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If a Virtual Tree Falls in a Simulated Forest, is the Sound Restorative? An Examination of the Role of Level of Immersion in the Restorative Capacity of Virtual Nature Environments

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IF A VIRTUAL TREE FALLS IN A SIMULATED FOREST, IS THE SOUND RESTORTAIVE? AN EXAMINATION OF THE ROLE OF LEVEL OF IMMERSION IN THE RESTORATIVE CAPACITY OF VIRTUAL NATURE ENVIRONMENTS

by

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ABSTRACT

Stress and cognitive fatigue have become a pervasive problem, especially in Western society. Stress and cognitive fatigue can have deleterious effects not only on performance, but also on one's physical and mental health. This dissertation presents a study in which the aim is to investigate the effects of virtual nature on stress reduction and cognitive restoration. Specifically, this study assessed the effects of Immersion (Non-immersive, Semi-immersive, Fully-immersive) and Exploration (Passive vs Active) on stress reduction and cognitive restoration. Additionally, restoration from the most effective virtual nature environment was compared to that of taking an active coloring break. Eighty-three university students with normal color vision, depth perception and good visual acuity participated in this study. The overall findings of the study suggest that virtual nature is able to reduce stress and anxiety, generally the more immersive and interactive the better. Moreover, though both the those in the passive VR nature condition and those in the coloring condition reported a reduction in stress, only those in the passive VR nature condition exhibited the physiological changes indicative of stress reduction.

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LIST OF ABBREVIATIONS

ANT	Attention Network Task
ART	Attention Restoration Theory
CNS	Connectedness to Nature Scale
DSSQ-S	Dundee State Stress Questionnaire Short Version
ECG	Electrocardiogram
HMD	Head Mounted Display
HR	Heart Rate
HRV	Heart Rate Variability
ITQ	Immersive Tendencies Questionnaire
PRS	Perceived Restorativeness Scale
SRT	Stress Recovery Theory
STAI	State Trait Anxiety Inventory
STM	Short Term Memory
SUS	Slater-Usoh-Steed (Presence Questionnaire)
SSQ	Simulator Sickness Questionnaire
UE4	Unreal Engine 4
VE	Virtual Environment
VR	Virtual Reality
WSD	Willingness to Suspend Disbelief

CHAPTER ONE: INTRODUCTION

According to the US Census Bureau (2015), more than half of the United States population live and work in cities. Though life in the "concrete jungle" has become so commonplace that many think little of it, there is a base of literature that indicates that such an environment is both stressful and mentally taxing (e.g. Guite, Clark, & Ackrill, 2006; Harris, Marett, & Harris, 2011; Kaplan, 1995; Kuo & Sullivan, 2001; Ulrich et al., 1991). As job demands continue to increase in both length (Hamermesh & Stancanelli, 2014) and complexity (Bresnahan, Brynjolfsson, & Hitt, 2002; Karoly, 2007) stress-related cognitive fatigue is an area of growing concern and increased interest to researchers.

One solution to this issue that has been suggested by researchers such as Kaplan and Kaplan (1989) is that directed attention fatigue might be reduced or mitigated through exposure to natural environments, and while the restorative powers of nature have only been a topic in the literature for the last three decades, the basic idea of nature as a restorative force has been a topic of interest and study for centuries. The works of Emerson (1836) and Thoreau (1854) and their contemporaries espoused the virtues of naturalism and the capacity of natural environments to restore and reenergize those who have been overworked and to provide a sense of wellbeing. These ideas began gaining traction at the beginning of the industrial era as more and more work opportunities were found in urban settings (i.e. factories), moving work away from nature and into the cities. Today that problem has only grown with many individuals working in critical, high stress jobs (i.e. medical professionals, 911 operators, air traffic controllers, military personnel, etc.) who have little or no opportunity to benefit from the possible benefits of nature exposure. The stress and mental fatigue caused by long periods of sustained work results in a myriad of mental and physical health consequences such as an increase in workload, anxiety,

heart rate variability, and errors in both judgement and performance (Boksem, Meijman, & Lorist, 2005; Herzog, Maguire, & Nebel, 2003; Kaplan, 1992; Olsson, 2010; Temple, et al., 2000). In an ideal world, these problems could be solved by simply suggesting that stressed and fatigued individuals spend more of their break or leisure time in natural settings, away from urban stressors, but for many people, this simply is not an option.

It is for this reason that recent research has focused on providing alternate methods of exposing people to nature to restore their cognitive capacity, reduce stress and increase positive affect. Although people have studied many different ways, such as the use of indoor plants (Bringslimark, Hartig, & Patil, 2009), viewing nature from a window (Tennessen & Cimprich, 1995; Holden & Mercer, 2014), and viewing images of nature (Berman, et al., 2008; Berto, 2005; Berto, Massaccesi, & Pasini, 2008; Claire, 2010; Emfield & Neider, 2014; Michaelis et al., 2011; Ulrich, 1981), the results are not conclusive on their restorative power. One reason for this may be the lack of immersion experienced by these static methods (Emfield & Neider, 2014; Michaelis et. al., 2011). As such, more recent research has focused on studying the effects of virtual representations of natural settings (Annerstedt, et al., 2013; Pals, 2011; Valtchanov, 2010; Valtchanov, Barton & Ellard, 2010). Additionally, Harrington et al. (2009) found that when the person is in control of his or her experience they find the experience more meaningful. As such, the aim of this study is to investigate the role of immersion in stress reduction and cognitive restoration as well as replicate the prior research finding that natural scenes are restorative. To do this, the current study will examine which level of immersion (non, semi, full) and level of interaction (passive, active) provides the greatest restorative effect.

CHAPTER TWO: LITERATURE REVIEW

Fatigue

Fatigue is a pervasive problem in our society. In fact, it is a frequently noted health complaint in Western society (Hockey, 2013; Lewis & Wessely, 1992; Nelson, et al. 1986). Fatigue can manifest itself emotionally, physiologically, or cognitively depending on both the person and situation at hand (Hockey, 2013). The focus of this dissertation will be on cognitive fatigue (also referred to as mental or attentional fatigue in the literature).

Cognitive fatigue can be due to many different factors. However, the two most notable factors are vigilance, or sustained attention over time (Kaplan & Kaplan, 1989; Parasuraman, 1998), and stress (Ulrich, 1981). Cognitive fatigue has been studied through many different cognitive tasks and physiological measures. These studies indicate that when people are cognitively fatigued they experience a myriad of physiological and mental health problems such as, increased workload (Cohen & Spacapan, 1976; Kakizaki, Oka, & Kurimori, 1992), anger (Kuo & Sullivan, 2001), stress (Hancock, 2013; Kocalevent, Hinz, Brähler, & Klapp, 2011), and negative affect (Grillon, Quispe-Escudero, Mathur, & Ernst, 2015), as well as reductions in task motivation (Chaudhuri & Behan, 2000; Holding, 1983; Hockey, 1997; Meijman, 2000; Tops, Lorist, Wijers, Meijman, 2004), heart rate variability (HRV; Olsson, 2010) skin conductance (De Kort,et al. 2006) and cognitive performance (e.g. Davies & Parasuraman, 1982, Matthews & Davies, 2001; Boksem, Meijman, & Lorist, 2006; Van der Linden, Frese, & Meijman, 2003). Fatigued individuals also have been found to have trouble with common tasks such as problem solving and planning, as well as other tasks that require executive functioning (Kaplan, 1995; Miyake, et al., 2000; Van der Linden, Frese, & Meijman, 2003).

Methods of Restoration

Attentional resources need to be maintained in the workplace and research has explored many ways to restore ones' cognitive resources and reduce stress. A summary of this research is provided below.

Exercise

Some of this research has focused on the restorative capacity of exercise. Exercise has been shown to have a restorative effect on stress and executive functioning (O'Leary, Pontifex, Scudder, Brown, & Hillman, 2011), however, these benefits generally occurred over time, as opposed to just a single bout of exercise (Colcumbe & Kramer, 2003; Etnier, et al. 1997). Additionally, the results of a meta-analysis indicated that exercising for periods of less than 30 minutes had no impact on executive functioning ability in older adults (Colcumbe & Kramer, 2003). Based on these findings, routine and consistent cardiovascular exercise can be a great way to restore ones cognitive abilities and reduce stress, however, more than 50% of Americans do not meet the Centers for Disease Control's (CDC) cardiovascular physical activity requirements (CDC, 2005). Some of the top reasons given for not exercising include, but are not limited to: lack of energy, lack of motivation, lack of safe places to exercise, and lack of time to exercise, etc. (CDC, 2011). Due to the fact that single bouts of exercise do not provide cognitive benefits and that people need to exercise at least 30 minutes a day on a routine basis to gain cognitive benefits, it appears that exercise is not the easiest or immediate answer to this problem.

Sleep and Meditation

One of the most traditional methods by which restoration occurs is through sleep (Baumeister, 2002; Kaplan, 1995), however, it is not an immediate solution to the problem. Another way to mitigate these effects is through meditation (Kaplan, 2001; Tang et al. 2007; Zeidan, Johnson, Diamond, David, & Goolkasian, 2009). Unfortunately, unlike sleep, mediation requires a lot of "practice, focus, and skill" (Kaplan, 2001, p. 483; Larkin, 1997), and learning how to meditate properly is both difficult and time consuming, which is not particularly helpful for the average individual who is fatigued.

Taking Breaks: The Use of Rest to Restore

Perhaps the most obvious way to restore depleted cognitive resources is simply to take a break: unlike exercise, breaks can be taken by anyone regardless of physical ability and, unlike sleep, the period of time needed for a break is relatively short. Like exercise or sleep, however, breaks allow for one to take their attention off the cognitively draining task and allow their minds to rest (Baumeister et al., 1998; Fritz, Ellis, Demsky, Lin, & Guros, 2013; Kaplan, 1995; Meijman & Mulder, 1998). Researchers have looked at the effectiveness of using short breaks from work to provide this restorative effect. Compared to participants tasked with focusing continuously, participants who employed short breaks for restoration demonstrated improved vigilance (Arrabito, Ho, Aghaei, Burns, & Hou, 2015; Fritz, et al., 2013; Finkbeiner, Russell, & Helton, 2016; Helton & Russell, 2015, 2017; Kanfer, Ackerman, Murtha, Dugdale, & Nelson, 1994; Lim & Kwok, 2015; Ross, Russell, & Helton, 2014) and affect (Fritz, et al., 2013), as well as reductions in workload (Ross, Russell, & Helton, 2014). Moreover, Helton and Russell (2015 & 2017) state that breaks are more effective when participants are provided with break length

and feedback on the amount of remaining time, because this allows participants to truly rest as opposed to remaining vigilant and wondering when the break will end.

Using Nature: A New Direction in Restoration Research

While breaks seem to be somewhat effective and practical as a cognitive resource restoration technique, there are alternatives that might provide greater restorative gains in shorter periods of time. A popular topic in the literature right now is the use of natural environments (i.e. forests, beaches, lakes, parks etc.) to provide restoration from stress and cognitive fatigue (e.g. Berman, Jonides, & Kaplan, 2008; Berto, 2005; Berto, Massaccesi, & Pasini, 2008; Ulrich, et al. 1991). Additionally, nature has also been found to increase positive affect and provide individuals with a sense of wellbeing (e.g. Hartig et al., 2003).

In addition to its ability to facilitate more rapid restoration than breaks, exposure to nature may also offer a number of mood-enhancing effects that make it a superior option for restoration.

Nature Explained

Dating far back, humans have realized that immersing oneself in nature restores the soul and increases overall wellbeing. The human affinity to nature can be explained by Wilson's (1984) psycho-evolutionary theory called the Biophillia Hypothesis. This theory posits that humans' positive response to natural environments is a product of our biological evolution, as we once lived in and gained all of our resources from nature. However, the urban environments in which most of the US population now lives and works are dominated by manmade objects (US Census Bureau, 2015).

Wilson's theory has been bolstered by research regarding people's preferences for visiting nature when stressed and/or cognitively fatigued over many other locations, stating that they feel more relaxed and less stressed when in nature (e.g. Berman, Jonides & Kaplan, 2008; Korpela et al., 2001; Hartig & Marcus, 2006; Hartig & Staats, 2006; Herzog, 1992; Herzog, Black, Fountaine, & Knotts, 1997; Staats, Kieviet, & Hartig, 2003; White et al., 2010). Although people's preference for visiting nature over urban environments when fatigued is undeniable, some researchers have found that some natural environments are preferred over others. For example, a number of researchers have found that most people prefer aquatic environments (i.e. lakes, oceans, streams, etc.) over green nature (i.e. parks, forests, etc.) (White, et al., 2010). In fact, people like aquatic environments so much that they are willing to pay more for houses and hotel rooms with views of water over views of green nature (Lange & Schaeffer, 2001; Luttik, 2000; White et al., 2010). This preference for green foliage and bodies of water have been said to stem from evolutionary survival (Kaplan, 1987, 1995; Ulrich, 1991; Van den Berg, Hartig, & Staats, 2007) as our ancestors evolved in nature environments. Environments that have an abundance of water and greenery were ideal locations to dwell, as the land could provide them with water to drink, and the opportunity to hunt, gather, fish, and bathe, among others (Kaplan, 1987, 1995; Ulrich, 1991).

Nature Based Cognitive Restoration Theories

As seen above there are many ways in which one can reduce or mitigate the effects of cognitive fatigue and stress, however, the most immediate way and the way that is getting much attention recently is restoration via exposure to natural environments. That being said, there are a few theories outlining the mechanisms by which nature restores, however the two most prevalent

in the literature are Kaplan and Kaplan's (1995) Attention Restoration Theory and Ulrich's (1991) Stress Recovery Theory. Both of these theories are based on evolutionary theory, such that human physiology developed in nature and as such can easily process natural content, as opposed to the manmade content that is found in abundance in urban areas. Although both theories are similar in that regard, they differ in what mechanisms are affected by nature to elicit a restorative effect.

Attention Restoration Theory

Kaplan and Kaplan's Attention Restoration Theory (ART; 1995) posits that natural environments are restorative due to the replenishment of attentional resources. According to ART, in order for an environment to be restorative it needs to contain the following four factors: being away, extent, compatibility, and soft fascination. In other words the environments needs to: (1) provide an individual with a mental or physical escape from the environment that is cognitively draining (*being away*), (2) provide an individual with the perception of *extent*, which Kaplan and Kaplan refer to this as the feeling of being "in a whole other world" (1995, p. 184), (3) it has to be *compatible* with one's needs and intended actions, and (4) it must elicit *soft fascination*, thereby grabbing ones attention in an effortless manner. Although Kaplan and Kaplan's theory posit that all four factors must be present to provide restoration, the majority of the current research focuses mainly on the latter factor "soft fascination".

The reason for the focusing strictly on soft fascination is because it best explains how ones attentional mechanisms are restored in natural environments. As previously mentioned, because humans evolved in natural environments our biological systems are able to process nature more efficiently than any urban or built environment. Soft fascination refers to the idea

that natural environments grab ones attention in an effortless manner through the use of involuntary attention, thereby conserving their attentional capacity to voluntarily direct attention to boring/uninteresting stimuli. When one directs one's attention to a particular task for a sustained period (voluntary attention), one becomes cognitively fatigued and natural environments are able to restore attentional capacity by grasping one's attention involuntarily, allowing for one's directed attention mechanisms a chance to rest and replenish (Kaplan, 1995).

Although nature can have restorative effects, it also has the potential to deplete one's attentional capacity as well. This is not normally the case but it can happen even in a setting that meets all of ARTs components except soft fascination. This generally occurs when there is a stimulus in nature that is too fascinating (e.g. rushing waterfalls, dangerous animals, etc.) requiring one to voluntarily direct one's attention to the stimulus (Herzog, Black, Fountaine, & Knotts, 1997; Kaplan, 1995; Kaplan & Kaplan, 1989; Staats, Kieviet, & Hartig, 2003). This is referred to as hard fascination.

Conversely, even though urban environments are notorious for being a source of cognitive fatigue due to a constant bombardment of stimuli demanding one's attention (i.e. traffic, car horns, ringing of cell phones, navigating through crowds, electronic billboards, flashing lights, etc.; e.g. Kaplan, et al. 1993; Hertzog, et al., 1997), they are in rare cases capable of providing all four factors of ART necessary for restoration. Built environments in which restoration has been found to be possible are places such as museums (Kaplan, Bardwell, & Slakter, 1993) and monasteries (Ouellette, Kaplan, & Kaplan, 2005).

Stress Recovery Theory

Ulrich’s Stress Recovery Theory (SRT) is similar to Kaplan and Kaplan’s ART in that they both are based on the notion that human physiology developed in nature and as such can easily process natural content, as opposed to manmade content. However, unlike ART where the replenishment of one’s attentional capacity is the source of restoration, SRT is more physiological in nature. Ulrich posits that it is ones initial affective response to an environment that determines whether or not an environment is restorative (Ulrich et al., 1991; Ulrich, 1993). He further states that aspects of nature that our ancestors needed for survival, such as water, expansive views, vegetation, etc. inherently elicit positive emotional reactions, which then inhibits negative emotions and reduces activity of the sympathetic nervous system, thereby reducing stress. This reduction in stress then leads to improved cognitive functioning (Ulrich, 1993).

The performance decrements of both stress and cognitive fatigue are discussed at length in the literature reviewed above, but it is important to also establish that the research has revealed a reciprocal relationship between these two constructs. Studies have found that increased levels of stress beget higher levels of cognitive fatigue (e.g. Hartig et al., 1991, 2003; Ulrich, 1981) and vice versa (e.g. Kaplan, 1995). Therefore, efforts to minimize levels of one of these detrimental constructs should also result in reductions of the other (Kaplan, 1995; Ulrich, 1981).

Presence in Nature

Numerous studies have found that when stressed and/or cognitively fatigued being present in nature generally as compared to urban environments, elicits various restorative effects (e.g. Berman et al. 2008; Kaplan, 1995; Hartig et al. 1991).

Upon closer review of the restoration literature, much of the research in which people are present in a natural or urban environment occurs while exercising in the environment (i.e. walking, running). In the literature this is often referred to green exercise (e.g. Pretty, Peacock, Sellens, & Griffin, 2005). For example, walking in natural environments have been shown to reduce stress (lower cortisol levels, reduced blood pressure & heart rate) (Bailey, Allen, Herndon, & Demastus, 2017; Gladwell, Brown, Wood, Sandercock, & Barton, 2013; Hartig et al. 2003; Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2010) increase positive affect (Berman, Jonides, & Kaplan, 2008; Berman et al., 2012; Hartig et al., 1991, 2003), and improve cognitive functions such as working memory (Backward Digit Span), inhibition (ANT), and concentration (Necker Cube) (Amicone et al., 2018; Berman et al. 2008, 2012; Hartig et al. 1991, 2003; Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009). These effects have also been found with individuals who have psychological disorders such as ADHD (Taylor & Kuo, 2009) and depression (Berman et al., 2012).

Even though exercise has been found in and of itself to provide many of the same benefits (Colcumbe & Kramer, 2003; O'Leary, Pontifex, Scudder, Brown, & Hillman, 2011), these results also hold true for non-exercise based interactions with the environment. Van Den Berg and Custers (2011) conducted a study in which they had participants either interact with nature via light gardening (e.g. pruning, weeding) or read a book indoors after completion of a stress inducing task and found that participants who gardened showed greater reductions in physiological stress (cortisol) than did the reading group. Ottoson and Grahn (2005) conducted a similar experiment in which they had older adults relax in an outdoor garden or in an indoor room and found that only those who spent time relaxing in the outdoor garden showed an increase in attentional capabilities. However, unlike Van Den Berg and Clusters (2011) they did

not find any reductions in physiological stress. This lack of significant reductions in stress may be the result of a ceiling effect, as the researchers did not induce stress before exposure to either experimental condition. Perhaps the reason that significant differences in attention capabilities were found was due to the fact that older adults tend to experience more cognitive declines in general, meaning that there was room for restoration.

Window View of Nature

During the day one is not always able to be present in nature to gain its restorative benefits. However, researchers have found that window views of nature can also provide health benefits across a wide range of settings. For example, those with window views of nature have been found to recover more quickly from surgery (Ulrich, 1984), and when in confined spaces (i.e. prison cells) make fewer trips to the infirmary (Moore, 1981; West, 1986), than those with a view of a brick wall or no view at all.

Not only have window views of nature provided physical health benefits, they have also been found to reduce stress and improve cognitive functioning. For example, Kahn et al. (2008) conducted a study in which they stressed participants via a battery of different tasks and then had participants either stare out of a window that overlooked nature or look at a blank wall, and they found that view of nature more rapidly reduced the participants heart rate as compared to staring at the blank wall for 5 minutes. Tennessen and Cimprich (1995) found that university students who had more natural views from their dormitory windows performed better on tests of directed attention than those with all urban or mostly urban views. Lastly, Holden and Mercer (2014) found that university students performed better on an exam when listening to the lecture in a

room with view of green nature than did students who listened to the lecture in a room with no windows.

Images of Nature

Although stress and cognitive fatigue can be mitigated by viewing nature from a window, not everyone is fortunate to have such views, if any view at all. Because of this, many have wondered whether the benefits of nature can be enjoyed by viewing images of nature, and studies have researched the effects of images of nature verses images of urban environments on stress reduction and cognitive restoration

In an early study, Ulrich (1979) found that viewing images of nature, as opposed to urban images, after taking an exam provided individuals with a better "mental outlook" and a self-reported reduction in stress and fear. A later experiment by Ulrich (1981) used more physiological measures to study the potential restorative effect of images of nature and found that when viewing vegetative nature (i.e. trees) participants had greater alpha activity than when viewing urban images. This increase in alpha activity is indicative of greater relaxation. Despite this finding, Ulrich did not find any significant differences in heart rate between the two conditions.

Other researchers have also studied the restoration of attentional resources via images. Berto (2005) found that images of nature can provide restoration from attentional fatigue, based on results of a pre and post sustained attention response test (SART). In this study participants were "fatigued" via the SART before viewing 25 images of natural environments (e.g. lakes, rivers, hills), urban environments (i.e. city streets, industrial areas, etc.), or geometrical patterns, for a maximum of 15 seconds each, then they completed the SART task again. Interestingly,

Berto (2005) found that regardless of exposure time, which varied, participants' performance improved from pre to post test, only after exposure to the images of natural environments. Furthermore, upon comparing urban and nature posttests, those who were exposed to nature images not only showed improvements in accuracy but also had a faster reaction time than those who viewed urban images. Berman, Jonides, and Kaplan (2008; Study 2) also studied the effects of nature verses urban images on attention abilities through the use of the Backward Digit Span (BDS) and the Attention Network Task (ANT). The results of the experiment further corroborated Berto's (2005) study in that they found significant improvement from pre to post test on the ANT. However, no significant differences in mood were found from pre to post test. Kaplan and Kaplan posited that one reason as to why nature is restorative is because it allows for one's attention resources a time to rest, through the use of involuntary attention. Berto, Massaccesi, and Pasini (2008) provided support for this notion through the use of eye tracking. They found that viewing urban images was more attentionally demanding (made more fixations) than viewing nature scenes, as they captured their attention effortlessly allowing for more exploration and fewer fixations.

Although this research on the use of images of nature to elicit restoration is valuable, these studies are not without their limitations. One such limitation is the lack of standardization of image quality and content (Larsen, 2011, Michaelis, 2013; White, et al. 2010). For example, the urban images used by Berman et al. (2008; Study 2) were approximately 3 to 4 decades old, as such many had low resolution, poor color and some fading, whereas the nature images that they used seemed to be much newer and of considerably higher resolution. This discrepancy in image quality can be considered a potential confound due to the fact that past stimulus degradation research has found that not only do people prefer non-degraded images over

degraded images regardless of content (Tinio, Leder,& Strasser, 2011), degraded images also require more cognitive processing than non-degraded images (Sternberg, 1967).

Another potential confound of Berman et al.'s (2008; Study 2) images, discussed in Michaelis (2013), was that there was a lack of standardization of content across both conditions. Some of the urban images were taken in inclement weather conditions or at night, whereas all the nature pictures were taken in optimal conditions during daylight hours. Additionally, Berman and colleagues did not rigorously control for manmade elements (e.g. benches, sidewalks, lampposts, etc.) in the nature images or natural content (e.g. trees, plants, grass, etc.) in the urban images. It can be argued that urban environments as a whole tend to have elements of green nature and places such as parks tend to have some manmade elements, as such using image sets that also incorporate these elements provides more ecological validity, however, without knowing exactly what dose of nature is necessary for restoration or where participants are looking in the images, incorporating these different elements can potentially influence the results. If one takes into consideration the discrepancies between picture types, it is entirely possible that their findings may have unknowingly been an artifact of the design.

In order to further study the effects of pictorial representations of nature as compared to urban environments Larson (2011), Emfield and Neider (2014) and Michaelis (2013) each conducted studies in which they controlled many of the aforementioned prior pictorial confounds. In doing so, they all found no significant differences in cognitive functioning between the urban and nature based picture sets. The lack of ability to replicate the results of prior research shed light on the fact that pictorial representations of nature may not be sufficient for restoration.

Perhaps static images of nature are not sufficient for restoration because they are not able to provide one with a sense of “being there”, as Kaplan states it is part of what makes an environment restorative (1995). His reference to being there is essentially the same thing as what the literature refers to as presence, ones subjective experience of being in a particular environment regardless of whether they are actually there physically or mentally (Sheridan, 1992; Witmer & Singer, 1998).

Videos of Nature

Nature environments are dynamic settings that cannot be accurately captured via images. As such, some studies have employed the use of video to better capture the complexities that nature has to offer.

The research that has examined the use of plasma HDTV displays to present real-time representations of outdoor natural environments (Friedman, Freier, Kahn, Lin & Sodeman, 2008; Kahn Jr. et al., 2008) has produced mixed results. Friedman, et al., (2008) found that people would prefer an office with a plasma window over an office with no window at all and that these technological windows increase self-reported cognitive functioning and wellbeing. However, Kahn Jr. et al. (2008) found that plasma windows do not provide any physiological health benefits above and beyond having an office with no window. Instead, they found a real window facing a natural environment was able to provide a reduction in stress, based on a rapid decrease in heart rate, as compared to a room with no view. The aforementioned studies did not include sound and it is possible that a more dynamic display coupled with sound would provide a more immersive experience for cognitive restoration to occur.

There have not been very many studies conducted using strictly video of nature. In fact, the early studies tended to use both still images coupled with environmental sounds to help re-create a walk in a nature versus an urban environment. For example, Van den Berg, Jorgensen, and Wilson (2014) conducted a study in which they used a combination of still images and 60 second videos of different environments to provide individuals with a sense of walking through a nature or urban environment, after being stressed by a scary video. They found that people reported increases in positive mood and perceived restoration when exposed to the simulated nature walks (parkland, tended woodland, wildwoods) as opposed to the simulated urban walk. However, the differences between natural settings themselves were non-significant even though there was a trend towards more restoration as "naturalness" increased. Laumann, Gärling, and Stomark (2003) found that viewing videos of a walk through a natural environment was able to not only provide restoration of one’s cognitive resources based on Posner’s Attention Orienting Task, but also showed marked decreased in heart rate (i.e. longer inter-beat intervals) as compared to a walk through an urban environment. Both of these studies presented their virtual “nature walks” via a series of still images displayed in sequence rather than through the use of continuous video of their environments.

Research that has employed continuous video of nature settings has demonstrated that such videos can have a stress-reducing and mood-improving capacity (Abkar, Kamal, Maulan, & Mariapan, 2009; De Kort et al., 2006). Specifically, the stress-reduction benefits of nature videos appears to be dependent, at least somewhat, on the level of immersion achieved by the video with larger displays facilitating greater immersion and higher levels of stress reduction according to physiological measures of stress (De Kort et al., 2006). Another study (Abkar, Kamal,

Maulan, & Mariapan, 2009) demonstrated that videos of nature offered higher levels of stress-recovery for participants who have viewed a gory accident.

Unfortunately, the stress-relieving and affective benefits of such nature videos do not always relate to higher levels of cognitive restoration or improved performance. In one study (Van den Berg, Koole, & Van der Wulp, 2003) participants who viewed nature videos experienced only a marginally significant improvement in attention restoration, based on the results of the concentration index scores. Other research (Pilotti, Klein, Golem, Piepenbrink & Kaplan, 2015) has found that task performance was negatively affected by viewing an urban video but remained stable after watching a nature video; while this finding is promising, it is unclear whether this study's findings are an indication of the performance benefits of the nature video or of the performance-degrading capacity of videos of urban environments.

The problem with studies with videos is that they are mostly 1) only measuring physiological aspects of stress, 2) subjective in nature, and 3) only induce stress, as opposed to cognitively fatiguing the participants. Therefore, this literature is lacking in whether or not videos of nature can provide not just stress recovery but also restoration from mental fatigue. Additionally, due to the majority of it being subjective in nature especially in regards to "perceived restoration" this is not enough evidence to suggest that the videos are actually able to restore depleted cognitive resources. For example, Finkbeiner, Russell, and Helton (2016) found that peoples' perceptions of restoration and actual restoration as measured by performance are not accurate. Therefore, although ones subjective feelings may factor in to affect, they are not reliable performance indicators. In other words people are not good judges of their own ability to potentially perform. Lastly, due to the fact that there is not one standardized way in which researchers stress or fatigue their participants, one may question how much stress or actual

mental fatigue they are experiencing. If participants are not sufficiently cognitively fatigued, improvements in cognitive functioning will not occur due to a ceiling effect, as they are already performing at their optimum level. Additionally, although video has the ability to provide a person with the sense of "being there", it may not be immersive enough to consistently elicit restorative effects. Perhaps if an individual is able to not only feel like they are in the environment, but are also able to interact with the environment, much like they would in the real world, this would provide greater feelings of being there and allow for restoration from stress and cognitive fatigue.

Presence and Immersion

One of the requirements of Kaplan's Theory on what makes an environment restorative is its ability to provide the user with the "feeling of being there" that the literature calls "presence." Though there are several differing definitions of presence in the literature (e.g. Slater & Wilbur, 1997; Witmer & Singer, 1998), this study will use Slater and Wilbur's (1997) conceptualization because it more clearly-defines the role that simulation hardware plays in determining presence. According to Slater and Wilbur (1997), presence refers to the psychological or subjective feeling of being in another environment, in this case a virtual environment. Virtual environments (VE) are multisensory, computer generated environments that in which users can interact with the displayed environment. Virtual environments can be displayed using a variety of different mediums, such as computers, gaming consoles, 3D head mounted displays (HMDs; i.e. Oculus Rift, Microsoft Vive, etc.), and CAVEs (room in which VE is projected on the walls). Although the virtual environments can be displayed on many different mediums, these different mediums can indirectly affect one's feeling of presence, because the hardware provides differing levels of

immersion. According to Slater and Wilbur (1997), immersion is not a subjective feeling, but rather it refers to ability of the technology to surround the user.

Research has identified a number of features of virtual reality systems that contribute to the degree of immersiveness in the experience. An ideal virtual reality system is inclusive, meaning that it is capable of limiting a participant's perceptions of stimuli that are external to the virtual environment. Immersive systems should also be extensive, meaning that the environment can be perceived via multiple sensory modalities and surrounding, meaning that those multi-modal stimuli should be presented from all directions. Another consideration is the vividness of the presentation system with displays capable of higher fidelity representations of the environment being more immersive to experience.

Immersion is a construct that exists on a broad continuum: a perfectly immersive system will embrace all of these features and the immesiveness of any system can be evaluated by examining each of these attributes. Research using virtual environments is typically separated into three main categories of systems: Non-immersive, Semi-Immersive, and Fully Immersive (Bohil, Owen, Alicea, & Biocca, 2009; Kalawsky, 1996 as seen in Gierloff, 2014; Ma & Zheng, 2011). Non-immersive systems are generally thought of as desktop based virtual reality as the VE is displayed on a desktop computer screen and can be navigated through with the use of a keyboard, mouse or joystick. Semi –immersive systems are similar to that of the non-immersive system, however, this system has a larger hi-definition display such as a large TV or a projector. Lastly, a fully immersive system is one that employs technology more capable of completely engrossing the user in the presented virtual environment. These systems usually utilize a Head Mounted Display (HMD) or CAVE that is capable of providing the user with a 360 degree field of regard (Bohil, Owen, Alicea, & Biocca, 2009).

Further, Slater and Wilbur stated that immersion is influenced by the amount of lag between ones real world motor movements and the system's response to those movements (1997). The more "matching" (i.e. movement of one's head in real world corresponds to the movement of one's head in the virtual world) the sensory input is, the greater level of immersion (Slater & Wilbur, 1997). Additionally, the more realistic the input is to one's natural movements (proprioceptive "matching") the more present one should feel. Lastly, they state that having a plot or the ability to interact/navigate the environment is important for immersion (Slater & Wilbur, 1997; Slater, Usoh, & Steed, 1995; Welch et al., 1996). Generally speaking, the more immersed one is in the virtual environment, the more presence one will feel (Blade & Padgett, 2002; Witmer & Singer; 1998). Slater, Linakis, and Kooper (1999) believe that when users experience high degrees of presence in the simulated environment they will refer to that simulated environment as a place that they have actually been as opposed to something that they have viewed.

Individual Differences.

Although the hardware and software of the system (factors of immersion) play a large role in presence, so do individual differences (IDs). This explains why people often experience different levels of presence when exposed to the same virtual environment. Researchers have proposed that human factors such as personality, past experiences with the technology, the capacity for imagination (Heeter, 2003; Lombard & Diton, 1997), willingness to forget the fact that they are in a VE ("suspend disbelief"), age (Lombard & Diton, 1997), empathy, (Davis, 1994; Sas & O'Hare, 2003), openness/willingness to experience (Sas & O'Hare, 2003,

Waterworth & Waterworth, 2006; Wirth et al., 2007), and immersive tendencies (Witmer & Singer, 1998) influence the level of presence an individual perceives.

The above factors have been proposed to play a significant role in the feeling of presence, however, research in this area has been both lacking and mixed. Based on a review of the literature, empirical evidence suggests that the following individual differences impact presence the most: immersive tendencies (Kaber et al., 2002; Wallach, Safir, & Samana, 2010, Witmer & Singer, 1998), the willingness to suspend disbelief (Murray, Fox, & Pettifer, 2007; Procci, 2015), and locus of control (Murray, Fox, & Pettifer, 2007; Procci, 2015). As such, these three IDs will be studied in this experiment.

Immersive tendencies.

Immersive Tendencies refers to an individuals' tendencies to become immersed in general activities. Witmer and Singer (1998) created the Immersive Tendencies Questionnaire (ITQ) which asks questions regarding ones' ability to become passively involved in an activity (i.e. reading a book), the ability to ward off distractions (focus), and game play frequency and involvement.

Willingness to suspend disbelief.

Willingness to suspend disbelief (WSD), or the ability of an individual to ignore any inconsistencies and the artificial nature of the virtual environment, is another individual difference that can play a role in ones feeling of presence in the virtual environment (Lombard & Ditton, 1997). Specifically, those who are more willing to suspend disbelief tend to experience greater levels of presence, whereas those who are not willing to suspend disbelief view the

environment as not being real and as such do not feel as present in the environment (Slater & Usoh, 1993).

Locus of control.

Locus of Control (LOC) is a psychological construct that refers to ones' perception of how in control they are over the events in their own lives (Rotter, 1966). If an individual perceives that they are not in control over what occurs then they are said to have an external LOC. On the other hand if an individual perceives that their actions influence what is occurring then they are said to have an internal LOC. Witmer and Singer (1998) state that the more control or interaction ones has in the VE the more presence one will feel. However, individuals with a greater internal LOC may feel more present the more control they have in the environment. Therefore, by varying the level of interactivity, thus control, an individual has over the environment one can further investigate the role of LOC in VR.

Interaction/Exploration/Navigation.

Interaction, the ability of an individual to navigate and interact with objects, is an important aspect of virtual reality. Harrington et al., (2009) and James et al, (2002) found that higher levels of navigational freedom within a learning based VE increased the acquisition of knowledge. This is likely due to the fact that when individuals have control over (interacted with) an environment they report greater levels of presence, than when they have no control (passively viewed VE) (James et al., 2002; Persky et al., 2009; Welch et al., 1996). Interactivity not only influences the level of presence felt in a VE, but also influences the degree of immersion. This occurs because the type of navigational input device affects how one can interact with the environment and the ability and ease of which (i.e. natural movements,

mapping) one navigates/interacts with/controls the environment influences the level of presence one feels. For example, there is a big difference between looking around a VE with the use of a gamepad joystick (i.e. Xbox controller) as compared to the use of a head tracking HMD. Both input devices are able to map the movement in the VE, however, the HMD does so in a more naturalistic and predictable way, which should theoretically increase immersion and ultimately presence (Groenegress, Thomsen, & Slater, 2009; Slater & Wilbur, 1997; Witmer & Singer, 1998). A number of researchers have supported this notion in the literature. For example, Shafer, Carbonara, and Popova, (2011) examined high (Microsoft Kinect), medium (Wii Remote) and low (standard gamepad, i.e. Xbox) game control device interactivity and feelings of presence, as their results indicated that the higher the level of control interactivity the greater the feelings of reported presence. Additionally in a similar study to that of Shafer et al., (2011), Skalski, et al. (2011) found that individuals who used control devices that are more naturally mapped (i.e. Wii Remote) felt greater levels of presence than those who used traditional devices such as gamepads.

Virtual Reality

Due to the continuing technological advances, VR headsets have become not only better quality but also more affordable as devices like the Oculus Rift, HTV Vive, Playstation VR, Google Cardboard, etc. have become popular in the mainstream market. Virtual reality is becoming more widely adopted not only by the general population as a form of leisure activity, but also by medical professionals for training and treatment purposes. For example, mental health professionals have employed the use of VR for exposure therapy to treat a myriad of phobias (Parsons & Rizzo, 2008) as well as PTSD (e.g. Rothbaum, Hodges, Ready, Graap &

Alarcon, 2001), anxiety (e.g. Owens & Beidel, 2015; Parsons & Rizzo, 2008), and depression (Hoffman, 2004) among others. Other medical applications of VR include the use of immersive virtual environments to help treat patients with a variety of physical health problems, such as using VR to distract severe burn patients during treatment to reduce pain levels (Hoffman, Patterson, Carrougher, & Sharar, 2001; Sharar et al. 2007) and to help with physical rehabilitation (Deutsch & Mirelman, 2007; Schultheis & Rizzo, 2001). While these patient-focused applications of VR are certainly indicative of the healing power of virtual worlds, little research has centered on the notion that VR might be used to improve the well-being and abilities of the doctors and nurses as well: the constant stressors and fatigue that is experienced by medical professionals can have deleterious effects on performance and VR might offer a method to combat these declines.

Virtual Reality and Stress Reduction

To date, very little research has studied the effects of virtual nature environments on stress reduction and/or cognitive restoration. Pals (2011) conducted a study which used presentations of nature and urban environments to determine the restorative effects of these environments and whether these restorative effects could be captured through VR. Over the course of two studies, participants would take real or virtual walks through real life urban and nature environments; in this way, the study could compare the representativeness of a virtual presentation of the same setting. Participants rated their preference, pleasure with, and perceived restoration for the environments, and the results suggested that individuals rated preference, pleasure and perceived restoration similarly high in both real and virtual nature environments, but rated them lower in both urban environments. This shows that VR nature has the potential to

be an effective tool for restoration. Knight, Stone, and Qian (2012) provided further support for this notion, as their study found that virtual nature environments are rated as more relaxing than urban nature environments.

Although Pals' (2011) study indicates that virtual nature has the potential to be an effective tool for restoration, the methodology of this study was based on subjective measures of preference and restoration. An extensive literature review has revealed only two studies that explored this relationship objectively. In the first of these (Valtchanov, Barton & Ellard, 2010), participants were either exposed to abstract paintings or allowed to explore a virtual forest with the use of a HMD (interactivity occurred, but details were not discussed). Results suggest that virtually generated nature can reduce some aspects of physiological stress (skin conductance; HR was *n.s.*) and increase positive affect. Although stress restoration was achieved in VR, the authors were unsure if it occurred due to the nature of the simulation or due to /the novelty of the virtual environment because no control condition was used in the study.

The second study (Valtchanov & Ellard, 2010), which was a follow-up of the first, rectified this lack of control by comparing virtual presentations of urban and nature environments to a neutral virtual environment that was comprised of geometrical shapes. They found that virtual nature viewed on a HMD with corresponding environmental sounds increased positive affect and decreased negative affect and stress (physiological & perceived) but they were unable to demonstrate significant improvements in cognitive functioning. This null finding may be due to a ceiling effect: they reported that their stress inducing task was not sufficient to induce cognitive fatigue, based on the fact that the results on the SART task remained stable (pre and post stressor and after immersion in VR nature). Additionally, no significant differences were found in perceived or physiological stress in a control (geometric shapes) or urban

environments. These findings suggest that stress recovery occurred as a result of the virtual nature and not due to novelty of the virtual environment.

The present study

This study will continue and expand upon the body of literature by addressing some of the limitations of past research and further exploring the restorative capacity of virtual presentations of nature.

Though past literature has shown that interacting with a virtual nature environment can elicit reductions in stress, this reduction in stress has not always been accompanied by the significant increases in cognitive functioning. A noted, one possible reason for this lack of finding is due to a ceiling effect caused by a lack of cognitive fatigue. As such the aim of the current study is to address this issue by ensuring participants are cognitively fatigued before exposure to the virtual environments.

Further, the research on this topic often fails to employ a control condition which makes it impossible to know how the benefits of virtual nature compare to a rest/break that people often take during the workday; one must wonder if restoration would have occurred regardless of the virtual nature presentation. As such, this study will also compare the active and/or passive virtual nature conditions in which participants experience restoration to an active break condition.

Finally, based on an extensive review of the literature, it appears that no research has evaluated the effects of level of immersion (non-immersive, semi-immersive, fully-immersive) and type of exploration (passive vs. active) in regards to stress reduction and cognitive restoration. This study will compare different levels and types of immersion to determine what characteristics of a virtual environment contribute most to any observed benefits.

Information gathered from the above literature review leads to the following research questions:

1) How immersive does the simulated natural environment need to be in order to elicit restoration?
2) Does the level of exploration/interaction with the environment make a difference?
3) Is it possible to replicate past research findings that natural environments are restorative?
4) Does one's perceived restorativeness relate to actual restoration?
5) What is the best overall method for increasing positive affect, reducing stress and eliciting cognitive restoration?
6) Is the best overall method for restoration better than taking an active break?

Hypotheses

Based on the above literature review, this study seeks to find support for the following hypotheses:

H1: Replicating past findings, presentations of virtual nature will significantly reduce stress and provide cognitive restoration regardless of the level of immersiveness (non, semi, and full) of that presentation.

H2: Level of immersion will impact stress reduction and cognitive restoration such that virtual nature environments presented through virtual reality will be significantly more effective at reducing stress and restoring depleted cognitive capacity than presentations through a large or small television.

H3: Though both levels of exploration will elicit restorative effects, those who actively explore virtual nature will have significantly greater stress reduction and cognitive restoration than those who passively explore virtual nature.

H4: The condition that combines virtual reality with active exploration will provide significantly greater restoration from stress and cognitive fatigue than the other five conditions.

H5: Individuals perceptions of restoration will correspond to physiological measures of restoration.

For each measure, the VE nature condition that provides the greatest stress reduction and cognitive restoration will be compared to the benefits of taking an active break.

H6: The most restorative VE nature environment will provide significantly greater stress reduction and cognitive restoration than what can be gained from taking an active break (i.e. coloring a mandala).

CHAPTER THREE: METHODOLOGY

The overall aim of this study was to determine the extent to which immersion and exploration play a role in restoration from stress and cognitive fatigue.

Participants

To determine the number of participants needed for this study a power analysis was conducted, using G*Power v.3.1, with a medium effect size (.36). Results of this power analysis indicated that a total of 84 participants were needed. Participants were recruited from the University of Central Florida via Sona Systems. All participants were compensated for their time with extra course credit based on the length of participation, with the maximum being 90 minutes of Sona Systems credits on day one and 150 minutes on day two. Additionally, those in the break condition received 150 minutes Sona System credits.

Although only 84 participants were needed based on the results of the power analysis mentioned above, a total of 132 participants were recruited for participation in this study. Due to attrition from study drop out, simulator sickness, and failure to meet requirements of this study a final sample of 83 participants was retained. The remaining participants consisted of 45 females and 38 males ranging in age from 18 to 30 years (M = 19.61, SD = 2.12) with a median age of 19. Overall the participants were comprised of mostly non-Hispanic, Caucasian, students (see Table 1 below for more details).

Table 1. Demographics Data

Factor	Frequency	Percent
Race/Ethnicity		
Asian	6	7.2
African American	14	16.9
Native Hawaiian/Other Pacific Islander	1	1.2
Caucasian	51	61.4
Other	11	13.3
Hispanic	63	75.9
Class Standing		
No Response	42	50.6
Freshman	13	15.7
Sophomore	10	12.0
Junior	13	15.7
Senior	3	3.6
Senior +	2	2.4
Major		
Advertising	2	2.4
Art	1	1.2
Biology	6	7.2
Biomedical Sciences	4	4.8
Business	3	3.6
Chemistry	1	1.2
Communication Sciences	5	6.0
Computer Engineering	6	7.2
Criminal Justice	4	4.8
Education	1	1.2
Electrical Engineering	1	1.2
English Literature	2	2.4
Entertainment Management	3	3.6
Film	2	2.4
Finance	2	2.4
Graphic Design	1	1.2
Health Sciences	4	4.8
Hospitality	1	1.2
Information Technology	1	1.2
Mathematics	1	1.2
Mechanical Engineering	4	4.8
Musical Theatre	3	3.6

Factor	Frequency	Percent
Nursing	2	2.4
Physics	2	2.4
Psychology	14	16.8
Real Estate	2	2.4
Sport and Exercise Sciences	3	3.6
Undeclared	2	2.4

Inclusion Criteria.

For this study, all participants were required to have no color deficiencies and have at least 20/40 corrected near and far visual acuity, as well as normal stereoscopic acuity (depth perception). However, due to the potential use of the Oculus Rift VR headset participants were also screened to determine their propensity for motion sickness, only those who were not susceptible based on a Motion History Questionnaire (Kennedy, Fowlkes, Berbaum, & Lilienthal, 1992) or who did not currently display symptoms of motion sickness (based on baseline SSQ scores) were able to participate. Participants were also screened for visual acuity as glasses could not be worn with the VR headset; participants were eligible to participate if they met the requirements for visual acuity normally or with contacts.

Additionally, the researcher had the right to end the study early in the event of simulator sickness. If this occurred participants were asked to sit down and wait for their symptoms to subside, during which time they were offered crackers and water or ginger ale. Every 15 minutes, participants were asked to complete a Simulator Sickness Questionnaire (SSQ) to assess their level of sickness. When their symptoms dissipated (SSQ score below 5) they were notified that they could leave. If they chose to leave before this occurred, participants were required to sign a

waiver stating that they accept and understand the risks associated with simulator sickness and that UCF Technology and Aging lab is not to be held liable for anything that occurs after their departure.

Measures/Apparatus

The following series of questionnaires were used in this study. All questionnaires listed below were presented electronically via Qualtrics, unless stated otherwise.

Arousal.

Because this study was designed to be cognitively fatiguing and stressful, it was essential to have a brief questionnaire to assess "wakefulness" throughout the experiment. In order to ensure that the participants were in fact alert, Hoddes, Zarcone, Smythe, Phillips, and Dement's (1973) Stanford Sleepiness Scale was administered to participants. This questionnaire is very quick to administer as it consists of one question in which participants are asked to rate their "degree of sleepiness" on a scale from 1 ("Feeling active, vital, alert, or awake") to 7 ("No longer fighting sleep, sleep onset soon…").

Simulator sickness screening.

Because this study may have required the use of the Oculus Rift (VR Headset), it was important to ensure that participants were not susceptible to, or are experienced, any simulator sickness throughout the study. Simulator sickness occurs typically when one's visual system perceives movement, but one's actual movement, or lack thereof, does not reflect their visual

input. Common symptoms of simulator sickness include feelings of dizziness, nausea, vertigo, and eyestrain, among others (Kennedy, Lane, Berbaum, & Lilienthal, 1993).

To help reduce the occurrence of motion sickness experienced in this study, participants' susceptibility to motion sickness was assessed with Kennedy, Fowlkes, Berbaum, and Lilienthal's (1992) Motion History Questionnaire (MHQ). The shortened questionnaire is comprised of 5 items regarding one's prior experiences with motion sickness (Kennedy et al., 2001). Participants with scores of seven or higher were not allowed to further participate in the study, as a score in this range is indicative of a greater risk for experiencing motion sickness (Kennedy et al., 2001).

To further reduce the likelihood of motion sickness negatively impacting participant well-being or research outcomes (research has demonstrated a negative relationship between motion sickness and presence; Witmer & Singer, 1994, 1998; Stanney & Salvendy, 1998), participants were also required to respond to Kennedy, Lane, Berbaum, and Lilienthal's 1993 Simulator Sickness Questionnaire (SSQ), the most common measure of simulator sickness. This self-report questionnaire consists of 16 items that measures the extent to which people are currently experiencing symptoms of simulator sickness on a 4-point Likert scale from none (0) to severe (3). Participant simulator sickness was assessed both before and after they were exposed to the virtual environment to ensure they did not experience any ill effects.

Stress/Anxiety.

Stress was assessed both subjectively and physiologically. The subjective measures of stress included the administration of the Short Dundee State Stress Questionnaire (DSSQ-S) as well as the State Trait Anxiety Inventory (STAI) Form-Y1 both before and after experiencing the

virtual environment. Heart rate and heart rate variability were used for the physiological measures of stress.

Dundee Stress State Questionnaire-Short.

The DSSQ was first developed Matthews, et al. (1999) to assess the multidimensionality of stress states and has since become a widely used measure of perceived stress. However, due to time limitations the short form of the DSSQ will be used (DSSQ-S; Matthews et al., 2002; Matthews, Emo, & Funke, 2005). The DSSQ-S is comprised of 30 items that are measured on a 7-point Likert scale which reflect the 3 meta-factors of stress: Task Engagement, Distress, and Worry. Numerous studies have used the DSSQ to assess perceived stress and have found that participants have marked declines in task engagement and increases in distress after a vigil (e.g. Helton, Dember, Warm, & Matthews, 1999; Helton et al., 2005; Szalma, Hancock, Dember, & Warm, 2006; Matthews et al., 2006).

State Trait Anxiety Inventory (Form Y-1).

The STAI Form Y-1 was developed by Spielberger, Gorsuch, Lushene, Vagg, & Jacobs (1983) consists of 20 items (e.g. "I am relaxed", I feel strained", etc.) which were used to assess one's current, or rather "state", anxiety using a four point Likert scale including the following responses in order of appearance: not at all, a little, somewhat, and very much so. Higher scores indicate greater degrees of anxiety.

Heart Rate and Heart Rate Variability.

Both heart rate (HR) and heart rate variability (HRV), the variability in the time interval between consecutive heart beats, were measured as physiological indicators of stress in this study. Many studies indicate that increased HR and decreased HRV, reduced variability between heartbeats (R-R interval), are indicative of increased stress (e.g.MacArthur & MacArthur, 2000; Vrijkotte, Van Doornen, & De Geus, 2000). Heart rate and heart rate variability (HRV) were continuously recorded via a BIOPAC MP150 electrocardiogram (ECG) monitor (BIOPAC Systems, Inc.) using general purpose pre-gelled ECG electrodes that were connected to the ECG amplifier via cable leads. Data from the ECG was processed with Acq*Knowledge* software (BIOPAC Systems, Inc.) on a separate Dell computer running Windows 7. Additionally, data was recorded using a standard lead II chest placement in which one ECG electrode is placed approximately 3 cm below the right clavicle and the second ECG electrode is placed on the bottom of the left ribcage. Throughout the experiments start and stop times of each measure were flagged in Acq*Knowledge.* Additionally, in order to analyze the raw data the .acq data files from Acq*Knowledge* were imported into Kubios HRV Version 2.2 (Biosignal Analysis & Medical Imaging Group, 2012). Data was pre-processed in Kubios to remove artifacts and then the data was broken into five-minute periods and each period was then averaged to create an epoch. Kubios was used to calculate time (RMSSD) and frequency (high and low frequency) HRV measures. Past research suggests that individuals with decreases in RMSSD (estimation of differences between R-R intervals in short time periods; of HRV; Vrijkotte, Van Doornen, & De Geus, 2000;Weber et al., 2010) is indicative of stress and has also been associated with increases in workload (e.g. Causse et al., 2011; Luque-Casado, Perales, Cardenas, & Sanabria, 2016; Wei, Zhuang, Wanyan, Liu & Zhuang, 2014). Additionally, heart rate (beats per minute) was derived

from inter-beat intervals (IBI). Vrijkotte, Van Doornen, and De Geus (2000), among others, have consistently found that increases in heart rate is associated with increased stress.

Working Memory/Executive Functioning (N-Back).

Working memory and executive control were measured using the N-Back, specifically the 2-Back (Kane et al., 2007). This task assessed executive functioning ability as it not only requires the storage of visual information in short term memory (STM) but also the ability to constantly update the STM store with new information, all while comparing the stored information to the current stimuli (Kane et al., 2007). All stimuli were presented for a duration of 500ms with an inter-stimulus interval of 500ms. This 2-Back task required participants to monitor the computer screen for a match between the letter (stimulus) that is currently being presented and what was presented two letters before. Participants completed a practice session to familiarize themselves with the task before recorded performance. The 2-Back practice session provided auditory feedback to the participant, as well as an accuracy score at the end of the practice session. All participants were required to score an 80% on the 2-Back practice before proceeding with the task. Accuracy will be calculated for this task. Greater accuracy values will indicate greater working memory ability.

Perceived restorativness scale.

In order to assess whether or not the participant perceived the intervention to be restorative, Hartig et al.'s (1996, 1997) Perceived Restorativeness Scale (PRS) was employed. The PRS was developed around Kaplan's four-factor theory of attention restoration. As such, it asks questions about one's experience that touch on each of the four factors (Being Away,

Fascination, Extent, Compatibility). For instance, participants were asked to rate on a seven point Likert scale (0 = Not at all, 6 = Completely) questions such as, “I have a sense I belong here”, “It is an escape experience”, and “There is much to explore and discover here”.

This scale allowed me to 1) determine whether or not the participant perceived the intervention to be restorative, and 2) examine whether ones’ perception of restoration is aligned with actual restoration, based on heart rate and executive functioning ability.

Individual Differences.

Immersive tendency questionnaire.

The Immersive Tendency Questionnaire (ITQ) developed by Witmer and Singer (1998) was used to measure an individual’s tendency to become immersed in a virtual environment. This measure consists of 29 items that ask questions on a 7 point Likert scale regarding how immersed individuals become in common activities, such as: “Do you ever get extremely involved in projects that are assigned to you by your boss or your instructor, to the exclusion of other tasks?”, “Do you ever become so involved in a movie that you are not aware of things happening around you?”, etc. However, the revised version only consists of 16 items measured on a Likert Scale from never (1) to very often (7).

The ITQ has also been significantly correlated with presence in a number of prior studies (Ling, Nefs, Brinkman, Qu, & Heynderickx, 2013; Laarni, Ravaja, Saari, & Hartmann, 2004; Wallach et al., 2010; Witmer & Singer, 1998).

Willingness to suspend disbelief (WSD).

Willingness to suspend disbelief, or the ability of an individual to ignore any inconsistencies and the artificial nature of the virtual environment, is another individual

difference that can play a role in ones feeling of presence in the virtual environment (Lombard & Ditton, 1997). Sas and O'Hare (2004) created a one-item measure of willingness to suspend disbelief. The question was "To what extent were you willing to be transported to the virtual world?" (Sas & O'Hare, p. 529). Participants had to rate the question on a 7 point Likert scale ranging in response from 1 (not at all) to 7(completely). Those who are more willing to suspend disbelief, tend to experience greater levels of presence (Slater & Usoh, 1993).

Locus of control (LOC) scale.

In order to assess ones' perceptions of control over events in ones' life, Rotter's (1966) Locus of Control Scale was used for this study. This scale consists of 23 items, which provide two options from which the individual has to choose between an internal or external option. For example, one item states, "a. Children get into trouble because their parents punish them too much. b. The trouble with most children nowadays is that their parents are too easy with them." (Rotter, 1996), and the participant would then choose the one that they believe the most. High scores on this scale represents an external locus of control whereas low scores represent an internal locus of control.

Presence questionnaire (SUS).

The Slater-Usoh-Steed (SUS) questionnaire was used for this study (Slater, Usoh, Steed, 1994). This questionnaire measured presence by responding, on a 7 point Likert scale, to 6 questions regarding the subjective feeling of "being in" the virtual environment, the extent to which the user finds the place to be the current reality and the event that this virtual environment is remembered as a place they have visited, as opposed to something they viewed. The SUS was then scored by counting the number of responses that were either a 6 or 7.

Connectedness with nature.

Mayer and Frantz's (2004) connectedness to nature scale (CNS) was used in this study to assess the level of participants' connectedness to nature. This scale has been deemed valid and reliable (Mayer & Frantz, 2004) and consists of 14 items that assess the way one generally feels toward nature (i.e. "I often feel a sense of oneness with the natural world around me") on a five point scale ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicate a greater connection to nature.

Demographics survey.

The demographics survey will ask basic questions such as, age, race, ethnicity, gender, and caffeine consumption.

Vigilance task.

A vigilance task was used to cognitively fatigue as well as stress the participants in the study to combat the concern in prior studies on the topic regarding experiencing a potential ceiling effect. To combat the concern for a ceiling effect, research conducted by Michaelis, Rupp, Montalvo, McConnell and Smither (2015) assessed different lengths, 12 minutes (unmodified) and 30 minutes (modified by researchers) compared to a 15-minute break (control), of the Temple and colleagues (2000) abbreviated vigilance task. Both Temples' abbreviated vigilance task and the modified vigilance task requires participants to monitor a specific fixation point on the computer screen in front of them for target stimulus, the letter "O", while ignoring the forwards or backwards letter D that was overlaid on a crosshatched visual mask (the distractors). The stimuli's high event rate (57.5 events/minute) and the low discriminability of the distractors makes this task fatiguing. Michaelis et al., (2015) found a slight non-significant

increase in committed errors on the 30 minute vigilance task, as such the researchers added another 15 to the end of this task. Therefore, an extended version (45 minutes) of Temple et al.'s, (2000) shortened vigilance was used to induce stress and cognitive fatigue in this study (See Figure 1).

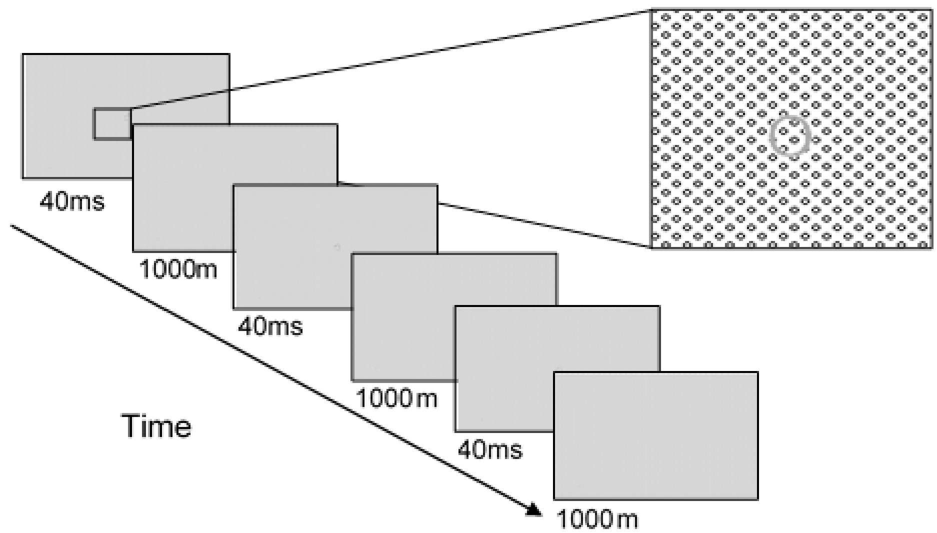

Figure 1. Abbreviated Vigilance Task. ISI = 1040ms.

VRE Hardware.

Computers.

Two computers were used for this study. The first of which was a Dell Optiplex 755 computer. This computer was used to run the Acq*Knowledge* software that the Biopac EGC data was collected on. The second computer is a Windows 10 computer with a 3.50GHz Intel® Core™ i5-6600K processor, and a NVIDIA GeForce GTX980 graphics card. This computer was used for all measures as well as to run the virtual environments. Further this computer was set up with dual monitors. One monitor was for the participants and the second was oriented away from

the participants and used to mirror the participants screen in order for the researcher to monitor the participants' progress throughout. Additionally, this computer was used to run the Unreal Development Software that contain the virtual nature environments. The output was sent to one of the three display types listed below.

Display types (level of immersion).

Small television: A 24 inch VIZIO LED 1080p full HD television with a refresh rate of 60hz was used as the non-immersive display.

Large Television: A 55 inch VIZIO LCD 1080p full HD television with a refresh rate of 120Hz was used as the semi-immersive display.

Head mounted display: The Oculus Rift Consumer Version 1 (CV1) head mounted display (HMD) was used in this study to fully immerse the participants into the virtual environments, as the display is able to block outside distractions by fully surrounding the user's visual system (Figure 2). The Oculus Rift provides 110 degree field of view, with two organic light emitting diodes (OLED) displays that have a combined resolution of 2160 x 1200 (1080 x 1200 per eye), and a refresh rate of 90hz (IFIXIT, 2016). The two displays allow for the division of the image between ones' eyes creating a 3D stereoscopic effect. Additionally, the Oculus Rift allows for 360-degree positional head tracking when coupled with the Constellation IR cameras, which then translate into actual head movements in the virtual environment (IFIXIT, 2016). Lastly, the Oculus Rift CV1 comes with integrated headphones that seamlessly incorporate audio for a more immersive effect.

Figure 2. Oculus Rift CV1 Head Mounted Display

Controls.

For this study viewing as well as self-locomotion through the environment was made with two different types of controllers depending on level of immersion. For instance, both the non-immersive (Small TV) and semi-immersive (Large TV) conditions used a traditional gamepad, an Xbox One controller, to look around in and/or navigate through the virtual environment (Figure 3). For this controller, the left thumb stick propelled the person through the environment in whatever direction the participant wanted to go, and the right thumb stick manipulated the field of view, essentially allowing the individual to make head movements in the virtual environment. For the fully immersive condition, the Oculus Rift was coupled with Oculus Touch VR controls. The reason this is considered a fully immersive system is because the Oculus Rift's head tracking technology can simulate real world actions by monitoring the location and orientation of the person's head in the physical world, and seamlessly update that information in real time in the virtual environment. Oculus has also developed an immersive control system called the Oculus Touch. These controls differ from a traditional gamepad as they allow one to control how they interact with the environment from two separate controls (one in each hand) and they are able to track hand movements with the constellation system, much like it does for head tracking.

Figure 3: Xbox One Controller (Left); Oculus Rift HMD & Oculus Touch Controller (Right)

Software.

Unreal Engine 4 (UE4), a game development suite, was used to modify a preexisting open world map/game to suit the needs of the study. The environment was simulated with daylight hours and with optimal weather conditions (e.g. sunny, no precipitation). The open world that was modified to serve as the nature environment condition was the Unreal Engine 4 Kite demo (Figure 4). The Kite Demo is a nature rich environment that include a long stretch of river, various trees, flowers, bushes, grasses, rocks and dirt paths. Not only are there trees and grass, but one could also see them sway from a gentle breeze (no feeling of breeze was simulated in the laboratory). Lastly, ambient sounds of nature such as the river flowing, tree leaves rustling, and animal noises (i.e. birds) could be heard in the environment. The Kite Demo was modified such that, some of the animals were removed, structurally walls were built (cannot be seen) so that participants cannot fall off cliffs or go into the river, and a standardized location for starting in the environment was created. Additionally, the method by which one moved though the environment was changed so that one could not fly over the environment like a kite but rather walked on the ground through the environment.

Figure 4. Virtual Nature Environment

Break Condition.

In order to determine if the effect of virtual nature is better than just taking a break from the fatiguing task, this study employed the use of 10-minute breaks in which participants in the active break condition completed a geometrical shaped color-by-numbers coloring page. A coloring task was used, as 1) adult coloring has become a popular activity that individuals engage in to aid in relaxation (Blackburn & Chamley, 2016; Carsley, Heath, & Fajnerova, 2015; Curry & Kaiser, 2005; Duong, Stargell, & Mauk, 2018; Petersen et al., 2015; Van der Vennet & Serice, 2012), 2) it is more realistic of an actual break, although the participants were not allowed to surfing the web, make a phone call, text, etc. they still actively performed a non-fatiguing task and 3) research has shown that just taking break and doing nothing can actually increase stress (Rupp, Sweetman, Sosa, McConnell, & Smither, 2017) and reduce task performance (Lim & Kwok, 2015).

Procedure

All participants were recruited through SONA Systems and randomly assigned to 1 of 7 conditions (6 VE and 1 active break). Those who were randomly assigned to one of the 6 VE conditions were asked to come back, within a three-day period, for a part two of the study. Whereas, those in the break condition were only required for one session.

Virtual Environment Conditions: Day 1.

Upon arrival to the lab the participants were given a brief summary of the study and were provided with the informed consent. Upon obtaining their consent to participate, they underwent a brief vision and motion sickness screening process (MHQ). This screening was designed to ensure that all participants had no visual deficits and that they were not susceptible to motion sickness. In addition to the MHQ, a Simulator Sickness Questionnaire was administered via Qualtrics to provide baseline measurement from which to compare the SSQ score with later, after interacting with the virtual environment.

Upon meeting the aforementioned criteria, participants were fitted with ECG sensors using a standard lead II placement and then completed an 8-minute quiet baseline while sitting, of which the first three minutes were discarded and the last five were used as the baseline. Participants were then asked to interact with one of the six conditions, based on a randomized block design, to help reduce any fascination that they might have had with the virtual environment and to become acclimated to the VR system and its controls. Participants were instructed on how the system works, and in the case of VR they were asked to move their head to look around as well as turn around to see that these actions are doable. After interacting with an environment, they were asked to complete the following series of questionnaires, via Qualtrics:

Post SSQ, ITQ, WSD, LOC, SUS, CNS and Demographics (see Figure 5 for procedure breakdown).

Figure 5. Day 1 Procedure

Virtual Environment Conditions: Day 2.

Upon arrival on the second day, participants were quickly briefed on what they were supposed to do that day. They were then fitted with ECG sensors using a standard lead II placement and then completed an 8-minute quiet baseline while seated (the last 5 minutes were used for the study). After obtaining the baseline measure of heart rate they turned to the computer to complete the sleepiness scale, Simulator Sickness questionnaire (SSQ), Dundee Stress State Questionnaire (DSSQ), the State Trait Anxiety Inventory Form Y-1 (STAI) and the N-Back. They then performed a 45-minute vigilance task that was designed to tax one's resources and induce cognitive fatigue. After completing the vigilance task, they were asked to complete the DSSQ-S and STAI questionnaires a second time as well as the NASA-TLX to capture the workload of the vigilance task. Then they completed a second N-Back to obtain a post-vigilance measure of working memory/executive functioning. Next the participant interacted with one of the six virtual nature environment conditions for 10 minutes and then completed the N-Back a third time followed by the SSQ, DSSQ-S, STAI, and PRS, before being debriefed (Figure 6).

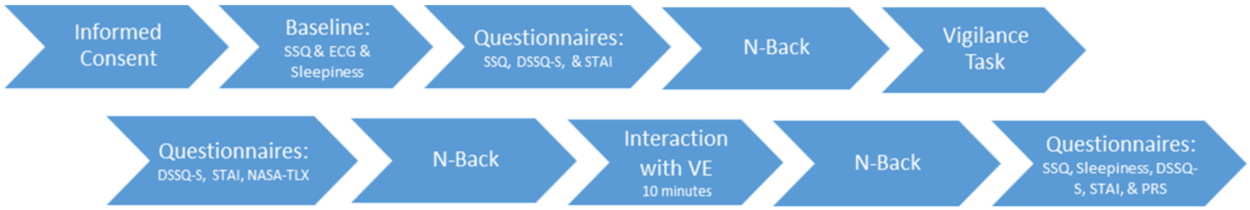

Figure 6. Day 2 Procedure

Break Condition: Day 1

The coloring break condition was a pared down version of Day 2 because 1) participants were not exposed to a virtual environment and 2) many of the questionnaires no longer applied. If participants were in break condition, they only needed to schedule one visit to the laboratory to complete the experiment.

Upon arrival to the laboratory participants were given the informed consent. Upon their consent to participate participants underwent vision screening (visual acuity and depth perception). If they had normal or corrected to normal visual acuity and normal depth perception, they were then fitted with the ECG sensors and then completed a 8-minute quiet baseline while seated (only the last 5 were used). Participants then completed baseline measures of the DSSQ-S, STAI and the N-Back before completing the 45-minute vigilance task. After which, they completed the sleepiness scale, DSSQ-S, STAI, NASA-TLX, and N-Back again, took a 10-minute active coloring break, and then completed the N-Back, SSQ, Sleepiness scale, DSSQ-S, and STAI a third time followed by the demographics questionnaire (Figure 7).

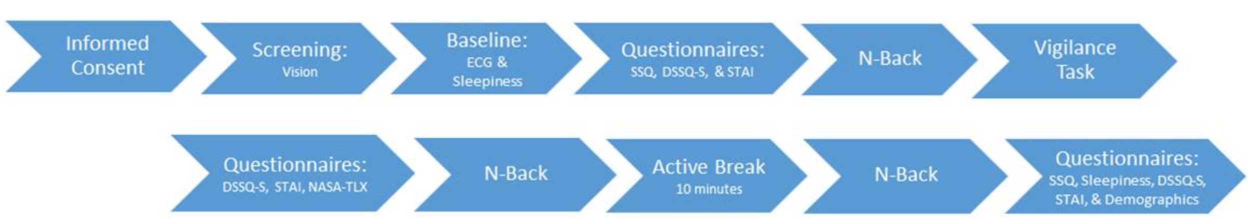

Figure 7. Break (Control) Procedure

CHAPTER FOUR: RESULTS

Data Screening

All data were screened for outliers. Anything that was two standard deviations from the mean was omitted from the study. Additionally, one participant's data, in the passive VR condition, was thrown out due to issues with response accuracy on the N-Back task; the participant obviously did not try to complete the task well.

Preliminary Analyses

A series of preliminary analyses were conducted to: 1) ensure participants did not experience simulator sickness, 2) determine if Immersive Tendencies, Willingness to Suspend Disbelief, and Connectedness to Nature are good covariates for this study, 3) ensure baseline equivalency between all groups, and 4) ensure the vigil was stress inducting and cognitively fatiguing.

Simulator Sickness Questionnaire

Before testing the aforementioned hypotheses, pre-post change SSQ scores were analyzed for significant differences between experimental groups to ensure that the outcomes are not influenced by feelings of simulator sickness. To test this, a mixed 2(SSQ) x 3(Immersion) x 2(Exploration) repeated measures ANOVA was conducted on Day 2, SSQ baseline and after treatment scores, with SSQ as the within groups factors and immersion and exploration as the between groups factors. Results indicate that there were no significant differences within or between groups in simulator sickness (Table 2).

Table 2. Simulator Sickness Results

SSQ Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p	η^2_p
RM Factor 1	7.441	1	7.441	0.150	0.699	0.002
RM Factor 1 ✻ Enviro	14.662	2	7.331	0.148	0.862	0.005
RM Factor 1 ✻ Interact	16.626	1	16.626	0.336	0.564	0.005
RM Factor 1 ✻ Enviro ✻ Interact	53.745	2	26.873	0.543	0.583	0.016
Residual	3214.022	65	49.446			
SSQ Between Subjects Effects						
Enviro	358.61	2	179.30	0.714	0.494	0.021
Interact	18.51	1	18.51	0.074	0.787	0.001
Enviro ✻ Interact	536.33	2	268.17	1.067	0.350	0.032
Residual	16329.30	65	251.22			

Note. Type III Sum of Squares

Covariates

Immersive Tendencies, Willingness to Suspend Disbelief, and Connectedness to Nature, were analyzed to determine if they would be good covariates for this study. The results of the correlations suggest that even though the scales were slightly correlated with one another they did not significantly correlate with the dependent variables (STAI, DSSQ-S, 2-Back), as such they were not considered good covariates for this study.

Baseline Equivalency Between Groups

A series of analyses were conducted to establish baseline equivalency between groups. All groups were found to be equivalent on all variables except for a main effect of immersion on Task Engagement (p = .004) and State Anxiety (p = .006). In each case one of the immersion groups experienced greater levels of stress or state anxiety than the other two groups. Though the reason for this initially heightened baseline level on these variables in these groups is unknown, further analysis revealed that these initially-elevated groups experienced a significantly steeper pre-to-mid-test change score, suggesting regression to the mean in both cases.

Vigilance Task Effectiveness

Consistent with the literature exploring the effects of a vigilance task, all groups experienced significant decreases in task engagement and significant increases in distress on the DSSQ-S (Matthews et al., 1999, 2002; Helton et al., 2000; Parsons et al., 2000; Temple et al., 2000, Alikonis et al., 2002; Grier et al., 2003; Helton et al., 2004, 2005; Szalma et al., 2004, 2006). According to Warm, Matthews, and Finmore Jr. (2008), a loss of task engagement is one of the best indicators of a stress response. Additionally, reduction in task engagement has also been found to be associated with attentional fatigue and decreased task performance (Grier et al., 2003; Warm, Mattews, & Finmore, Jr., 2008). State anxiety scores also significantly increased in all conditions after the vigil, indicating that the vigil was effective at increasing participants' anxiety.

Furthermore, physiological measures bolster the self-report measures mentioned above, as participants showed an initial spike in workload and stress as indicated by measures of HR and HRV (increased HR and decreased RMSSD; Carter & Beh, 1989; Kalsbeek, 1971; Proges,

1972) followed by a gradual decline in workload and stress to the point that it is below baseline levels. This pattern is a typical response to increased workload and stress as experienced in a vigilance task (Adamson & Beh, 1988; Pieper et al., 2007; Verkuil, Brosschot, deBeurs, Thayer, 2009; Weidner et al., 1989).

N-Back

The N-Back data were analyzed using a 3(Immersion) by 2(Exploration) ANOVA. Results indicated a ceiling effect occurred in the N-Back made worse by practice effects from administration of the measure three times (Figure 8). Due to these findings a log10 transformation was employed to help correct this ceiling effect; however, it was not effective, deeming this measure unusable.

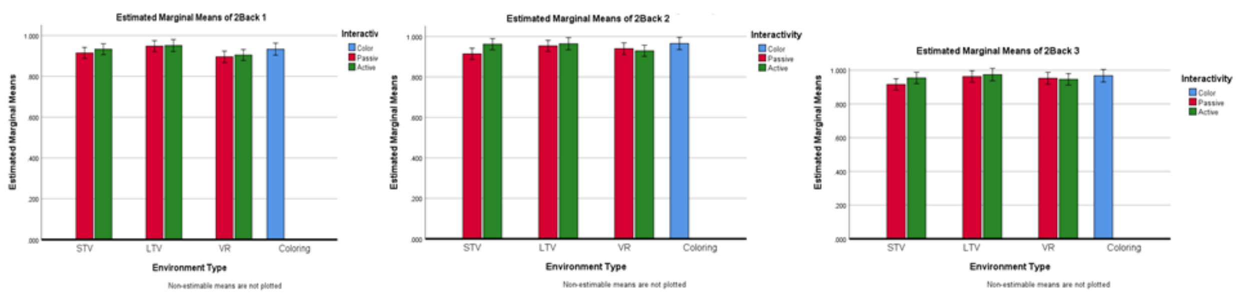

Figure 8. N-Back Accuracy at Pre, Mid, and Post Test

DSSQ-S Engagement

In order to evaluate the effect of the treatment on task engagement, a 3(Immersion) x 2(Exploration) ANOVA was calculated on Mid to Post Engagement change scores. Results revealed a significant main effect of immersion, $F(1,65) = 7.51.$, $p = .001$, $\eta^2_p = .188$. Bonferroni post hoc tests indicated that there was a significant difference in mid to post task engagement change scores between VR and STV ($p = .009$) and LTV ($p = .002$) conditions, such that change

scores for the VR (M = 9.13, SD = 6.47) condition increased more than both the STV (M = 3.71, SD = 5.84) and LTV (M = 2.67, SD = 5.78) conditions. Even though there were significant differences in task engagement between the levels of immersion as stated above, all levels of immersion (STV, LTV, VR) showed significant increases in task engagement from mid to post test. No significant between groups difference in mid to post task engagement change scores were found for Exploration type, $F(1,65) = 0.04$, $p = .846$, $\eta^2_p = .001$, however, both the active (95% CI [3.28, 7.34]) and passive (95% CI [2.96, 7.08]) groups showed significant increases in task engagement from mid to post test. Additionally, the interaction between Immersion and Exploration ($F(2,65) = 27.53$, $p = .481$, $\eta^2_p = .022$) was not significant. Confidence intervals indicate that only the STVA, LTVP, VRA and VRP treatment conditions showed significant increases in task engagement change scores (Figure 9).

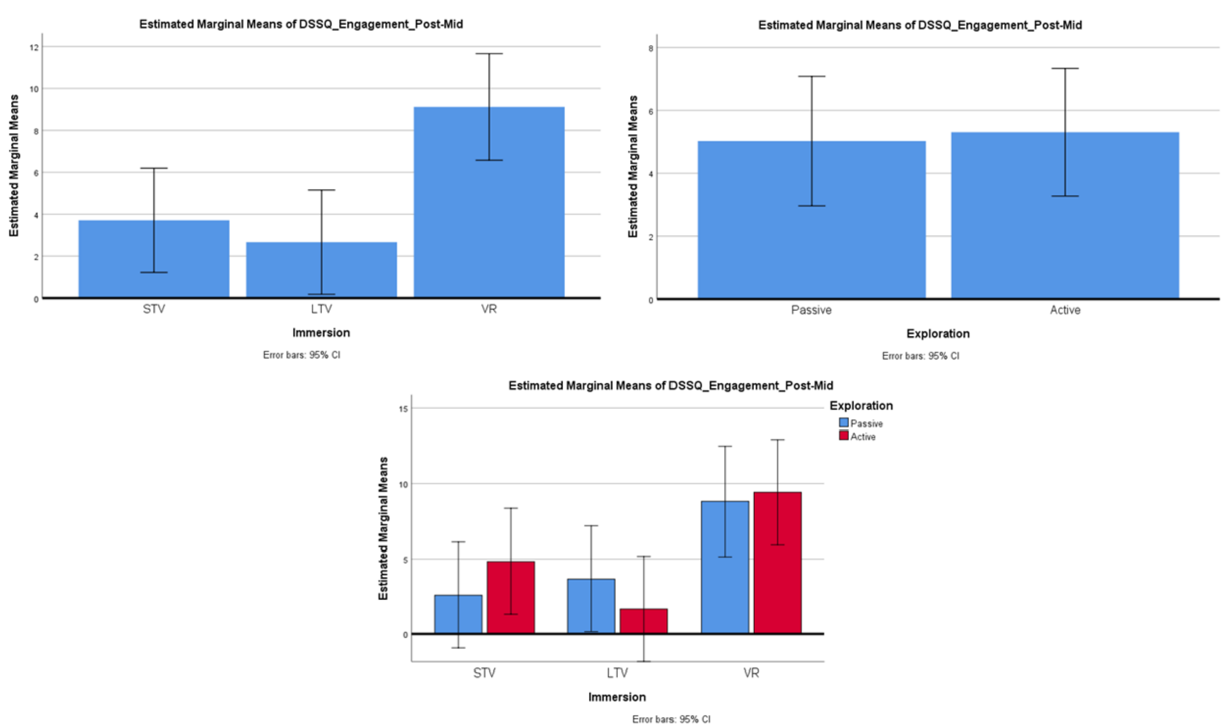

Figure 9. Mid to Post-Test Change in Task Engagement

DSSQ-S Engagement VR and Coloring

Due to the fact that both the VRA and VRP conditions showed significant increases in mid-to-post task change in task engagement, the VRA and VRP conditions were collapsed and then compared to coloring. A one-way ANOVA was conducted on mid to post task engagement change scores. Results revealed a significant effect of level of immersion, $F(1,33) = 7.67$, $p = .009$, $\eta^2_p = .19$. These results indicate that those in the VR condition ($M = 9.13$, $SD = 6.47$) were significantly more engaged than those in the Coloring condition ($M = 2.75$, $SD = 6.47$). Additionally, confidence intervals revealed that only the VR condition (95% CI [6.39, 11.88]) showed significant increases in task engagement from mid-to-post test. No significant increase in engagement from mid to post test was found for those in the coloring condition (95% CI [-1.05, 6.55]) (see Figure 10).

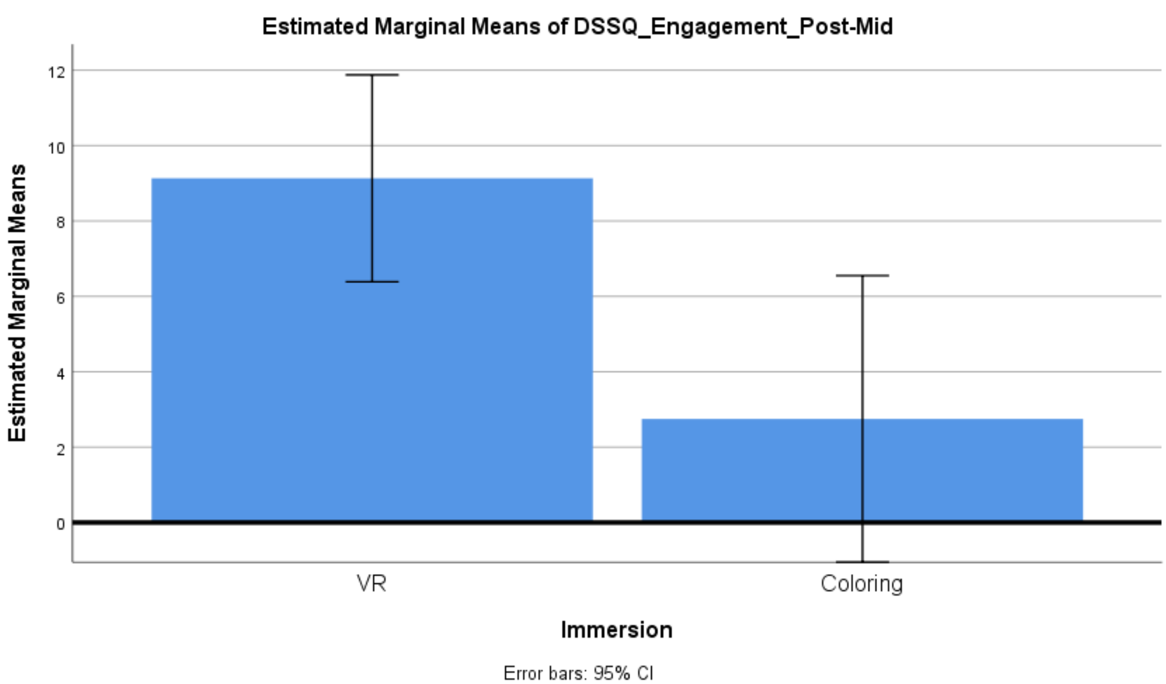

Figure 10. VR vs Coloring Mid-to-Post Test Change in Task Engagement

DSSQ-S Distress

To assess the restorative effects of treatment conditions, a 3(Immersion) by 2(Exploration) ANOVA was conducted on mid to post Distress change scores. Results indicate that there was no significant change differences in Immersion ($F(2,65) = 0.52$, $p = .60$, $\eta^2_p = .016$), Exploration ($F(1,65) = 1.85$, $p = .18$, $\eta^2_p = .03$) or interaction ($F(2,65) = 1.33$, $p = .27$, $\eta^2_p = .04$) between the groups. However, the confidence intervals for all six conditions showed significant reductions in distress from mid-to-post test, except for STVP (Figure 11).

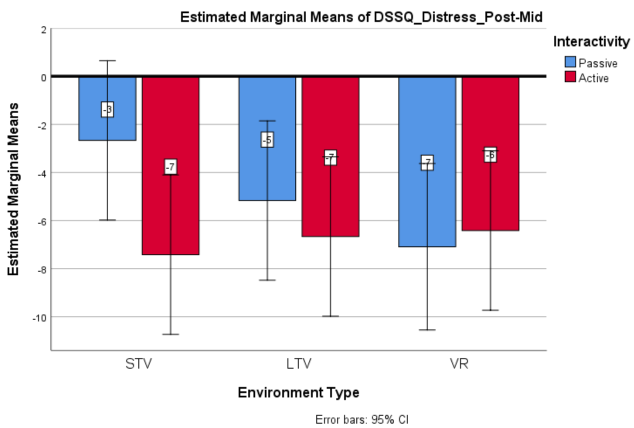

Figure 11. Mid-to-Post Test Change in Distress

VR vs Coloring Change in Distress

Change in mid-to-post test distress was analyzed to assess the potential restorative effects of the coloring and VR nature breaks. The results indicated that that there was no significant change in distress, $F(1,33) = 0.207$, $p = .652$, $\eta^2_p = .006$, found between break types. Despite this null finding between groups, both the VR nature break condition ($M = -6.74$, $SD = 5.93$; 95% CI[-9.11, -4.37]) and the active coloring condition ($M = -5.83$, $SD = 4.84$; 95% CI[-9.12, -2.55]) showed significant reductions in distress from mid to post test (Figure 12).

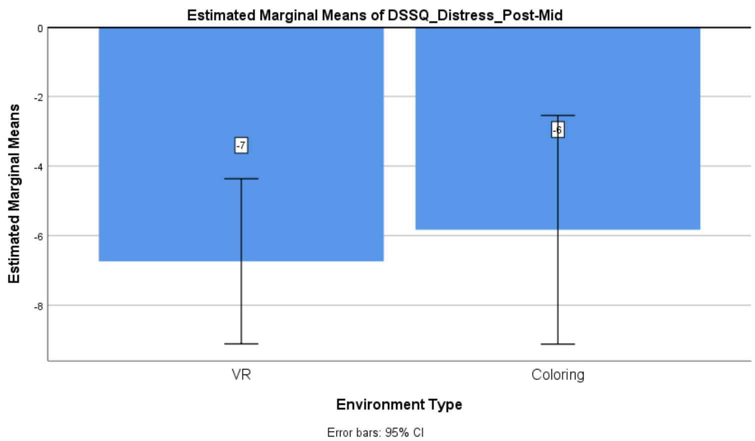

Figure 12. VR vs Coloring Mid to Post-Test Change in Distress

DSSQ-S Worry

To assess the effect of the treatment conditions a 3(Immersion) x 2(Exploration) ANOVA was conducted on mid to post-test worry change. No significant differences in mid to post-test worry change scores were found for immersion ($F(2,65) = 1.86$, $p = .16$, $\eta^2_p = .05$) or exploration ($F(1,65) = 0.12$, $p = .73$, $\eta^2_p = .002$). However, a significant immersion by exploration interaction, $F(2,65) = 3.96.$, $p = .02$, $\eta^2_p = .11$ was found (Figure 13).

Tests of simple effects were conducted collapsing across levels of Exploration. Results indicate that there was a significant difference in worry between environment types in the passive condition, $F(2,65) = 4.36$, $p = .02$, $\eta^2_p = .12$). Bonferroni post hoc tests revealed that Passive VR and Passive LTV conditions experienced significantly different levels of change in worry from mid to post test, such that those is in the Passive VR condition reported an increase ($M = 0.27$) in level of worry where those in the passive LTV condition reported a decrease ($M = -5.75$) in level of worry.

Tests of simple effects, collapsing across Immersion type revealed a significant difference between the VR conditions, $F(1,65) = 4.21$, $p = .041$, $\eta^2_p = .06$, such that those in the

VRA condition (*M* = -3.92) experienced significant reductions in worry compared to those in the VRP condition (*M* = 0.27), who experienced increases in worry.

Lastly, based on inspection of the confidence intervals only those in the LTV passive condition and the VR active conditions displayed significant reductions in worry from mid to post test (Figure 13).

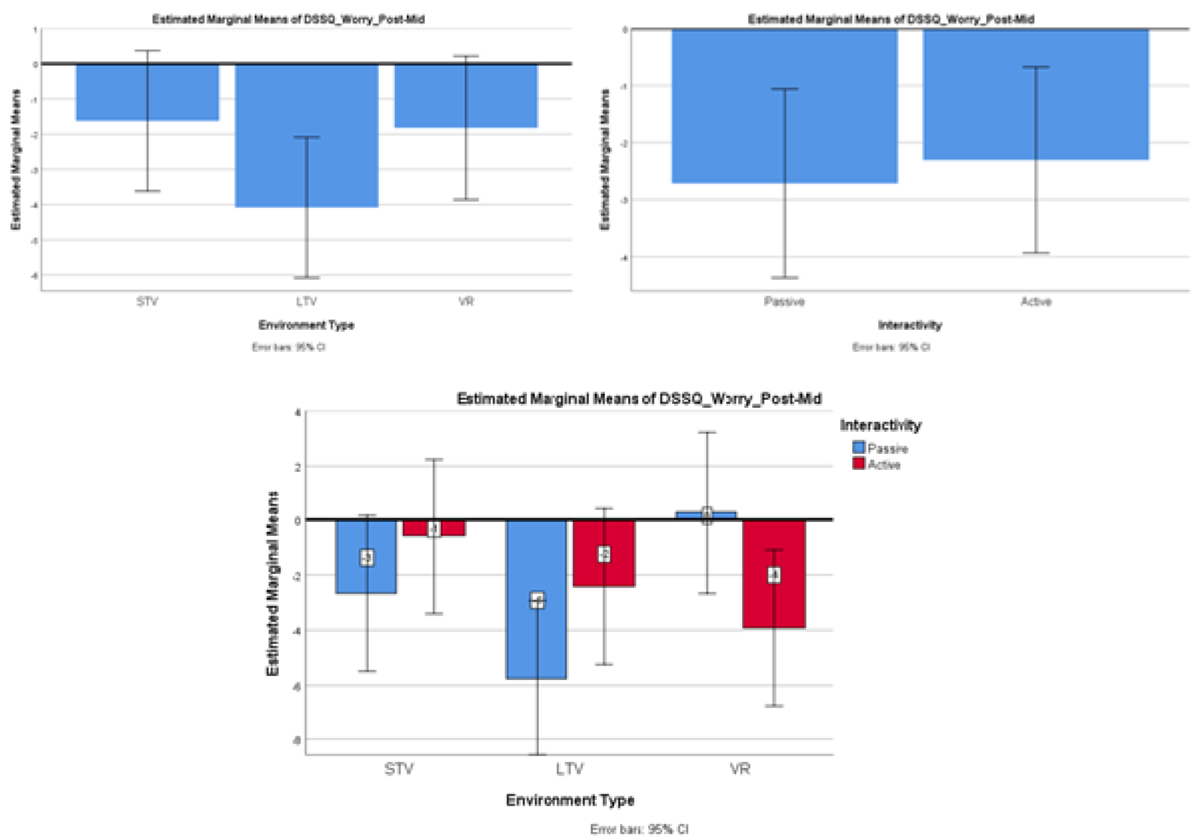

Figure 13. Mid to Post Change in Worry

VRA vs Coloring Mid to Post-Test Changes in Worry

A paired samples t-test was conducted to determine if the VRA condition is significantly better than the coloring condition in reducing worry. Results indicate that there was no significant difference between the two treatments, VRA (*M* = -3.92, *SD* = 5.50) and coloring (*M*

= -3.08, *SD* = 4.64), in reducing worry after the vigil (*t*(11) = -0.40, *p* =.70). Furthermore, mid to post test results indicated that both the coloring (95% CI [-6.94, -0.87]) and VRA (95% CI [-6.13, -0.04]) treatments significantly reduced worry after the vigilance task (see Figure 14).

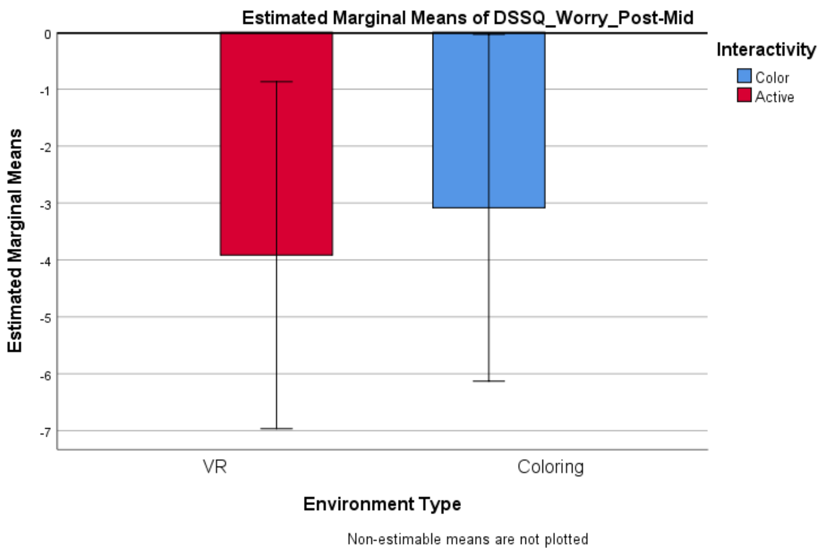

Figure 14. VRA vs Coloring Mid to Post Change in Worry

Mid to Post-Test Change in State Anxiety

Next a 3(Immersion) by 2 (Exploration) ANOVA was conducted on mid to post-test change in level of self-reported state anxiety. Results revealed no significant effects of Environment, ($F(2,65) = 1.57$, $p = .22$, $\eta^2_p = .05$), Exploration, ($F(1,65) = 0.03$, $p = .86$, $\eta^2_p = .000$), or the interaction ($F(2,65) = 0.11$, $p = .90$, $\eta^2_p = .003$) between the two. Furthermore, confidence intervals indicate that only the LTVA, VRA, and VRP conditions showed significant decreases in state anxiety from mid to post-test (see Figure 15).

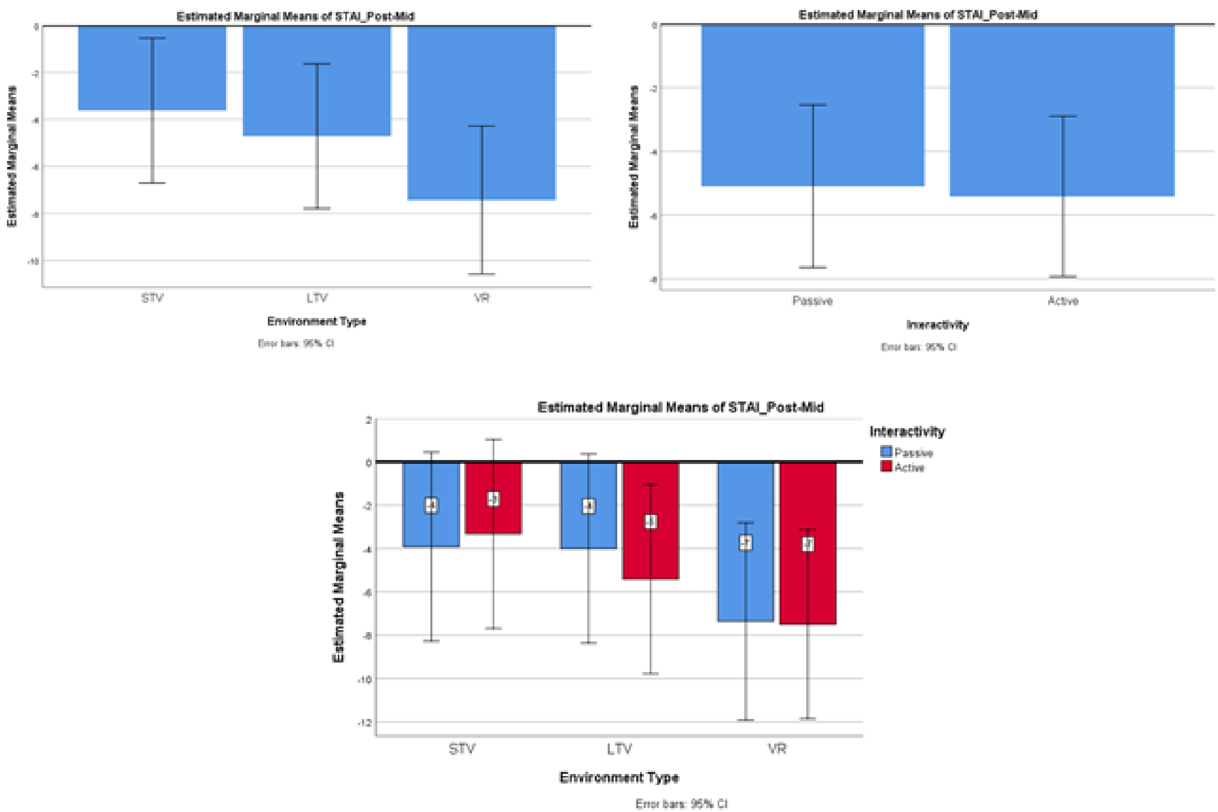

Figure 15. Mid to Post-Test Change in State Anxiety

VR vs. Coloring Mid to Post-Test Change in State Anxiety

In order to assess mid to post change in anxiety, a one way ANOVA was conducted on mid to post STAI change scores. Results indicate that there were no significant difference in anxiety change scores between the coloring and VR conditions, $F(1,33) = 0.272$, $p = .605$, $\eta^2_p = .008$. However, participants in both the VR and Coloring conditions showed significant decreases in anxiety from mid to post test (see Figure 16).

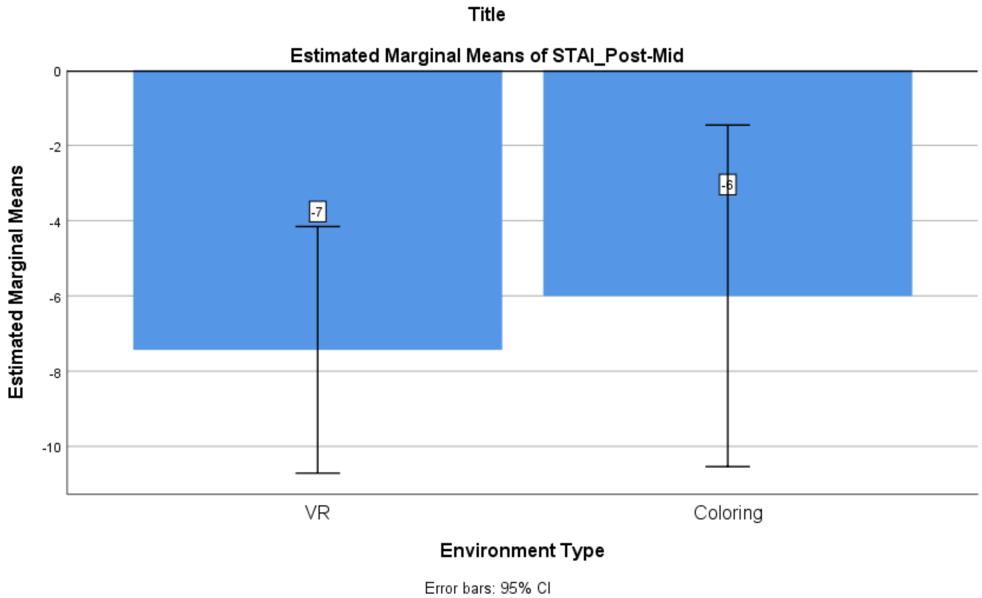

Figure 16. VR vs Coloring Mid to Post-Test Change in State Anxiety

SUS

A 3x2 ANOVA was conducted on SUS scores to determine if participants differed on perceived presence between the six treatment conditions. Results of the SUS indicate that there was a significant main effect of Immersion, $F(2,65) = 10.84$, $p < .001$, $\eta^2_p = .25$. Post Hoc test revealed that there was a significant difference between the VR and STV ($p = .000$) and LTV ($p = .000$) conditions, such that those in the VR ($M = 4.46$, $SD = 0.79$) condition reported significantly higher levels of presence than those in the STV ($M = 3.41$, $SD = 0.98$) and LTV ($M = 3.40$, $SD = 0.86$) conditions. No main effect of Exploration $F(1,65) = 0.03$, $p = .85$, $\eta^2_p = .001$ or immersion by exploration interaction, $F(2,65) = 0.914$, $p = .41$, $\eta^2_p = .03$, was found (Figure 17).

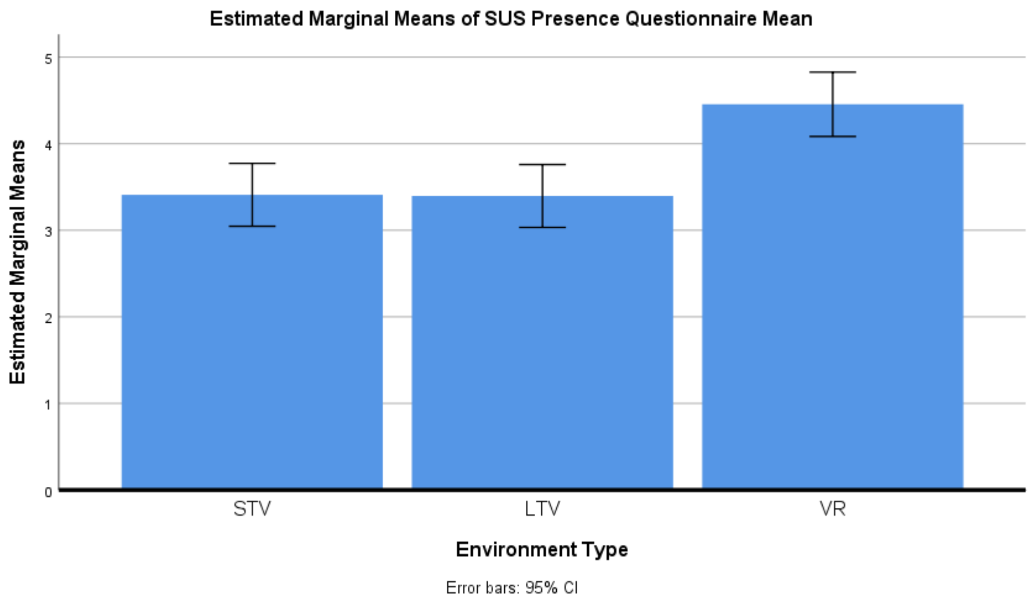

Figure 17. Perceived Presence in Different Levels of Immersion

PRS

A 3(Immersion) by 2(Exploration) ANOVA was conducted to analyze the effect the six treatment conditions on perceived restorativeness of the virtual nature environments. The scores on the PRS can range from 0 (“not at all restorative”) to 6 (“completely restorative”). Results indicate that there was a significant main effect of Immersion, $F(2,65) = 14.95$, $p < .001$, $\eta^2_p = .32$. Post hoc tests further revealed that people in the VR conditions ($M = 4.22$, $SD = 0.82$) perceived VR as significantly more restorative ($p < .001$) than did those in the LTV ($M = 2.67$, $SD = 1.12$) and STV ($M = 2.96$, $SD = 1.09$) conditions (see Figure 18).

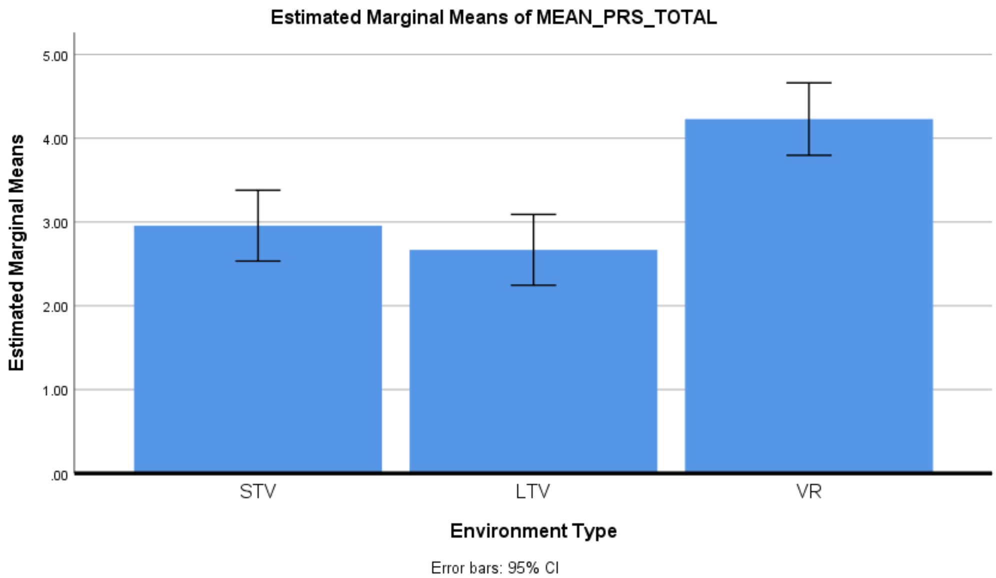

Figure 18. Perceived Restorativeness of Immersive Nature Environments

"Being Away" Subcomponent of the PRS

Kaplan and Kaplan (1995) state that the feeling of "being away" is an important component of restoration. The PRS was created to look at the four components of a restorative environment according to Kaplan and Kaplan but as a result only the "being away" sub-component was applicable to a task and not just an environment so it was used to compare the ability of coloring a mandala to the ability of virtual nature experience to provide the feeling of being away. Results of the 2x3 ANOVA indicate that there was a significant main effect of immersion, $F(2,65) = 12.63$, $p < .001$, $\eta^2_p = .28$. Bonferroni post hoc test revealed that the those in the VR ($M = 3.90$) condition experienced a stronger feeling of being away than the LTV ($M = 1.62$) and STV ($M = 2.13$) conditions ($p \leq .001$)

VR vs Coloring "Being Away" Subcomponent of the PRS

Due to the fact that the VR condition elicited the greatest feeling of "being away" as compared to the STV and LTV conditions, it was chosen to be compared to the active break condition. The results indicate that there was no significant difference between the two conditions, $t(33) = -1.41$, $p = .17$. Both the both the VR ($M = 3.90$, $SD = 1.39$) and the Coloring ($M = 4.55$, $SD = 1.05$) breaks elicited strong feelings of being away.

Physiological Measures (HR & HRV)

Refer to Figures 19 and 20 for general overview of the trend of HR and HRV data over key points of the study. Each number corresponds to one five-minute epoch during a particular task or measure and can be read as follows: Baseline (1), Pre N-Back (2), 45-minute Vigil (3–11), Mid N-Back (12), During Treatment (13,14), and Post N-Back (15).

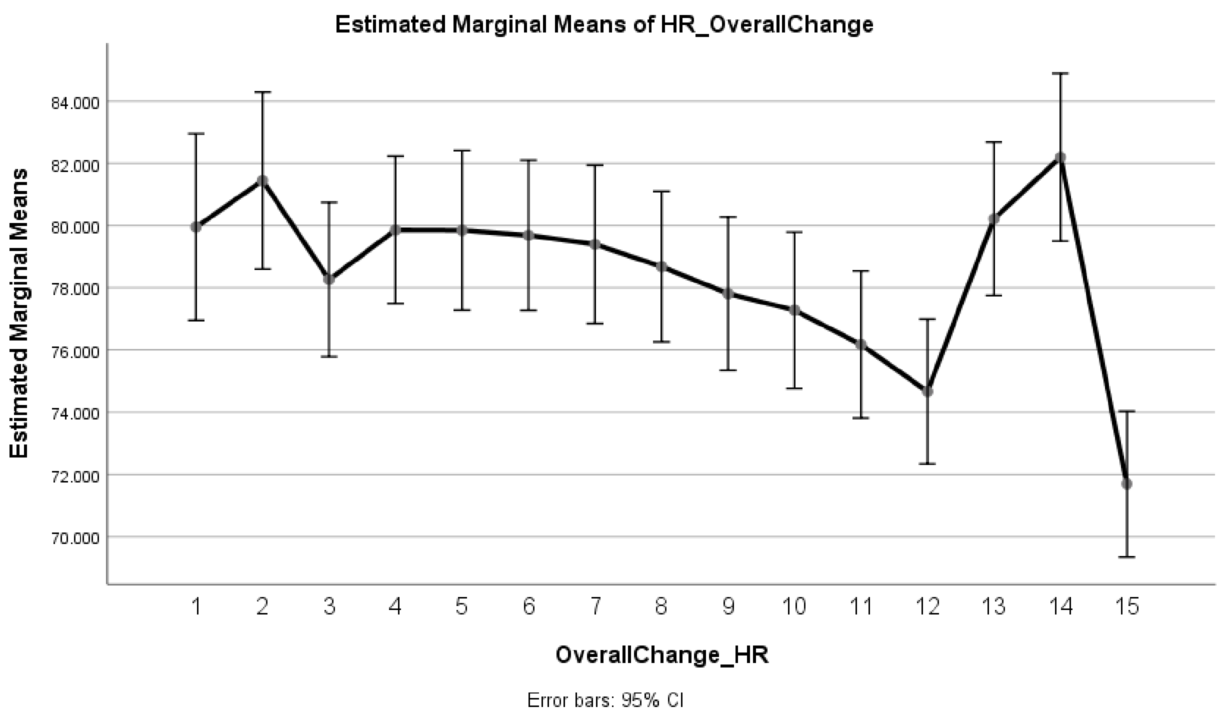

Figure 19. Raw HR data over the course of the experiment

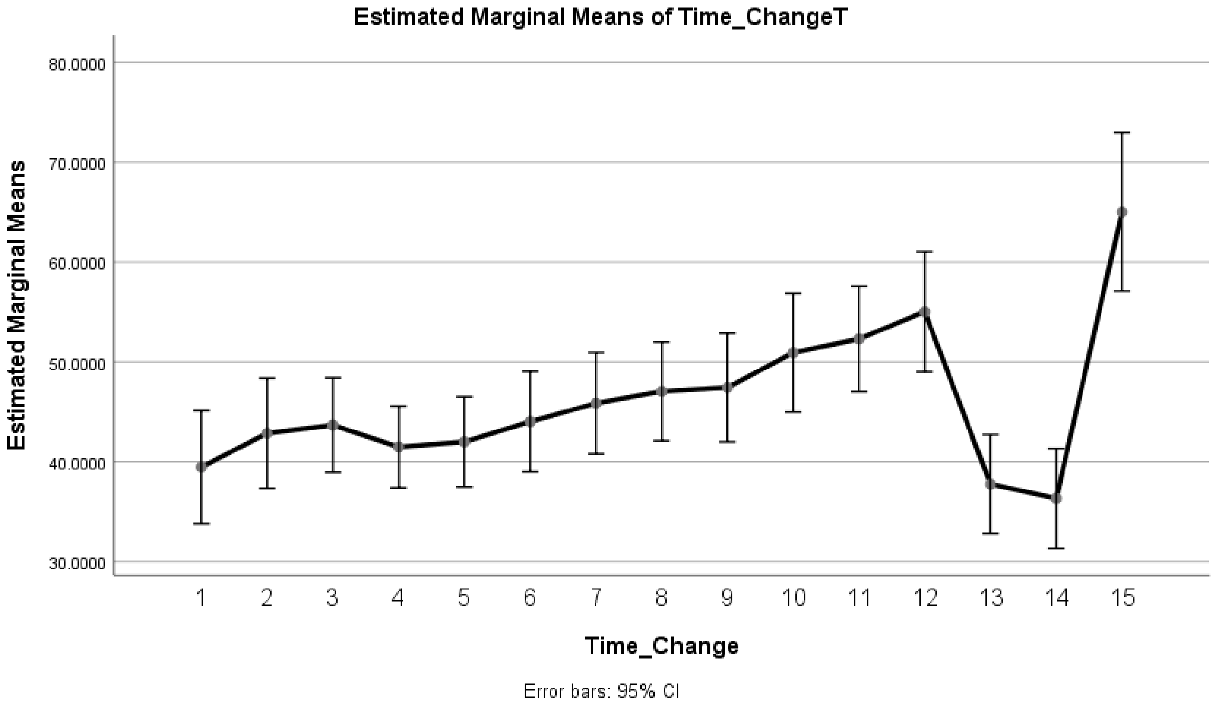

Figure 20. Raw HRV data (RMSSD) over the course of the experiment

Post Depletion Changes in Arousal during Treatment

In this section, results regarding the change in HR and HRV during the virtual nature environment treatments will be presented followed by a comparison of the best method of displaying VE nature, to a 10-minute active break (broken into two 5-minute) epochs during which participants colored-by-number a mandala.

HR Change

To examine HR after vigil (2nd administration of N-Back) to treatment change a 2 (Epoch) x 3 (Immersion) x 2 (Exploration) repeated measures ANOVA was conducted, where epoch was the within groups factor and immersion and exploration were the between groups factors. First, confidence intervals show that there was a significant increase in after vigil to treatment HR.

This increase is indicative of arousal during the 10-minute treatment conditions. Additionally, a significant within groups main effect of Treatment $F(1,65) = 25.65$, $p < .001$, $\eta_p^2 = .29$, was found, indicating that the change in HR from the second 2-Back task differed significantly throughout the treatment. Results indicate that at the 1st epoch of the treatment ($M = 5.72$, $SD = 4.72$) HR increased from after the vigil (2-Back Mid) and then increased even more during the last 5 minutes of the treatment (2nd epoch) ($M = 7.69$, $SD = 5.85$) (see Figure 21). Additionally, a significant between groups effect of immersion was found on after vigil to treatment change scores, $F(2,64) = 3.67$, $p =.03$, $\eta_p^2 = .10$. Although Bonferroni post hoc tests did not detect significant differences in after vigil to treatment change in HR between the STV, LTV and VR conditions, it is apparent that the VR condition experienced the least arousal during the treatment. No other significant within or between groups effects were found.

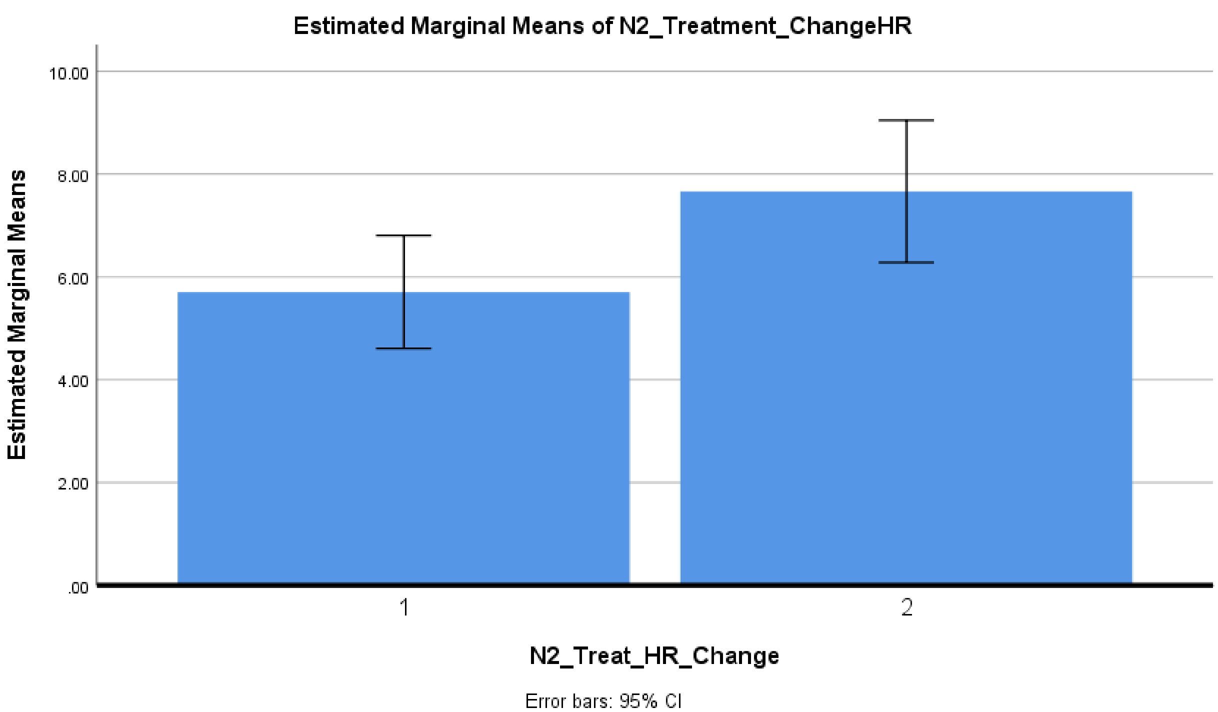

Figure 21. After Depletion to During Treatment (Epochs 1 and 2) Change in HR

VR vs Coloring Post Vigil to Treatment Change HR

The post vigil to treatment change in heart rate in the VR condition was next compared to the change experienced in the coloring condition. Results of the 2 (Epoch) by 2 (Break Type) mixed groups ANOVA indicate that there is a significant difference from after vigil to Treatment change HR between epochs one and two of the treatment, $F(1,33) = 11.48$, $p = .002$, $\eta^2_p = .26$, such that change in after vigil to treatment HR increased significantly from Epoch 1 ($M = 2.89$, 95% CI [1.27, 4.52]) to Epoch 2 ($M = 4.37$; 95% CI [2.56, 6.17]). Additionally, based on the CIs reported above it is clear that the change in HR significantly increased during both epoch 1 and epoch 2 of the treatment. No significant epoch by break within group interaction was found for changes in HR. Additionally, no significant post vigil to treatment change was found between the coloring ($M = 2.85$, 95% CI [0.16, 5.54]) and VR ($M = 4.41$, 95% CI [2.47, 6.35]) conditions, $F(1,33) = 0.91$, $p = .35$, $\eta^2_p = .03$ (see Figure 22). However, both the coloring and VR conditions showed significant increases in HR from post vigil (see Figure 22).

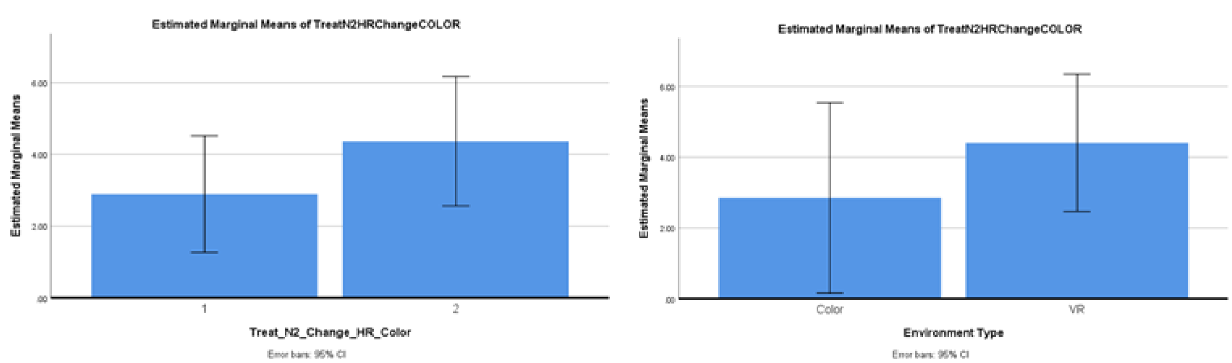

Figure 22. VR vs Coloring Change in HR during Treatment

RMSSD Change

To examine RMSSD after vigil to treatment change a 2 (Epoch) x 3 (Immersion) x 2 (Exploration) repeated measures ANOVA was conducted, where epoch was the within groups measure and immersion and exploration were the between groups factors. The results indicate that there are no significant within groups effects of Treatment, $F(1,65) = 1.642$, $p = .21$, $\eta^2_p = .03$, Immersion $F(2,65) = 0.47$, $p = .63$, $\eta^2_p = .01$, Exploration $F(1,65) = 0.021$, $p = .886$, $\eta^2_p = .000$, or the interaction between them $F(2,65) = 1.00$, $p = .37$, $\eta^2_p = .03$. However, there was a significant between groups main effect of immersion, $F(2,65) = 3.29$, $p = .04$, $\eta^2_p = .09$ (see Figure 23). Bonferroni post hoc tests reveal that there is a marginally significant ($p = .06$) difference in RMSSD change scores between the VR and LTV conditions, such that participants in LTV condition had greater decreases in HRV meaning and increase in arousal/stress than those in the VR. No other significant between groups main effect or interaction was found.

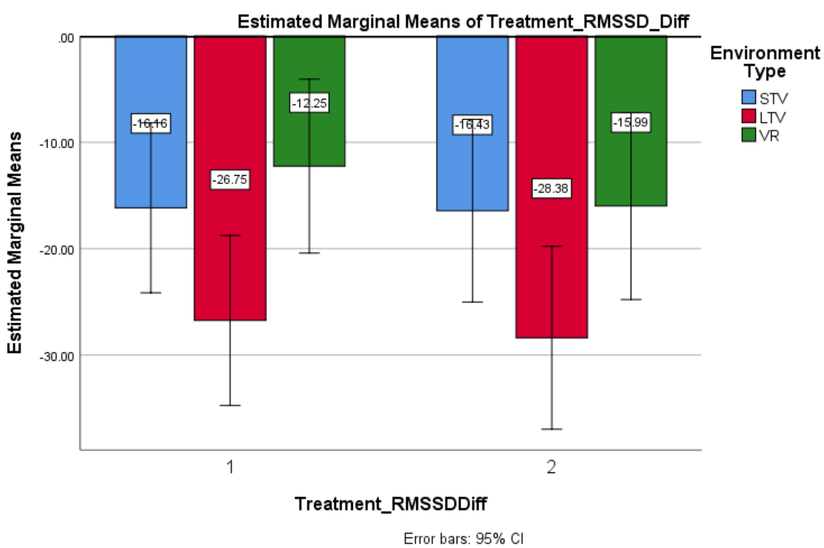

Figure 23. Mid to Post-Test Change in RMSSD

Coloring vs VR Change RMSSD

The VR condition was then compared to the Coloring condition using a 2 (Epoch) by 2 (Break) Mixed ANOVA. Results indicated that there was a significant within groups interaction between Epoch and Break type (coloring vs. VR), F (1,33) = 4.42, p =.04, η^2_p = .12). This interaction indicated that those in the coloring condition showed initial declines in HRV during epoch 1(M = -15.99, 95% CI [-26.11, -5.87]) but then decreased even more in epoch 2 (M = -11.04, 95% CI [-21.50, -0.58]). Whereas the opposite pattern emerged for the VR condition as they showed greater declines in post vigil change in HRV during Epoch 1 (M = -12.34, 95% CI [-19.65, -5.03]) and these declines reduced during epoch 2 (M = -16.01, 95% CI [-23.57, -8.46]) (Figure 24 below). No significant between groups effects were found (p = .76) (see Figure 25). CIs indicate that overall variability decreased, however based on the aforementioned results it did not decrease any more in one condition over the other.

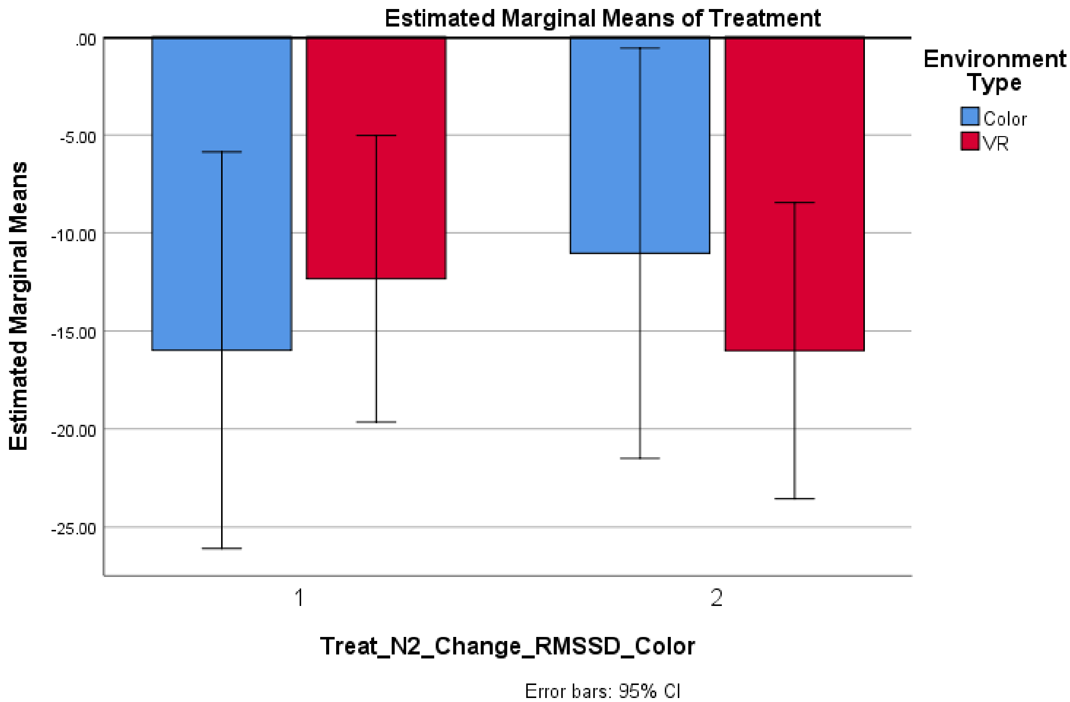

Figure 24. Within Groups Epochs 1 and 2 and Break type Interaction

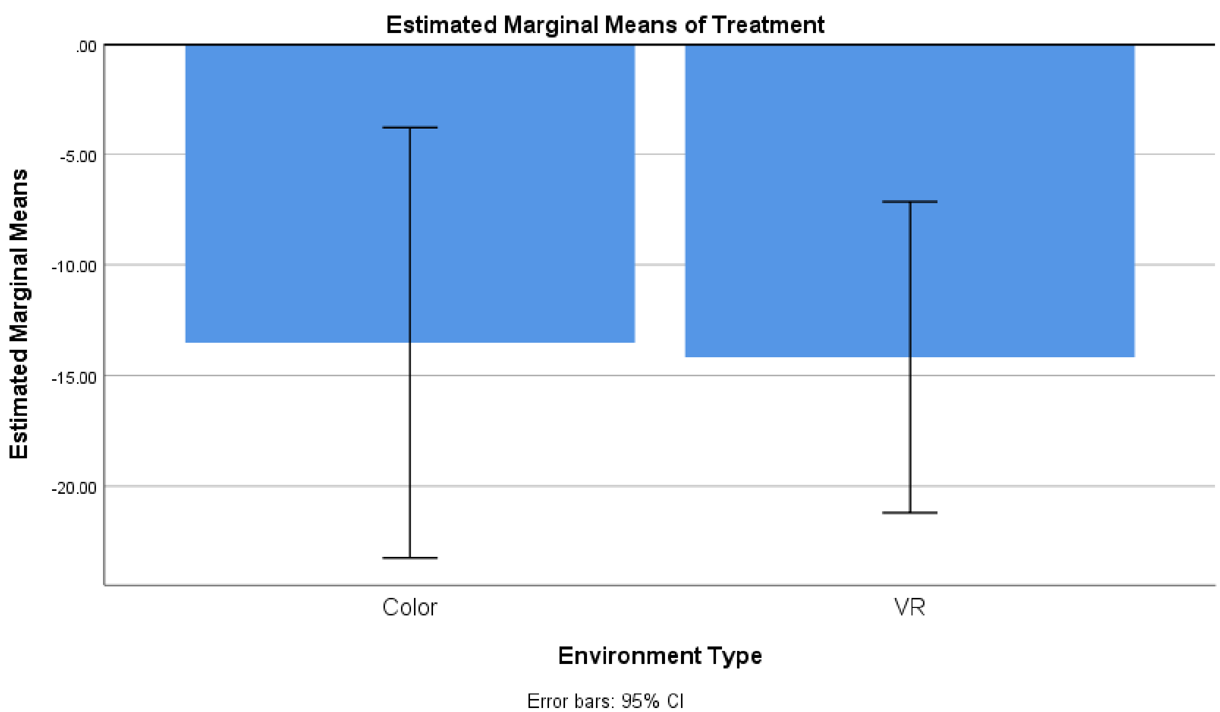

Figure 25. VR vs Coloring Declines in HRV During Treatment

Post Depletion to Post Treatment Change

Though the N-Back experienced issues with ceiling effects as stated previously, physiological measures of HR and HRV will still be used to assess after vigil to after treatment changes, as prior results indicated that HR and HRV was negatively impacted from the vigilance task.

Change in Heart Rate

Results of a 3(Immersion) by 2(Exploration) ANOVA indicate that there are no significant between groups differences in change in HR from mid to post N-Back. Additionally, based on inspection of the confidence intervals across all 6 treatment conditions showed significant decreases in change in HR from mid to post N-Back administrations, which is indicative of a reduction in arousal (Figure 26).

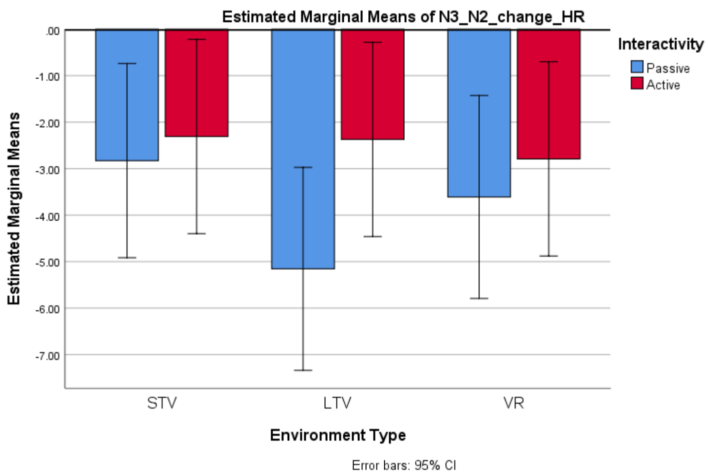

Figure 26. Post Depletion to Post Treatment Change in HR

VR vs Coloring Post Depletion to Post Treatment Change in HR

Although all six conditions showed significant decreases in HR, because of the above-mentioned lack of significant differences between the six conditions, scores from the VRA and VRP conditions were collapsed so that post-vigil-to-post-treatment changes in HR could be compared between the VR and coloring break conditions. To assess this change, a oneway ANOVA was conducted. Results indicate that there is a significant main effect of Break type, $F(1,33) = 7.06$, $p = .01$, $\eta^2_p = .18$. The results further revealed that the participants who experienced nature in VR ($M = -3.18$) experienced a greater mid to post change in HR during the 2-Back than those who took a coloring ($M = -0.41$) break. Furthermore, confidence intervals indicated that there was a significant decrease in after vigil to after treatment change in HR in for those who experience nature in VR (95% CI [-4.43,-1.94]) but this was not found for those who spent the break coloring (95% CI [-2.13,1.32]) (see Figure 27).

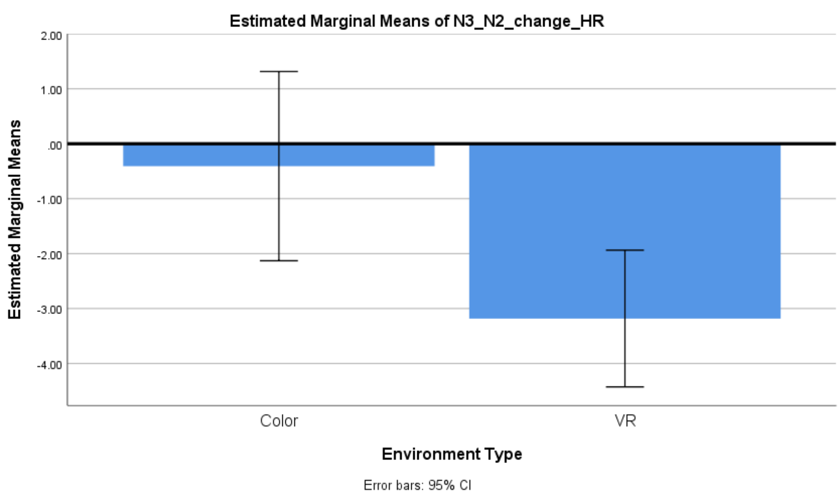

Figure 27. VR vs Coloring Post Depletion to Post Treatment Change

Change in RMSSD

Results of a 3(Immersion) by 2 (Exploration) ANOVA indicate that there are no significant between groups differences in change in RMSSD from after vigil to after treatment N-Back administrations. Additionally, based on inspection of the confidence intervals all treatment conditions showed significant increases in change in RMSSD from post vigil to post treatment, except for those who were in the VRA condition (see Figure 28).

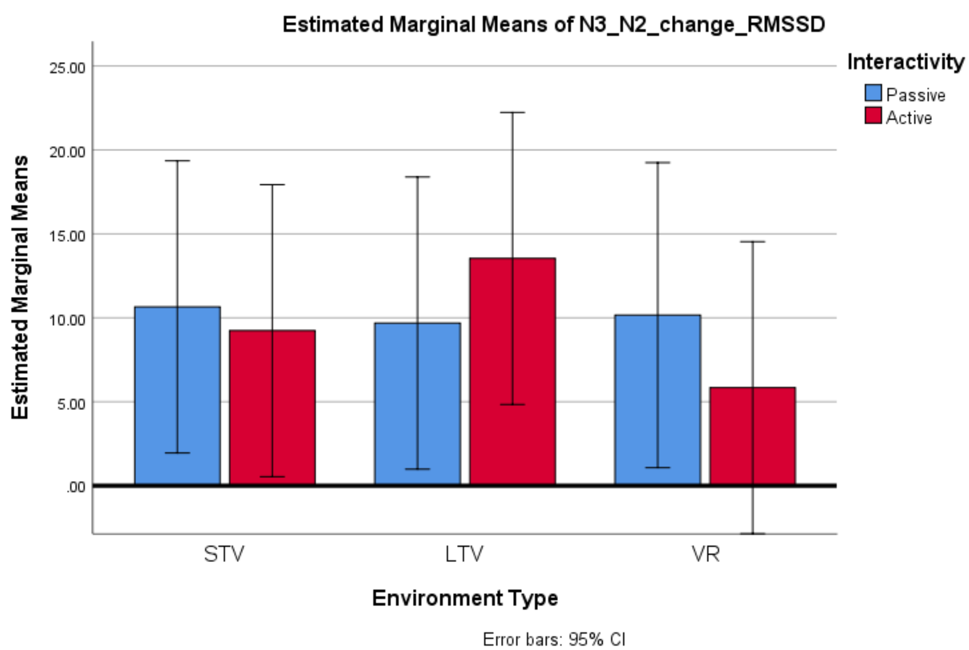

Figure 28. After Vigil to Treatment Change in RMSSD

VRP vs. Coloring Change in RMSSD

Based on the findings above, the post vigil to post treatment change was compared between those who passively experienced nature in VR and those who took a coloring break. To determine if there are any differences in post vigil to post treatment changes in RMSSD between the two break conditions a oneway ANOVA was conducted. Results suggest that there are no significant differences in RMSSD change scores between those who passively experience nature

in VR or those who took a break to color, $F(1,23) = 3.83$, $p = .06$, $\eta^2_p = .15$. However, confidence intervals indicate that there was a significant increase in post vigil to post treatment change in RMSSD for those who passively experienced nature in the VR condition (95% CI [2.92, 17.40]) that was not found for those who colored (95% CI [-6.20,7.67]) during their break (see Figure 29).

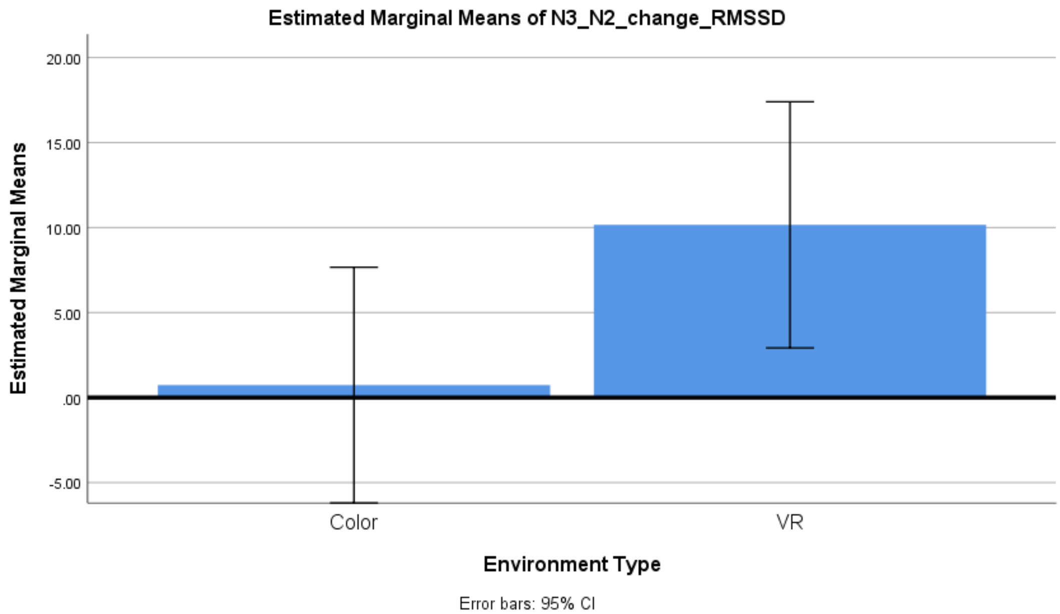

Figure 29. VRP vs Coloring Post Depletion to Post Treatment Change in RMSSD

Perceived Restoration vs. Subjective and Physiological Measures of Stress

Lastly, in order to determine if individuals' perceptions of restoration are related to actual restoration a correlation was conducted on PRS scores and all mid-to-post test measures of subjective and physiological stress. Overall the results indicated that perceptions of restoration do not correlate with measures of stress, with one exception, perceived restoration was positively correlated with task engagement ($r(71) = .42$, $p < .001$; See Figure 30).

Correlations Perceived Restoration with Mid to Post-Test Measures of Stress

		Perceived Restoration	Engagement	Distress	Worry	STAI	HR	HRV
Perceived Restoration	Pearson Correlation	1	.417**	-.158	.005	-.216	-.024	.031
	Sig. (2-tailed)		.000	.187	.970	.071	.845	.799

Figure 30. Correlations between Perceived Restoration and Actual Restoration

A summary of the study results is provided below for reference (See Table 3).

Table 3. Summary of Study Results (Mid to Post-Test Change)

Measures	**Results**
Subjective	
N-Back (Working Memory)	• Ceiling and Practice effects were observed as such no conclusions can be made for this measure.
DSSQ-S (Stress)	
Task Engagement	
Virtual Environments	• All levels of immersion showed significant increases in Task Engagement. • Main Effect of Immersion VR conditions increased significantly more than LTV and STV conditions • Active and Passive Exploration showed significant increases in Task Engagement; No between groups differences were observed • Only STVA, LTVP, VRA and VRP conditions had significant increases in task engagement; Immersion by Exploration Interaction was not significant
Coloring vs VR	• Significant between groups differences. VR condition experienced significantly greater increases in Task Engagement than Coloring. • Only the VR condition experienced increases in Task Engagement. This significant result found only in the VR condition may have been due to unequal sample sizes (VR = 24 & Coloring = 12).
Distress	
Virtual Environments	• No significant between groups differences were found. • All levels of immersion and exploration showed reductions in distress. • All six VE conditions are effective at reducing distress except the STVP condition
Coloring vs VR	• No significant differences in distress were found between the VR and Coloring conditions • Both VR and Coloring are effective at reducing distress
Worry	
Virtual Environments	• No significant main effects were found. • Interaction between Immersion and Exploration was significant. • Test of simple effects collapsing across immersion indicate that in the VRA condition worry reduced but in the VRP condition worry increased.

Measures	**Results**
	Additionally, when collapsing across exploration VRP showed an increase in worry and LTVP decrease in worry.
Coloring vs VRA	• No significant differences between groups were found. • Both the coloring and active VR nature conditions were effective at significantly reducing worry.
STAI (State Anxiety)	
Virtual Environments	• No significant between groups differences were found for Immersion or Exploration or the interaction thereof • All levels of immersion significantly decreased state anxiety • All levels of exploration showed significant decreases in state anxiety • Only those in the LTVA, VRA, and VRP conditions experienced significant decreases in state anxiety.
Coloring vs VR	• Experiencing nature in VR and Coloring are both similarly effective in reducing state anxiety.
SUS (Presence)	• The STV, LTV and VR conditions all reported high levels of presence, however, the those in the VR condition reported significantly greater levels of presence than the LTV and STV conditions
PRS (Perceived Restoration)	• The VR condition was perceived overall as more restorative than the STV and LTV conditions.
PRS "Being Away" Subcomponent	• The those in the VR condition reported greater levels of being away than those in the STV and LTV conditions. • Both the VR and Coloring conditions reported experiencing similarly high levels of "being away".
Physiological	All HR and HRV measures were broken down into 5-minute epochs. Increases in HR and decreases in RMSSD (HRV) are indicative of increased arousal/stress.
Change During Treatment	After vigil to treatment change (treatment consisted of two epochs; total of 10 minutes)
Heart Rate: VEs	• Significant increases in HR were observed while experiencing the nature VE, however these increases were even greater during the last five minutes. • Participants HR significantly increased in the STV, LTV and VR conditions, however, it is apparent HR increased the least for those in the VR condition.
Heart Rate: Coloring vs VR	• HR increased in both the coloring and Nature VR break conditions; however, these increases were even greater during the last half of the break. • Similar elevated levels of arousal were observed during the VR nature and Coloring conditions.
HRV: VEs	• Significant within group interaction was found between epoch and treatment type. Interaction indicated that those in the coloring condition showed greater initial declines in HR during epoch 1 but then and then declined to a lesser extent in epoch 2. Whereas the opposite pattern emerged for the VR condition as they initially showed declines in post vigil change in RMSSD during Epoch 1 and these declines became even greater during epoch 2. • No significant between groups differences were found. • HRV significantly decreased in all conditions.

Measures	Results
HRV: Coloring vs VR	• A significant within groups interaction was found between epoch and treatment type. • No significant between groups differences were found. • Both the coloring and VR nature treatment conditions showed significant reductions in HRV, indicating arousal increased during both conditions.
After Vigil to After Treatment Change	
Heart Rate: VEs	• No significant between groups differences in HR were found. • Significant decreases in HR were observed for all six VE nature conditions.
Heart Rate: Coloring vs VR	• Significant reductions in HR were observed in the HR reduced significantly in the VR condition but not in the coloring condition.
HRV: VE	• Significant increases in HRV were observed for all six VE nature conditions except VRA.
HRV: Coloring vs VRP	• No significant differences were found in HRV between the Passive VR nature and Coloring conditions. • Only the Passive VR nature condition experienced a significant increase HRV, which is indicative of stress reduction. This significant result found only in the Passive VR condition could potentially be attributed to unequal sample sizes (VR = 24 & Coloring = 12), as the coloring condition did show increases in HRV although they were not significant.

CHAPTER FIVE: DISCUSSION

There is an extensive body of evidence showing that stress and cognitive fatigue, and the deleterious effects on attention, performance, and mental health that they cause, is an ever-growing problem that affect workplaces, older adults, college students, etc. alike. Although there are numerous, scientifically documented ways in which one can reduce cognitive fatigue and stress, the literature has recently has focused much of its attention on the restorative benefits of nature. The preponderance of evidence supports that presentations of nature are effective at reducing stress and restoring cognition but this body of research has not been consistent in the relative effectiveness of different presentation mediums (e.g. pictures, videos). The mixed results of these studies might be attributable primarily to two major factors. The first is that much of this research may have been unsuccessful in inducing mental fatigue and stress (so that this fatigue and stress can later be reduced) and the second is that many of the presentation mediums explored in the literature did not allow for an interactive, immersive experience similar to what one would experience from being present in a natural environment. As such this study aimed to 1) ensure that all participants were both stressed and cognitively fatigued, 2) investigate the impact on level of immersion (non, semi, and full) and exploration (passive, active) on cognitive restoration and stress reduction, and 3) determine if the best version of virtual nature offers greater benefits than taking an active break (i.e. coloring a mandala).

Cognitive Measure

Although one of the primary purposes of this study was to determine the impact of virtual natural environments on cognitive restoration, due to a ceiling effect that occurred with the 2-Back data, this was not possible.

This effect was unexpected as this pattern of results was not seen in pilot testing. In retrospect, it could be argued that the 2-Back test was not a sufficiently difficult task to begin with and, when coupled with three administrations of the measure, practice effects contributed to the observed ceiling effects. As a result, the 2-bask task is not considered a good measure of cognitive ability for this study.

Stress Measures

Both the DSSQ-S and the STAI were used in this study as indicators of stress. The three factors on the DSSQ-S were Task Engagement, Distress, and Worry, each of which will be discussed in detail below.

Task Engagement

Analysis of baseline measures indicated that there were significant differences between groups in task engagement at the beginning of the study. Specifically, those in the VR condition reported being significantly more engaged than those in the STV and LTV conditions. Based on the fact that nothing was manipulated on day 2 from pre to mid administration of the survey, this finding was unexpected. However, this finding may have been influenced by the fact that participants knew what treatment condition they were in, due to being assigned to and interacting with the technology on Day 1, one or two days prior and are now looking forward to experiencing the VE again. Furthermore, it is likely that this finding was more exaggerated in the VR condition, as VR is more immersive and potentially exciting to the participants. The pre to mid test revealed that participants assigned to the VR condition experienced significantly greater reductions in task engagement after the vigil, arguably due to regression to the mean.

Results provided support for hypothesis one, such that individuals experienced increases in task engagement as a result of exposure to nature after a period of stress and cognitive fatigue regardless of level of immersion. Hypothesis two was also supported, as participants who experienced nature via VR reported significantly greater levels of task engagement than those in the STV and LTV conditions. The active and passive exploration conditions also showed restorative effects, as participants experienced greater task engagement after the vigil in both conditions, however, this increase did not significantly differ between the two conditions. As such Hypothesis four was not supported. Additionally, no significant immersion by exploration interaction was found, as a result there was no support for hypothesis five as only the STVA, LTVP, VRA and VRP conditions experienced significant increases in task engagement from mid to post test.

Based on aforementioned findings, one can conclude that VR nature is the best at increasing task engagement. This may be due to the fact that it provided the most immersive way to experience virtual nature environments. Slater, Linakis, and Kooper (1999) found that fully immersive environments are viewed as more lifelike and as a result should reduce stress like nature environments have been found to do (e.g. Ulrich, 1991).

Task Engagement VR vs Coloring.

Based on the above findings, participants' reported level of engagement in the VR condition was compared to that of those in the active break condition, in which participants colored by number the mandala. Results indicated that there was a significant difference between the two groups on reported levels of engagement, such that the VR condition reported higher levels of task engagement than the coloring condition. Furthermore, only the VR condition experienced a

significant increase in task engagement from mid to post, indicating the VR condition was effective at increasing task engagement after a long vigil, supporting hypothesis six.

DSSQ-S Distress

The results revealed that hypothesis one and three were supported. All levels of Immersion and all levels of Exploration significantly decreased distress. However, hypotheses two and four were not supported as there were no significant main effects of immersion or exploration, so the VR immersion and Active Exploration conditions were not significantly better at decreasing distress than the STV, LTV and Passive Exploration conditions respectively.

No significant interaction between immersion and exploration was found, therefore Hypothesis five was also was not supported on this measure. The VRA condition was not significantly better than the other five treatment conditions at reducing distress. Additionally, all virtual nature conditions, except STVP significantly reduced distress following the vigil.

Distress VR vs Coloring.

Based on the fact that the VR condition showed the greatest reduction in distress, though not significantly different from the other display types, it was compared to the coloring condition. Results did not provide support for hypothesis six, as viewing nature environments in VR is not more effective at reducing distress than coloring a mandala.

DSSQ-S Worry

A significant immersion by exploration interaction was found, results indicated that passive exploration benefits individuals when interacting with a large TV but has the opposite effect when displayed in VR. This effect may be seen because people are used to passively viewing

nature images on large TVs, but have a potential expectation of exploration when using virtual reality devices (Grodal, 2012). This may also be why people in the VRP condition did not experience any reductions in worry after the vigil but people in the VRA condition experienced large reductions in worry. Lastly the only two conditions that show decreases in worry after the vigil are the LTV passive and VR active conditions. Based on these findings, hypotheses 1, 2, 4 and 5 were not supported.

VRA vs Coloring Change in Worry.

Upon comparing the two breaks, coloring and VRA, no significant between group differences in worry were found. However, those who colored mandalas experienced significant reductions in worry, but this was not the case for those who experienced nature in VR. This finding is surprising as the vigilance task did not significantly increase worry, as expected based on the literature (Szalma et al., 2004; Temple et al., 2000; Warm, Matthews, & Finomore, 2008), nor did participants vary in levels of worry at baseline.

State Anxiety

State anxiety was measured by the STAI, both after the vigil and after viewing virtual nature. Despite no significant between groups findings in all VE conditions, significant confidence intervals indicate all levels of immersion and all levels of exploration showed decreases in state anxiety, as hypothesized. Furthermore, though the interaction between immersion and exploration was not significant, confidence intervals indicate that only the VRA, VRP, and LTVA treatment conditions are effective at reducing state anxiety.

State Anxiety Coloring vs VR.

Though there was no significant difference in reductions in state anxiety between these three conditions as mentioned above, a combination of VRA and VRP were selected for comparison to the active break condition (coloring) because VR presentations of nature were the primary area of focus for this study. The results suggest that whether you take a break and experience nature in virtual reality or take a break and color doesn't matter, they both are effective methods to reduce state anxiety.

SUS

The results indicated that level of immersion was the only significant determinant of perceived presence. The mean score on the SUS for the participants in the VR condition was 4.46 which is considered quite high (Usoh, Catena, Arman, & Slater, 2000). More specifically, people in the VR conditions reported feeling significantly more presence than the STV and LTV conditions (mean scores were 3.41 and 3.40 respectively). This result coincides with the finding that more immersive environments contribute to greater the levels of presence (e.g. Bindman, Castaneda, Scanlon, & Cechony, 2018; De Kort et al., 2006; Lombard, Reich, Grabe, & Bracken, 2000; Schubert, Friedmann & Regenbrecht, 2001) and with past research others found SUS scores of 4.5 out of 7 in realistic VR environments (Schwind, Knierim, Haas, & Henze, 2019).

PRS

Participants reported how restorative they perceived their assigned environment to be using the Perceived Restoration Scale. The results of this study indicate that people perceived the VR condition to be significantly more restorative that the two TV conditions. This finding is not

surprising as the VR condition provides one with a more immersive experience than both the STV and LTV conditions.

Presence, or rather feeling of being away from whatever is triggering stress, is a variable of interest in this study, as such the “being away” subcomponent of the PRS was analyzed. Results indicated VE nature as a whole does elicit this feeling of being away, which is consistent with attention restoration theory (Kaplan & Kaplan, 1995). However, individuals in the VR condition reported the greatest feelings of being away, and as a result it was compared to the coloring condition. Results indicated that both viewing nature in VR and coloring mandalas are effective at eliciting the feeling of “being away”.

Physiological Measures

Physiological measures were captured in real time with all other study materials and processes to objectively demonstrate cognitive fatigue and stress via the vigilance decrement and the resulting physiological response to the different treatment conditions and N-Back tasks.

Discussion of Post Depletion Changes in Arousal during Treatment

Changes in Arousal during Exposure to VE Conditions

Post vigil to treatment changes in HR were assessed for all six conditions in which people viewed virtual nature environments during a 10-minute break. An unexpected increase in HR was observed for individuals in all six virtual nature conditions. Specifically, HR increased during the first five minutes of the treatment and then continued to increase even more in the last 5 minutes of the treatment. Based on prior literature regarding natural environments, it was

expected that a decrease in HR when exposed to virtual nature would be observed (e.g. Ulrich, 1991).

A similar pattern immerged for the RMSSD data as well. There was a significant decrease in RMSSD seen in all six treatment conditions, however there were not significant reduction between the first and last five minutes of the treatment. Furthermore, there was a significant effect of immersion on RMSSD levels, such that those in the VR condition experienced smaller reductions in RMSSD than those who experienced virtual nature in the LTV condition.

Changes in Arousal during the Break (VR vs. Coloring Break)

Based on the above results and due to the fact that this study is most interested in the use of VR to restore cognitive faculties and reduce stress, the VR treatment was compared directly to the Coloring treatment. The results indicated that the VR and coloring conditions both significantly increased HR in a similar manner with an increase in the first five minutes followed by a greater increase in the last five minutes of the treatment.

RMSSD was found to decrease in all six conditions after being stressed from the 45-minute vigil. However, there was a significant within groups interaction between treatment and epoch such that those in the coloring condition experienced significantly greater declines in RMSSD in the first five minutes of the break (epoch 1) then these declines became less pronounced during the last five minutes of the break (epoch 2). The opposite pattern emerged in the VR condition, as the declines were more pronounced during the latter half of the treatment.

Based on the information presented above on post depletion changes in HR and HRV during treatment, it can be seen that overall participants experienced an increase in arousal

during their interaction with one of the six virtual nature environments as well as during the active break condition in which they colored.

Although the literature generally discusses the changes in HR or HRV during a measure both before and after the actual exposure to nature or simulated nature environments, as opposed to during exposure to nature environments, a few studies have reported cardiac measures of arousal during actual exposure to nature or simulated nature environments (e.g. window view, pictures, videos). Regardless of when the physiological measures were taken, the general consensus in the literature, albeit limited, shows significant reductions in arousal which is claimed to be indicative of reductions in stress (e.g. Laughman, Garling, & Stormark, 2003; Parsons, et al., 2008; Sponselee & DeKort, 2004; Ulrich et al., 2003; Ulrich et al., 1991).

In one such study, Sponselee and DeKort (2004) manipulated level of immersion by providing a small and a large TV on which to view a nature video. They found that the nature video was effective at reducing stress regardless of the size of the TV the nature video was viewed on, however, the more immersive viewing platform (large TV) did not elicit significantly greater reductions in physiological stress (IBI) than the small TV, as was expected. They proposed this lack of significant difference between the two display types was due to a minimal stress state.

This lack of stress state was not an issue in this current study as evidenced by after vigil self-report and physiological measures. However, instead of observing a decrease in arousal (decrease in HR and an increase in RMSSD) during the treatment as expected based on prior research, there was a significant increase in arousal observed for all virtual nature environment and coloring treatment conditions. One potential reason for this divergent finding is that unlike previous studies on restoration, this study used more immersive and engaging break types. As a

result, this increase in arousal during the treatment may have occurred due to the participants' level of presence or engagement they experienced in the virtual nature environments or while coloring.

Although this increase in physiological arousal has not been observed in restoration research, it is consistent with findings in gaming literature (Reeves & Reed, 2009). This is considered relevant to this study as the level of immersion and interaction with a simulated environment is similar to what one would experience while gaming. Though the treatments explored in this study have been classified as active and passive, all of them contained an interactive component which allowed greater control over the environment than would be seen in a video-based presentation of nature. Although participants were only able to manipulate their avatar's position within the virtual world in the active treatments all participants were given control over their visual angle, either through an Xbox thumb stick control or through their head movements while wearing the HMD. For this reason, it is reasonable to assume that this study may have more in common with gaming research than other studies of restoration.

Wise and Reeves (2007) found that having control over the environment or what you see, which is typical of interactive game play, increases heart rate because you are actively engaged in what you are doing and gives you a sense of "being there". Presence or sense of "being there", in this case is being elicited by immersion and task engagement, and it is one of the main tenets of Kaplan and Kaplan's (1989) Attention Restoration Theory. It is possible that this increased level of task engagement, as well as the feeling of being away that was experienced in all levels of immersion in this study with the highest levels reported by the VR condition, could potentially explain this increase in HR and HRV that participants experienced during the 10-minute virtual nature environment treatment.

Additionally, this increase in arousal as well increase in task engagement and presence occurred during exposures to the virtual nature environment in VR as well as during the coloring break, indicating that task engagement and the feeling of getting away from the stressor that is mentally taxing play a role in the restorative process.

Post Vigil to Post Treatment Change in HR and HRV

As previously mentioned, the majority of stress reduction and cognitive restoration studies that examined the effects of actual and simulated nature have assessed post vigil to post treatment change in cardiac measures, as opposed to during exposure to the nature rich environment and found a significant reduction in stress and increase in restoration. Even though participants experienced increased levels of arousal during the treatment, the overall decrease in HR and increase in HRV observed between the end of the vigil and the end of the treatment is indicative of restoration, replicating prior research.

The one exception to the above finding was observed in the active virtual reality condition. This inconsistency might be explained by the fact that the movements in VR were not naturally mapped to the participants inputs. In this condition, though their changes in visual angle were controlled naturally through head movements, their movement through the virtual environment was controlled through the thumb stick inputs on the oculus touch controllers. Additionally, perhaps due to this partial lack of natural mapping this increase in arousal was indicative of higher task workload, and not from more positive forms arousal resulting from task engagement and presence as Reeves and Read (2009) and Vorderer (2000) proposed.

Theoretical Implications

This study contributes to the existing theoretical research in two significant ways. This is, to my knowledge, the first study to combine a cognitively depleting task with self-report and physiological measures of stress and cognition to truly assess the value of virtual presentations of natural environments. Though there are a couple of existing studies that have attempted to determine whether virtually-displayed natural settings could produce restoration, those studies either only looked at perceived restoration from virtual nature environments (Knight, Stone, & Qian, 2012; Pals, 2011) or looked at subjective and cardiac measures of stress reduction while actively exploring VR nature environments, however, perceived restoration may be faulty and even though actively exploring virtual nature in VR was found to reduce self-report and physiological measures of stress, it did not parse out the effects of immersion and exploration (Valtchanov, Barton & Ellard, 2010; Valtchanov & Ellard, 2010). This study has addressed these concerns and questions to produce the most rigorous existing evaluation of the impact of virtual nature on cognitive restoration.

This study also addresses a substantial gap in the existing literature evaluating strategies for restoring depleted cognition. A number of past studies have highlighted strategies for cognitive restoration (e.g. sleeping, glucose, breaks, etc.; Baumeister et al., 1998; Baumeister, 2002; ; Fritz et al, 2013; Kaplan, 1995; Kaplan, 2001; Meijman & Mulder, 1998; Tang et al. 2007), some of which demonstrated the restorative value of active breaks (Rupp, et al., 2017; Zeidan, et al., 2009) and, in particular, the ability of coloring to restore cognition or reduce stress (Carsley, Heath, & Fajnerova, 2015; Curry & Kasser, 2005; Duong, Stargell, & Mauk, 2018; van der Vennet & Serice, 2012). A separate body of research has explored the restorative capabilities of natural environments and the psychological benefits they offer when presented both in person

(e.g. Berman et al. 2008; Hartig et al. 1991; Kaplan, 1995; Ulrich, 1991) and virtually (Annerstedt, et al., 2013; Pals, 2011; Valtchanov, 2010; Valtchanov, Barton & Ellard, 2010). This study is believed to be the first to bridge these two areas of research, comparing the value of taking a break in a simulated nature environment to another form of active break (i.e. coloring). The findings of this research forward the notion that, though both strategies are effective, virtual presentations seem to offer some benefits that other active breaks do not.

Practical Implications

The results of this study suggest that virtual nature environments could conceivably act as a potential method for restoration when access to nature is not feasible, as is the case for many medical personnel, first responders, military personnel, among many others. Additionally, if TV, or better yet, VR presentations of nature are cost or space prohibitive, then offering an active break will provide many of the same advantages (decreases in self-report stress and anxiety). However, the gains of passively viewing a nature environment in VR are greater, based on the fact that physiological measures reinforced the subjective measures in the VRP condition as compared to the coloring condition.

Limitations & Suggestions for Future Research

Although it is not uncommon in the literature to use a 5-minute baseline measure of cardiac activity (e.g. Alvarsson, Wiens, Nilsson, 2010; Salahuddin, Cho, Jeong & Kim, 2007; Shaffer & Ginsberg, 2017), it did not prove to be an accurate depiction of participants true baseline for this study. Future research should implement a method similar to Contrada, Wright, and Glass (1984), in which one calculates two-minute epochs (average of each two-minute

period) and waits until the average stabilizes for at least two epochs. They would then use the average of the last two epochs as their baseline measure of HRV. By implementing this method, one would ensure greater accuracy in participants resting HR and HRV.

Another limitation of this study is that a 2-Back task was used as a measure of cognitive ability, and 2-Back task was not a challenging enough as evidenced by a ceiling effect observed in the obtained data. There are a couple of ways in which one could rectify this problem. One, researchers could use a 3-Back task instead of the 2-Back, as it is more challenging and would potentially reduce the chances of the occurrence of a ceiling effect in the future. Another reason as to why a ceiling effect was observed with the 2-Back task is that practice effects may have occurred due to the multiple administrations of the task. The second way in which one can rectify this issue with the N-Back is to find a cognitive measure that is not as susceptible to practice effects to ensure that future research can accurately capture improvements in cognition after stress and cognitive fatigue.

Another potential limitation of this study is that, in retrospect, both cardiac measures and subjective measures of stress should have been monitored for a further five minutes to see if any further reductions in stress occurred as has been observed in a prior study (Annerstedt et al., 2013).

It is important that future studies also incorporate physiological measures along with self-report measures of stress and state anxiety, it was found that people's perception of restoration do not always parallel physiological indicators of stress and fatigue. Additionally, future studies on stress reduction and cognitive restoration should not only use self-report measures, but also physiological measures as this study, like many others, has indicated that people's perceptions of restoration are not always in line with actual restoration.

Additionally, future research should also focus on other types of nature settings such as beaches and lake fronts as past research has found that people pay more for and tend to prefer these environments over green nature (Luttik, 2000; van den Berg, Koole, & van der Wulp, 2003; White et al., 2010). However, due to individual differences future research should also investigate the role of environment preference in restoration from stress and cognitive fatigue.

Conclusion

This research supports the prior literature that nature does indeed provide a restorative effect, it decreases anxiety and stress and has the potential for cognitive restoration, though in this study improvements in cognitive measures were not seen due to a ceiling effect. This study also highlights the effect that people's subjective perceptions of how anxious, stressed and engaged they are in an environment or during an active break are not necessarily in line with their physiological responses to those different break types. In fact, people perceive that virtual nature environments that are displayed or interacted with on small and large TVs as well as in virtual reality provide restorative effects, and in some cases the more immersive the experience the greater the restorative benefit. An active break, in this case coloring, also produced a restorative effect on subjective measures of stress and anxiety indicating that exposure to virtual nature is not necessarily special. Engaging in activities that take your mind off of the experienced stressor are just as good as virtual nature in decreasing perceptions or anxiety and stress. However, this only held true for subjective measures, physiological indicators of workload and stress reduction were only significant for virtual nature. Thus, indicating that exposure to or interaction with virtual nature environments are effective beyond what an active break is capable of.

APPENDIX A: UCF IRB LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization

12201 Research Parkway, Suite 501

Orlando, Florida 32826-3246

Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Jessica R. Michaelis** and Co-PIs if applicable: **Daniel S. McConnell, Janan A. Smither, & Michael A. Rupp**

Date: **September 07, 2016**

Dear Researcher:

On 09/07/2016 the IRB approved the following minor modifications to human participant research until 09/06/2017 inclusive:

Type of Review:	IRB Addendum and Modification Request Form Expedited Review
Modification Type:	Removal of study personnel
Project Title:	Cognitive Restoration in Virtual Environments
Investigator:	Jessica R. Michaelis
IRB Number:	SBE-13-09759
Funding Agency:	Psi Chi

Grant Title: 2013-14 Graduate Research Grants - Fall
Research ID: N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 09/06/2017, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol.

Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the [Investigator Manual](#).

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Kamille Chaparro on 09/07/2016 04:09:17 PM EDT

IRB Coordinator

APPENDIX B: MOTION HISTORY QUESTIONNAIRE

MOTION HISTORY QUESTIONNAIRE

Developed by Robert S. Kennedy & colleagues under various projects. For additional information contact: Robert S. Kennedy, RSK Assessments, Inc., 1040 Woodcock Road, Suite 227, Orlando, FL 32803 (407) 894-5090

1. How often would you say you get airsick?

   Always_3_ Frequently_3_ Sometimes_2_ Rarely_1_ Never_0_

2. From your experience at sea, how often would you say you get seasick?

   Always_3_ Frequently_3_ Sometimes_2_ Rarely_1_ Never 0

3. In general, how susceptible to motion sickness are you?

   Extremely_3_ Very_3_ Moderately_2_ Minimally_1_ Not at all_0_

4. If you were in an experiment where 50% of the subjects get sick, what do you think your chances of getting sick would be?
   Almost certainly would_3_ Probably would_2_ Almost probably would not_1_
   Certainly would not_0_

5. Most people experience slight dizziness (not a result of motion) three to five times a year. The past year you have been dizzy:
   More than this _3_ The same as_2_ Less than_1_ Never dizzy_0_

Score:

Notes:

1) Scores of seven (7) or higher indicate a higher probability of experiencing motion sickness while using the simulator. Therefore, participants scoring seven or higher should be excluded from further participation.

APPENDIX C: SIMULATOR SICKNESS QUESTIONNAIRE

Simulator Sickness Questionnaire (SSQ)

Developed by Robert S. Kennedy & colleagues under various projects. For additional information contact:
Robert S. Kennedy, RSK Assessments, Inc., 1040 Woodcock Road, Suite 227, Orlando, FL 32803 (407) 894-5090

Subject Number: _______ Date: __________

PRE-EXPOSURE BACKGROUND INFORMATION

1. How long has it been since your last exposure in a simulator? _______ days
   How long has it been since your last flight in an aircraft? _______ days
   How long has it been since your last voyage at sea? _______ days
   How long has it been since your last exposure in a virtual environment? _______ days
2. What other experience have you had recently in a device with unusual motion?

PRE-EXPOSURE PHYSIOLOGICAL STATUS INFORMATION

3. Are you in your usual state of fitness? (Circle one) YES NO
   If not, please indicate the reason:

4. Have you been ill in the past week? (Circle one) YES NO
   If "Yes", please indicate:
   a) The nature of the illness (flu, cold, etc.):
   b) Severity of the illness: Very Mild _________________ Very Severe
   c) Length of illness: _________________ Hours / Days
   d) Major symptoms:
   e) Are you fully recovered? YES NO
5. How much alcohol have you consumed during the past 24 hours?
   ____ 12 oz. cans/bottles of beer ____ ounces wine ____ ounces hard liquor
6. Please indicate all medication you have used in the past 24 hours. If none, check the first line:
   a) NONE
   b) Sedatives or tranquilizers
   c) Aspirin, Tylenol, other analgesics
   d) Anti-histamines
   e) Decongestants
   f) Other (specify):
7. a) How many hours of sleep did you get last night? _____ hours
   b) Was this amount sufficient? (Circle one) YES NO
8. Please list any other comments regarding your present physical state which might affect your performance on our test battery.

APPENDIX D: CONNECTEDNESS TO NATURE

APPENDIX E: DUNDEE STRESS STATE QUESTIONNAIRE SHORT VERSION

DSSQ-3 STATE QUESTIONNAIRE

PRE-TASK QUESTIONNAIRE

Instructions. This questionnaire is concerned with your feelings and thoughts at the moment. Please answer **every** question, even if you find it difficult. Answer, as honestly as you can, what is true of **you**. Please do not choose a reply just because it seems like the 'right thing to say'. Your answers will be kept entirely confidential. Also, be sure to answer according to how you feel **AT THE MOMENT**. Don't just put down how you usually feel. You should try and work quite quickly: there is no need to think very hard about the answers. The first answer you think of is usually the best.

Before you start, please provide some general information about yourself.

Age............. (years) Sex. M F (Circle one)
Occupation..
If student, state your course..................................
Date today.................... Time of day now.............

For each statement, circle an answer from 0 to 4, so as to indicate how accurately it describes your feelings **AT THE MOMENT**.

Definitely false = 0, Somewhat false = 1,
Neither true nor false = 2, Somewhat true = 3, Definitely true = 4

1. I feel concerned about the impression I am making.	0	1	2	3	4
2. I feel relaxed.	0	1	2	3	4
3. The content of the task will be dull.	0	1	2	3	4
4. I am thinking about how other people might judge my performance.	0	1	2	3	4
5. I am determined to succeed on the task.	0	1	2	3	4
6. I feel tense.	0	1	2	3	4
7. I am worried about what other people think of me.	0	1	2	3	4
8. I am thinking about how I would feel if I were told how I performed	0	1	2	3	4
9. Generally, I feel in control of things.	0	1	2	3	4
10. I am reflecting about myself.	0	1	2	3	4
11. My attention will be directed towards the task.	0	1	2	3	4
12. I am thinking deeply about myself.	0	1	2	3	4
13. I feel energetic.	0	1	2	3	4
14. I am thinking about things that happened to me in the past	0	1	2	3	4
15. I am thinking about how other people might perform on this task	0	1	2	3	4
16. I am thinking about something that happened earlier today.	0	1	2	3	4
17. I expect that the task will be too difficult for me.	0	1	2	3	4
18. I will find it hard to keep my concentration on the task.	0	1	2	3	4
19. I am thinking about personal concerns and interests.	0	1	2	3	4
20. I feel confident about my performance.	0	1	2	3	4
21. I am examining my motives.	0	1	2	3	4
22. I can handle any difficulties I may encounter	0	1	2	3	4
23. I am thinking about how I have dealt with similar tasks in the past	0	1	2	3	4
24. I am reflecting on my reasons for doing the task	0	1	2	3	4
25. I am motivated to try hard at the task.	0	1	2	3	4
26. I am thinking about things important to me.	0	1	2	3	4
27. I feel uneasy.	0	1	2	3	4
28. I feel tired.	0	1	2	3	4
29. I feel that I cannot deal with the situation effectively.	0	1	2	3	4
30. I feel bored.	0	1	2	3	4

DSSQ-3 STATE QUESTIONNAIRE

POST-TASK QUESTIONNAIRE

Instructions. This questionnaire is concerned with your feelings and thoughts while you were performing the task. Please answer **every** question, even if you find it difficult. Answer, as honestly as you can, what is true of **you**. Please do not choose a reply just because it seems like the 'right thing to say'. Your answers will be kept entirely confidential. Also, be sure to answer according to how you felt **WHILE PERFORMING THE TASK**. Don't just put down how you usually feel. You should try and work quite quickly: there is no need to think very hard about the answers. The first answer you think of is usually the best.

For each statement, circle an answer from 0 to 4, so as to indicate how accurately it describes your feelings **WHILE PERFORMING THE TASK**.

Definitely false = 0, Somewhat false = 1,
Neither true nor false = 2, Somewhat true = 3, Definitely true = 4

1. I felt concerned about the impression I am making.	0	1	2	3	4
2. I felt relaxed.	0	1	2	3	4
3. The content of the task was dull.	0	1	2	3	4
4. I thought about how other people might judge my performance	0	1	2	3	4
5. I was determined to succeed on the task.	0	1	2	3	4
6. I felt tense.	0	1	2	3	4
7. I was worried about what other people think of me.	0	1	2	3	4
8. I thought about how I would felt if I were told how I performed	0	1	2	3	4
9. Generally, I felt in control of things.	0	1	2	3	4
10. I reflected about myself.	0	1	2	3	4
11. My attention was directed towards the task.	0	1	2	3	4
12. I thought deeply about myself.	0	1	2	3	4
13. I felt energetic.	0	1	2	3	4
14. I thought about things that happened to me in the past	0	1	2	3	4
15. I thought about how other people might perform on this task	0	1	2	3	4
16. I thought about something that happened earlier today.	0	1	2	3	4
17. I found the task was too difficult for me.	0	1	2	3	4
18. I found it hard to keep my concentration on the task.	0	1	2	3	4
19. I thought about personal concerns and interests.	0	1	2	3	4
20. I felt confident about my performance.	0	1	2	3	4
21. I examined my motives.	0	1	2	3	4
22. I felt like I could handle any difficulties I encountered	0	1	2	3	4
23. I thought about how I have dealt with similar tasks in the past	0	1	2	3	4
24. I reflected on my reasons for doing the task	0	1	2	3	4
25. I was motivated to try hard at the task.	0	1	2	3	4
26. I thought about things important to me.	0	1	2	3	4
27. I felt uneasy.	0	1	2	3	4
28. I felt tired.	0	1	2	3	4
29. I felt that I could not deal with the situation effectively.	0	1	2	3	4
30. I felt bored.	0	1	2	3	4

The following candidate items were not included in this study: 4, 8, 14, 15, 23, and 24.

APPENDIX F: STATE TRAIT ANXIETY INVENTORY (FORM Y-1)

State Trait Anxiety Inventory Sample

Read each statement and select the appropriate response to indicate how you feel right now, that is, at this very moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1	2	3	4
Not at all	**A little**	**Somewhat**	**Very Much So**

1. I feel calm	1	2	3	4
2. I feel uncomfortable	1	2	3	4
3. I am relaxed	1	2	3	4
4. I am worried	1	2	3	4
5. I feel pleasant	1	2	3	4

APPENDIX G: CONNECTEDNESS TO NATURE

Connectedness to Nature

Please answer each of these questions in terms of the way you generally feel. There are no right or wrong answers. Using the following scale, in the space provided next to each question simply state as honestly and candidly as you can what you are presently experiencing.

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

____1. I often feel a sense of oneness with the natural world around me.

____2. I think of the natural world as a community to which I belong.

____3. I recognize and appreciate the intelligence of other living organisms.

____4. I often feel disconnected from nature.

____5. When I think of my life, I imagine myself to be part of a larger cyclical process of living.

____6. I often feel a kinship with animals and plants.

____7. I feel as though I belong to the Earth as equally as it belongs to me.

____8. I have a deep understanding of how my actions affect the natural world.

____9. I often feel part of the web of life.

____10. I feel that all inhabitants of Earth, human, and nonhuman, share a common ‘life force’.

____11. Like a tree can be part of a forest, I feel embedded within the broader natural world.

____12. When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature.

____13. I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.

____14. My personal welfare is independent of the welfare of the natural world

APPENDIX H: IMMERSIVE TENDENCIES QUESTIONNAIRE

ITQ

Instructions: Answer each question by circling your answer. This is scored from – to + indicating your level of agreement with the question. Ex. for #1 If I get extremely involved with projects I would answer 7 if I completely did not I would answer 1.

#	Item	-	Ratings					+
1	Do you ever get extremely involved in projects that are assigned to you by your boss or your instructor, to the exclusion of other tasks?	1	2	3	4	5	6	7
2	How easily can you switch your attention from the task in which you are currently involved to a new task?	1	2	3	4	5	6	7
3	How frequently do you get emotionally involved (angry, sad, happy) in the news stories that you read or hear?	1	2	3	4	5	6	7
4	How well do you feel today?	1	2	3	4	5	6	7
5	Do you easily become deeply involved in movies or TV dramas?	1	2	3	4	5	6	7
6	Do you ever become so involved in a television program or book that people have problems getting your attention?	1	2	3	4	5	6	7
7	How mentally alert do you feel at the present time?	1	2	3	4	5	6	7
8	Do you ever become so involved in a movie that you are not aware of things happening around you?	1	2	3	4	5	6	7
9	How frequently do you find yourself closely identifying with the characters in a story line?	1	2	3	4	5	6	7
10	Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?	1	2	3	4	5	6	7
11	On average, how many books do you read for enjoyment in a month?	1	2	3	4	5	6	7
12	How physically fit do you feel today?	1	2	3	4	5	6	7
13	How good are you at blocking out external distractions when you are involved in something?	1	2	3	4	5	6	7
14	When watching sports, do you ever become so involved in the game that you react as if you were one of the players?	1	2	3	4	5	6	7
15	Do you ever become so involved in a daydream that you are not aware of things happening around you?	1	2	3	4	5	6	7
16	Do you ever have dreams that are so real that you feel disoriented when you awake?	1	2	3	4	5	6	7
17	When playing sports, do you become so involved in the game that you lose track of time?	1	2	3	4	5	6	7
18	Are you easily disturbed when working on a task?	1	2	3	4	5	6	7
19	How well do you concentrate on enjoyable activities?	1	2	3	4	5	6	7
20	How often do you play arcade or video games? (OFTEN should be taken to mean every day or every two days, on average.)	1	2	3	4	5	6	7
21	How well do you concentrate on disagreeable tasks?	1	2	3	4	5	6	7
22	How often do you get excited during a chase or fight scene on TV or in the movies?	1	2	3	4	5	6	7
23	How often have you have you dwelled on personal problems in the last 48 hours?	1	2	3	4	5	6	7

APPENDIX I: PERCEIVED RESTORATIVENESS SCALE

TABLE 1

Orthotran/varimax rotated loadings from factor analysis of the ratings of nature and city environment (Study 1)

	Nature						City					
	Factor					Communalities	Factor					Communalities
	1	2	3	4	5		1	2	3	4	5	
1. I am in a different setting than usual	**0·71**	0·01	0·03	−0·02	−0·04	0·66	**0·69**	0·03	0·04	−0·05	0·08	0·62
2. I do something different than I usually do	**0·71**	0·04	−0·03	0·03	0·08	0·65	**0·58**	0·08	−0.03	0·09	−0·04	0·54
3. I am in a different environment than usual	**0·75**	−0·05	0·03	0·00	−0·07	0·72	**0·69**	0·01	0·00	−0·00	−0·03	0·66
4. When I am here I feel free from work and routine	0·24	**0·39**	−0·03	0·13	0·08	0·49	0·10	**0·59**	−0·08	0·14	0·04	0·59
5. When I am here I feel free from other peoples' demand and expectations	−0·09	**0·57**	0·12	0·00	0·04	0·54	0·01	**0·75**	0·09	−0·07	0·01	0·72
6. When I am here I do not need to think of my responsibility	−0·04	**0·62**	0·00	−0·03	0·02	0·55	0·00	**0·67**	0·03	−0·05	0·03	0·55
7. I am away from my obligations	0·00	**0·83**	0·01	−0·02	−0·04	0·92	0·00	**0·77**	−0·01	−0·00	−0·02	0·74
8. The elements here go together	0·11	−0·04	**0·44**	−0·07	−0·01	0·29	−0·03	0·04	**0·67**	0·03	−0·07	0·58
9. The surroundings are coherent	−0·05	0·10	**0·57**	0·02	0·01	0·55	−0·08	0·15	**0·66**	−0·05	−0·06	0·57
10. All the elements constitute a larger whole	−0·10	0·01	**0·62**	0·09	−0·01	0·63	0·08	−0·14	**0·57**	0·09	0·03	0·49
11. The existing elements belong here	0·08	0·08	**0·35**	0·17	0·05	0·44	0·11	−0·04	**0·52**	0·00	0·17	0·49
12. There is plenty to discover here	0·03	0·03	−0·03	**0·54**	−0·09	0·43	0·14	0·05	−0·04	**0·51**	0·07	0·49
13. There are many things here that I find beautiful	0·22	−0·03	0·04	**0·37**	0·20	0·49	−0·10	0·08	0·14	**0·43**	0·07	0·49
14. There is plenty that I want to linger on here	0·00	−0·01	0·08	**0·50**	0·05	0·54	−0·06	0·13	0·12	**0·57**	−0·08	0·60
15. This setting has many things that I wonder about	−0·07	−0·05	0·13	**0·44**	−0·07	0·37	0·08	−0·19	−0·01	**0·60**	−0·21	0·42
16. There are many objects here that attract my attention	0·01	0·02	−0·03	**0·61**	−0·02	0·59	0·12	−0·08	0·01	**0·58**	0·05	0·57
17. I am absorbed in these surroundings	−0·01	0·04	0·05	**0·53**	0·07	0·61	−0·08	0·03	0·12	**0·54**	−0·05	0·51
18. The environment gives me the opportunity to do activities that I like	0·03	0·07	−0·12	0·16	**0·59**	0·68	−0·05	0·13	−0·15	**0·39**	**0·33**	0·59
19. I can handle the kinds of problems that arise here	−0·01	−0·05	0·11	−0·21	**0·64**	0·48	−0·06	0·08	0·13	−0·06	**0·46**	0·44
20. I rapidly adapt to this setting	−0·02	−0·00	−0·09	0·20	**0·49**	0·52	−0·14	0·03	0·06	0·14	**0·48**	0·66
21. There is an accordance between what I like to do and these surroundings	−0·11	0·14	−0·07	0·23	**0·47**	0·67	−0·14	0·12	−0·06	**0·35**	**0·35**	0·65
22. I am capable of meeting the challenge of this setting	0·05	−0·03	0·12	−0·09	**0·69**	0·64	0·15	−0·19	0·04	−0·12	**0·72**	0·74

*Factor loadings over 0·30 or highest loadings on the factor are shown in bold

Table 2. *The Perceived Restorativeness Scale (PRS) items used in the present studies, grouped according to their intended subscale designation.*

Being Away

It is an escape experience.

Spending time here gives me a good break from my day-to-day routine.

Fascination

The setting has fascinating qualities.

My attention is drawn to many interesting things.

I would like to get to know this place better.

I want to explore the area. (In Study 2 this item was replaced by the item below.)

There is much to explore and discover here.

I would like to spend more time looking at the surroundings.

Coherence (Extent)

There is too much going on.

It is a confusing place.

There is a great deal of distraction.

It is chaotic here.

Compatibility

I can do things I like here.

I have a sense that I belong here.

I have a sense of oneness with this setting.

Being here suits my personality.

I could find ways to enjoy myself in a place like this.

APPENDIX J: LOCUS OF CONTROL SCALE

Rotter's Locus of Control Scale

This is a questionnaire to find out the way in which certain important events in our society affect different people. Each item consists of a pair of alternatives lettered a or b. Please select the one statement of each pair (and only one) which you more strongly believe to be the case as far as you're concerned. Be sure to select the one you actually believe to be more true rather than the one you think you should choose or the one you would like to be true. This is a measure of personal belief: obviously there are no right or wrong answers.

Please answer these items carefully but do not spend too much time on any one item. Be sure to find an answer for every choice. In some instances you may discover that you believe both statements or neither one. In such cases, be sure to select the one you more strongly believe to be the case as far as you're concerned. Also try to respond to each item independently when making your choice; do not be influenced by your previous choices.

1. a. Children get into trouble because their patents punish them too much.	b. The trouble with most children nowadays is that their parents are too easy with them.
2. a. Many of the unhappy things in people's lives are partly due to bad luck.	b. People's misfortunes result from the mistakes they make.
3. a. One of the major reasons why we have wars is because people don't take enough interest in politics.	b. There will always be wars, no matter how hard people try to prevent them.
4. a. In the long run people get the respect they deserve in this world	b. Unfortunately, an individual's worth often passes unrecognized no matter how hard he tries
5. a. The idea that teachers are unfair to students is nonsense.	b. Most students don't realize the extent to which their grades are influenced by accidental happenings.
6. a. Without the right breaks one cannot be an effective leader.	b. Capable people who fail to become leaders have not taken advantage of their opportunities.
7. a. No matter how hard you try some people just don't like you.	b. People who can't get others to like them don't understand how to get along with others.

8. a. Heredity plays the major role in determining one's personality	b. It is one's experiences in life which determine what they're like.

9. a. I have often found that what is going to happen will happen.	b. Trusting to fate has never turned out as well for me as making a decision to take a definite course of action.
10. a. In the case of the well prepared student there is rarely if ever such a thing as an unfair test.	b. Many times exam questions tend to be so unrelated to course work that studying in really useless.
11. a. Becoming a success is a matter of hard work, luck has little or nothing to do with it.	b. Getting a good job depends mainly on being in the right place at the right time.
12. a. The average citizen can have an influence in government decisions.	b. This world is run by the few people in power, and there is not much the little guy can do about it.
13. a. When I make plans, I am almost certain that I can make them work.	b. It is not always wise to plan too far ahead because many things turn out to be a matter of good or bad fortune anyhow.
14. a. There are certain people who are just no good.	b. There is some good in everybody.
15. a. In my case getting what I want has little or nothing to do with luck.	b. Many times we might just as well decide what to do by flipping a coin.
16. a. Who gets to be the boss often depends on who was lucky enough to be in the right place first.	b. Getting people to do the right thing depends upon ability. Luck has little or nothing to do with it.
17. a. As far as world affairs are concerned, most of us are the victims of forces we can neither understand, nor control.	b. By taking an active part in political and social affairs the people can control world events.
18. a. Most people don't realize the extent to which their lives are controlled by accidental happenings.	b. There really is no such thing as "luck."
19. a. One should always be willing to admit mistakes.	b. It is usually best to cover up one's mistakes.

20. a. It is hard to know whether or not a person really likes you.	b. How many friends you have depends upon how nice a person you are.
21. a. In the long run the bad things that happen to us are balanced by the good ones.	b. Most misfortunes are the result of lack of ability, ignorance, laziness, or all three.
22. a. With enough effort we can wipe out political corruption.	b. It is difficult for people to have much control over the things politicians do in office.
23. a. Sometimes I can't understand how teachers arrive at the grades they give.	b. There is a direct connection between how hard I study and the grades I get.
24. a. A good leader expects people to decide for themselves what they should do.	b. A good leader makes it clear to everybody what their jobs are.
25. a. Many times I feel that I have little influence over the things that happen to me.	b. It is impossible for me to believe that chance or luck plays an important role in my life.
26. a. People are lonely because they don't try to be friendly.	b. There's not much use in trying too hard to please people, if they like you, they like you.
27. a. There is too much emphasis on athletics in high school.	b. Team sports are an excellent way to build character.
28. a. What happens to me is my own doing.	b. Sometimes I feel that I don't have enough control over the direction my life is taking.
29. a. Most of the time I can't understand why politicians behave the way they do.	b. In the long run the people are responsible for bad government on a national as well as on a local level.

APPENDIX K: SLATER-USOH-STEED SCALE

SLATER-USOH-STEED QUESTIONNAIRE (SUS)

1. Please rate your *sense of being in the* virtual environment, on a scale of 1 to 7, where 7 represents your *normal experience of being in a place.*

2. To what extent were there times during the experience when the virtual environment was the reality for you?

3. When you think back to the experience, do you think of the virtual environment more as *images that you saw* or more as *somewhere that you visited*?

4. During the time of the experience, which was the strongest on the whole, your sense of being in the virtual environment or of being elsewhere?

5. Consider your memory of being in the virtual environment. How similar in terms of the *structure of the memory* is this to the structure of the memory of other *places* you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such *structural* elements.

6. During the time of your experience, did you often think to yourself that you were actually in the virtual environment?

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