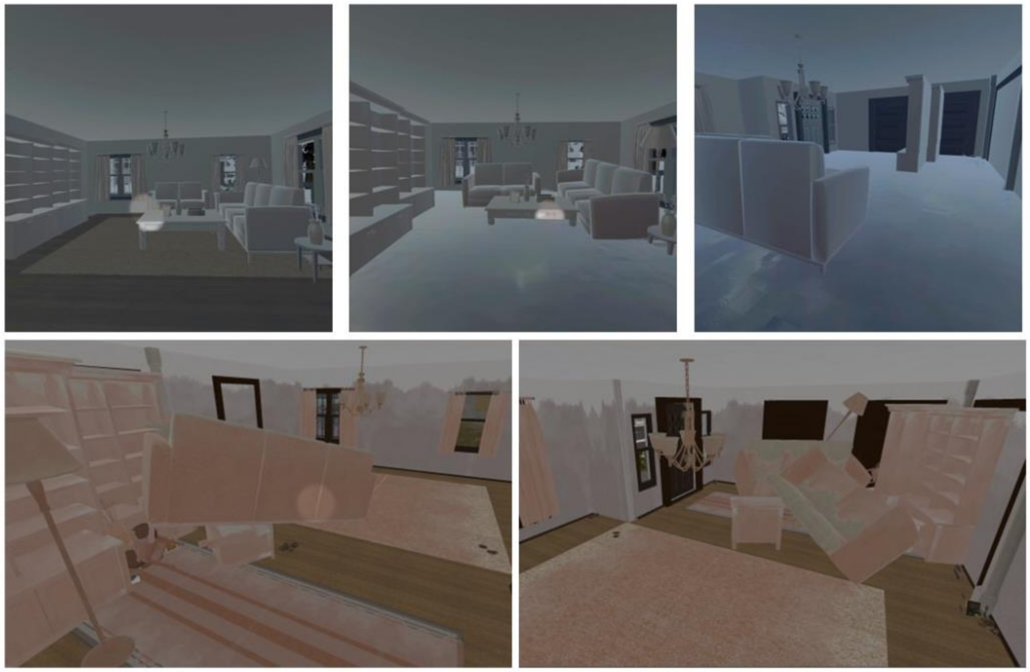

Figure 4. Storm surge sequence as it floods the virtual home (*top*) and the resulting damage to the home (*bottom*).

and storm surge risk mitigation strategies in VR to receive efficacy information. The second part of the public-facing VR experience was used to provide the users with the opportunity to interactively practice implementing five FEMA-recommended risk prevention strategies (FEMA, n.d.) including: 1) elevating their home, 2) purchasing flood insurance, 3) boarding up their windows, 4) packing an evacuation kit, and 5) following evacuation routes ahead of an impending storm (Figure 5). This was a guided, narrated, seated experience that lasted approximately eight minutes.

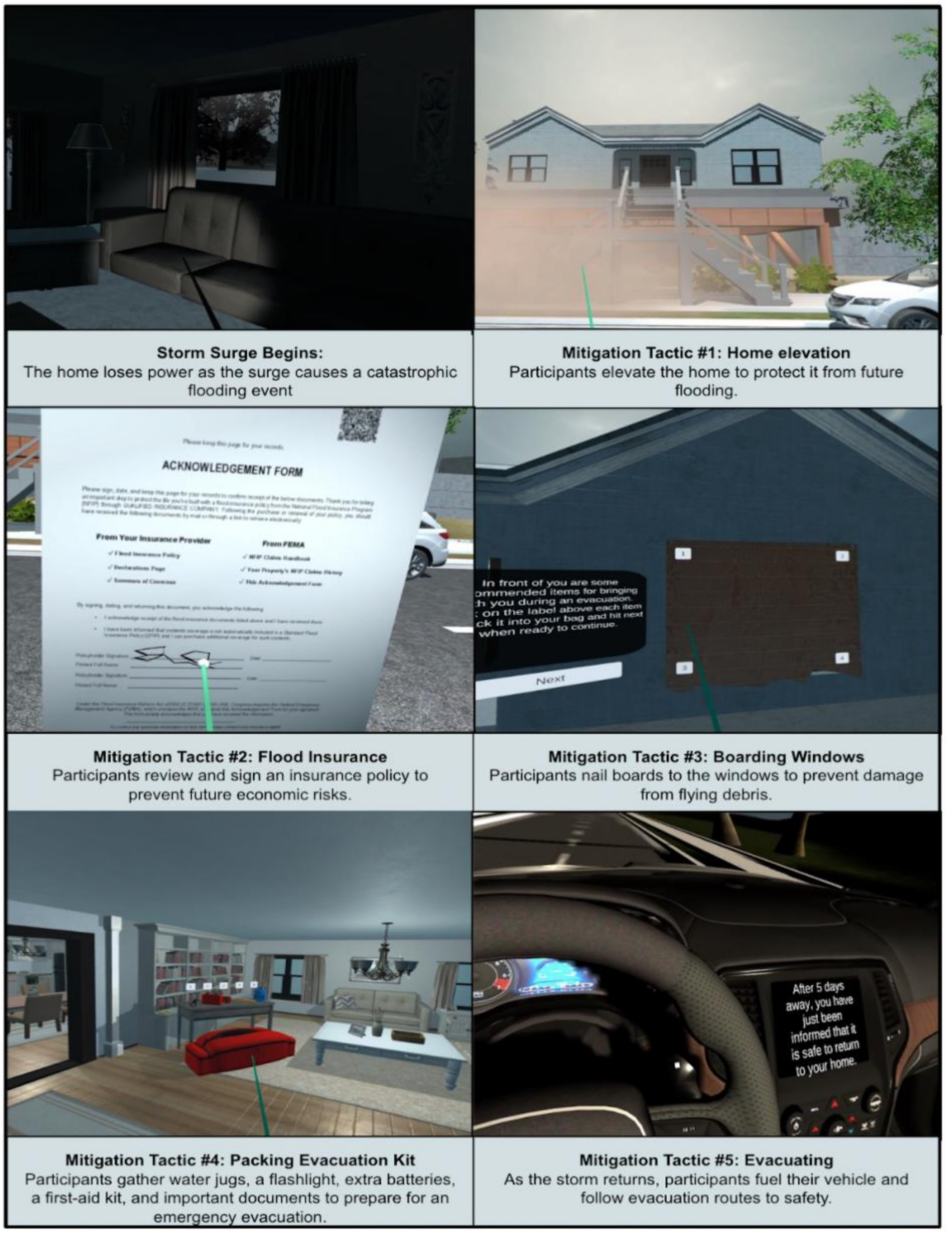

Figure 5. Storm surge mitigation tactics in VR.

Procedure

The study was approved following the requirements of the University of Georgia's Institutional Review Board (IRB ID: VERSION00004057). Participants expressed their interest in participating in the study by using the university's online SONA system participant pool, responding to flyers placed around campus, or to departmental and college email listservs. Once a participant reached out, they were sent a link that included additional information about the study and an option to choose a 45-minute time slot for their participation. When participants arrived at the lab, they were provided with a paper consent form that included further details regarding the study and were allowed to have their questions and concerns addressed before providing their written consent.

Participants were randomly assigned to one of the conditions (i.e., customization present or customization absent) before completing a pre-questionnaire to measure existing perceptions of the variables of interest and to collect relevant demographic information (i.e., gender, race, ethnicity, age, education, prior experience with VR and storm surges). Participants were then prepped to collect skin conductance level (arousal) and heart rate (cognitive resource allocation) measurements before beginning the VR experience.

After the storm surge sequence concluded (threat portion), participants responded to a brief online survey on iPad. This survey was designed to measure their feelings of *spatial presence, psychological ownership* of the home, *negative affect* in response to the destructive storm, and their *risk perceptions* of storm surges. Then, participants completed the VR second half of the experience (efficacy portion), where they practiced implementing storm surge risk prevention strategies. Once participants had finished the

VR experiences, all sensors were removed, and they then completed a post-experience questionnaire on an iPad. The post-survey questionnaire included questions related to participants' feelings of *spatial presence*, *perceived efficacy*, and behavioral intentions to engage in storm surge *risk prevention strategies*. Finally, all participants were formally debriefed on the purpose of the study before they provided consent for their self-report and physiological data to be used analyses.

Self-report Measures

The following key variables were measured through self-report to help explore individuals' responses to the virtual storm surge experience. Users' self-report responses were collected once following the threat portion and again after the efficacy portion of the experience.

Self-Report Measures: Post-Threat Survey

Spatial presence was measured directly after the storm surge sequence and adapted eight items from the battery established by Hartman et al. (2015), which were used to assess how present individuals felt in the virtual environment. Participants indicated how much they agreed or disagreed with the eight statements using a 7-point Likert type scale *(1= strongly disagree, 7= strongly agree)*. Four statements were used to measure self-location: "I felt as though I was physically present in the virtual environment," "It was as though my true location had shifted into the virtual environment," and "It seemed as though I actually took part in the action in the virtual environment." An additional four items measured action possibilities: "I had the impression that I could be active in the virtual environment," "The objects in the virtual environment gave me the feeling that I could do things with them," "I felt like I could move around among the objects in the virtual environment," and "It seemed to me that I could do whatever I wanted in the virtual environment." All eight items were averaged to create an index. (Cronbach' s α= .858; *M*= 5.12, *SD*= 0.93).

Risk perception was measured by adapting the following items to measure users' perceived severity of storm surges (Griffin et al., 1999; Witte et al., 1996), "I believe that the threat of storm surge is severe, "I believe that the threat of storm surge is serious," and "I believe that the threat of storm surge is significant." Additionally, the following items were adapted to measure individuals' perceived susceptibility to storm surges, "I am at risk of encountering a storm surge," "I will likely come across a storm surge," and "It is possible that I will be faced with a storm surge." Participants indicated how much they agreed or disagreed with risk perception items using a 7-point Likert-type scale *(1= Strongly disagree, 7= Strongly agree)*. All items were averaged to create an index (Cronbach' s α= .592; *M*= 5.53, *SD*= 0.68).

Psychological ownership is often measured across multiple dimensions to provide nuanced insights into how individuals feel a sense of ownership over their work, an object, or even a place (Ocklers et al., 2013; Piece et al., 2003). However, recent studies exploring the concept of psychological ownership in virtual and augmented realities have narrowed the focus to a few key dimensions: possession, control, identity, and responsibility (Jackson et al., 2024; Poretski et al., 2021; Wang et al., 2024). Therefore, this study focused on these key dimensions previously identified as important in virtual and augmented spaces.

Specifically, psychological ownership was measured by adapting items from Poretski et al., 2021 and asking participants to respond to a series of statements on a 7-point Likert scale *(1= strongly disagree, 7= strongly agree)*: "I had a feeling that the home in the virtual experience belongs to me," "I felt that I owned the home in the virtual experience," "This is MY home," "It is easy to think of the home in the virtual experience as MINE," "I had the right to customize the home," "I had the freedom of choice regarding how to move the home in the virtual experience," "I had the right to change the home whenever I choose to do so," "I felt a personal connection to the home in this," "I felt a bond with the home in this scenario," "I felt emotionally invested in the home in the virtual experience," "It was my fault if the home in the virtual experience is damaged by a storm surge," "I am accountable for anything that may have happened to the home in the virtual experience." Items were averaged to create an index of psychological ownership (Cronbach' s α= .872; *M*= 3.53, *SD*= 1.12).

Negative affect was measured by averaging responses to 13 discrete negative emotions items adapted from (Nabi et al., 2007). Participants will indicate the extent to which they felt each of the following emotions after the virtual home was destroyed in the storm surge using a 7-point Likert scale *(1= strongly disagree, 7= strongly agree)*: "distressed, sad, guilty, regret, lonely, afraid, worried, scared, disappointed, upset, angry, frustrated, and disgusted" (Cronbach' s α= .917; *M*= 3.89, *SD*= 1.18).

Self-Report Measures: Post-Efficacy Survey

Spatial presence was measured following the efficacy VR experience. For initial analyses, the same eight items and scale outlined above were used and were then averaged to create an index (Cronbach' s α= .911; *M*= 4.57, *SD*= 1.22).

Self-efficacy was measured by asking participants to indicate how confident they were in their ability to engage in the following storm surge risk prevention strategies on a 5-point Likert-type scale *(1=not at all, 5= extremely)*: "follow guidelines to protect

yourself and your family during a storm surge," "elevate your home to protect your life and property," "buy flood insurance to cover potential storm surge damage," "prepare an emergency evacuation kit at home," "evacuate when authorities give orders to evacuate," and "learn the best evacuation route before the next storm surge," (Choi & Hart, 2021; Witte et al., 1996). All items were averaged to create an
index (Cronbach' s α= .779; *M*= 4.01, *SD*= 0.56).

Risk prevention intentions were measured by asking participants to use a 5-point Likert scale *(1=Not at all, 5= Extremely)* to indicate how likely they are to engage in the following storm surge risk prevention actions adapted from Witte et al., 1996: "follow guidelines to protect yourself and your family during a storm surge," "elevate your home to protect your life and property," "buy flood insurance to cover potential storm surge damage," "prepare an emergency evacuation kit at home," "evacuate when authorities give orders to evacuate," and "learn the best evacuation route before the next storm surge" (Cronbach' s α= .803; *M*= 4.09, *SD*= 0.73).

Psychophysiological Measures

All psychophysiological data were recorded using a BIOPAC systems inc. BIONOMADIX wireless MP160 amplifier. All data were recorded with AcqKnowledge software (BIOPAC Systems Inc n.d.). Data were sampled at 2,000 Hz well above the Nyquist function of both heart rate and skin conductance level (Potter & Bolls, 2012; Cacioppo et al., 2007). Acqknowledge software was used to filter and clean the signal for each measure. Heart rate and skin conductance level data were collected throughout the exposure to the VR experience, but analyses focused on the 145-second storm surge sequence–i.e., the risk information. Additional analyses were performed on the key 20-

second interval when water from the surge entered the home and flooded the virtual home, rising above the participants' heads. New change scores were created for these additional analyses by averaging the 5-seconds of data prior to the onset of the surge entering the home. Manual event markers were used to mark 1) a five-second baseline period before the storm surge experience began, 2) the start of the storm surge sequence, and 3) when the storm surge sequence ended. During data collection, spectral analyses were conducted periodically to ensure minimal electrical noise was present in the data.

S*kin conductance level* was used to measure users' arousal levels, and *Heart rate deceleration* was measured as an increase in resource allocation associated with attention and cognitive processing (Cacioppo et al., 2007; Lang, 2014; Potter & Bolls, 2012). Tonic *skin conductance data* was recorded using the bipolar placement of two 8 mm (Ag/AgCl) shielded, floating electrodes placed on a non-dominant hand's hyperthyroid eminence, outer palm (Potter & Bolls, 2012). Before placing the EDA electrodes, a paper towel and distilled water were used to clean and prep the skin. After collection, data is then cleaned and processed using Acknowledge software (Biopac Systems Inc., n.d.).

Heart rate was measured by placing three 8mm Ag/AgCl floating, disposable Electrocardiogram electrodes on the torso in accordance with Einthoven's Triangle, with one of the electrodes to be used as a ground (Cacioppo et al., 2007). Before placing the ECG electrodes, a wet paper towel was used to clean and prep the skin (Potter & Bolls, 2012). Data were collected as milliseconds between the QRS complex within the electrocardiogram waveform (Cacioppo et al., 2007; Potter & Bolls, 2012) and averaged over 1-second intervals. The electrocardiogram signal was amplified using a gain setting of 5K with low and high pass band filters set to 30 and 1hz, respectively (Clayton et al., 2019; Potter & Bolls, 2012). Heart rate data were then converted into beats per minute (BPM).

Preprocessing of Psychophysiological Measures

Preprocessing for electrodermal activity and electrocardiogram data was done offline after data collection was completed. Heart rate data underwent manual inspection for irregularities offline, and any missing data will be replaced with the average heart rate for that period. Specifically, any change of 20 beats-per-minute (BPM) or more from the previous interval was treated coded as an abnormality and the BPM value was changed to match the BPM values that surrounded the abnormality. Any participant with over one-third of their data points (49 times) coded as abnormal was removed from the sample for insufficient quality data. For this reason, 11 participants were removed from the dataset, resulting in the final n= 56 heart rate analyses.

Electrodermal activity data was down sampled from the original frequency (2,000 Hz) used during data collection to 62 Hz, as electrodermal activity is a slower signal (Potter & Bolls, 2012). Due to participants' mobility during data collection, the electrodermal activity data experienced signal dropouts, which occurred when a participant's back was when they traveled too far from the amplifier. The electrodermal activity data was inspected and corrected for signal dropouts using Acqknowledge software's *connect endpoints* function. This technique allowed these dropouts to be connected while preserving the normal fluctuations of the physiological data. Signal dropouts occurred in 90% of the sample. Participants with a significant amount of signal dropout that required over 1/3 of data points to be changed were removed from the sample.

Additionally, any participant with negative values was considered invalid, as electrodermal activity signals can never truly be negative (Cacioppo et al., 2007). Finally, change scores representing changes from the baseline values are calculated and used for analysis (Potter & Bolls, 2012). These pre-processing steps resulted in 26 participants being excluded from the data, leaving a final $n = 41$ to be used in analyses. See Appendix A for further details on preprocessing steps.

Analytical Plan

IBM SPSS software version 29 was used to conduct all analyses. Independent-sample *t*-tests were conducted to address H1 and H2 to determine how the conditions affected individuals' feeling of ownership over the virtual home and their perceived risks of storm surges. Additionally, Hayes PROCESS 3.3 (Hayes & Matthes, 2009) was utilized to address the remaining hypotheses and research questions regarding individual's self-report responses. Specifically, a moderated mediation model (model 14) was conducted to address H3 and RQ1 that apply elements of the RISP model to examine how individuals reported negative affect may be explained by how spatially present they feel in the VR experience and how this relationship is moderated by their feelings of ownership over the virtual home (See Table 1). Post-hoc power analysis revealed the current sample will be able to detect medium to large effects ($f^2 = .17$) for the model proposed by H3 and RQ1. Additionally, a sequential moderated mediation model (model 87) was conducted to address H4 and RQ2. Post-hoc power analysis revealed the current sample will be able to detect medium to large effects ($f^2 = .21$) for the model proposed by H4 and RQ2. This hypothesis and research question apply principles of EPPM to investigate how individuals' feelings of spatial presence and efficacy appraisal influence their reported mitigation intentions and how these behavioral intentions are affected by individuals' feelings of ownership over the virtual home. Finally, repeated measures ANOVAs were used to address the final hypothesis and research question (RQ3 & H5) regarding underlying mechanisms that occur as individuals process the storm surge sequence.

Table 1. *Hypotheses and Research Questions*

Users' Self-Report Responses:
H1: Users in the customization present condition will report greater psychological ownership over the virtual home than users in the customization absent condition.
H2: Users in the customization present condition will report greater risk perceptions of storm surges than those in customization absent condition.
RQ1: How will users' psychological ownership of the virtual home affect the relationship between their feelings of spatial presence and their reported negative affect? (Figure 1)
H3: Spatial presence and perceived self-efficacy will sequentially mediate the relationship between experimental conditions and users' mitigation intentions. (Figure 2)
RQ2: How will psychological ownership affect users' perceived efficacy and their hurricane risk mitigation intentions? (Figure 2)
Users' Psychophysiological Responses:
RQ3: How does the users' ability to customize their virtual home (customization present) in a virtual environment influence their cognitive resource allocation, as measured by heart rate deceleration over time, compared to those who did not customize their virtual home (customization absent)?
H4: Users in customization present condition will exhibit increased skin conductance levels, indicating heightened physiological arousal, during the storm surge experience compared to those in the customization absent condition.

CHAPTER 7

RESULTS AND FINDINGS

Self-Report Findings

Mean comparison reveals that users in the customization present condition reported greater psychological ownership over the virtual home (*M*=4.09, *SD*= 0.92) than those in the customization absent condition (*M*=3.02, *SD*= 1.05), $t(1, 65) = 2.33$, $p < .001$, $d = .99$. Thus, H1 is supported which replicates the results of the pilot study. However, the experimental manipulation (Customization absent: *M*=5.42, *SD*= 0.69; Customization present *M*= 5.52, *SD*= 0.67) did not significantly affect users risk perceptions of hurricanes and storm surges, $t(1, 65) = 0.12$, $p = .892$, $d = .68$. Thus, H2 was not supported (see Table 2). The overall fit of the moderated mediation model proposed in RQ1 was significant, $F(4, 62) = 4.16$, $p = .005$, $R^2 = .21$. The customization manipulation did not significantly impact users' feelings of spatial presence ($b = .16$, $bSE= .17$ $p = .633$) even when the dimensions of spatial presence (action possibility, self-location) were examined individually. Furthermore, the findings (See Table 3 and Figure 6) offered no support for the interaction between spatial presence and psychological ownership affecting users' reported negative affect ($b = .17$, $bSE= .13$ $p = .192$). However, the mediation model did reveal a significant positive relationship between psychological ownership and users' negative affect (Table 3). The absence of this interaction suggests that users' psychological ownership over the virtual home does not moderate (e.g., strengthen or weaken) the relationship between spatial presence and negative affect.

Table 2. *Means, Standard Deviations and t-test Statistics for Key Variables.*

	Customization present (n= 32)		Customization absent (n= 35)		ANOVA		
Variable	*M*	*SD*	*M*	*SD*	*t*	*df*	*Cohen's d*
<u>Post Storm Surge (Threat) Experience</u>						1,65	
Risk perceptions	5.42	0.69	5.52	0.67	0.17	1,65	0.68
Spatial presence	5.06	1.03	5.17	0.83	0.48	1,65	0.93
Psychological ownership	4.09	0.92	3.02	1.05	2.33***	1,65	0.99
Negative affect	4.11	1.21	3.71	1.14	0.11	1,65	1.18
<u>Post Risk Prevention (Efficacy) Experience</u>							
Spatial presence	4.29	1.34	4.81	1.04	0.89	1,65	1.19
Perceived self-efficacy	4.12	0.57	3.98	0.55	0.53	1,65	0.44
Risk prevention intentions	4.06	0.74	4.14	0.72	0.42	1,65	0.73

*Note. N=67. *p <.05. ***p<.001*

Table 3. *Estimated Coefficients, Standard Errors (SE), indirect effects showing moderated mediation, bootstrap 95% confidence intervals for Negative affect.*

	Spatial presence		Negative affect	
	Coefficient (SE)	95% CI	Coefficient (SE)	95% CI
Constant	0.16 (.36)	[-0.55, 0.87]	3.85 (.49)	[2.86, 4.84]
Customization (present coded high)	-0.11 (.23)	[-0.56, 0.35]	-0.02 (.32)	[-0.66, 0.62]
Spatial Presence	———	———	0.16 (.17)	[-0.17, 0.49]
Psychological ownership	———	———	0.41 (.16)	[0.09, 0.72]**
Psychological ownership X Spatial presence	———	———	0.17 (.13)	[-0.09, 0.44]
	R^2= 0.003 F(1, 65) = 0.23 *p*= .633		R^2= 0.212 F(4,62) = 4.16 p= .005	
Conditional Effects at Moderator level *Psychological ownership*	Effect	*bSE*	Boot LLCI	Boot ULCI
-1.44(16th Percentile)	.01	.09	-0.12	0.09
0.11 (50th Percentile)	-.02	.06	-0.18	0.09
1.12 (84th Percentile)	-.04	.11	-0.23	0.15

*Notes. Customization present coded high in analysis; SE= standard error; CI= Confidence Interval. Bootstrap resampling= 10,000. ***p < .001.*

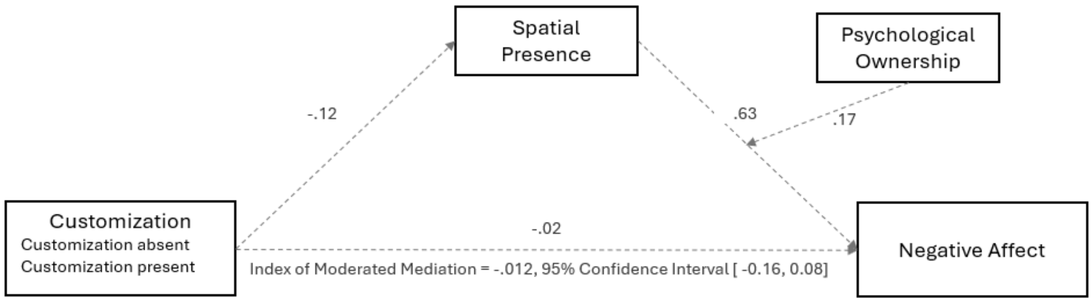

Figure 6. Moderated Mediation Results for RQ1.

Taken together, H3 and RQ2 posited a serial moderated mediation model that predicted 1) that spatial presence and perceived self-efficacy would sequentially mediate to increase users' risk prevention intentions and 2) psychological ownership would moderate the relationship between perceived self-efficacy and risk prevention intentions. The overall fit for users' risk prevention intentions was significant, $F(5, 61) = 5.43$, $p < .001$, $R^2 = .32$. There were significant direct effects (see Table 4) of customization on spatial presence (b = -.07, bSE= .19 p = .701). However, spatial presence did not significantly affect perceived self-efficacy (b = .09, bSE= .06 p = .10). In line with EPPM (Witte, 1992), perceived self-efficacy did significantly affect users' risk prevention intentions (b = .72, bSE= .15 p < .001). However, there was no significant interaction between self-efficacy and psychological ownership (b = -.08, bSE= .13 p = .555, see Figure 7)

Table 4. *Estimated Coefficients, Standard Errors (SE), indirect effects showing moderated mediation, bootstrap 95% confidence intervals for Risk prevention intentions.*

	Spatial presence		Perceived Self-efficacy		Risk prevention intentions	
	Coefficient (SE)	95% CI	Coefficient (SE)	95% CI	Coefficient (SE)	95% CI
Constant	5.34 (.46)	[4.42, 6.25]	-0.81 (.37)	[-1.55, -0.07]	3.91 (.49)	[2.91, 4.91]
Customization (present coded high)	-5.21 (.29)	[-1.11, 0.06]	0.25 (.14)	[-0.02, 0.53]	-0.07 (.19)	[-.45, 0.31]
Spatial presence	———	———	0.09 (.06)	[-0.02, 0.21]	0.07 (.07)	[-.07, 0.21]***
Self-efficacy	———	———	———	———	0.78 (.14)	[0.42, 1.01]
Psychological ownership	———	———	———	———	-0.10 (.09)	[-.28, 0.07]
Psychological ownership X Self-efficacy	———	———	———	———	-0.08 (.13)	[-.33, 0.18]
	R^2= 0.046		R^2= 0.743		R^2= 0.308	
	$F(1, 65)$ = 0.23 *p*= .08		$F(4,64)$ = 4.16 *p*= .005		$F(5,61)$ = 5.43 *p*< .001	

Conditional Effects at Moderator level *Psychological ownership*	Effect	*bSE*	Boot LLCI	Boot ULCI
-1.44(16th Percentile)	.83	.25	.33	1.34
0.11 (50th Percentile)	.71	.15	.42	1.01
1.12 (84th Percentile)	.63	.19	.01	1.03

*Notes. Customization present coded high in analysis; SE= standard error; CI= Confidence Interval. Bootstrap resampling= 10,000. ***p < .001*

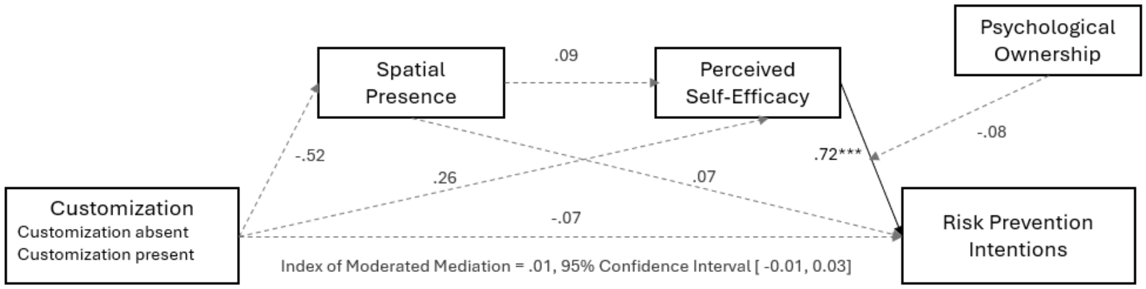

Figure 7. Moderated Serial Mediation Results for H3 and RQ2.

Psychophysiological Findings

Repeated measures ANOVA were conducted to address RQ3 and H4 that made predictions about users' physiological responses to the virtual storm surge. First, analyses were conducted to analyze the change of heart rate and skin conductance level for the entire 145 second period. In regard to RQ3, analyses indicated that the customization task did not significantly impact users heart rate during the experience, $F(1, 54) = 0.39$, $p = .54$, $\eta^2 = .007$. There was no significant effect of time, $F(1, 15.11) = 1.58$, $p = .072$, $\eta^2 = .028$ or an interaction between time and the customization task, $F(1, 15.11) = 1.09$, $p = .365$, $\eta^2 = .020$. Contrast analyses revealed a significant quadratic trend for the interaction of time and experimental condition, $F(1, 55) = 4.95$, $p = .03$, $\eta^2 = .084$ for users' heart rate throughout the storm surge experience. This quadratic trend showed that users' heart rate decreased during the most intense part of the storm surge experience before accelerating after the home was fully flooded (see figure 8).

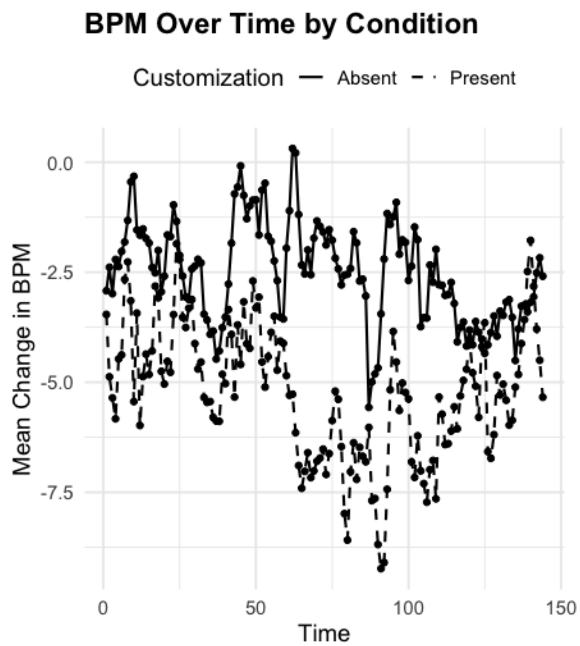

Figure 8. Mean change in Heart rate in Beats Per Minute (BPM) over 145 storm surge experience by experimental condition (*customization present*= **--** *customization absent*= —).

Additional repeated measures ANOVA analyses that focused on that 20-second period when the surge flooded the virtual home found there to be a significant between-subjects effect of the experimental manipulation on users' heart rate $F(1, 54) = 6.55$, $p = .013$, $\eta^2 = .108$. This between-subjects effect shows that users who customized their virtual home had a higher average decrease in heat rate during this period than those in the customization absent group (see Figure 9). There were no significant within-subjects effects found for time nor the interaction of condition and time (see Table 5).

Table 5. Repeated Measures ANOVA results for within and between subjects testing for the effects of time, the interaction of time and condition and, condition on Heart rate change (n= 56).

	SS	*df*	*MS*	*F*	*p*	η^2
Within-Subjects						
Time	624.85	4.89	127.85	1.35	.244	.024
Time × Condition	271.87	4.89	55.63	0.59	.705	.011
Error (Time)	24963.58	263.91	94.59			
Between-Subjects						
Intercept	407.843	1	407.843	0.86	.358	.016
Condition	3106.93	1	3106.93	6.55	.013*	.108
Error	25623.86	54	474.52			

In regard to H3, results indicated that the customization of the virtual home did not significantly affect users skin conductance level, $F(1, 37) = 0.92$, $p = .344$, $\eta^2 = .024$. There was no significant effect of time, $F(1, 23.21) = 1.25$, $p = .309$, $\eta^2 = .030$ or an interaction between time and the customization task, $F(1, 23.21) = 0.77$, $p = .773$, $\eta^2 = .020$. Additionally, unlike heart rate contrast analyses did not reveal any significant linear or quadratic trends. The repeated measures ANOVA conducted for the 20-second flooding period also indicated that users' skin conductance level did not significantly differ, $F(1, 37) = 0.92$, $p = .343$, $\eta^2 = .024$ between experimental conditions (see Figure

8). Again, there were no significant within-subjects effects found for time nor the interaction of condition and time (see Table 6).

Table 6. Repeated Measures ANOVA results for within and between subjects testing for the effects of time, the interaction of time and condition and, condition on Skin Conductance Level change (n= 41).

	SS	*df*	*MS*	*F*	*p*	η^2
Within-Subjects						
Time	0.036	10.02	0.004	1.16	.319	.030
Time × Condition	0.031	10.02	0.003	1.00	.446	.026
Between-Subjects						
Intercept	0.006	1	0.006	0.36	.552	.010
Condition	0.014	1	0.014	0.92	.343	.024
Error	0.569	37	.015			

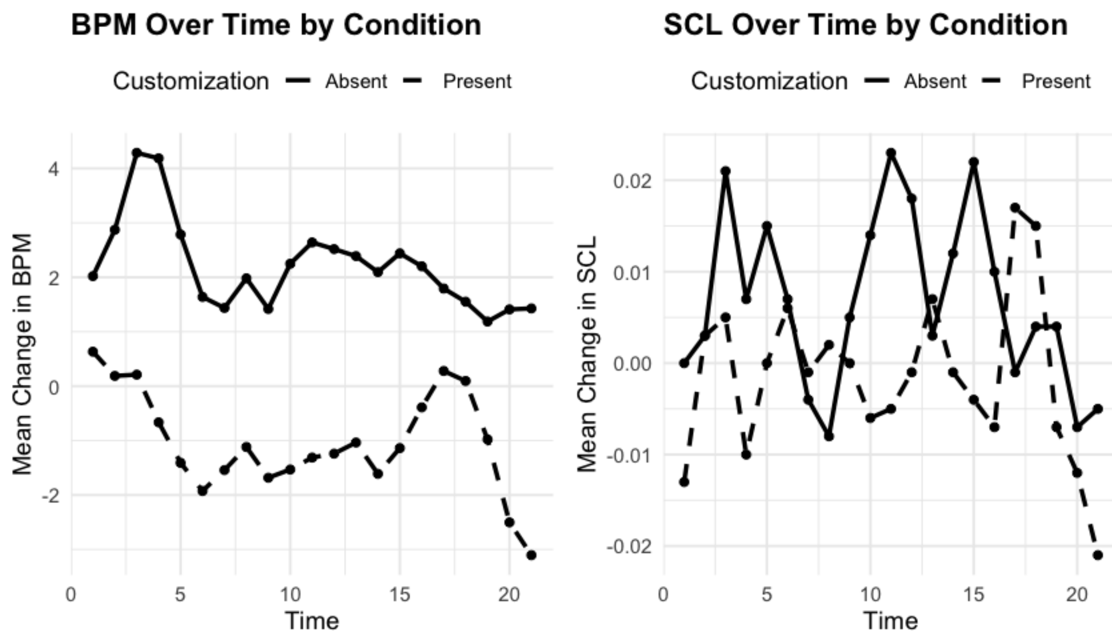

Figure 9. Mean change in Heart rate (*left*) in Beats Per Minute (BPM) and Skin conductance level (SCL) by experimental condition.

Post Hoc Exploratory Analyses

Given the importance that literature places on the role of spatial presence and the trends of increased spatial presence reported in the pilot study (Frank et al., in preparation; Lee et al., 2023; Wirth et al., 2007), presence was predicted to be the primary driver of user responses. As reported above, users in both conditions perceived similarly high levels of spatial presence. This null result may be attributed to all users experiencing the same visceral sensory cues of the virtual storm surge event (Frank et al., 2025). Therefore, there is a need to probe these results further to determine whether psychological ownership, rather than spatial presence, is shaping users' responses. Consumer psychologists and organizational communication scholars have found that psychological ownership acts as both a moderator and a mediator (Chang et al., 2012;

Mayhew et al., 2007; Van Dyne & Pierce, 2004). However, there is a dearth of literature on the role psychological ownership plays in risk communication processes and outcomes. Therefore, to properly answer the study questions and provide essential insights not available in the existing body of literature, it is crucial to conduct further analyses to uncover how users' feelings of ownership impact their responses to risk and efficacy information (Peirce et al., 2013). To investigate the effects of virtual psychological ownership on influencing users' responses to both the risk (i.e., storm surge sequence) and the efficacy information (i.e., practicing risk prevention behaviors in VR) in more detail, additional analyses were conducted. Specifically, analyses were conducted to examine whether psychological ownership explained users' perceptions and behavioral intentions, as opposed to moderating the effects of spatial presence. By narrowing the focus to the role of psychological ownership can help determine if the VR experience elicited emotional responses similar to those reported by natural disaster survivors). If these emotional responses are indeed similar, these findings can provide practical insights into how these virtual disaster simulations can be effective at delivering a realistic and impactful experience for users. Additionally centering users' psychological ownership, instead of spatial presence, allows for broader insights into how psychological ownership can affect risk communication efforts that employ other media than VR.

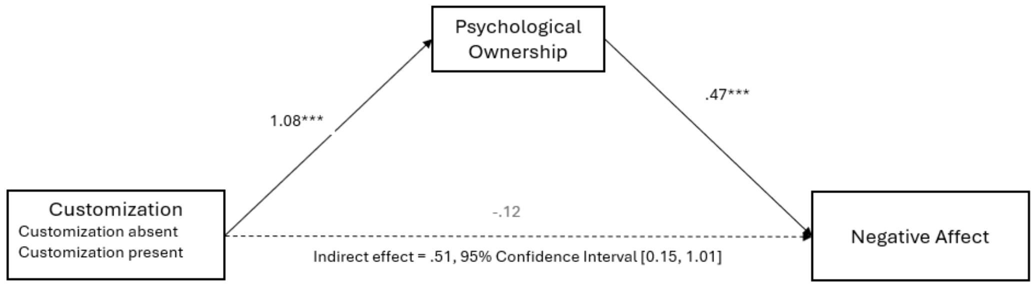

Figure 10. Mediation results for post hoc analyses examining the mediating role of psychological ownership on users' reported Negative affect.

First, a simple mediation model was conducted to determine if the significant model (PROCESS model 4) posited in the pilot study was replicated in the present study (Frank et al., in preparation). This model examined whether psychological ownership once again acted as a mediator that explained users reports of negative affect after their virtual home was destroyed by the storm surge (see Figure 10). Analyses of the direct and indirect effects (*b* = .51, *bSE*= .22; 95% CI [0.16, 1.01]) revealed that this original model was fully replicated (See Table 7).

Table 7. *Estimated Coefficients, Standard Errors (SE), indirect effects for simple mediation, bootstrap 95% confidence intervals for Negative affect.*

	Psychological ownership		Negative Affect	
	Coefficient (SE)	95% CI	Coefficient (SE)	95% CI
Constant	1.94 (.38)	[1.19, 2.69]	2.41 (.49)	[1.42, 3.39]
Customization (present coded high)	1.07 (.43)	[0.59, 1.56]***	-0.12 (.31)	[-0.72, 0.49]
Psychological ownership	———	———	0.47 (.14)	[0.19, 0.75]**
	R^2= 0.234 F(1, 65) = 19.86 *p*<.001		R^2= 0.181 F(2,64) = 7.06 *p*= .001	
Indirect and Total Effects	Effect	*bSE*	Boot LLCI	Boot ULCI
<u>Indirect Effect</u>				
Customization→PO→Negative affect	.51	.22	0.15	1.01
<u>Total Effect</u>				
Customization	.39	.29	-0.18	0.97

Notes. Customization present coded high in analysis; PO= Psychological ownership; SE= standard error; CI= Confidence *Interval. Bootstrap resampling= 10,000. **p <. 01. **p<.001*

Given these results placing psychological ownership once again in a mediating role, the serial mediation model hypothesized in H3 and RQ2 was revised and re-analyzed (see Figure 11).

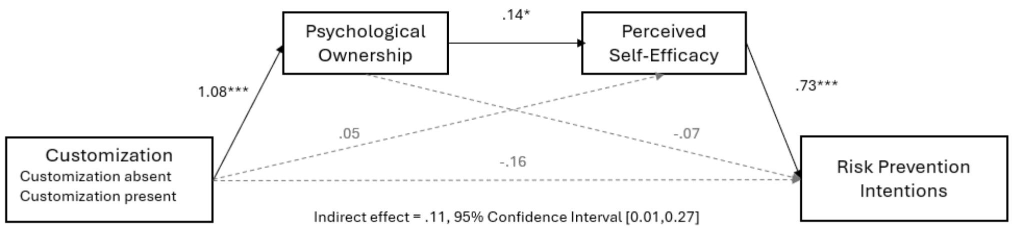

Figure 11. Serial mediation results for post hoc analyses examining the mediating roles of Psychological ownership and Self-efficacy on users' Risk prevention intentions.

A serial mediation model (Process Model 6) revealed that users' psychological ownership over the virtual home led them to feel more confident in their ability—i.e., perceived self-efficacy—to enact the risk prevention strategies that they practiced in VR, which was positively associated to users' intentions to engage in risk prevention strategies (Indirect Effects $B = .11$, $SE = .07$; 95% CI [0.14, 0.27]) in the physical world (See Table 8).

Table 8. *Estimated Coefficients, Standard Errors (SE), indirect effects showing sequential mediation, bootstrap 95% confidence intervals for Risk prevention intentions.*

	Psychological ownership		Perceived Self-efficacy		Risk prevention intentions	
	Coefficient (SE)	95% CI	Coefficient (SE)	95% CI	Coefficient (SE)	95% CI
Constant	1.94 (.38)	[1.19, 2.69]	3.49 (.25)	[3.01, 3.98]	1.61 (.58)	[0.45, 2.76]
Customization	1.08 (.24)	[0.59, 1.56]***	.05 (.15)	[-0.25, 0.36]	-.16 (.18)	[-0.51, 0.19]
Psychological ownership	———	———	.14 (.07)	[0.01,0.28]*	-.07 (.08)	[-0.23, 0.09]
Self-efficacy	———	———	———	———	.73 (.14)	[0.44,1.02]***
	R^2= 0.234		R^2= 0.10		R^2= 0.293	
	F(1, 65) = 0.23 *p*< .001		F(4,64) = 3.43 *p*= .038		F(3,63) = 8.69 p< .001	

Indirect and Total Effects	Effect	*bSE*	Boot LLCI	Boot ULCI
<u>Indirect Effects</u>				
Customization→PO→ Risk prevention intentions	-.07	.08	-.23	.11
Customization→Self-efficacy→Risk prevention intentions	.04	.12	-.20	.28
Customization→PO→Self-efficacy→risk prevention intentions	.11	.07	.01	.27
<u>Total Effect</u>				
Customization	-.08	.18	-.44	.28

*Notes. Customization present coded high in analysis; PO= Psychological ownership; SE= standard error; CI= Confidence Interval. Bootstrap resampling= 10,000. **p <. 01. **p<.001*

CHAPTER 8

DISCUSSION FOR EXPERIMENTAL RESULTS AND FINDINGS

This experimental study investigated how eliciting psychological ownership over virtual objects and locations could influence users' processing and responses to a VR experience designed to communicate the risks of storm surges. The VR experience aimed to evoke a sense of ownership by incorporating customization features that allowed users to decorate and personalize their virtual home. The experiment then examined how users responded cognitively, emotionally, and physiologically as they (1) experienced a catastrophic storm surge and (2) practiced implementing risk prevention strategies to protect their virtual home from future storms. Although psychological ownership was initially expected to moderate and amplify users' responses, post hoc exploratory analyses revealed that it played a more central role in shaping users' affective reactions, perceived efficacy, and behavioral intentions.

General Findings

As expected, users who customized their virtual home felt greater ownership over the home. This finding replicates the pilot study and is in line with literature that emphasizes the importance of perceived control and identity extension when seeking to foster psychological ownership (Peck & Shu, 2018; Peirce et al, 2018; Watkins et al., 2016). As findings suggest, enabling users to decorate the virtual home to their personal taste with customizable virtual objects provided them with a sufficient amount of control and identity extension to foster psychological ownership. However, the customization element did not significantly increase users' risk perceptions of storm surges. This finding could be due to the in-land sample that is not at risk of experiencing a storm surge in their current residence. Additionally, reported risk perceptions were relatively high across both conditions, which suggests that the virtual storm surge sequence was sufficient to elicit high-risk perceptions regardless of the customization capacity of the virtual environment.

Despite the customizable VR condition's increased interactivity providing users with more opportunities for action possibilities, allowing them to feel more located in the virtual home, it elicited marginally less spatial presence than the customization absent condition. This finding has two possible explanations. First, all users experienced the same virtual storm surge sequence that has previously been shown to make users feel highly present, some even describing feeling intense fear as the surge waters rise (Frank et al., 2025). The virtual storm surge had a high level of interaction fidelity as it was carefully constructed to mimic a real-life catastrophic flood. The sounds and visuals were designed to provide users with a potent sensory experience and enhance the perceptual realism of the experience. Importantly, VR experiences that optimize perceptual realism and interaction fidelity can significantly increase how present users feel in the virtual environment (Lombard & Ditton, 1997; Slater & Wilbur, 1997; Wirth et al., 2007). Thus, the intense virtual storm surge experience may be the primary driver of spatial presence, rather than the customization task that preceded it.

Second, this insignificant finding may be attributed to the sample's lack of VR experience and the cognitive load of the interactive task of customization. Previous research suggests that novice users generally report less presence than experienced users due to the increased effort needed to learn how to interact with the environment (Brade et al., 2017; Gamito et al., 2010; Lombard & Ditton, 1997; Sacau et al., 2007; Witmer & Singer, 1998). Due to the increased interactivity and task—e.g., customizing the virtual home—requiring the use of various controls to select, place, and customize the virtual objects, these novice users may have been too focused on learning the interface and controls for customization rather than focusing on the activity of personalizing their virtual home.

Spatial presence did not drive users' negative affect when the storm surge destroyed their virtual home, nor did psychological ownership moderate this relationship. This finding suggests that user's spatial presence was not explaining their negative emotional responses to their virtual home being destroyed. Users' spatial presence during the efficacy portion of the VR experience did not significantly boost their perceived self-efficacy. This is in line with more recent VR research that suggests that eliciting presence alone may not be enough to drive attitudinal and behavioral attitudes and behaviors (Ahn et al., 2022; Herrera et al., 2018; Lee et al., 2023).

As expected, users' perceived efficacy was positively related to their intentions to engage in risk prevention strategies. This provides further evidence for the process described in the EPPM and RISP frameworks (Griffin et al., 1999; Witte, 1992). However, psychological ownership did not moderate this relationship. The body of literature surrounding psychological ownership encompasses various fields including consumer behavior, gaming, and organization communication (Van Dyne & Piece, 2004; Peck & Shu, 2018; Watkins et al., 2016). While psychological ownership has been shown to moderate consumer satisfaction and pro-environmental behaviors (Ding et al., 2021; Li & Atkinson, 2020; Wang et al., 2022), it has also been used as a mediator to explain why and how individuals develop their attitudes and perceptions (Jiang et al., 2021; Lee & Suh, 2015; Lee & Chen, 2011). Thus, this lack of an interaction could be due to psychological ownership acting as a mediator instead of a moderator. As there is a dearth of research on the effects of psychological ownership, much less virtual psychological ownership, in risk communication, post-hoc analyses explore this possible explanation further to determine if pilot study results are replicated.

Users' psychophysiological responses indicated that the customization manipulation affected users' cognitive resource allocation but not their physiological arousal. There was a significant interaction of time and condition that produced different quadratic trends for the user's heart rate during the 145-second storm surge sequence. This trend suggests that the customization manipulation affected how users allocated resources during the 20-second period of intense flooding. During this period, water from the surge entered the home and quickly rose above users' heads until their entire home was underwater. Additional analyses of this period indicated that users who customized the virtual home, and therefore felt more ownership over it, allocated more resources to cognitively attune to the storm as it destroyed their home.

This finding, in the absence of any effects on users' physiological arousal, can be indicative of multiple things. First, similar to the null findings for effects on spatial presence and risk perception, the virtual storm surge sequence may be sufficiently intense to activate users' aversive motivational system (see Frank et al., 2025). However, the act of witnessing a personalized virtual space being destroyed did not significantly elevate users' arousal levels. Visual inspection of the trend of the skin conductance level (see Figure 8) suggests that users in the customization absent condition exhibited a greater increase in arousal levels compared to those in the customization present condition. Additionally, the quadratic trend for users in the customization absent group showed their heart rate accelerated, indicating a decrease in cognitive resource allocation during the intense period of threat. Additionally, a quadratic trend in heart rate indicated that users in the customization-absent condition experienced heart rate acceleration during the storm surge, which is consistent with reduced cognitive resource allocation and a mobilization (fight-or-flight) response within the defense cascade. Thus, users in this condition had begun to devote resources away from cognitively encoding the environment and began to allocate resources to respond to the threat of the storm surge (Kozlowska et al., 2015; Lang & Bradley, 2013).

Conversely, users in the customization-present condition exhibited a significant decrease in heart rate and a non-significant decrease in skin conductance level, a pattern consistent with the freezing or immobility response. These users were still allocating cognitive resources to process the information and environment around them (Kozlowska et al., 2015; Lang, 2006). Overall, this interpretation of the data indicates increasing the personal relevancy of the risk such as developing customizable VR experiences 1) can lead to users allocating more resources to cognitively process risk information 2) does not cause users to become emotionally reactive to hinder their engagement with the risk information (Clayton et al., 2019 & Kozlowska e al., 2015).

Second, the customization process acted as a cognitive task that increased users' cognitive engagement, resulting in sustained resources allocated to encoding the environment during the threat (i.e., the storm surge sequence, Bradley et al., 2001; Lang 2014; Lang, 2006). However, viewing the customization process as a cognitive task that may have challenged users unfamiliar with VR suggests that these results could have been influenced by users' cognitive overload (Lang, 2006; Potter & Bolls, 2012). As investigating users' responses to the VR risk experience was the central focus of this study, no self-report, behavioral, or psychophysiological measures were employed to examine any potential cognitive overload specifically. Additionally, predictions regarding users' psychophysiological responses focused on their processing of the storm surge sequence. Therefore, any heart rate and skin conductance levels collected prior to the storm surge were not processed or analyzed, as participant movement and controller use is predicted to impede accurate collection of users' physiological responses. Importantly, available data do not suggest that the customization task induced cognitive overload during the virtual storm surge. Prior research suggests that sympathetic nervous system activation, marked by increased heart rate, or a sustained plateau in heart rate (Lang, 2006; Solhjoo et al., 2019) can signal cognitive overload. The significant u-shape quadratic trend present in the data suggests that users' heart rate is still variable and that they are not cognitively overloaded (see Figure 8).

The argument that the customization task resulted in sustained cognitive resource allocation is further supported when considering that the development of psychological ownership engages primarily cognitive rather than emotional processes (Peck & Luangrath, 2023). The increased allocation of cognitive resources, in the presence of relatively steady physiological arousal, suggests that the customization process may have prompted these users to systematically process the risk information without experiencing excessive arousal. This pattern is in line with EPPM and RISP models that posit that effective risk communication should elicit optimal levels of arousal and fear so that individuals are motivated to engage with the essential risk mitigation information (Griffin et al., 2013; Witte, 1992). When arousal and fear responses are sufficient, but not excessive, they aid in the cognitive processing of risks that is associated with individuals engaging in behavioral responses to control the danger of the risk rather than their intense fear(Witte, 1992; Griffin et al., 1999).

Post-Hoc Exploratory Analyses

The post-hoc analyses provided additional insights into how the psychological ownership cultivated through the customization process, as predicted in H1 (see Table 2), affected users' emotional responses, efficacy perceptions, and behavioral intentions. The first post hoc analysis replicated the model in the pilot study and showed that psychological ownership was the primary driver of users' emotional responses. This finding suggests that feeling ownership can lead to a strong emotional response when the target of that ownership is destroyed, consistent with disaster management literature and the RISP model, which predicts that heightened psychological relevance and perceived loss increase negative affect (Claire et al., 2021; Griffin et al., 1999; Paton, 2007).

In addition to increasing users' negative affect, psychological ownership also influenced how users responded to efficacy information after the hazard destroyed the object of their ownership. Specifically, psychological ownership was positively associated with users' perceived efficacy following the second VR experience. This finding aligns with our conceptualization of psychological ownership, which suggests that once individuals claim something as their own, they feel a responsibility to protect it from harm (Freedy et al., 1992; Olckers, 2013). Consequently, this motivation helps enhance users' confidence in their ability to implement the risk prevention strategies they practiced in VR.

This increased self-efficacy was once again positively related to users' intentions to engage in risk prevention strategies. This positive relationship between perceived efficacy and behavioral intentions here highlights the connection between the perceived responsibility dimension of psychological ownership and the core tenants of the EPPM. This finding demonstrates how a strong sense of ownership increases perceived efficacy to protect the virtual home and motivates risk prevention behaviors (Lee et al., 2023; Sayre, 1994; Witte, 1994). These frameworks explain how emotional and cognitive appraisals interact to shape individuals' responses to threats and encourage effective risk prevention. These post hoc analyses focused on psychological ownership to provide nuanced insights into how it influences users' emotional responses, self-efficacy perceptions, and behavioral intentions. The findings align with the RISP and EPPM models, as well as literature on risk communication, psychological ownership, and disaster management.

Strengths and Limitations

One of the core strengths of this work is its interdisciplinary approach, which combines psychological ownership, fundamental risk communication theories, psychophysiological measures, and virtual reality (VR) technology. The EPPM and RISP models provided a solid foundation for the more exploratory aspects, helping to ground the findings within the large body of risk communication literature. The experiment design allowed for a close examination of the effects of the VR experience on users' emotional responses, efficacy perceptions, and behavioral intentions. Additionally, the psychophysiological measures allowed for a deeper inspection of the underlying processes that occurred as users completed the VR experience.

However, all studies have limitations, and this project is no different. First, the relatively small, in-land sample may harm the generalizability of these findings. The sample size for the psychophysiological measures was further constrained due to electrical signal drop and movement artifact (e.g., noise in the signals due to users' movement during the VR experience). Due to these signal dropouts, data was reconciled manually using data from before and after signal dropouts to replace missing data, and even though best practices were followed (Cacioppo et al., 2007; Potter & Bolls, 2012), this process still augments users' physiological data. Furthermore, all events were marked manually using Acqknowledge's event marking system, which introduces potential human error causing the event timing to be less than exact. Lastly, the exploratory nature of using virtual psychological ownership in a risk communication context required post hoc analyses to better understand its role in shaping users' perceptions and behaviors. Future research should address these limitations by expanding sample sizes and include coastal residents who are more vulnerable to the risks posed by hurricanes and storm surges than the current sample.

Despite the limited, inland sample, the findings are encouraging as they indicated that 1) virtual disaster experiences can readily foster virtual psychological ownership and 2) psychological ownership can promote users to allocate increased cognitive resources to encoding risk information. Further, findings showed that when users develop feelings of ownership over a virtual space, they perceive themselves to be more capable of engaging in adaptive behaviors to protect their virtual property. Unlike Digital Twin technology, which aims to replicate a specific location, this VR experience is not tied to a single location and allows each user to customize their own experience to build feelings of ownership. Fostering psychological ownership over a virtual space can create a personalized experience for each user regardless of where they are located in the physical space, which allows for this VR experience to be widely implemented without needing significant content modification.

Implications for VR Development in Risk Communication

Findings from this experiment add to the growing body of work that provides empirical evidence for the effectiveness of incorporating VR technology in risk communication efforts (Frank et al., 2025; Lee et al., 2023; Mol et al., 2022). It builds on previous work that showed that virtual storm surge experiences can elicit strong emotions and significantly increase users' willingness to actively engage with information about the risks these storms pose, as well as their intentions to implement risk prevention strategies in the physical world (Bakhtiari et al., 2023; Frank et al., 2025; Mol et al., 2022). This study shows how readily users can develop psychological ownership over virtual objects. A brief customization task was sufficient to elicit feelings of ownership, this psychological ownership had significant impacts on their emotional responses and efficacy perceptions. While this finding has significant implications for VR development across all fields, in a risk communication context it underscores the importance of tailoring messaging and highlights how VR may be an effective way to create a personalized experience for each user (Bakhtiari et al., 2023; Frank et al., 2025; Fusco & Zhu, 2023).

The effect psychological ownership had on users' negative affect mirrors the responses observed in natural disaster survivors emphasizes the power of the technology to provide users with near first-hand experiences. By allowing users to safely experience the consequences of a risk, the risk becomes more tangible, which can reduce individuals' tendency to underestimate their risk (Ahn et al., 2022; Wirth e al., 2007). Furthermore, the immersive qualities of VR provide users with a valuable opportunity to practice responding to emergent and dangerous situations.

Due to the intense emotional responses users have reported when experiencing virtual disaster simulations there was concern that adding personalization might heighten these responses to the point that users are unable to effectively process the information. While users reported that the destruction of the virtual home caused them to experience negative emotions, the psychophysiological data suggest that this did not overwhelm their nervous system. In fact, these data suggest that the customization task and development of psychological ownership engaged users' cognitive processes. These users allocated more resources to process risk information (i.e., the storm surge sequence) cognitively without experiencing a significant increase in arousal, which can disrupt environmental encoding (Clayton et al., 2019; Kozlowska et al., 2013; Lang & Bradley, 2013).

Importantly, the EPPM and RISP models suggest that the cognitive processing of a risk is associated adoption of adaptive behaviors (Griffin et al., 1999; 2013; Witte, 1996). These findings are supported by the downstream effects psychological ownership had on self-efficacy and risk prevention behaviors. Thus, including customizable elements in VR experiences to elicit psychological ownership can be an effective way to increase users' engagement with risk and efficacy information. Overall, this study demonstrates how even minimal customization in VR can foster psychological ownership, enhance cognitive engagement, and promote adaptive responses to risk. These findings offer nuanced insights into how the unique qualities of VR can be harnessed to increase the effectiveness of risk communication efforts.

CHAPTER 9

CONCLUSION

The overarching objective of this research was to provide nuanced insights into how users cognitively and emotionally process risk and efficacy information within a customizable VR experience. As discussed in the previous chapter, these findings have important implications for understanding user responses to VR in risk communication, particularly from a media psychology perspective. Beyond theoretical contributions, this work offers practical guidance for emergency managers seeking to incorporate VR into community outreach efforts. Additionally, it lays a foundation for future research on virtual psychological ownership and its role in shaping risk-related attitudes and behaviors.

Practical Implications and Implementation Considerations

These findings have significant implications for how VR is used in future disaster management efforts. The ability of VR to provide custom experience for each user is incredibly advantageous for coastal leaders and emergency managers. This customization allows users to better resonate with the VR experience and invites them to implicitly draw connections between the virtual physical worlds. The psychological ownership that this customization elicits is a complex cognitive and emotional process that not only impacts how users respond to risk information but also has spillover effects that impacts their response to efficacy information. Due to the cognitive processes that underly the development of psychological ownership, users are also predisposed to actively process essential information emergency managers are disseminating.

These VR experiences also allow users to practice responding to a disaster and to witness the consequences of inadequate preparation. This immersive approach can help emergency managers communicate the importance of proper preparedness to inexperienced or desensitized residents in a tangible and personally relevant way. However, there are some crucial details emergency managers should consider when implementing VR technology in their disaster preparedness efforts.

First, as previously discussed, virtual simulations of disaster scenarios can elicit similar psychological and physiological responses as real-world disasters (Fraustino et al., 2018; Meijers et al., 2023; Mol et al., 2022). Exposing users to these experiences can cause them increased stress, which should be considered and mitigated. Additionally, there is a slight risk of eliciting a fear nature (biophobia) by exposing individuals to a potentially frightening event (Beall et al., 2023; Soga et al., 2023). The primary way to mitigate these risks is at the development and prototype stage. Testing the VR experience with small groups can provide essential insights into adjustments needed for users' comfort—e.g., lowering the flood waters so that they do not rise over user's heads (Frank et al., 2025). Additionally, providing clear information that details what an individual will experience in the virtual simulation will allow them to make an informed choice regarding their participation.

Second, the critical limitation of implementing VR in disaster management is the cost of development and distribution. Developing these VR experiences requires both a significant time and a significant financial investment. Developing these experiences requires access to a coding or game-engine software such as Unity, which can cost over $2,000 an annual license (Unity, n.d.). That does not include the costs of acquiring the necessary expertise/paying a professional to develop the experience. Further, to create an effective simulation, one must also obtain topical knowledge of the disaster and conduct usability prototype testing, which increases time and financial investment. Additionally, implementing the VR experience requires further investment. Purchasing hardware such as HDM is necessary. The popular Meta Quest 3 devices cost approximately $500 for each headset (Meta, n.d.). Altogether, the number of resources needed to develop a simulation of this kind is significant. These factors limit the feasibility of large-scale project implementation, as the more these projects are scaled up, additional hardware is needed. Thus, developing and implementing virtual simulations for disaster preparedness require substantial resources, expertise, and motivation.

Due to the significant investment required, a growing number of development teams have made the choice to make these VR experiences publicly available. The virtual experiences used as stimuli in this experiment were modified versions of existing VR experiences developed for a larger NOAA funded research and outreach project. These experiences were developed over the course of five years by an interdisciplinary team of researchers, VR programmers, and coastal educators. Several rounds of prototypes were developed and lab-tested to assess psychological effects and refine the user experience (Frank et al., 2025). To increase access to these materials are available to the public to download at no cost (see *Weather the Storm: A Life-Saving VR Simulation from Center for Advanced Computer-Human Ecosystems*). In addition to ensuring the materials are accessible, the project team is also partnering with public libraries throughout the southeast U.S. to provide increased access to the hardware needed to view the experiences. This distribution method illustrates one way the limitations of scaling VR can be addressed.

Future Directions

Future research should continue to explore how users develop psychological ownership over virtual objects and the impact it can have on users' responses to VR-based risk communication efforts. This research could include longitudinal studies that examine the effects of long-term interaction with virtual objects and how that may impact users' responses when those objects are destroyed by a disaster. Additionally, future research could utilize additional psychophysiological measures such as facial electromyography to examine users' negative affect through corrugator activity (Potter & Bolls, 2012).

Perhaps most importantly, more research is needed to examine these effects in the context of other types of natural disasters. A recent systematic review found that immersive technologies are commonly used to depict flooding scenarios and earthquakes, while less attention is devoted to tornados and heat waves that pose significant safety and health risks to a growing number of people (McAnirlin et al., under review). It is crucial for researchers and developers to continue advancing this emerging technology to depict a wide range of disasters, especially as the public's risk of encountering a natural disaster is at an all-time high.

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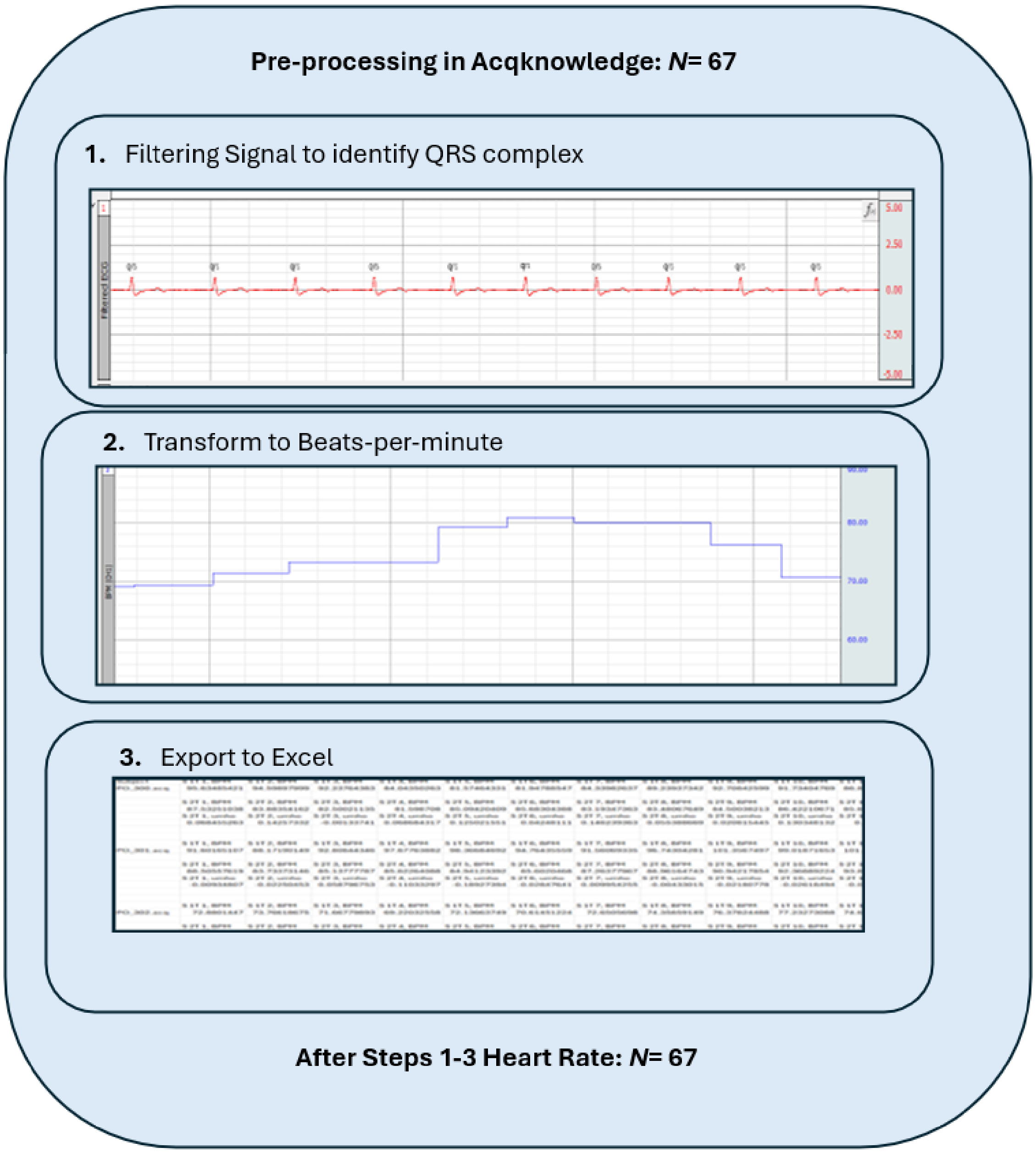
APPENDIX A

PREPROCESSING OF PSYCHOPHYSIOLOGICAL MEASURES

Heart Rate Data Preprocessing:



Pre-processing in Excel (Manual Inspection) *N*= 67

4. Change in 20 bpm for each interval was identified and highlighted

Subject	Condition	BPM Change	BPM1	BPM2	BPM3	BPM4	BPM5	BPM6	BPM7	BPM8	BPM9	BPM10
300	2	74.13865657	87.53251	83.883542	82.500211	81.59871	85.094204	85.68304	83.19347	83.48068	84.500382	86.422
301	1	88.09046676	88.50558	83.733731	85.137778	85.62264	84.941234	85.60205	87.26378	88.96165	90.942179	92.368
302	1	69.07568272	63.41408	59.575913	65.24283	63.29392	64.369559	67.28548	61.34122	57.32842	60.342216	54.557
304	2	84.14258303	93.07255	93.817057	93.830803	92.13758	86.926207	86.78038	87.46729	89.70963	92.338544	92.895
305	2	94.43292436	87.55468	87.115415	85.111504	90.03592	88.105875	85.53419	87.00503	89.71538	92.971176	95.455
306	1	65.14071708	64.93983	61.55595	61.197305	60.93726	59.450972	60.27148	60.27851	61.08751	64.243927	64.806
307	2	74.21043521	72.96844	77.38361	80.967872	76.84866	76.994024	78.33789	79.72393	82.72671	84.831313	86.167
308	2	114.295996	104.0212	104.02118	108.18734	110.4428	108.48647	107.7284	108.3502	107.5204	107.17989	103.33
309	2	78.64061462	71.77782	71.777825	[illegible]	[illegible]	[illegible]	71.77782	71.39259	73.94177	77.708099	82.652
310	1	72.71380079	66.1018	66.101796	65.271998	62.48805	60.165626	59.66774	60.40996	61.09666	62.982631	65.912
311	1	104.1185466	105.8093	102.06558	100.6826	104.526	103.37201	102.2807	102.6161	105.87	105.58722	105.16
312	1	70.94704385	72.26003	72.891816	[illegible]	70.84799	73.825617	74.03433	75.666	79.30087	[illegible]	79.751
313	2	88.66361708	84.65297	82.200483	79.786441	81.08075	83.522994	88.29694	91.8787	90.58107	88.671064	83.035

5. Irregularities changed to match the surrounding values.

Subject	Condition	BPM Change	BPM1	BPM2	BPM3	BPM4	BPM5	BPM6	BPM7	BPM8	BPM9
300	2	74.13865657	87.53251	83.883542	82.500211	81.59871	85.094204	85.68304	83.19347	83.48068	84.500382
301	1	88.09046676	88.50558	83.733731	85.137778	85.62264	84.941234	85.60205	87.26378	88.96165	90.942179
302	1	69.07568272	63.41408	59.575913	65.24283	63.29392	64.369559	67.28548	61.34122	57.32842	60.342216
304	2	84.14258303	93.07255	93.817057	93.830803	92.13758	86.926207	86.78038	87.46729	89.70963	92.338544
305	2	94.43292436	87.55468	87.115415	85.111504	90.03592	88.105875	85.53419	87.00503	89.71538	92.971176
306	1	65.14071708	64.93983	61.55595	61.197305	60.93726	59.450972	60.27148	60.27851	61.08751	64.243927
307	2	74.21043521	72.96844	77.38361	80.967872	76.84866	76.994024	78.33789	79.72393	82.72671	84.831313
308	2	114.295996	104.0212	104.02118	108.18734	110.4428	108.48647	107.7284	108.3502	107.5204	107.17989
309	2	78.64061462	71.77782	71.777825	71.777825	71.77782	71.777825	71.77782	71.39259	73.94177	77.708099
310	1	72.71380079	66.1018	66.101796	65.271998	62.48805	60.165626	59.66774	60.40996	61.09666	62.982631
311	1	104.1185466	105.8093	102.06558	100.6826	104.526	103.37201	102.2807	102.6161	105.87	105.58722
312	1	70.94704385	72.26003	72.891816	72.891816	70.84799	73.825617	74.03433	75.666	79.30087	79.300872
313	2	88.66361708	84.65297	82.200483	79.786441	81.08075	83.522994	88.29694	91.8787	90.58107	88.671064
314	2	28.62205673	67.62985	67.62985	67.62985	86.56761	85.697954	84.2857	84.18513	87.21482	87.723762

6. Participants with more than 49 data points (1/3 of the data) changed were dropped from the sample.

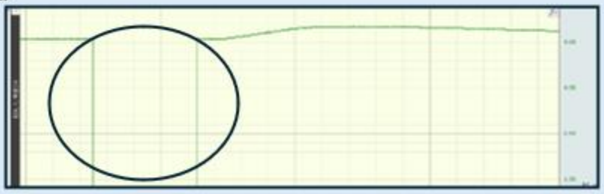
Subject	Condition	BPM Change	BPM1	BPM2	BPM3	BPM4	BPM5	BPM6	BPM7	BPM8	BPM9	BPM10	BPM11
300	2	74.13865657	87.5325104	83.8835416	82.5002114	81.598708	85.0942041	85.6830439	83.1934736	83.4806765	84.50038213	86.4221067	85.659196
301	1	88.09046676	88.5055762	83.7337315	85.1377779	85.6226409	84.9412339	85.6020468	87.2637797	88.9616474	90.94217854	92.3688922	93.602297
302	1	69.07568272	63.4140803	59.5759131	65.2428296	63.2939179	64.3695591	67.285479	61.3412247	57.3284156	60.34221594	54.5574856	57.528693
304	2	84.14258303	93.0725528	93.8170566	93.830803	92.1375784	86.9262072	86.7803845	87.4672871	89.709628	92.33854353	92.8955756	95.973916
305	2	94.43292436	87.5546818	87.1154152	85.1115041	90.0359193	88.1058747	85.5341918	87.0050335	89.7153765	92.97117611	95.455475	96.525188
306	1	65.14071708	64.9398258	61.5559495	61.1973051	60.937263	59.4509718	60.2714823	60.2785085	61.0875104	64.24392708	64.8065516	60.715639
307	2	74.21043521	72.968441	77.3836105	80.9678722	76.8486613	76.9940241	78.3378901	79.7239281	82.7267078	84.83131324	86.1673535	83.829833
308	2	114.295996	104.021179	104.021179	108.187339	110.44281	108.486467	107.728374	108.350238	107.520424	107.1798927	103.33694	102.55953
309	2	78.64061462	71.7778249	71.7778249	71.7778249	71.7778249	71.7778249	71.7778249	71.3925863	73.9417683	77.70809807	82.6523692	89.220507
310	1	72.71380079	66.1017965	66.1017965	65.271998	62.4880477	60.1656256	59.6677419	60.4099553	61.0966592	62.98263094	65.9127477	65.529763
311	1	104.1185466	105.809299	102.06558	100.682599	104.525957	103.372006	102.280749	102.616097	105.869977	105.5872164	105.163876	107.22477
312	1	70.94704385	72.2600333	72.891816	72.891816	70.6479677	73.825617	74.0343255	75.6660018	79.3008716	79.30087156	79.75177	80.308813

After Steps 1-7 Heart Rate: *n*= 56

Skin Conductance Data Preprocessing:

Pre-processing in Acqknowledge: N =67

1. 2,000 Hz signal down sampled to 62 Hz & Signal Dropouts Identified



2. The Connect End-points function was used to interpolate participants data during the signal dropout period.

Before:

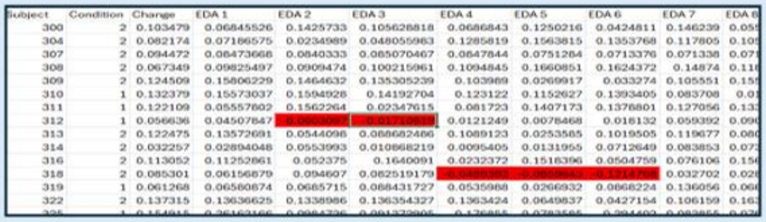
After

3. Participant data that required interpolation for more than 49 data points (1/3 of the data) were dropped from the sample before exporting data to Excel.

After Steps 1-3 Skin Conductance Level: *n*= 64

Pre-processing in Excel (Manual Inspection) *n*=

4. Participants with remaining negative values were removed from the sample as this data can never be truly negative.



Subject	Condition	Change	EDA 1	EDA 2	EDA 3	EDA 4	EDA 5	EDA 6	EDA 7	EDA 8
300	2	0.103479	0.06845526	0.1425733	0.105628818	0.0686843	0.1250216	0.0424811	0.146239	0.05
304	2	0.082174	0.07186575	0.0234989	0.048055963	0.1285819	0.1563815	0.1353768	0.117805	0.10
307	2	0.094472	0.08473668	0.0840333	0.085070467	0.0847844	0.0751284	0.0713376	0.071338	0.07
308	2	0.067349	0.09825497	0.0909474	0.100215961	0.1094845	0.1660851	0.1624372	0.14874	0.11
309	2	0.124509	0.15806229	0.1464632	0.135305239	0.103989	0.0269917	0.033274	0.105551	0.15
310	1	0.132379	0.15573037	0.1594928	0.14192704	0.123122	0.1152627	0.1393405	0.083708	0.0
311	1	0.122109	0.05557602	0.1562264	0.02347615	0.081723	0.1407173	0.1376801	0.127056	0.13
312	1	0.056636	0.04507847	[illegible]	[illegible]	0.0121249	0.0078468	0.018132	0.059392	0.09
313	2	0.122475	0.13572691	0.0544096	0.088682486	0.1089123	0.0253585	0.1019505	0.119677	0.08
314	2	0.032257	0.02894048	0.0553993	0.010868219	0.0095405	0.0131955	0.0712649	0.083853	0.07
316	2	0.113052	0.11252861	0.052375	0.1640091	0.0232372	0.1516396	0.0504759	0.076106	0.15
318	2	0.085301	0.06156879	0.094607	0.082519179	[illegible]	[illegible]	[illegible]	0.032702	0.02
319	1	0.061268	0.06580674	0.0685715	0.088431727	0.0535988	0.0266932	0.0868224	0.136056	0.06
322	2	0.137315	0.13636625	0.1338986	0.136354327	0.1363424	0.0649837	0.0427154	0.106159	0.16

After Steps 1-4 Skin Conductance Level: *n*= 41