ABSTRACT

Title of Thesis: THE BRAIN DOES NOT LIE: A CASE STUDY OF PSYCHOPHYSIOLOGY AND LANDSCAPE IN SOUTH CLIFTON PARK

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Researchers have long explored how humans respond psychologically and physiologically to distinct landscapes and natural features. Walking in nature and viewing photographs of natural landscapes have been shown to reduce stress measured through physiological responses of blood pressure, salivary cortisol concentration, and pulse rate. Exposure to natural landscapes has also been shown to improve feelings of relaxation and positive emotion. The increased popularity of virtual reality (VR) in landscape architecture provides an additional visualization tool to immerse a participant in a landscape at human scale. Little research has focused on the potential impact of visualization through VR, studied the impact of urban nature, or compared the impact of landscape design using the same site. This study explores how employment of psychophysiological measures provides objective assessment of humans' landscape perception in response to the restorativeness of a virtual place. Twenty students were recruited to view an actual site in South Clifton Park, Baltimore City. Utilizing VR, participants observed the site as it exists currently and reimagined using the tenets of Attention Restoration Theory (ART), Stress Reduction Theory (SRT),

and community vision. Psychological response was analyzed using the Perceived Restorativeness Scale (PRS-16), a survey designed to evaluate a place's restorativeness through principles of ART, and physiological response was analyzed using electroencephalogram (EEG), the non-invasive measurements of the electrical brain activity. Findings indicated that perceived restorativeness increased in the designed site for the factors Being Away/Fascination and Compatibility; however, no significant difference was identified for the factor Extent. Regarding EEG data, alpha brain frequencies (broadband alpha, low alpha, and high alpha) were not significantly different when viewing the vacant versus designed site within the frontal or parietal lobes; however, beta brain frequencies (broadband beta, low beta, and high beta) demonstrated a marginally significant effect of sex in the frontal and parietal lobes with male beta brain frequencies decreasing when viewing the designed site and female beta brain frequencies increasing. Finally, frontal alpha asymmetry, a measure of approach-withdrawal motivation, demonstrated a marginally significant decrease when viewing the designed site, indicating increased withdrawal motivation in the designed site. The present research seeks to fill a gap in understanding objective indicators of restorativeness of a place and explore the power of VR as a tool for visualizing place.

THE BRAIN DOES NOT LIE: A CASE STUDY OF PSYCHOPHYSIOLOGY AND LANDSCAPE IN SOUTH CLIFTON PARK

by

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List of Abbreviations

ANOVA- Analysis of Variance

ART- Attention Restoration Theory

BP- Blood pressure

DSB- Digit Span Backward

DSF- Digital Span Forward

EEG- Electroencephalogram

FAA- Frontal alpha asymmetry

HR- Heart rate

HRV- Heart rate variability

Hz- Hertz

NCPC- Necker Cube Pattern Control

PANAS- Positive Affect Negative Affect Scale

PRS- Perceived Restorativeness Scale

PS- Power spectral

POMS- Profile of Mood States

SART- Sustained Attention to Response Task

SDMT- Symbol Digit Modalities Test

SRT- Stress Reduction Theory

VR- Virtual reality

VRISE- Virtual reality-induced symptoms and effects

ZIPERS- Zuckerman Inventory of Personal Reactions

Chapter 1: Introduction

Study Intention

In Baltimore City, the stark divisions between neighborhoods, often the longstanding remnants of racist redlining policy, are marked by changes in the number of parks, play spaces, and trees lining city streets. Baltimore City is not alone; however, with so many urban areas facing greenspace inequity and environmental injustice. This is not the future for our designed landscapes, and this study embraces the challenging work needed to untangle us from the status quo and create an equitable, inclusive, community-driven future using research as a powerful tool to explore, document, and advocate for change.

Study Purpose, Research Questions, and Scope

Through previous conversations with community members living in East Baltimore neighborhoods of Broadway East, South Clifton Park, and Oliver, the critical topics for these communities often centered around housing vacancy, neighborhood crime, air quality, and solid waste dumping. Residents discussed the impacts of the built environment on their personal finances (high cooling costs), physical health (prevalence of asthma), and emotional health (high stress levels). These conversations sparked an interest in exploring how to quantitatively measure the physiological and psychological impacts of environments on humans and investigate how the employment of these psychophysiological measures provides objective assessment of humans' landscape perception in response to the restorativeness of a place. This study asks three research questions:

- Does viewing a virtual vacant site versus the site as a designed greenspace alter brain activities and/or perception of restorativeness?
- How do the two different stimulus environments impact brain activities and perception of restorativeness?
- Do the two different stimulus environments impact approach-withdrawal motivation?

To answer these research questions, this study developed a design for a vacant site in South Clifton Park, Baltimore based on site inventory, community vision, and the principles of Attention Restoration Theory (ART) and Stress Reduction Theory (SRT). Virtual reality (VR) visualizations of the design, and the existing site, were used as part of the human subject study of 20 University of Maryland students. The study collected original data on brain activities using an electroencephalogram (EEG) and perceived restorativeness through surveys. Although community engagement on the site design was not within the scope of this study, it would be critical throughout the design process if this site were to be developed.

Chapter 2: Literature Review

Two Theories Supporting the Restorative Capacity of Nature

Researchers have long been using psychophysiological measures to examine the restorative capacity of nature on human beings. The two main theories underpinning a substantial amount of this research in restoration and nature are Attention Restoration Theory (ART) and Stress Reduction Theory (SRT). ART and SRT both stem from an evolutionary assumption that, in general, because humans evolved for most of their existence in natural environments, humans are adapted psychologically and physiologically to the natural world versus an urban environment (Kaplan & Kaplan, 1989; Ulrich, 1983). This assumption is strongly associated with E.O. Wilson's biophilia hypothesis, which contends that humans have a predisposition to attend to and emotionally connect with the nature owing to a series of innate, phylogenetic values (Kellert & Wilson, 1993; Wilson, 1984). Both ART and SRT also consider the element of stress as playing a role within the restoration models (Kaplan, 1995; Ulrich, 1983). The mechanism through which restoration is achieved for humans in natural environments; however, establishes the division between these theories. Both theories also provide attributes of environments that promote restoration based on the underlying mechanisms of the theory (Hartig et al., 1997a).

Attention Restoration Theory

ART establishes that a natural space has restorative potential because of its impact on human cognition. Utilizing a two-pronged approach to attention established in James (1892), ART posits that directed attention requires effort while fascination requires no effort (Kaplan, 1995). Directed attention is a finite resource for humans that is crucial for information-processing, and over time utilization of this resource can cause mental fatigue that impacts elements of human perception, thought, action, and emotion (Kaplan, 1995). Since directed attention is limited, ART offers the concept of fascination, involuntary human attention, as a vehicle to lower cognitive effort and rebuild directed attention capacity (Kaplan, 1995; Hartig et al., 1991). Fascination can come from a variety of sources including natural environments. Kaplan (1995) deemed fascination in natural environments “soft fascination”, which promotes reflection to aid directed attention recovery (p. 172).

In addition to fascination, three other attributes of the environment must be present to establish a restorative experience- being away, extent, and compatibility (Kaplan & Kaplan, 1989; Kaplan, 1995). Being away is described as the feeling of breaking away from routine environments, extent relates to the connectedness of features within an environment at scale to enhance the feeling of being somewhere else, and compatibility references the relatedness of the environment to a human’s goals for using a space (Kaplan & Kaplan, 1989; Kaplan, 1995; Hartig et al., 1997b). When all four attributes are present, then a restorative experience in an environment is possible that facilitates recovery from mental fatigue (Kaplan, 1995).

As it relates to stress, ART focuses on the aspects that generate an inevitable stress response, not the aftereffects of that response. The first aspect is “harm”, either direct or indirect, in the form of a threat, and the second aspect is “resource inadequacy” (Kaplan, 1995, p. 177). “Resource inadequacy” suggests that a human may not always have the appropriate resources to manage a situation that he or she is facing or expected to face (Kaplan, 1995). Kaplan (1995) argues that psychological resources, such as directed attention, are often critical resources that when depleted can lead to a stress response. Research evaluating ART, therefore, examines the impacts of environments on directed attention and cognition, discussed in *Psychological Responses to Environment-ART***.**

Stress Reduction Theory

SRT asserts that a human's analysis of an environment originally depends on emotion (affect) not cognition (Ulrich, 1983). The theory describes a process where an immediate emotional reaction (like or dislike) to an environment is derived by our initial emotional state prior to a change in environment as well as generalized visual cues (Hartig et al., 1991; Ulrich, 1983). This initial emotional reaction causes arousal that then sparks the cognitive processing of the environment that could further alter arousal and emotional response (Ulrich, 1983). Arousal and emotional response are proceeded by a behavior or motivation, which is often oriented towards approach or withdrawal from an environment (Ulrich, 1983). SRT documents a series of visual cues that impact a human's immediate reaction to a natural environment. Generally, humans prefer complex environments with some ordering that has clear sightlines, a continuous and even ground surface texture, hidden vistas, and a water feature (Ulrich, 1983).

SRT argues that an environment can provide emotional and physiological restoration after interacting with a stress-inducing stimulus (Hartig et al., 1991; Ulrich, 1983). Specifically, viewing a natural environment following a stressful stimulus alters a human's emotional state to facilitate immediate positive emotional reactions that in turn reduce arousal while still maintaining interest (Hartig et al., 1991; Ulrich, 1983). Research exploring the theory of SRT, therefore, should capture metrics of human emotion and physiological traits before and after a stress stimulus, discussed in *Physiological and Affective Responses to Environment- SRT*.

Virtual Reality and Virtual Reality Induced Symptoms and Effects

Virtual reality (VR) is expanding in access throughout a multitude of disciplines; however, within the literature, a universal definition of virtual reality is difficult to identify (Kardong-Edgren et al., 2019; Portman et al., 2015; Wohlgenannt et al., 2019). Milgram & Kishino (1994) developed a spectrum that is still widely referenced with real environments on one end and virtual environments on the opposing end that exclusively contains computer-generated simulations (Figure 1). Wohlgenannt et al. (2019) proposes that the three components of a VR experience are "(tele-)presence, interactivity, and immersion" leading to a comprehensive definition, adopted for this study, that states, "VR leverages immersive technologies to simulate interactive virtual environments or virtual worlds with which users become subjectively involved and in which they feel physically present" (p. 457). Within landscape architecture practice, VR technology is more readily being used as a visualization tool for presenting final designs (Hill, 2019); however, the use of the technology is trailing behind other related fields, such as architecture and environmental planning (Portman et al., 2015).

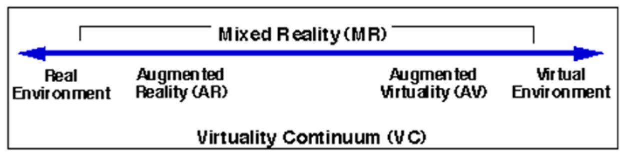


Figure 1: Milgram & Kishino (1994) Virtuality Continuum

Side effects from virtual reality use have been well documented in the literature (Souchet et al., 2022). VR-induced symptoms and effects (VRISE) include physiological symptoms, such as motion sickness (cybersickness), visual fatigue, muscle fatigue, nausea, dizziness, and disorientation, as well as psychological symptoms, such as stress or mental overload (Kourtesis et al., 2019; Souchet et al., 2022). Time spent and motion in virtual reality seems to predictably impact VRISE with increase duration and/or motion increasing the likelihood of VRISE in users (Kourtesis et al., 2019). In addition, hardware and software capacities, such as refresh rates, latency, and display flickering, impact susceptibility to VRISE (Kourtesis et al., 2019; Chang et al., 2020). Individual factors of age, gender, and VR experience have also been explored as potential predictors of VRISE; however, only frequent VR experience has been demonstrated to consistently decrease VRISE (Chang et al., 2020).

Brain Anatomy, Frequencies, and Measurement

The cerebral cortex is the outermost layer of the human brain, which contains a complex organization of nerve cells (neurons) that create the characteristic tissue enfolding (Vachha et al., 2022). It is divided into right and left hemispheres, and each hemisphere consists of four major lobes with differing functions- the frontal lobe, the parietal lobe, the temporal lobe, and the occipital lobe (Borden et al., 2016). Although the intricacies of the lobe functions are still being explored, there are commonly accepted capacities that are impacted by damage to these lobes. The frontal lobe is the largest in the hemisphere at the front of the skull and is involved in the capacity for motor function, including speech production, muscle movement, controlled behavior, emotion regulation, including personality and social interactions, and executive function, including decision making and selective attention (Firat, 2019). The parietal lobe is located behind the frontal lobe and manages sensory and spatial perception and processing as well as language skills (Berlucchi & Vallar, 2018). The temporal lobe sits below the frontal and parietal lobes and provides auditory and olfactory processing, language formation as well as learning and memory consolidation, which allows humans to form long-term memory (Kiernan, 2012). Finally, the occipital lobe rests behind the parietal lobe and facilitates visual input processing and recognition (Nehmad, 1998).

When a human encounters a sensory input, the neurons in the brain send communication via electrical signals within a neuron and chemical signals between neurons (Lovinger, 2008). These electrical signals oscillate at distinct rate creating waves, and researchers have categorized the electrical signals into five brain frequencies based on the rate of these oscillations per second- delta, theta, alpha, beta, and gamma (Table 1) (Grassini et al., 2019). Dominance of certain brain frequencies is associated with cognitive states that relate to human experience. As such, increased power of delta activity is not normally seen in adults during waking; however, is present during sleep, theta activity reflects a deeply relaxed and meditative mind, alpha activity represents a relaxed but wakeful mind, beta activity signifies an alert and attentive mind, and gamma activity often indicates a cognitively engaged or hyperactive mind (Khosla et al. 2020). In addition, alpha and beta brain frequencies are further categorized into low and high frequencies. Low alpha is associated with attentional processing and high alpha cognitive processing, specifically memory (Schomer & Lopes de Silva, 2018). Low beta is oriented toward concentration, anxiety, and performance whereas high beta relates to stress, anxiety, and arousal (Schomer & Lopes de Silva, 2018).

Table 1: Summary of brain frequencies

Name	Frequency (Hertz)
Delta	0.5-4 Hz
Theta	4-8 Hz
Broadband Alpha	8-13 Hz
Low Alpha	8-10 Hz
High Alpha	10-13 Hz
Broadband Beta	13-30 Hz
Low Beta	13-20 Hz
High Beta	20-30 Hz
Gamma	>30 Hz

Brain frequencies are measured and visualized using an electroencephalogram (EEG), a noninvasive instrument composed of a series of electrodes fitted onto a cap that adheres to a human's scalp (Abhang et al., 2016). Although the number of electrodes present on a cap can vary, the current placement of electrodes is standardized using a 10/20 international electrode placement system that organizes electrodes by brain region (a series of letters) and hemisphere (right hemisphere is even numbers and left hemisphere is odd numbers) (Abhang et al., 2016). With the addition of a conductive element on the electrode, often gel if the electrode is dry, it measures the neural electrical activity in the brain area below the electrode, providing a direct opportunity to measure brain functioning (Abhang et al., 2016). EEG represents a psychophysiological metric because it is measuring brain electrical activity (physiological) that is associated with cognition (psychology).

Psychological Responses to Environment- Attention Restoration Theory

Perceived Restorativeness

The Perceived Restorativeness Scale (PRS) is the predominant metric for analyzing a participant's self-reported feeling about the restorativeness of an environment with questions targeting ART's four attributes of a restorative experience (Berto, 2014). Initially devised by Hartig et al. (1991), PRS has been adapted and modified to fully target the attributes of fascination, being away, compatibility, and extent through distinct types of statements (Berto, 2005; Hartig et al., 1996; Hartig et al., 1997a; Hartig et al., 1997b; Pasini et al., 2014; Purcell et al., 2001). Although variations of this metric do exist, there are apparent trends between perceived restorativeness and environment. Studies utilizing imagery of a series of urban versus natural environments reported natural environments were rated as more restorative when compared to urban environments (Berto, 2005; Mahamane et al., 2020; Purcell et al., 2001). In addition, when experiencing environments in-situ, participants demonstrated higher perceived restoration for natural settings (Hartig et al., 1997a; Hartig et al., 1997b; Stigsdotter et al., 2017).

Nature in urban environments can also impact the perceived restorativeness of a human's experience. Studies investigated viewing urban settings with and without greenspace found that urban greenspace was perceived as more restorative than urban areas without greenspace (Hernández & Hidalgo, 2005; Lee et al., 2015; Wang et al., 2016). Research comparing a natural, urban greenspace, and urban street reported higher perceived restorativeness for natural setting, urban greenspace, and urban street, respectively; however, human preference plays a vital role in perceived restoration, specifically in urban greenspace environments (Korpela, 2013; Wilkie & Clouston, 2015).

Little research has explored virtual nature and its impact on perceived restorativeness. Schutte et al. (2017) used VR to display images of an Australian natural landscape and a small town, and results indicated the virtual natural setting was significantly more restorative than the urban environment. One additional study compared exposure to nature outdoors versus virtual nature, and the study determined that both virtual and outdoor statistically increased restorativeness relative to the control environment with no nature present. This indicated that virtual nature could facilitate a restorative experience for humans (Browning et al., 2020).

Overall, perceived restorativeness seems to improve when viewing or experiencing natural environments compared to urban streets. In addition, greenspace in urban environments improves perceived restorativeness; however, not to the same degree as natural settings. Further research is needed to understand how virtual nature influences perceived restorativeness, but initial studies indicate that virtual nature does increase perceived restorativeness.

Physiological and Emotional Responses to Environment- Stress Reduction Theory

Physiological Metrics with a Stress Stimulus

A human's physiological response to stress and stress recovery are fundamental factors for research investigating SRT. Skin conductance, or sweat production, is one involuntary, physiological, autonomous nervous system metrics that is activated when the body needs to act due to a stress-inducing stimulus- fight or flight (Ulrich et al., 1991). Once a threat is no longer perceived, the body regulates its response back to baseline conditions that conserve energy (Jiang et al., 2014; Ulrich et al., 1991). Several studies provided participants with a stress stimulus to see how stress recovery changed depending on the environment. Ulrich et al. (1991) found that watching a video of a natural setting returned skin conductance to baseline levels after 10 minutes, a recovery that was not seen in participants that watched an urban setting video. This study also found that natural settings restored cardiovascular and muscle tension responses (Ulrich et al., 1991). Jiang et al. (2014) identified that stress recovery in different densities of urban trees demonstrated a gender-specific effect with female stress recovery unimpacted by tree density while males showed an improved skin conductance response and salivary cortisol levels at low and high tree densities. Wang et al. (2016) evaluated the impact of urban settings after a stress stimulus and determined that viewing a lawn (with or without people), a lake or a walkway significantly improved skin conductance response and stress recovery when compared to viewing an urban road.

Physiological Metrics without a Stress Stimulus

Many research studies have investigated stress responses to environments without the use of stress stimulus, but skin conductance findings are varied depending on the research study conditions. Generally, skin conductance decreased, a sign of stress reduction, when viewing a natural setting compared to an urban area (Elsadek et al., 2020; Elsadek et al., 2021); however, Grassini et al. (2022) found that urban environments in fact had the lower skin conductance. When in-situ, vegetation in an urban setting decreased skin conductance (Elsadek et al., 2019), but did not impact skin conductance when comparing an urban and natural environment (Reeves et al., 2019). One study examining tree density in urban environments found that skin conductance increased regardless of the environment (Wang et al., 2020a).

Cardiovascular metrics such as heart rate (HR), heart rate variability (HRV), blood pressure (BP), and salivary cortisol are also frequently utilized in research as metrics of stress response. Significant research indicates that whether viewing or immersed in urban greenspace or natural settings, HR and BP decrease when compared to a fully urban space (Elsadek et al., 2020; Hassan et al., 2018; Jiang et al., 2019; Lanki et al., 2017; Lee et al., 2009; Liu et al., 2021; Park et al., 2010; Song et al., 2014; Sonntag-Öström et al., 2014; Tsunetsugu et al., 2013). However, Ottosson & Grahn (2005) and Gladwell et al. (2012) found no significant change in heart rate or blood pressure when experience or viewing nature. HRV indicated that the fight or flight response decreased, and body relaxation increased when viewing or immersed in natural versus urban settings (Elsadek et al., 2019; Elsadek et al., 2021; Lee et al., 2011; Park et al., 2010; Song et al., 2014; Tsunetsugu et al., 2013) except for Gidlow et al. (2016), which showed no specific trend. Salivary cortisol markedly decreased when viewing or immersed in natural settings versus urban environments, a sign of lowered stress (Lee et al., 2009; Lee et al., 2011; Park et al., 2010; Triguero-Mas et al., 2017); however, in an urban greenspace versus urban settings without greenspace, no significant difference between salivary cortisol was discovered (Tyrväinen et al., 2014).

Limited virtual nature studies have been conducted; however, those completed have focused on the metrics of skin conductance, HR, and HRV. When compared to a control or urban environment, skin conductance and heart rate decreased in virtual natural environments (Huang et al., 2020; Valtchanov et al., 2010), a trend that was not identified in Yu et al. (2018). However, in studies comparing virtual nature to images or immersion in real nature, the findings were diverse. Browning et al. (2020) found that skin conductance increased in both outdoor or virtual nature in comparison to a control. Jo et al. (2021) found that HRV improved more significantly within virtual forest versus images of a forest; however, Knaust et al. (2021) found that HR was unimpacted by condition but both virtual and images of nature decreased skin conductance with no difference between the two nature conditions. More research examining VR can help clarify the physiological impacts of virtual nature.

Emotion

Three surveys are frequently used in research to measure affect or emotion- Positive Affect Negative Affect Scale (POMS), Positive Affect Negative Affect Scale

(PANAS), and Zuckerman Inventory of Personal Reactions (ZIPERS). Many studies exploring human self-reported mood have determined that viewing or immersion in natural environments or urban greenspace versus urban environments increase positive affect and decrease negative affect (Elsadek et al., 2019; Elsadek et al., 2020; Elsadek et al., 2021; Hartig et al., 1991; Hartig et al., 2003; Reeves et al., 2019; Song et al., 2014). Triguero-Mas et al. (2017) determined that negative affect was significantly lower in both natural outdoor space with and without water when compared to an urban environment. Multiple studies found that viewing or immersion in urban greenspace improved mood with and without a stress stimulus (Stigsdotter et al., 2017; Tyrväinen et al., 2014; Ulrich et al., 1991). Three studies; however, did not find significant differences in affect when viewing fully urban, natural, or urban greenspace (Karmanov & Hamel, 2008; Olszewska-Guizzo et al., 2021; Tennessen & Cimprich, 1995). Research with VR often found a benefit of virtual nature on positive mood (Browning et al., 2020; Schutte et al., 2017; Valtchanov et al., 2010), and after a stress stimulus, Yu et al. (2018) found an increase in both positive affect and decrease in negative affect when viewing a forest versus urban setting.

Regarding physiological response, skin conductance is an impactful metric for assessing stress recovery in distinct environments after a stressful event. In addition, without that stimulus, cardiovascular metrics are significantly affected by green environments and decrease HR and BP. Emotion, overall, is impacted by environments with virtual and non-virtual greenspace increasing positive emotion, decreasing negative emotion or both.

Electroencephalogram- A Psychophysiological Metric Relating to Stress Reduction and Attention Restoration Theories

Images and Videos

Ulrich (1991) was a foundational study exploring the impact of natural versus urban images on brain activities. The study of 18 participants, utilizing an electroencephalogram (EEG) with four electrodes positioned in the central parietal, found that alpha was significantly higher when participants viewed vegetation or water in comparison to urban images (Ulrich, 1991). This study indicated that natural spaces increased a relaxed but awake cognitive state based on an increase in alpha brain activity (Ulrich, 1991). Ulrich's study only investigated alpha power, but these results spurred further research with mixed results regarding patterns of brain activities and environment.

Numerous studies identified significant results associated with alpha power when juxtaposing environments. When compared to a control, alpha power brain activity increased in the medial prefrontal cortex (Chang et al., 2008) as well as high alpha and low theta brain activities in central and occipital areas (Grassini et al., 2022). Elsadek et al. (2021) found significantly higher alpha power in the frontal electrode F3 and prefrontal electrode AF4 and marginally significant higher alpha power in the frontal electrode F4 and prefrontal electrode AF3 when comparing images of nature to built environments. Jiang et al. (2019) found a marginally significant increase in high and low alpha power when comparing an urban image to a series of natural environments with no significant effects on other brain activities (beta, theta, delta, or gamma); however, it is unclear from the study the location and number of electrodes used to determine the raw EEG data. Window views of a greenspace versus urban setting resulted in marginally higher alpha power in prefrontal electrode AF3 and occipital electrode O1 and significantly higher alpha power in prefrontal electrode AF4 and occipital electrode O2 (Elsadek et al., 2020). Grassini et al. (2019) reported an increase in low alpha power when comparing built and natural environments; however, high alpha, beta, theta, and delta all decreased across 64 electrodes. In a study exploring forest types and tree density, Chiang et al. (2017) found that interior forest significantly increases alpha frequency in the prefrontal region compared to forest edge and forest exterior, a signal that unification of vegetation may improve cognitive relaxation.

Few studies have explored impacts of beta power on natural versus built environment or examined solely urban or natural settings. As previously mentioned, Grassini et al. (2019) determined a decrease in beta power in natural environments compared to urban spaces across all electrodes; however, Olszewska-Guizzo et al. (2018) reported no significant impact of "contemplative" versus "non-contemplative" environments on frontal beta power. The distinction between these two environmental types was difficult to categorize from the provided photographs. Wang et al. (2020a) did not find any difference between alpha or beta brain activities when comparing urban bamboo forest settings, yet the number and location of electrodes is unclear.

The results of these studies demonstrate that substantial work is still needed to understand that impacts of natural and built environments on brain activities. In addition, a lack of homogenization within the research regarding electrodes of interest or brain regions of interest as well as EEG equipment makes identifying brain activity trends challenging. More research is also needed to target the effects of urban nature on brain activities within brain regions.

Outdoor Immersion

Like the indoor EEG studies, outdoor EEG results varied widely between studies. Two studies compared the impacts of natural setting only, and the first study found that posterior alpha power was significantly lowered during nature exposure as compared to pre- or post-exposure (Hopman et al., 2020). The second study exploring solely natural exposure found that active forest walking increased alpha whereas Qigong, an exercise practice, in the forest decreased alpha and beta in the pre-frontal region (Yi et al., 2021).

Two studies contrasted urban and natural environments. Hassan et al. (2018) identified a significant increase in both high alpha and high beta at the end of a 15-minute walk in a bamboo forest versus urban environment, and similarly Reeves et al. (2019) found an increased high beta band activity, with no significant change for low beta, alpha, theta, or delta, in the wetland compared to the urban environment. The unexpected increase in beta power was qualified as related to attentional requirements or data collection challenges associated with movement in an outdoor environment (Reeves et al., 2019).

Several studies examined solely urban settings as environmental conditions. Deng et al. (2020) and Herman et al. (2021) found no significant difference between urban conditions for alpha, beta, delta, gamma, and theta power. When viewing a green façade, participants had significantly higher alpha power in the occipital and frontal lobes (Elsadek et al., 2019). Neale et al. (2020), interested in low beta, high beta, and alpha, found that low beta increased when walking in a busy urban setting compared to an urban quiet or urban greenspace; however, alpha increased in a busy urban setting compared to the two other environments, which is counter to the proposed hypothesis that alpha would in fact decrease. No significant differences were found between the urban greenspace and urban quiet setting, emphasizing that the quantity of greenspace may play a role in the effect on brain activities (Neale et al., 2020). Several outdoor studies used a specific brand of EEG that did not provide raw data, but instead provided “mental states;” however, it is unclear how this data was interpreted (Al-barrak et al., 2017; Aspinall et al., 2015; Bailey et al., 2018; Lin et al., 2020).

Studies of outdoor immersion in environments examining EEG are still critically needed. Research currently spans a wide range of environmental locations with limited repetition of sites. In addition, numerous studies published do not utilize EEG equipment that provides raw data for analysis, which makes result interpretation difficult to interpret.

Virtual Reality

VR has been used as a tool in tandem with a variety of EEG studies, often associated with rehabilitation (Teo et al., 2016); however, few studies have used VR to explore environments and EEG. Gao et al. (2019), focused on alpha activity, found there was not a significant difference in alpha power between environments ranging from zero to greater than 70 % tree canopy; however, only one electrode was utilized for the study, and it is unclear where the electrode was positioned on the forehead. Wang et al. (2020b) found that twenty minutes of exercise viewing virtual nature or viewing virtual abstract art significantly increased alpha power when comparing the pre-test to the post-test, indicating that exercise, not environment, led to increased cognitive relaxation. One study exploring the impact of urban greenspace vegetation on structure and degree of greening provided inconclusive EEG results (Zhu et al., 2021). Two studies (Hu & Roberts, 2020; Rounds et al., 2020) focused on built development and design; however, Hu & Roberts

(2020) provided no raw EEG data as part of the study. Rounds et al. (2020) examined theta bands and found that contrasting architectural design elements, including twisting buildings, increased posterior parietal theta power, yet posterior parietal theta power decreased when buildings contained green facades. More data is needed to understand the associations between VR, EEG, and environment.

Frontal Alpha Asymmetry

Frontal alpha asymmetry (FAA) in relationship to emotion has been studied for many decades (Allen et al., 2004). Normalized FAA is currently measured by subtracting a frontal electrode on the right hemisphere from that same electrode on the left hemisphere and dividing that by the sum of that same right and left electrode, which provides a value between -1 and 1 (Allen et al. 2004). Several studies and reviews have determined that this normalized FAA has been demonstrated association with state and trait emotion as well as approach-withdrawal motivation with greater left frontal activity, or a positive normalized FAA, indicating approach motivation and greater right frontal activity, or negative normalized FAA, indicating withdrawal motivation (Coan & Allen, 2003; Coan & Allen, 2004; Davidson, 1993; Smith et al., 2017). Although frequently associated with positive emotion, it is noteworthy that approach motivation can be associated with negative emotions, such as anger (Harmon-Jones, 2003).

This indication of emotion and arousal, through normalized FAA, relates to SRT and a human's initial emotional response that informs cognition and behavior; however, there is minimal research examining FAA and environment. Olszewska-Guizzo et al. (2018) determined no effect of "contemplative" versus "non-contemplative" environment, and two additional studies, Olszewska-Guizzo et al. (2020) and Olszewska-

Guizzo et al. (2021), inappropriately measured frontal alpha asymmetry. Additional study could reveal the connection between environment and approach-withdrawal motivation through FAA.

Landscape Architecture's Place in Neurourbanism and Environmental Justice

Neurourbanism is an evolving discipline that engages a multidisciplinary group of researchers from architecture, urban planning, neuroscience, and public health to investigate the impacts of urban cities on human mental health and brain function (Adli et al., 2017; Interdisciplinary Forum Neurourbanism, n.d.; Ndaguba et al., 2022). In addition, this discipline seeks to provide evidence-based design practices to promote equity within urban cities (Buttazzoni et al., 2022). This second objective speaks directly to the importance of environmental justice in urban spaces, a movement sparked by African American communities disproportionally impacted by environment health hazards (Bullard, 1983; Bullard & Wright, 1990). Distributive justice, one of four components of environmental justice according to Kuehn (2000), states that humans should have equal access to assets within communities. One of these assets, identified in environmental justice research, is access to high-quality urban greenspace (Jennings et al., 2012; Kephart, 2022). Although several analyses of the framework of Neurourbanism have mentioned the value of greenspace on mental health and cognition, (Buttazzoni et al., 2021; Interdisciplinary Forum Neurourbanism, n.d.; Küçük & Yüceer, 2022), with specific reference to ART, landscape architecture is not mentioned as a collaborator in the Neurourbanism discipline. As designers of public and private space in urban environments, landscape architecture research plays a crucial role in the effort to research design's impact on mental health and advocate for equity in access to healthful greenspaces for all urban communities.

Study Framework and Hypothesis

Based on the above review, this study seeks to fill the following gaps in the literature:

1. No comparative studies exploring an existing site that is redesigned,
2. Few studies examining brain frequencies solely in urban settings,
3. Little data about FAA and nature, and
4. Limited VR studies.

Using VR, a comparative study was developed that collected EEG and perceived restorativeness data from participants after viewing a vacant and designed site to explore restorativeness, cognitive states, and approach-withdrawal motivation within two urban stimulus environments. The hypotheses for this study are as follows:

1. The two stimulus environments will differently impact brain activities and perception of restorativeness,
2. Perceived restorativeness factors will increase when viewing the designed versus vacant site,
3. Alpha frequency will increase, and beta frequency will decrease when viewing the designed versus vacant site, and
4. Approach motivation will increase when viewing the designed versus vacant images.

Chapter 3: Methods

Below is an explanation of the methods that informed the site selection and design as well as the methods used to collect data about feelings of perceived restorativeness and brain frequencies associated with viewing the vacant and designed site in virtual reality (VR).

Site Location, Inventory, and Analysis

Site Selection with Community Leader

Prior to selecting a site for the study, I met with the President of the Broadway East Community & CDC- Dr. Doris Minor-Terrell. I had previously worked on a series of greening projects throughout Broadway East and proposed the study idea to Dr. Minor-Terrell to ask for her expert opinion on a site location within her community advocacy network that could benefit from conceptual site design. Dr. Minor-Terrell recommended the vacant lots addressed 1738-1752 E. North Avenue in the South Clifton Park neighborhood. South Clifton Park is located just south of Clifton Park and north of Baltimore City's Inner Harbor and Patterson Park (Figure 2). Dr. Minor-Terrell's justification for this site selection was threefold:

Figure 2: Neighborhood context map

1. The site is in high visibility area,
2. The site is accessible to two early childhood education institutions, and
3. The site is located near future planned redevelopment.

Site Inventory

After speaking with Dr. Doris Minor-Terrell to determine the site location, site inventory was performed at the neighborhood and site scale. Open-source GIS data of Baltimore City, additional online resources, as well as site visits to examine physical, biological, and cultural attributes all informed the final site design.

Neighborhood Inventory

History

Baltimore City was founded through town charter in 1729 (Baltimore City Department of Planning, 2006). Although, Baltimore had relatively slow growth between 1730 and the early 1750s, Dr. John Stevenson was one the first settlers to utilize the potential of Baltimore's port through his export of flour to Ireland (Baltimore City Department of Planning, 2006). Over the next 100 years, Baltimore's port was a central economic driver for the city and its millwork industry. The port was also a location of critical ship building during Revolutionary War and War of 1812 (Baltimore City Department of Planning, 2006).

Beginning in the mid-1800s, Baltimore City took hold as one of the leaders in the canning industry, fertilizer industry, and manufacturing of chrome, copper, and steel due to technological advances such as steam power (Baltimore City Department of Planning, 2006). Between 1850 and 1900, Baltimore's population grew from 169,000 to 508,957 (Baltimore City Department of Planning, 2006). This population growth required the annexation of more land for working class housing, and the 1888 annexation incorporated more land to the north and west of the existing boundary, including South Clifton Park

(Figure 3) (Baltimore City Commission for Historical and Architectural Preservation, 2002).

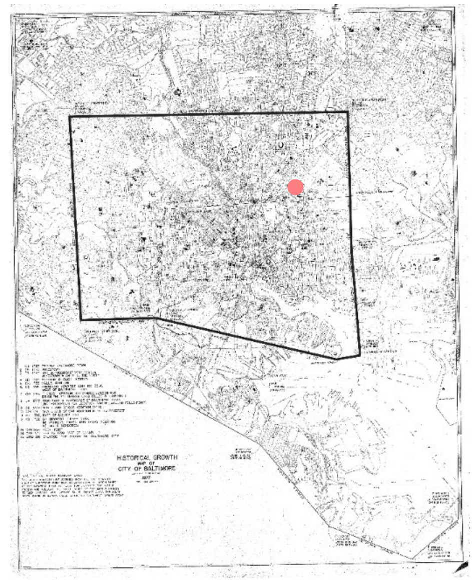


Figure 3: Growth map of the City of Baltimore – the black line is the 1888 boundary, and the pink dot is South Clifton Park (Department of Public Works, 1977)

This diverse, residential neighborhood thrived in the late 1800s and early 1900s as a prime example of rowhome architecture of its time—so much so that the majority of South Clifton Park is now designated as a historic district along with Broadway East (Baltimore City Commission for Historical and Architectural Preservation, 2002). In 1937; however, the federally run Home Owners' Loan Corporation (HOLC) developed a "residential security map" that categorized neighborhoods in Baltimore City as first, second, third, and fourth grade (Badger, 2016). These grades were designated based on racist and classist policies, and South Clifton Park was designated as third grade due to its working class and African American population (Badger, 2016). The federal government no longer supported loans in the South Clifton Park neighborhood, leading to chronic disinvestment and white flight from the neighborhood (Figure 4) (Badger, 2016).

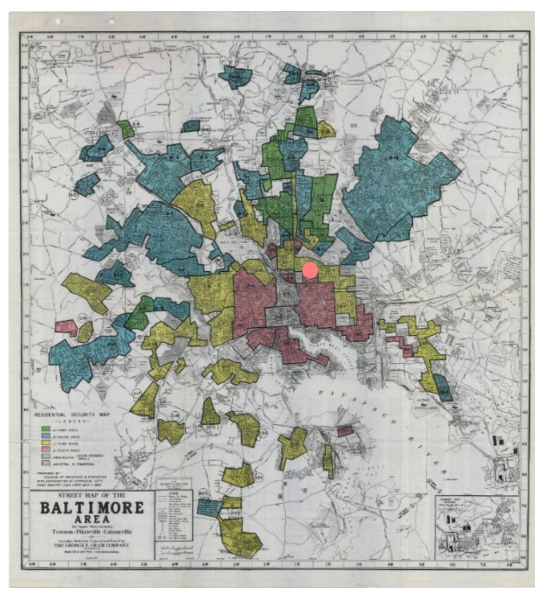


Figure 4: HOLC map for Baltimore City- the pink dot is South Clifton Park (Nelson et al., n.d.)

Today, this 60-acre neighborhood in East Baltimore City is surrounded by seven neighborhoods: East Baltimore Midway, Darley Park, Oliver, Broadway East, Berea, Clifton Park, and Four-by-Four.

Watersheds, Topography, and Tree Canopy

Approximately 58-acres of South Clifton Park lie within the Inner Harbor watershed; however, two-acres on the northwest side of the neighborhood are part of the Jones Falls watershed. No above ground water sources are present in the South Clifton Park neighborhood. The highest point elevation is approximately 176 feet, and the lowest elevation is 94 feet located in the northwest and southcentral portions of the neighborhood, respectively.

South Clifton Park contains no City-run public run parks; however, a southern entry Clifton Park (a 267-acre city park) adjoins South Clifton Park to the north (The Cultural Landscape Foundation, n.d.). The tree canopy coverage in South Clifton Park is 12%, approximately 7 -acres, compared to City's tree canopy coverage of 28% (Figure 5) (TreeBaltimore, 2007).

Figure 5: Watersheds, topography, and tree canopy in South Clifton Park

Demographics

The total population of South Clifton Park in 2020 was 567 compared to Baltimore City's population of 585,708 (Baltimore City Department of Planning, 2020). Ninety percent of the residents are Black compared to 58% of Baltimore City's population (Baltimore City Department of Planning, 2020). In addition, South Clifton Park's population has decreased by -23% from 2010 to 2020 compared to the -6% decrease in overall population in Baltimore City (Figure 6) (Baltimore City Department of Planning, 2020).

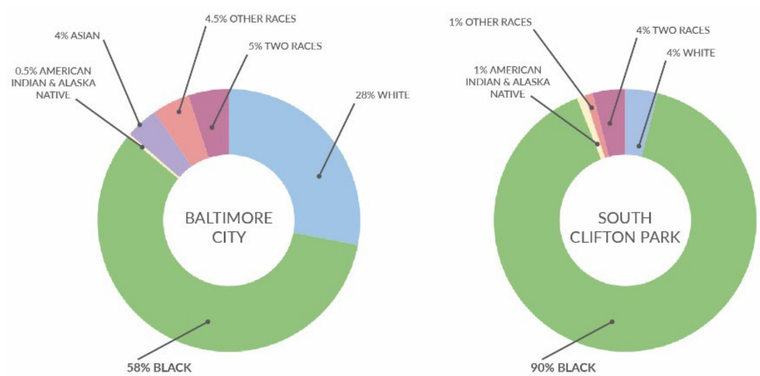


Figure 6: Racial demographics of Baltimore City and South Clifton Park

Median household income is $40,032 compared to Baltimore City's median income of $50,379 (Data USA, 2019; U.S. Census Bureau, 2019). Within the South Clifton Park population, 72% of residents are adults (18 years or older) compared to 83% in Baltimore City (Data USA, 2019; U.S. Census Bureau, 2019). Of those adults, 37% have completed a high school education and 2% have completed a college education compared to 24% and 15% in Baltimore City, respectively (Table 2) (U.S. Census Bureau, 2019).

Table 2: Baltimore City and South Clifton Park income, age, and education demographics

Demographics	Baltimore City	South Clifton Park
Median Household Income	$50,379	$40,032
Percent of Population Adults (18+)	83%	72%
Percent of Population Children (<)	17%	28%
Percent of Population Completed High School	24%	37%
Percent of Population Completed College	15%	2%

South Clifton Park has a lower median income and education completion percentage for high school and college compared to Baltimore City at-large.

Regarding transportation, 57% of South Clifton Park residents do not have a have vehicle, and 58% of residents utilize public transit to commute and 39% of the population use a personal car, truck, or other vehicle to commute (U.S. Census Bureau, 2019). Four bus routes run along South Clifton Park- three routes running north/south and one running east west within Baltimore City providing opportunities for public transportation use for residents in the neighborhood (Figure 7) (Maryland Transit Administration, n.d.).

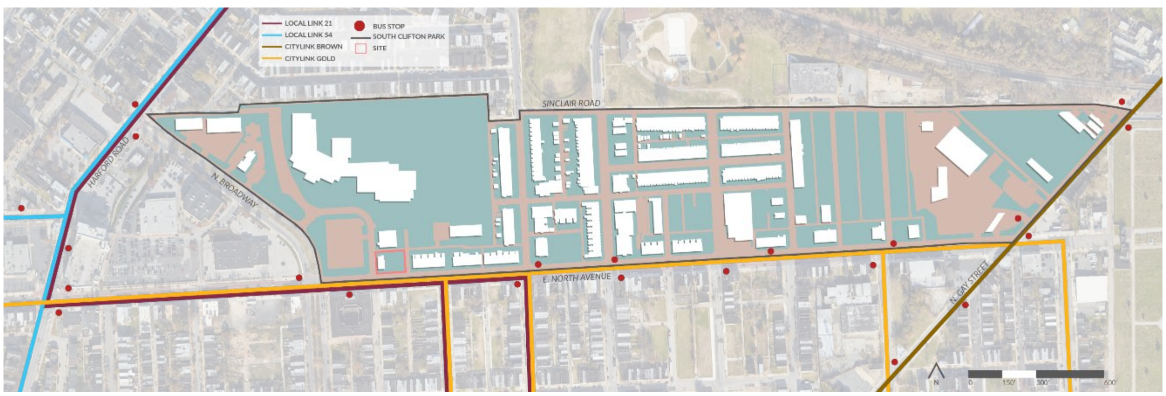


Figure 7: Bus routes and bus stops of South Clifton Park

Vacancy

South Clifton Park has a total of 589 property parcels designed for the neighborhood. Of those 589 parcels, there are a total of 243 vacant lots (41% of the total number of parcels), 89 vacant building notices (15% of the total number of parcels), and six recently rehabbed vacant houses (2% of the total number of parcels) (Figure 8) (Baltimore City Department of Housing & Community Development, n.d.).

Figure 8: Vacant lots and buildings in South Clifton Park

Crime

In the past year, 97 crimes were committed in South Clifton Park. Most crimes are concentrated along E. North Avenue. Both violent crimes and non-violent crimes have been committed in the neighborhood with most violent crimes being aggravated assault and most non-violent crimes being larceny. For comparison, 2,546 crimes were committed in Baltimore's Eastern Police District. Crime in South Clifton Park accounts for approximately 4% of the crime in the Eastern District and represents 6% of its geographic area (Baltimore Police Department, n.d.)

Community Assets

South Clifton Park has a series of community assets throughout the neighborhood. Based on site visits and a review of Google Maps, these assets include three faith institutions, three schools, one library (temporarily closed), one urban farm, and two community gardens. In addition, a future development for the Equality Equation is planned on the east side of South Clifton Park- an organization that provides disadvantaged community members with workforce development training and access to government contracted work opportunities (Figure 9) (The Equality Equation, 2021).

Figure 9: Community assets in South Clifton Park

<u>Site Specific Inventory</u>

Site Context

The site, addressed 1738-1752 E. North Avenue, is in the southwestern portion of the South Clifton Park neighborhood. The site is 0.22-acres and is adjoined by:

- An alley and Rising Sun Baptist Church to the north,
- N. Regester Street and a parking lot to the west,
- E. North Avenue (Bypass 40) and Gompers School to the southwest,
- E. North Avenue and rowhomes (vacant and occupied) to the south,
- E. North Avenue and vacant land to the southeast,
- McDonogh Street and rowhomes to the east.

Gompers School is on Maryland's National Register of Historic Properties. The building was built between 1904 and 1906 and serves as a monument to a "progressive" reform in Baltimore City's education system during the early 1900s that elevated the standards of public education and the facilities where students were taught (Figure 10) (Department of Planning Maryland Historical Trust, 1984).

Figure 10: Site context map and site images (original images)

Hydrology and Topography

Within the site area, there is about a 10-foot change in elevation from the high point in the northwestern portion of the site to the low point in the southeastern corner of the site. Most water flows to the southeast where there are two stormwater drains present- one in E. North Avenue and one in McDonogh Street (Figure 11).

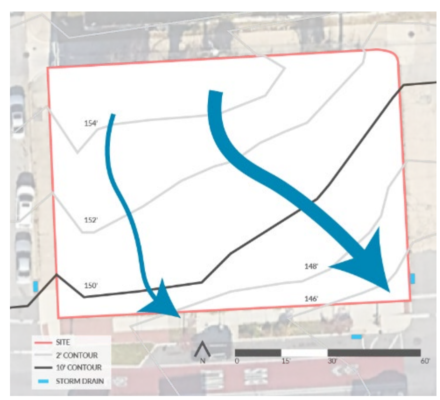


Figure 11: Site hydrology, topography, and surrounding storm drains

Zoning, Land Use, and Ownership

Zoning on the site is Residential-8 District, which permits community-managed open space gardens, parks, and playgrounds (Baltimore City Department of Legislative Reference, 2022). Currently, the site contains two vacant building structures (1738-1740 E. North Avenue) and six vacant lots (1742-1752 E. North Avenue). Five of the parcels are privately owned, two are owned by a corporation, and one is owned by the Baltimore City Housing Authority (Baltimore City Department of Housing & Community Development, n.d.) (Figure 12).

Figure 12: Land ownership and parcel boundaries

Vegetation and Soil

Identification of plant material occurred during visits to the site and may not include all plant species present on site. Most of the site is covered in grassy lawn weeds, including crabgrass, Bermuda grass, broad-leafed dock, dandelion, and purple deadnettle. The trees on the site's northern edge are Tree of Heaven, or *Ailanthus altissima*, a deciduous, invasive species throughout much of the United States that is often found in disturbed, urban areas (Fryer, 2010) and provide a tree canopy over approximately 20% of the site. In addition, several of the trees on site are enwrapped by English Ivy, or *Hedera helix*. Soil in northern and western portions of the site are Hydrologic Soil Group C with slow infiltration rates, and soil in the southern and western portions of the site are Hydrologic Soil Group D with very slow infiltration rates and high runoff potential (United States Department of Agriculture Natural Resources Conservation Service, n.d.) (Figure 13).

Figure 13: Soils and tree canopy

Site Analysis

<u>Opportunities and Constraints</u>

Utilizing the data collected from the inventory, site visits and conversations with Dr. Minor-Terrell, the following opportunities and constraints were developed for the site:

Table 3: Site opportunities and constraints

Opportunities	**Constraints**
• Incorporate bioretention to facilitate stormwater infiltration • Utilize topography that exists on site as design feature • Increase tree canopy within the neighborhood • Create the first programmed public park within the neighborhood • Incorporate stakeholder groups near the site that could become future stewards/users of the park • Utilize vegetation as a screen for unwanted views	• Minimal outdoor activation currently around the site • Site safety and sightlines • Budget for future park maintenance • Invasive species • Rowhome demolition timeline • Private ownership of most of the site parcels • Substantial topographic change within a small site area • N. Regester and E. North Avenue are high traffic roads

These opportunities and constraints led to a series of valuable design decisions when placed spatially on the site. First, bioretention must be located in the southeastern corner of the site to capture stormwater within the site at the lowest elevation. Additionally, vegetation screening could be used along the western portion of the site to block views of the adjoining parking lot. Also, lighting within the park and sightlines from E. North Avenue and N. Regester Street could help improve safety as a site user or law enforcement officer. Finally, easy pedestrian accessibility for nearby stakeholders requires access from the southwest, northwest, and northeast corners of the site (Figure 14).

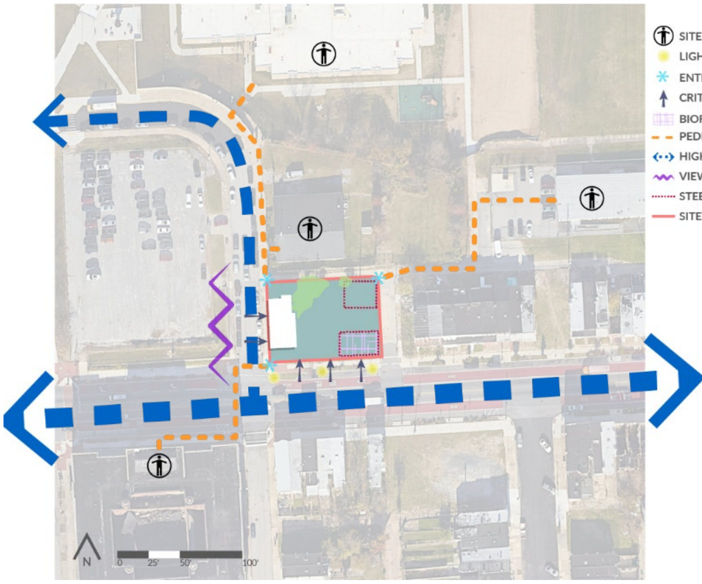


Figure 14: Site analysis diagram

Experimental Data Collection

IRB Application

An application for the study was submitted to the Institutional Review Boards and approved after expedited review on August 30th, 2022. An amendment was made to change the study location, and that amendment was approved on November 4th, 2022. Finally, an amendment was made to allow Ph.D candidate, Kyle Pietro, and Assistant Research Professor, Dr. Hyuk Oh, in the Department of Kinesiology to conduct the post-processing of deidentified EEG data, and that amendment was approved on December 2nd, 2022 (see Appendix I).

Participant Recruitment

UMD students were recruited to be participants of the study beginning in November 2022. A total of 21 participants were recruited using the following methods:

- Flyering throughout UMD's Plant Sciences building (see Appendix II),
- Email blasts to all landscape architecture students,

- Conversations with students and word of mouth, and
- An announcement in an urban agriculture course.

Students that were interested in participating in the study reached out via email and were provided with additional information about the study and offered dates to sign up for study appointment. Initially participants were scheduled within two weeks between Tuesday, November 29th, 2022 and Friday December 9th, 2022; however, concerns expressed about additional noise in the EEG recording required halting data collection on December 1st and December 2nd. Importantly, the concerns regarding additional noise did not alter the EEG data collection procedure. The study data collection was extended through Thursday, December 15th, 2022 to accommodate study participant rescheduling.

Digital Modeling and Stereoscopic Images

One digital model was built for this study using Rhinoceros 3D (Rhino). The model contained layers for the site context, site as it is currently, and site redesigned. The model was brought into Lumion 12 for rendering, and four images were captured from all sides of the site for both the vacant and designed models in the same location using Lumion LiveSync for Rhino (Figure 15).

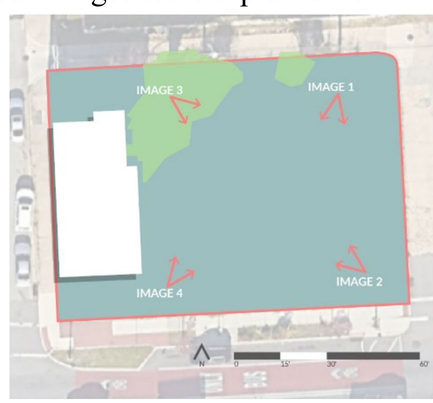


Figure 15: Location and view direction of experimental images

All images were exported as large format (8192x8192), stereoscopic, 360-degree panoramas. To create a boundary for the image and discourage participants from looking around in the VR headset, the images were all brought into Adobe Photoshop, and a black border was placed on the left and right sides of the image.

Figure 16 and Figure 17 exemplify the two-dimensional version of the stereoscopic images that participants saw in the experimental study.

Figure 16: Vacant and designed views at Location 1 and Location 2

Figure 17: Vacant and designed views at Location 3 and Location 4

Data Collection Procedure

Data collection occurred in UMD's Hornbake Library on the ground floor in Room 0302E. The study room was arranged so that the participant faced away from the door towards the wall, and a sign was posted that read, "Study in progress! Please wait" (Figure 18).

Figure 18: Study room and room setup (original images)

The day before participants were scheduled to complete the study, an email was sent to remind them of the date, time, and location of the appointment as well as the approximate study length (1.5 hours). Before a participant entered the study room, the eight stereoscopic images were loaded into an Oculus Quest 2 VR headset using Pigasus VR Media Player, and the ANT Neuro eego^{TM}sports EEG recording platform was set-up. An image matrix was created to ensure that there was counterbalance of the two stimulus environments (vacant versus designed) and four image views (Table 4).

Table 4: Image matrix for the experimental study by participant- V indicates images of the vacant site and D indicates designed images

Sex	**Image Order**	**Sex**	**Image Order**
Female	V1, V2, V3, V4	Male	V1, V2, V4, V3
	D1, D2, D3, D4		D1, D2, D4, D3
Female	D4, D1, D2, D3	Male	D2, D4, D1, D3
	V4, V1, V2, V3		V2, V4, V1, V3

Female	V2, V1, V4, V3 D2, D1, D4, D3	Male	V2, V1, V3, V4 D2, D1, D3, D4
Female	D3, D2, D4, D1 V3, V2, V4, V1	Male	D1, D4, D3, D2 V1, V4, V3, V2
Female	V2, V3, V1, V4 D2, D3, D1, D4	Male	V3, V1, V4, V2 D3, D1, D4, D2
Female	D2, D3, D4, D1 V2, V3, V4, V1	Male	D3, D2, D1, D4 V3. V2, V1, V4
Female	V4, V3, V2, V1 D4, D3, D2, D1	Male	V4, V3, V1, V2 D4, D3, D1, D2
Female	D1, D3, D2, D4 V1, V3, V2, V4	Male	D4, D1, D3, D2 V4, V1, V3, V2
Female	V1, V4, V2, V3 D1, D4, D2, D3	**Total Male Participants: 8**	
Female	D4, D2, D3, D1 V4, V2, V3, V1		
Female	V3, V4, V1, V2 D3, D4, D1, D2		
Female	D3, D4, D2, D1 V3, V4, V2, V1		
Total Female Participants: 12			

One participant initially recruited was removed from the final data analysis because it was not possible to collect EEG data due to dreadlocks.

An overview of the experimental study design is provided in Figure 19.

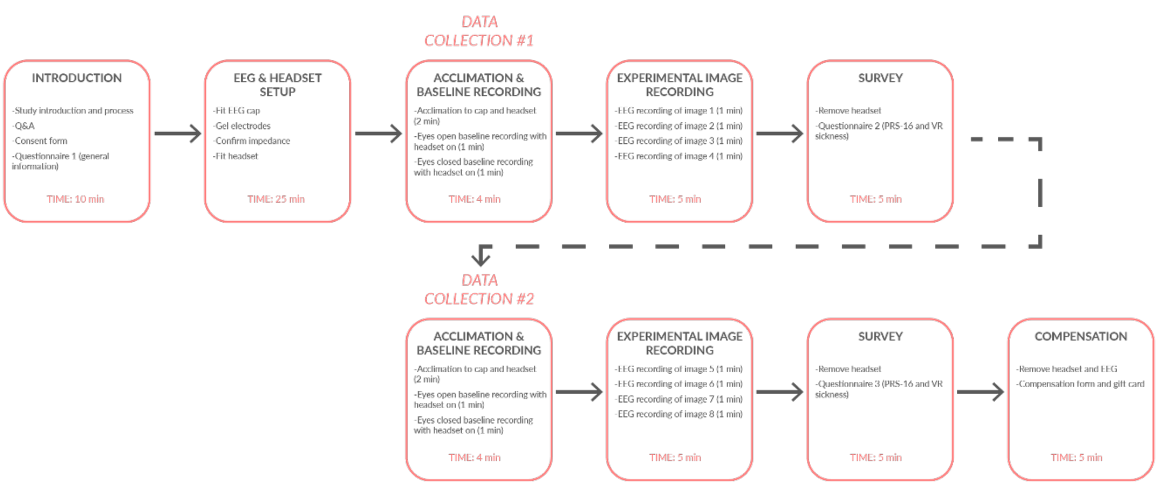


Figure 19: Experimental study design conducted for each participant

Upon entering the study room, participants were given an overview of the study process and had an opportunity to ask any questions. Participants were also reminded to try to limit any head or body movement when viewing the images; this statement was reiterated before each image was shown during data collection. Participants then reviewed and completed a Consent Form followed by Questionnaire 1, which was a general information form focused on age, sex, and experience with VR (see Appendix III and IV). All questionnaires were completed online using an iPad via Qualtrics.

Participants were next fitted with a 32 channel, ANT Neuro waveguard^{TM}original electroencephalogram (EEG) cap based on the circumference of the participant's head (22-24" = Large, 20-22" = Medium, and 18.5-20" = Small). After selecting the size and placing on the cap, all 32 electrodes were prepared with highly conductive electrolyte gel using a blunt needle, and the impedance was checked and re-gelled to confirm that impedance of electrodes were below 25kOhm. Figure 20 shows the location of the channels on the EEG cap.

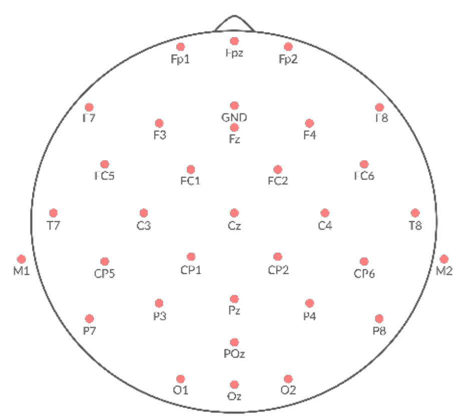


Figure 20: Map of the 32 channel locations on the EEG cap

The VR headset was then fitted on top of the EEG cap, and EEG data was continuously recorded at 500 Hz throughout the remainder of the study. Annotations within the eego^{TM} software were utilized to identify the start and end of any event that occurred during the recording. Participants were asked to take two minutes to settle in and adjust to the set-up before the study commenced.

To begin, two, one minute baseline conditions were collected- first with eyes open viewing a green image displaying the text "Study will begin shortly" and second with eyes closed. Then participants were shown a series of four images from a stimulus environment (vacant or designed) per Table 4 above. Each image was viewed for one minute, and in between each experimental image, a green image displaying the text "Please wait" was presented. Participants were asked to confirm that they were viewing the "Please wait" image before proceeding to the next experimental image. Once all four experimental images were viewed, the VR headset was removed, and participants completed Questionnaire 2, which asked about VR side effects and perceived restorativeness using Perceived Restorativeness Scale (PRS)-16 from Hartig et al. (1997b) (see Appendix V). The VR headset was then re-fitted, and participants completed the same process including the acclimation, baseline conditions, and viewing of four experimental images that were not seen in the previous data collection phase per Table 4 above. The VR headset was removed, and participants completed Questionnaire 3, which was identical to Questionnaire 2.

Finally, the recording was stopped, the EEG cap was removed, a Compensation Form was filled out, and participants were given a $20 gift certificate for their time (see Appendix VI). After the appointment, a copy of the Consent Form was sent to the email address provided in the Compensation Form.

Raw EEG Data Processing

Data processing was required to convert the raw EEG data into a usable format for statistical analysis. The brain frequencies of interest were broadband alpha, low alpha (alpha I), high alpha (alpha II), broadband beta, low beta (beta I), and high beta (beta II). EEG data processing was completed by Kyle Pietro, and an account of the EEG processing methodology is present in Appendix VII.

Statistical Analysis

For the PRS data, a Varimax Rotation factor analysis was conducted separately by stimulus environment (vacant and designed) to reduce the 16 PRS questions into common factors. The mean of each PRS factor by stimulus environment was determined by averaging the PRS score for each of the PRS questions associated with a factor per participant. Using SPSS Statistics, an outlier analysis identified outliers and extreme outliers within each PRS factor with an extreme outlier is identified as outside of the range of 3rd quartile + 3*interquartile range or 1st quartile – 3*interquartile range (Parke, 2013). Extreme outliers were removed from the analysis, and notably if an outlier was found in one of the two stimulus conditions, then it was removed from both conditions for consistency. Descriptive statistics including central tendency, dispersion, skewness, and kurtosis were determined for each factor in each stimulus environment. In addition, paired t-tests were performed to determine if there were statistically significant differences between means by factor in the vacant versus designed stimulus environments.

After processing, EEG data was aggregated into mean power spectral (PS) for each frequency of interest per participant by frontal and parietal lobe. Specifically, F3 and F4 as well as F7 and F8 were aggregated for the frontal lobe, and P3 and P4 as well as P7 and P8 were aggregated for the parietal lobe. In addition, normalized frontal alpha asymmetry (FAA) was calculated for the electrode pairings F3 and F4 and F7 and F8 (Allen et al., 2004). An outlier analysis, descriptive statistics, paired t-tests, and a repeated measures analysis of variance (ANOVA) with sex as a between-subjects factor was completed for each brain frequency of interest in the frontal and parietal lobes; however, only alpha was examined in the repeated measures ANOVA for FAA.

Chapter 4: Results

Design Program

Vision, Goals, and Strategies

The vision for the site is that it will be a beloved greenspace in South Clifton Park providing opportunities for exploration, restoration, and community building for neighboring institutions, residents, and visitors. The design goals of the site respond to the existing conditions, opportunities and constraints, components of Attention Restoration Theory (ART) and Stress Reduction Theory (SRT), as well as conversations with Dr. Minor-Terrell regarding the community's site goals. Table 5 outlines these goals and specific programmatic strategies suggested to attain them.

Table 5: Site design goals and strategies

1. Promote the multifunctional use of the space • Present a series of flexible spaces throughout the site, specifically for gathering. • Locate larger gathering spaces near existing community institutions.
2. Provide accessibility, order, and safety • Incorporate navigable, even pathways that are universally accessible. • Maintain sightlines and layer planting appropriately to encourage proposed uses of the space. • Display path lighting for visibility within the site at night.
3. Encourage interactions with nature • Provide opportunities for structured and unstructured play with natural materials. • Offer seating surrounded by plant material. • Incorporate educational signage within planting beds.
4. Increase tree canopy • Plant canopy trees on the site. • Provide understory canopy cover to create a diversity of canopy experience.
5. Bolster fascination and complexity • Create diverse planting material and natural elements within the site. • Encourage views and experience in nature throughout the site.

Site Design

Goal 1- Promote the multifunctional use of space

The site plan for this greenspace illustrates the multifunctional use of the space, a key goal for the South Clifton Park community (Figure 21).

Figure 21: Site plan of South Clifton Park greenspace

Flexible spaces included two paved gathering areas, one covered and one uncovered, which are located on the southwestern and northwestern edges of the site with the most direct access to potential future users of the space – Rising Sun Baptist Church and the future Gompers School redevelopment (Figure 22).

Figure 22: Image 1- View of the main plaza

These gathering areas could be used for individuals or a group to host events, like concerts or markets, or simply as a place to enjoy an afternoon break. In addition, the greenspace offered play space, informal lawn area, bench seating, and walking paths throughout.

Goal 2- Provide accessibility, order, and safety

Within the greenspace, all paths were paved and graded to a maximum of a 5% slope to allow for ADA accessibility without the need for handrails or stairs (Figure 23).

Figure 23: Section A-A$_1$ of greenspace grading north to south

Planting beds were structured to provide clear distinction between the paths and natural spaces, a crucial element for preferential landscape noted in Stress Reduction Theory (SRT) (Ulrich, 1983). Safety, a priority issue for the community, was addressed with the addition of path and overhead lighting throughout the site as well as limited large plantings along the southern and southeastern boundaries of the site to enable sightlines from E. North Avenue to the south and N. Regester Street to the west. Sightlines into and within landscapes were also noted in SRT to help enhance landscape preference (Ulrich, 1983) (Figure 24).

Figure 24: Image 2- View from E. North Avenue

Goal 3- Encourage interaction with nature

Play and exploration were supported throughout the site using interpretive signage to engage visitors in the ecology present in this urban setting. Bench seating throughout the site was also predominantly placed in areas surrounded by planting to encourage passive or unstructured interactions with nature. A formal play area was located on the southeastern edge of the site with opportunities to climb, jump, and balance, and a lawn connected to the formal play space to support informal discovery or leisure (Figure 25).

Figure 25: Image 3- View of formal play area and lawn

Goal 4- Increase tree canopy

The tree canopy coverage in the South Clifton Park neighborhood is approximately 16% lower than the coverage in the average of Baltimore City. The design for the site added 10 canopy trees and four understory trees, which increased the tree canopy coverage from approximately 20% to 40%.

Goal 5- Bolster fascination and complexity

Complexity within environment is wide ranging according to SRT, but for natural settings tends to associate with a variety of planting materials and textures (Ulrich, 1983). Within the design, a collection of various planting materials with a variation in size, texture, and structure created that complexity for the user. Regarding fascination, a key component for restorativeness of spaces in Attention Restoration Theory (ART), this effortless attention is inherent and described as “soft fascination” in natural space

(Kaplan, 1995). The design offered a variety of views of nature throughout the greenspace to facilitate a restorative experience for users (Figure 26).

Figure 26: Image 4- View of vegetated areas and walking paths

Experimental Results

Participant Demographics and Previous Virtual Reality Experience

A total of 12 females and eight males (N=20) participated in the study ranging in age from 18-44 years old with an average age of 25 years old. Seventeen participants (85%) had used virtual reality before, specifically 11 females and six males. Five of the 17 participants (29%) experienced virtual reality symptoms, including nausea, disorientation, visual fatigue, and/or discomfort. On a scale from 0 (none at all) to 6 (completely), the average previous enjoyment for these participants was 4.5.

Perceived Restorativeness

Factor Analysis

The factor analysis for the vacant and designed lots identified three factors based on the PRS questions. Question 6 (There is much to explore and discover here) and Question 12 (I can do things I like here) were excluded from the vacant site factor analysis because the factor loading was less than 0.7. The three factors, Being Away/Fascination (6 items), Extent (4 items), and Compatibility (4 items), were found to be highly reliable (α=0.941; α=0.915; α=0.929, respectively) (Table 6).

Table 6: Results of Varimax rotation factor analysis for the vacant site

	Component		
	1	2	3
Q1	0.825	0.069	-0.039
Q2	0.787	0.355	-0.056
Q3	0.815	0.383	0.237
Q4	0.732	0.496	0.053
Q5	0.770	0.508	0.114
Q6	0.661	0.351	0.337
Q7	0.778	0.485	-0.059
Q8	-0.144	0.229	0.896
Q9	0.115	-0.155	0.921
Q10	-0.015	0.141	0.926
Q11	0.287	-0.046	0.864
Q12	0.519	0.596	-0.131
Q13	0.258	0.912	0.109
Q14	0.378	0.819	0.055
Q15	0.360	0.866	-0.246
Q16	0.458	0.709	0.255

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization
a. Rotation converged in 5 iterations

Being Away/Fascination is highlighted in red
Extent is highlighted in blue
Compatibility is highlighted in green

Question 2 (Spending time here gives a good break from my day-to-day routine) was excluded from the designed site factor analysis because the factor loading was less than

0.7, and Question 10 (There is a great deal of distraction) was excluded from the designed site factor analysis because it was the only question within a factor. The three factors, Being Away/Fascination (6 items), Extent (3 items), and Compatibility (5 items), were found to be highly reliable (α=0.921; α=0.897; α=0.920, respectively) (Table 7).

Table 7: Results of Varimax rotation factor analysis for the designed site

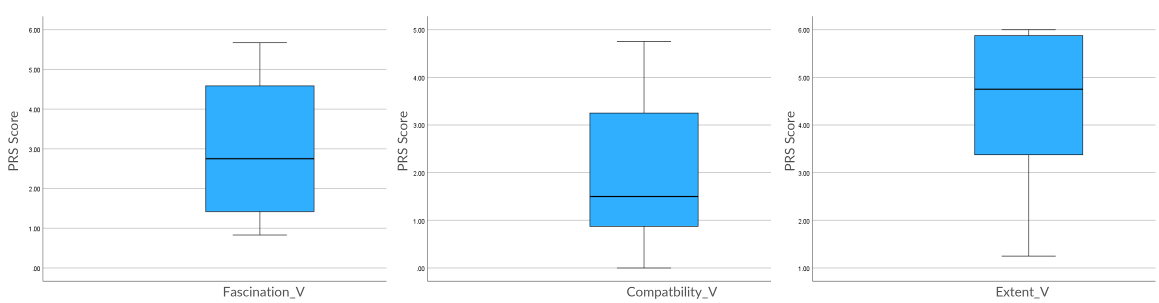
	Component			
	1	2	3	4
Q1	0.705	0.355	-0.201	-0.264
Q2	0.586	0.512	0.192	-0.258
Q3	0.784	0.402	0.076	-0.178
Q4	0.836	0.396	0.045	-0.047
Q5	0.820	0.307	-0.080	0.064
Q6	0.852	0.141	-0.078	-0.111
Q7	0.793	0.013	-0.311	0.126
Q8	-0.111	-0.066	0.925	0.034
Q9	-0.070	0.165	0.888	0.012
Q10	-0.113	0.013	0.187	0.944
Q11	-0.048	-0.237	0.862	0.207
Q12	0.252	0.801	-0.125	-0.019
Q13	0.051	0.950	-0.088	0.036
Q14	0.446	0.799	0.049	0.075
Q15	0.333	0.796	-0.148	-0.048
Q16	0.435	0.719	0.290	-0.140

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization
a. Rotation converged in 6 iterations

Being Away/Fascination is highlighted in red
Extent is highlighted in blue
Compatibility is highlighted in green

Outlier Analysis and Descriptive Statistics

Participant 8 was an extreme outlier for the Being Away/Fascination factor for the designed site (Figure 27).



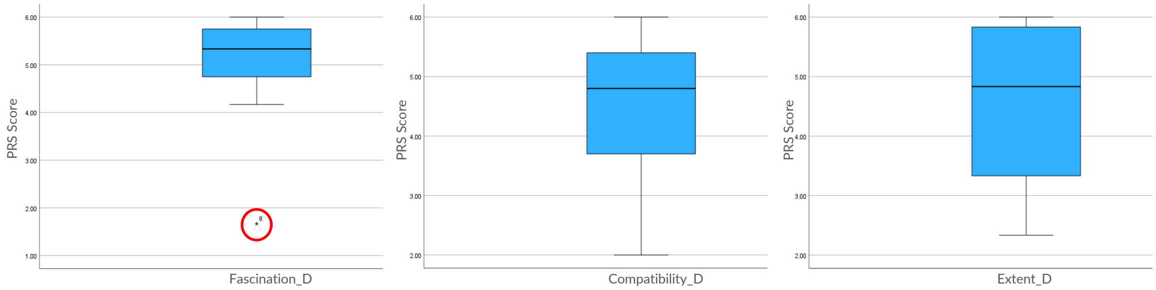


Figure 27: Box plot showing median, interquartile range, minimum and maximum value, and extreme outliers for each perceived restorativeness factor by stimulus environment

Participant 8 was removed from further analysis of both the vacant and designed site for the Being Away/Fascination factor. Descriptive statistics of skewness and kurtosis determined that each factor represented normal distribution (Table 8).

Table 8: Descriptive statistics for the vacant and designed site by factor

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Excess Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V_Being Away/ Fascination	19	4.84	0.83	5.67	3.044	0.394	1.718	2.950	0.198	0.524	-1.421	1.014
D_Being Away/ Fascination	19	1.83	4.17	6.00	5.298	0.123	0.535	0.286	-0.363	0.524	-0.626	1.014
V_Compatibility	20	4.75	0.00	4.75	2.075	0.344	1.537	2.363	0.597	0.512	-0.945	0.992
D_Compatibility	20	4.00	2.00	6.00	4.560	0.259	1.156	1.337	-0.561	0.512	-0.551	0.992
V_Extent	20	4.75	1.25	6.00	4.388	0.333	1.488	2.214	-0.627	0.512	-0.570	0.992
D_Extent	20	3.67	2.33	6.00	4.617	0.285	1.276	1.629	-0.448	0.512	-1.302	0.992

Paired T-Test

Table 9 shows the results of the paired t-test performed to compare the mean scores of each perceived restorativeness factor between the two stimulus environments.

Table 9: Results of the paired t-test showing the difference in perceived restorativeness between the two stimulus environments

		95% Confidence Interval					
	Mean	**Lower**	**Upper**	**t**	**df**	**One-Sided p**	**Two-Sided p**
V_Being Away/ Fascination - D_Being Away/ Fascination	-2.254	-3.032	-1.476	-6.089	18	<0.001	<0.00001****
V_Compatibility - D_Compatibility	-2.485	-3.349	-1.621	-6.019	19	<0.001	<0.00001****
V_Extent – D_Extent	-0.229	-0.681	0.223	-1.061	19	0.151	0.302

**** $p < 0.00001$

The mean score of the factor Being Away/Fascination for the vacant lot (M= 3.044, SD= 1.718) was significantly lower than the mean score of the factor Being Away/Fascination for the designed site (M= 5.298, SD= 0.535); t (18) =-6.089, p<0.001. In addition, the mean score of the factor Compatibility for the vacant lot (M= 2.075, SD= 1.537) was significantly lower than the mean score of the factor Compatibility for the designed site (M= 4.560, SD= 1.156); t (19) =-6.019, p<0.001. The mean score of the factor Extent; however, did not significantly differ between the vacant (M= 4.388, SD= 1.488) and designed site (M= 4.617, SD= 1.276); t (19) =-6.019, p=0.151 (Figure 28).

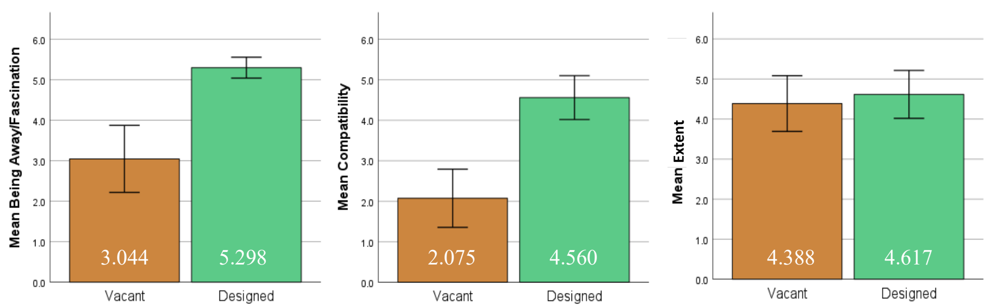


Figure 28: Mean perceived restorativeness factor score by stimulus environment

Electroencephalogram Data

<u>Outlier Analysis and Descriptive Statistics- Frontal Lobe</u>

Table 10 establishes the extreme outliers of each brain frequency for the mean frontal F3 and F4 electrodes and the mean frontal F7 and F8 electrodes.

Table 10: Summary of extreme outliers of each brain frequency in frontal electrodes

Mean F3 & F4

	Alpha	Alpha I	Alpha II	Beta	Beta I	Beta II
Vacant	10	10	10	10	10	10
Designed	10	10	10	10	10	10

Mean F7 & F8

	Alpha	Alpha I	Alpha II	Beta	Beta I	Beta II
Vacant	10		10	10	10	10

Designed						

Extreme outliers identified in either of the stimulus environments were removed from both stimulus environments to enable comparisons between the two environments. Descriptive statistics of skewness and kurtosis determined that each brain frequency for the mean of F3 and F4 electrodes and the mean of F7 and F8 electrodes represented normal distribution (Table 11).

Table 11: Descriptive statistics of brain frequencies for the vacant and designed site in frontal electrodes

	N	**Range**	**Minimum**	**Maximum**	**Mean**		**Std. Deviation**	**Variance**	**Skewness**		**Excess Kurtosis**	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V_alpha_F3F4	19	0.0344	0.0044	0.0387	0.0161	0.0019	0.0083	0.0001	1.2152	0.5238	1.9471	1.0143
D_alpha_F3F4	19	0.0300	0.0049	0.0348	0.0164	0.0019	0.0082	0.0001	0.9327	0.5238	0.2704	1.0143
V_alpha I_F3F4	19	0.0101	0.0017	0.0118	0.0062	0.0007	0.0029	0.0000	0.4123	0.5238	-0.7500	1.0143
D_alpha I_F3F4	19	0.0110	0.0019	0.0129	0.0064	0.0007	0.0030	0.0000	0.5600	0.5238	-0.1689	1.0143
V_alpha II_F3F4	19	0.0236	0.0026	0.0262	0.0094	0.0013	0.0058	0.0000	1.5044	0.5238	2.8095	1.0143
D_alpha II_F3F4	19	0.0184	0.0027	0.0211	0.0096	0.0013	0.0056	0.0000	0.9853	0.5238	-0.1379	1.0143
V_beta_F3F4	19	0.2756	0.0054	0.2810	0.0973	0.0201	0.0878	0.0077	0.9121	0.5238	-0.4931	1.0143
D_beta_F3F4	19	0.3348	0.0065	0.3413	0.1126	0.0250	0.1090	0.0119	1.0916	0.5238	-0.1943	1.0143
V_beta I_F3F4	19	0.1100	0.0025	0.1125	0.0330	0.0071	0.0310	0.0010	1.3412	0.5238	1.1557	1.0143
D_beta I_F3F4	19	0.1048	0.0026	0.1074	0.0366	0.0078	0.0339	0.0012	1.0923	0.5238	-0.1786	1.0143
V_beta II_F3F4	19	0.1806	0.0028	0.1834	0.0635	0.0133	0.0582	0.0034	0.8625	0.5238	-0.6315	1.0143
D_beta II_F3F4	19	0.2553	0.0038	0.2591	0.0751	0.0175	0.0764	0.0058	1.2049	0.5238	0.3847	1.0143
V_alpha_F7F8	19	0.0418	0.0139	0.0558	0.0272	0.0030	0.0130	0.0002	1.3278	0.5238	0.9019	1.0143
D_alpha_F7F8	19	0.0448	0.0085	0.0533	0.0269	0.0028	0.0122	0.0001	0.7860	0.5238	0.3643	1.0143
V_alpha I_F7F8	20	0.0199	0.0047	0.0246	0.0112	0.0012	0.0055	0.0000	1.1735	0.5121	0.7453	0.9924
D_alpha I_F7F8	20	0.0205	0.0037	0.0242	0.0111	0.0012	0.0054	0.0000	1.0418	0.5121	1.1172	0.9924
V_alpha II_F7F8	19	0.0276	0.0064	0.0340	0.0156	0.0018	0.0079	0.0001	1.1776	0.5238	0.8790	1.0143
D_alpha II_F7F8	19	0.0233	0.0045	0.0278	0.0152	0.0015	0.0067	0.0000	0.4457	0.5238	-0.3544	1.0143
V_beta_F7F8	19	0.6666	0.0242	0.6909	0.1577	0.0380	0.1658	0.0275	2.1376	0.5238	5.1912	1.0143
D_beta_F7F8	19	0.4496	0.0202	0.4698	0.1532	0.0300	0.1307	0.0171	1.3356	0.5238	0.8539	1.0143
V_beta I_F7F8	19	0.1549	0.0121	0.1670	0.0499	0.0101	0.0440	0.0019	1.7215	0.5238	2.3526	1.0143
D_beta I_F7F8	19	0.1347	0.0082	0.1429	0.0495	0.0089	0.0387	0.0015	1.5162	0.5238	1.5996	1.0143
V_beta II_F7F8	19	0.5083	0.0120	0.5203	0.1066	0.0287	0.1249	0.0156	2.3522	0.5238	6.2531	1.0143
D_beta II_F7F8	19	0.3101	0.0119	0.3220	0.1025	0.0215	0.0935	0.0088	1.3289	0.5238	0.7411	1.0143

Paired T-Test and Repeated Measures ANOVA- Frontal Lobe

A paired t-test revealed no significant difference between means of the vacant versus design brain frequencies in the frontal electrodes (Table 12).

Table 12: Results of the paired t-test showing the difference in brain frequencies between the two stimulus environments in frontal electrodes

		95% Confidence Interval					
	Mean	**Lower**	**Upper**	**t**	**dt**	**One-Sided p**	**Two-Sided p**
V_alpha_F3F4 - D_alpha_F3F4	-0.00034	-0.00377	0.00309	-0.207	18	0.419	0.838
V_alpha I_F3F4 - D_alpha I_F3F4	-0.00017	-0.00116	0.00083	-0.351	18	0.365	0.730
V_alpha II_F3F4 - D_alpha II_F3F4	-0.00016	-0.00253	0.00221	-0.144	18	0.443	0.887
V_beta_F3F4 - D_beta_F3F4	-0.01525	-0.05571	0.02521	-0.792	18	0.219	0.439
V_beta I_F3F4 - D_beta I_F3F4	-0.00358	-0.01662	0.00945	-0.577	18	0.285	0.571
V_beta II_F3F4 - D_beta II_F3F4	-0.01158	-0.03919	0.01603	-0.881	18	0.195	0.390
V_alpha_F7F8 - D_alpha_F7F8	0.00021	-0.00408	0.00450	0.103	18	0.459	0.919
V_alpha I_F7F8 - D_alpha I_F7F8	0.00007	-0.00143	0.00157	0.096	19	0.462	0.924
V_alpha II_F7F8 - D_alpha II_F7F8	0.00038	-0.00241	0.00317	0.289	18	0.388	0.776
V_beta_F7F8 - D_beta_F7F8	0.00448	-0.06926	0.07823	0.128	18	0.450	0.900
V_beta I_F7F8 - D_beta I_F7F8	0.00038	-0.01625	0.01700	0.047	18	0.481	0.963
V_beta II_F7F8- D_beta II_F7F8	0.00419	-0.05299	0.06137	0.154	18	0.440	0.879

A repeated measures analysis of variance (ANOVA) was also conducted to explore the impact of sex on brain frequencies of participants between the two stimulus environments. Table 13 provides the results of the repeated measures ANOVA per brain frequency for the mean of F3 and F4 electrodes and the mean of F7 and F8 electrodes.

Table 13: Results of the repeated measures ANOVA per brain frequency in the frontal electrodes

Brain Frequency	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Alpha_F3F4	Stimulus Environment	0.0000006	1	0.0000006	0.021	0.887
	Stimulus Environment x Sex	0.0000010	1	0.0000010	0.037	0.850
	Error (Stimulus Environment)	0.0004540	17	0.0000267		
Alpha I_F3F4	Stimulus Environment	0.0000002	1	0.0000002	0.082	0.778
	Stimulus Environment x Sex	0.0000001	1	0.0000001	0.026	0.873
	Error (Stimulus Environment)	0.0000384	17	0.0000023		
Alpha II_F3F4	Stimulus Environment	0.0000001	1	0.0000001	0.007	0.935
	Stimulus Environment x Sex	0.0000005	1	0.0000005	0.041	0.842
	Error (Stimulus Environment)	0.0002174	17	0.0000128		
Beta_F3F4	Stimulus Environment	0.0009154	1	0.0009154	0.259	0.618
	Stimulus Environment x Sex	0.0032887	1	0.0032887	0.930	0.348
	Error (Stimulus Environment)	0.0601379	17	0.0035375		
Beta I_F3F4	Stimulus Environment	0.0000501	1	0.0000501	0.133	0.720
	Stimulus Environment x Sex	0.0001844	1	0.0001844	0.490	0.493
	Error (Stimulus Environment)	0.0063989	17	0.0003764		
Beta II_F3F4	Stimulus Environment	0.0005298	1	0.0005298	0.326	0.576
	Stimulus Environment x Sex	0.0018828	1	0.0018828	1.158	0.297
	Error (Stimulus Environment)	0.0276429	17	0.0016261		
Alpha_F7F8	Stimulus Environment	0.0000065	1	0.0000065	0.166	0.689
	Stimulus Environment x Sex	0.0000528	1	0.0000528	1.359	0.260
	Error (Stimulus Environment)	0.0006608	17	0.0000389		
Alpha I_F7F8	Stimulus Environment	0.0000007	1	0.0000007	0.150	0.703
	Stimulus Environment x Sex	0.0000102	1	0.0000102	2.102	0.164
	Error (Stimulus Environment)	0.0000877	18	0.0000049		
Alpha II_F7F8	Stimulus Environment	0.0000057	1	0.0000057	0.344	0.565
	Stimulus Environment x Sex	0.0000221	1	0.0000221	1.343	0.262
	Error (Stimulus Environment)	0.0002795	17	0.0000164		
Beta_F7F8	Stimulus Environment	0.0038216	1	0.0038216	0.368	0.552
	Stimulus Environment x Sex	0.0339466	1	0.0339466	3.265	0.088*
	Error (Stimulus Environment)	0.1767241	17	0.0103955		
Beta I_F7F8	Stimulus Environment	0.0001592	1	0.0001592	0.308	0.586
	Stimulus Environment x Sex	0.0019104	1	0.0019104	3.692	0.072*
	Error (Stimulus Environment)	0.0087975	17	0.0005175		
Beta II_F7F8	Stimulus Environment	0.0024108	1	0.0024108	0.382	0.545
	Stimulus Environment x Sex	0.0193894	1	0.0193894	3.073	0.098*
	Error (Stimulus Environment)	0.1072637	17	0.0063096		

* p < 0.1

Alpha brain frequencies were not significantly impacted by stimulus environment or the relationship between stimulus environment and sex for the mean of frontal electrodes F3 and F4 or F7 and F8. Additionally, beta brain frequencies were not significantly impacted by stimulus environment or the relationship between stimulus environment and sex for the mean of frontal electrodes F3 and F4. The relationship between stimulus environment and sex; however, had a marginally significant effect on the broadband beta F (1,17) = 3.265, p = 0.088, beta I F (1,17) = 3.692, p = 0.072, and beta II F (1,17) = 3.073, p = 0.098 mean power spectral (PS) for the frontal electrodes F7 and F8. Specifically, male broadband beta, beta I, and beta II mean PS decreased when viewing the vacant versus designed site, yet female broadband beta, beta I, and beta II mean PS increased (Figure 29).

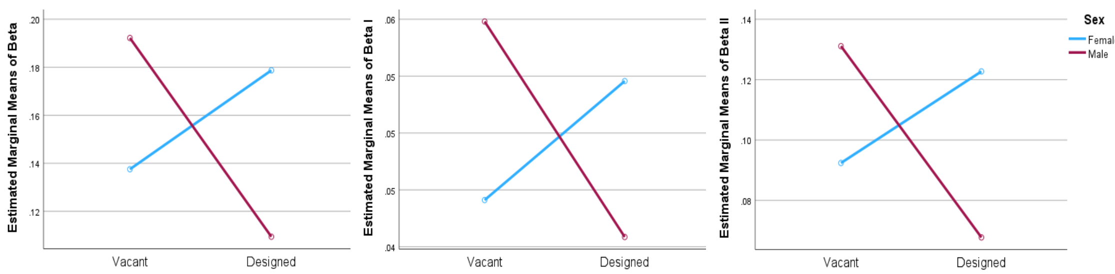


Figure 29: Graphs of beta, beta I, and beta II mean PS for the frontal electrodes F7 and F8 in the vacant and designed stimulus environments

<u>Outlier Analysis and Descriptive Statistics- Parietal Lobe</u>

Table 14 shows the extreme outliers of each brain frequency for the mean parietal P3 and P4 electrodes and the mean parietal P7 and P8 electrodes.

Table 14: Summary of extreme outliers of each brain frequency in parietal electrodes

Mean P3 & P4						
	Alpha	Alpha I	Alpha II	Beta	Beta I	Beta II
Vacant	9	9		10 & 17	10 & 17	10 & 17
Designed	10	9	10	10 & 17	17	10 & 17
Mean P7 & P8						
	Alpha	Alpha I	Alpha II	Beta	Beta I	Beta II
Vacant	9 & 10	9	10	10	10	10
Designed						

Extreme outliers identified in either of the stimulus environments were removed from both stimulus environments to enable comparisons between the two environments. Descriptive statistics of skewness and kurtosis determined that each brain frequency for the mean of P3 and P4 electrodes and the mean of P7 and P8 electrodes represented normal distribution (Table 15).

Table 15: Descriptive statistics of brain frequencies for the vacant and designed site in parietal electrodes

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Excess Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V_alpha_P3P4	18	0.0266	0.0044	0.0309	0.0128	0.0017	0.0071	0.0000	1.0379	0.5363	0.9536	1.0378
D_alpha_P3P4	18	0.0288	0.0038	0.0326	0.0132	0.0017	0.0072	0.0001	1.0923	0.5363	1.7717	1.0378
V_alpha I_P3P4	19	0.0127	0.0014	0.0141	0.0050	0.0008	0.0034	0.0000	1.4307	0.5238	1.5811	1.0143
D_alpha I_P3P4	19	0.0134	0.0015	0.0149	0.0053	0.0008	0.0037	0.0000	1.3328	0.5238	1.2294	1.0143
V_alpha II_P3P4	19	0.0170	0.0024	0.0194	0.0081	0.0012	0.0051	0.0000	0.9014	0.5238	-0.3899	1.0143
D_alpha II_P3P4	19	0.0180	0.0022	0.0202	0.0084	0.0011	0.0050	0.0000	0.8826	0.5238	0.0959	1.0143
V_beta_P3P4	18	0.0355	0.0073	0.0428	0.0183	0.0023	0.0096	0.0001	1.1601	0.5363	1.0862	1.0378
D_beta_P3P4	18	0.0376	0.0031	0.0407	0.0177	0.0022	0.0093	0.0001	0.9749	0.5363	1.1287	1.0378
V_beta I_P3P4	18	0.0117	0.0036	0.0153	0.0081	0.0008	0.0035	0.0000	0.7283	0.5363	-0.5149	1.0378
D_beta I_P3P4	18	0.0172	0.0016	0.0188	0.0080	0.0009	0.0040	0.0000	1.0895	0.5363	2.0190	1.0378
V_beta II_P3P4	18	0.0263	0.0019	0.0282	0.0101	0.0016	0.0067	0.0000	1.3291	0.5363	1.9697	1.0378
D_beta II_P3P4	18	0.0203	0.0016	0.0218	0.0096	0.0014	0.0058	0.0000	0.7238	0.5363	-0.1897	1.0378
V_alpha_P7P8	18	0.0430	0.0065	0.0495	0.0214	0.0028	0.0119	0.0001	1.1175	0.5363	0.8135	1.0378
D_alpha_P7P8	18	0.0416	0.0044	0.0461	0.0213	0.0030	0.0126	0.0002	0.9022	0.5363	-0.3363	1.0378
V_alpha I_P7P8	19	0.0333	0.0022	0.0355	0.0099	0.0019	0.0081	0.0001	1.9915	0.5238	4.8576	1.0143
D_alpha I_P7P8	19	0.0195	0.0017	0.0211	0.0090	0.0014	0.0060	0.0000	0.8222	0.5238	-0.5230	1.0143
V_alpha II_P7P8	19	0.0281	0.0041	0.0323	0.0130	0.0017	0.0075	0.0001	1.0819	0.5238	0.8726	1.0143
D_alpha II_P7P8	19	0.0217	0.0025	0.0242	0.0127	0.0017	0.0072	0.0001	0.6256	0.5238	-1.2127	1.0143
V_beta_P7P8	19	0.3298	0.0138	0.3436	0.0921	0.0214	0.0935	0.0087	1.6227	0.5238	1.9958	1.0143
D_beta_P7P8	19	0.3187	0.0059	0.3246	0.0960	0.0219	0.0954	0.0091	1.5221	0.5238	1.3758	1.0143
V_beta I_P7P8	19	0.0889	0.0089	0.0979	0.0306	0.0060	0.0261	0.0007	1.6533	0.5238	1.8652	1.0143
D_beta I_P7P8	19	0.1106	0.0028	0.1133	0.0320	0.0065	0.0285	0.0008	1.9108	0.5238	3.2953	1.0143
V_beta II_P7P8	19	0.2553	0.0033	0.2586	0.0609	0.0159	0.0695	0.0048	1.7536	0.5238	2.6465	1.0143
D_beta II_P7P8	19	0.2135	0.0031	0.2167	0.0633	0.0155	0.0676	0.0046	1.3600	0.5238	0.6876	1.0143

Paired T-Test and Repeated Measures ANOVA- Parietal Lobe

A paired t-test revealed no significant difference between means of the vacant versus design brain frequencies in the parietal electrodes (Table 16).

Table 16: Results of the paired t-test showing the difference in brain frequencies between the two stimulus environments in parietal electrodes

		95% Confidence Interval					
	Mean	**Lower**	**Upper**	**t**	**dt**	**One-Sided p**	**Two-Sided p**
V_alpha_P3P4 - D_alpha_P3P4	-0.00045	-0.00232	0.00142	-0.507	17	0.309	0.619
V_alpha I_P3P4 - D_alpha I_P3P4	-0.00031	-0.00110	0.00049	-0.817	18	0.212	0.425
V_alpha II_P3P4 - D_alpha II_P3P4	-0.00031	-0.00157	0.00096	-0.510	18	0.308	0.616
V_beta_P3P4 - D_beta_P3P4	0.00058	-0.00301	0.00417	0.340	17	0.369	0.738
V_beta I_P3P4 - D_beta I_P3P4	0.00010	-0.00078	0.00097	0.230	17	0.411	0.821
V_beta II_P3P4 - D_beta II_P3P4	0.00048	-0.00234	0.00330	0.356	17	0.363	0.726
V_alpha_P7P8 - D_alpha_P7P8	0.00014	-0.00361	0.00390	0.080	17	0.468	0.937
V_alpha I_P7P8 - D_alpha I_P7P8	0.00085	-0.00139	0.00310	0.796	18	0.218	0.436
V_alpha II_P7P8 - D_alpha II_P7P8	0.00032	-0.00209	0.00273	0.279	18	0.392	0.784
V_beta_P7P8 - D_beta_P7P8	-0.00387	-0.04454	0.03679	-0.200	18	0.422	0.844
V_beta I_P7P8 - D_beta I_P7P8	-0.00138	-0.01065	0.00789	-0.312	18	0.379	0.758
V_beta II_P7P8 - D_beta II_P7P8	-0.00244	-0.03411	0.02923	-0.162	18	0.437	0.873

A repeated measures ANOVA was also conducted to explore the impact of sex on brain frequencies of participants between the two stimulus environments. Table 17 provides the results of the repeated measures ANOVA per brain frequency for the mean of P3 and P4 electrodes and the mean of P7 and P8 electrodes.

Table 17: Results of the repeated measures ANOVA per brain frequency in the parietal electrodes

Brain Frequency	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Alpha_P3P4	Stimulus Environment	0.000001658	1	0.000001658	0.221	0.644
	Stimulus Environment x Sex	0.000000003	1	0.000000003	0.000	0.984
	Error (Stimulus Environment)	0.000119898	16	0.000007494		
Alpha I_P3P4	Stimulus Environment	0.000001546	1	0.000001546	1.144	0.300
	Stimulus Environment x Sex	0.000001515	1	0.000001515	1.121	0.304
	Error (Stimulus Environment)	0.000022969	17	0.000001351		
Alpha II_P3P4	Stimulus Environment	0.000000573	1	0.000000573	0.158	0.696
	Stimulus Environment x Sex	0.000000353	1	0.000000353	0.097	0.759
	Error (Stimulus Environment)	0.000061761	17	0.000003633		
Beta_P3P4	Stimulus Environment	0.000013609	1	0.000013609	0.601	0.449
	Stimulus Environment x Sex	0.000080710	1	0.000080710	3.565	0.077*
	Error (Stimulus Environment)	0.000362242	16	0.000022640		
Beta I_P3P4	Stimulus Environment	0.000000641	1	0.000000641	0.497	0.491
	Stimulus Environment x Sex	0.000005537	1	0.000005537	4.289	0.055*
	Error (Stimulus Environment)	0.000020654	16	0.000001291		
Beta II_P3P4	Stimulus Environment	0.000008149	1	0.000008149	0.566	0.463
	Stimulus Environment x Sex	0.000043277	1	0.000043277	3.007	0.102
	Error (Stimulus Environment)	0.000230282	16	0.000014393		
Alpha_P7P8	Stimulus Environment	0.000007734	1	0.000007734	0.285	0.601
	Stimulus Environment x Sex	0.000050840	1	0.000050840	1.872	0.190
	Error (Stimulus Environment)	0.000434515	16	0.000027157		
Alpha I_P7P8	Stimulus Environment	0.000015533	1	0.000015533	1.585	0.225
	Stimulus Environment x Sex	0.000028759	1	0.000028759	2.934	0.105
	Error (Stimulus Environment)	0.000166622	17	0.000009801		
Alpha II_P7P8	Stimulus Environment	0.000005405	1	0.000005405	0.466	0.504
	Stimulus Environment x Sex	0.000027293	1	0.000027293	2.352	0.144
	Error (Stimulus Environment)	0.000197291	17	0.000011605		
Beta_P7P8	Stimulus Environment	0.000274949	1	0.000274949	0.089	0.769
	Stimulus Environment x Sex	0.011404846	1	0.011404846	3.682	0.072*
	Error (Stimulus Environment)	0.052652411	17	0.003097201		
Beta I_P7P8	Stimulus Environment	0.000006007	1	0.000006007	0.038	0.848
	Stimulus Environment x Sex	0.000619247	1	0.000619247	3.886	0.065*
	Error (Stimulus Environment)	0.002709286	17	0.000159370		
Beta II_P7P8	Stimulus Environment	0.000198630	1	0.000198630	0.105	0.750
	Stimulus Environment x Sex	0.006578250	1	0.006578250	3.464	0.080*
	Error (Stimulus Environment)	0.032280665	17	0.001898863		

* $p < 0.1$

Alpha brain frequencies and beta II were not significantly impacted by stimulus environment or the relationship between stimulus environment and sex for the mean of frontal electrodes P3 and P4. The relationship between stimulus environment and sex had a marginally significant effect on the beta $F\ (1,16) = 3.565$, $p = 0.077$ and beta I $F\ (1,16) = 4.289$, $p = 0.055$ mean PS for the frontal electrodes P3 and P4. Again, male broadband beta and beta I mean PS decreased when viewing the vacant versus designed site; however, female broadband beta and beta I mean PS increased (Figure 30).

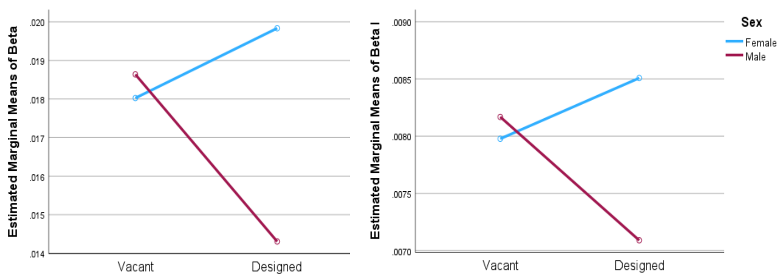


Figure 30: Graphs of beta and beta I mean PS for the parietal electrodes P3 and P4 in the vacant and designed stimulus environments

Alpha brain frequencies were not significantly impacted by stimulus environment or the relationship between stimulus environment and sex for the mean of frontal electrodes P7 and P8. The relationship between stimulus environment and sex had a marginally significant effect on the broadband beta $F\ (1,17) = 3.682$, p = 0. 0.072, beta I $F\ (1,17) = 3.886$, $p = 0.065$, and beta II $F\ (1,17) = 3.464$, $p = 0.080$ mean PS for the frontal electrodes P7 and P8. Similarly, male broadband beta, beta I, and beta II mean PS decreased when viewing the vacant versus designed site, yet female broadband beta, beta I, and beta II mean PS increased (Figure 31).

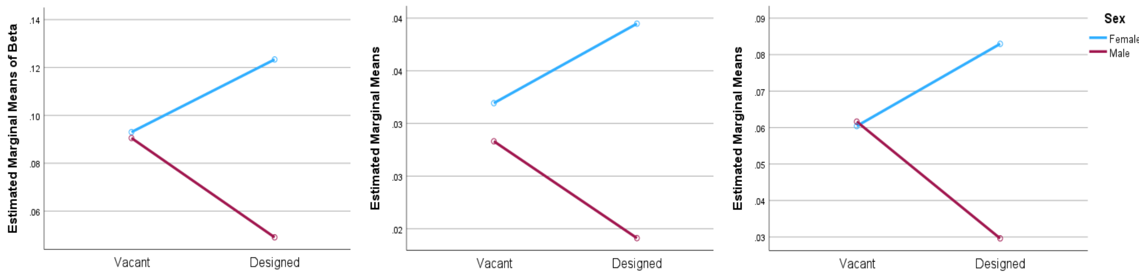


Figure 31: Graphs of beta, beta I, and beta II mean PS for the parietal electrodes P7 and P8 in the vacant and designed stimulus environments

<u>Outlier Analysis and Descriptive Statistics- Frontal Alpha Asymmetry</u>

Participant 20 was an extreme outlier for frontal alpha asymmetry (FAA) in electrodes F7 and F8 for the designed site (Figure 32).

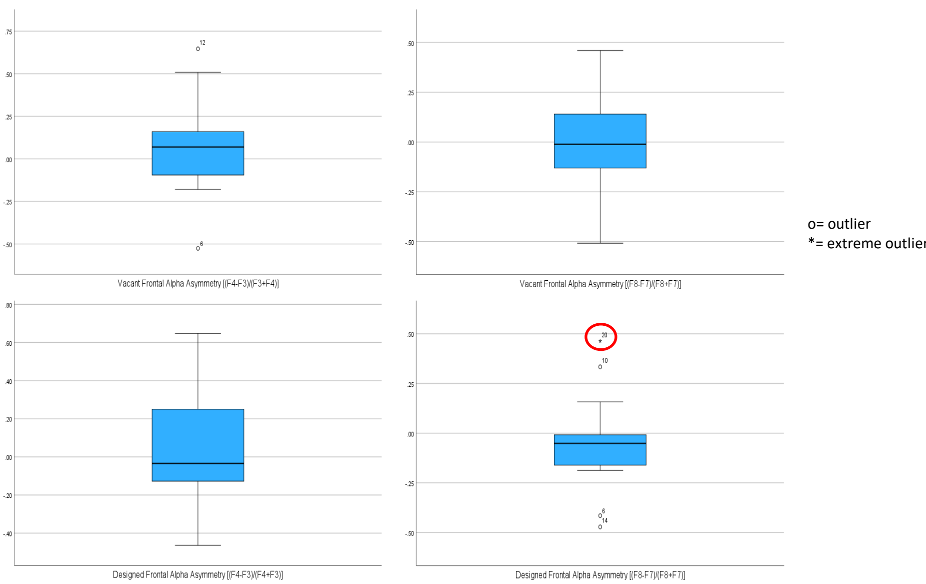


Figure 32: Box plot showing median, interquartile range, minimum and maximum value, and outliers and extreme outliers for FAA by stimulus environment

Participant 20 was removed from further analysis of both the vacant and designed site FAA in electrodes F7 and F8. Descriptive statistics of skewness and kurtosis determined that FAA represented normal distribution (Table 18).

Table 18: Descriptive statistics of FAA for the vacant and designed site

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Excess Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
V_AAsym_F3F4	20	1.1722	-0.5260	0.6462	0.0643	0.0586	0.2619	0.0686	0.2160	0.5121	1.0198	0.9924

D_AAsym_F3F4	20	1.1124	-0.4643	0.6481	0.0682	0.0674	0.3012	0.0907	0.3045	0.5121	-0.7023	0.9924
V_AAsym_F7F8	19	0.7998	-0.5080	0.2918	-0.0310	0.0450	0.1962	0.0385	-0.6320	0.5238	0.6760	1.0143
D_AAsym_F7F8	19	0.8051	-0.4715	0.3335	-0.0793	0.0405	0.1767	0.0312	-0.1789	0.5238	1.9350	1.0143

<u>Paired T-Test and Repeated Measures ANOVA- Frontal Alpha Asymmetry</u>

There was a marginally significant difference in the PS for FAA in F7 and F8 electrodes for the vacant (M = -0.0310, SD = 0.1962) and designed site (M= -0.0793, SD= 0.1767); t (19) =1.5268, p=0.0721. Specifically, FAA decreased when viewing the vacant versus designed site- an indication of higher withdrawal motivation towards the designed site. There was no significant difference in the PS for FAA in F3 and F4 electrodes for the vacant (M= 4.388, SD= 1.488) and designed site (M= 4.617, SD= 1.276); t (19) =-6.019, p=0.151 (Table 19).

Table 19: Results of the paired t-test showing the difference in FAA between the two stimulus environments

		95% Confidence Interval					
	Mean	**Lower**	**Upper**	**t**	**dt**	**One-Sided p**	**Two-Sided p**
V_AAsym_F3F4-D_AAsym_F3F4	-0.0039	-0.0949	0.0870	-0.0902	19	0.4645	0.9291
V_AAsym_F7F8-D_AAsym_F7F8	0.0483	-0.0182	0.1149	1.5268	18	0.0721*	0.1442

* p < 0.1

A repeated measures ANOVA was also conducted to explore the impact of sex on FAA of participants between the two stimulus environments. Table 20 provides the results of the repeated measures ANOVA for FAA for electrode pairings F3 and F4 and F7 and F8.

Table 20: Results of the repeated measures ANOVA for FAA

Electrode	**Source**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
AAsym_F3F4	Stimulus Environment	0.000	1	0.000	0.017	0.897
	Stimulus Environment x Sex	0.001	1	0.001	0.052	0.822
	Error (Stimulus Environment)	0.358	18	0.020		
AAsym_F7F8	Stimulus Environment	0.025	1	0.025	2.475	0.134

	Stimulus Environment x Sex	0.002	1	0.002	0.249	0.624
	Error (Stimulus Environment)	0.169	17	0.010		

FAA not significantly impacted by stimulus environment or the relationship between stimulus environment and sex for electrode pairings F3 and F4 or F7 and F8.

Chapter 5: Discussion

Site Design

Implications

This study aims to provide a design that incorporates both community vision and theoretical principles. The community vision, to establish a multifunctional greenspace that is safe, peaceful, and welcoming, is reinforced by environmental tenets of Attention Restoration Theory (ART) and Stress Reduction Theory (SRT) to establish a launching point for future design work in South Clifton Park. In addition, this study describes a model for the site design that is applicable to other communities with similar challenges of disinvestment in community greenspace.

Although this design addresses the specific vision of the South Clifton Park community, it incorporates goals that are universal to communities lacking high-quality greenspace by:

1. Creating flexible, unprogrammed gathering spaces that encourage users to engage with the site in a variety of ways,
2. Providing accessible, organized, and safe greenspace through sightlines, lighting, and even pathways to reduce stress within the site,
3. Encouraging interaction with nature through a variety of different structured and unstructured experiences,
4. Increasing tree canopy on the site to reduce the impacts of heat on urban spaces, and
5. Supporting fascination and complexity on the site through diverse planting and views.

These goals emphasize the community vision but more broadly seek to develop a site that provides a restorative space for all that visit.

Limitations and Future Study

The scope of this study did not incorporate community engagement after the initial vision for the site was identified with Dr. Doris Minor-Terrell. The vision and initial site design proposed here must be presented to the community for feedback, and a series of community workshops must be conducted to ensure that the design reflects the vision of the South Clifton Park community. Several community groups already exist that cater to residents of the South Clifton Park neighborhood including the Broadway East Community & CDC, Midway CDC, and the East Baltimore Neighborhood Coalition (Broadway East Community & CDC, 2022). Discussion and feedback from these community groups would be a starting point for community participation and codesign. In addition, community partner organizations need to be recruited to assist with the funding, design, implementation, and maintenance of this redesigned site. The Broadway East Community & CDC already has a large network of partnerships including the Baltimore's Office of Sustainability, Midway CDC, The Neighborhood Design Center, Division Landscaping and The 6th Branch that are resources for turning this concept plan into a reality for the residents of South Clifton Park (Broadway East Community & CDC, 2022).

Experimental Results

Implications

This study also examined the impact of virtual environments on physiological and psychological metrics. More specifically, the study explored differences in brain frequencies and perceived restorativeness when viewing a vacant lot versus the site redesigned in virtual reality (VR).

The results of the Perceived Restorativeness Scale (PRS)-16 demonstrate that this designed greenspace encourages effortless attention, provides a reprieve from a daily routine, and establishes relatedness to the environment. This capacity for a designed greenspace to promote a restorative human experience illuminates the value of high-quality greenspace in urban settings. This design; however, did not influence the sense of being in a different world, Attention Restoration Theory's (ART) tenet of Extent. This lack of extent may simply be explained by the size of the site, which did not allow study participants to feel fully engulfed by an alternate space. All the images shown in VR had some element of the urban context visible, which may have grounded the participant in an urban setting regardless of the changes to the environment. Additionally, the PRS-16 survey resulted in 3-factors with the questions associated with Being Away and Fascination combined into a single factor while the factors of Compatibility and Extent remained separate. This finding highlights the need for additional refinement of the PRS questions that target each of the four tenets of ART separately.

Alpha brain frequencies were not significantly altered by the two stimulus environments. This result is similar to several studies exploring outdoor immersion in urban environments (Deng et al., 2020; Herman et al., 2021; Reeves et al., 2019); however, these results were not identified in the limited VR studies of environment and brain frequencies. One possible explanation for a lack of significant change in alpha brain frequencies between stimulus environments is that the degree of difference between the urban stimulus environments. Neale et al. (2019) found no significant differences in alpha brain activity when comparing an urban quiet street versus an urban park and emphasized that both experiences were overall appealing. Similarly, the vacant and designed site both included vegetated areas with no additional sensory experience, such as noise, heat, or smell, so consistent levels of relaxation may have been present in both stimulus environments.

Beta brain frequencies demonstrated a marginally significant effect of sex in both the frontal and parietal lobes. In both frontal and parietal electrodes, broadband beta, beta I, and beta II decreased when viewing the vacant versus designed site for males, indicating a decrease in alert attention, but increased when viewing the vacant versus designed site for females, indicating an increase in alert attention. This trend is not identified in brain activity literature exploring environmental variables; however, researchers are beginning to unearth the effects of sex and environment on other aspects of physiological health, including stress (Jiang et al., 2014; Sillman et al., 2022; Wang et al. 2007). The explanation for these results is currently unclear but indicates that sex may play a role in our cognitive processing of environments. This finding should be more holistically explored to develop additional evidence for this trend of differential brain activity response to environment based on sex.

There was a marginally significant difference between mean frontal alpha asymmetry (FAA), specifically in the F7 and F8 pairing, with FAA decreasing when viewing the designed site. The trend in FAA signifies increased withdrawal motivation in the designed site, which is contradictory to the expectations based on previous research of FAA, Stress Reduction Theory (SRT) and its association to approach-withdrawal motivation (Coan & Allen, 2003; Coan & Allen, 2004; Davidson, 1993; Smith et al., 2017, Ulrich, 1983). In addition, the trend of approach-withdrawal motivation in stimulus environments is inversely related to feelings of perceived restorativeness. One possible explanation for this trend could be that while self-reported perceived restorativeness improved when viewing designed images, perceived restorativeness is not an appropriate indicator of a participant's approach-withdrawal motivation. An understanding of a participant's emotional response to an environment, through surveys like the Positive Affect Negative Affect Scale (POMS) or Positive Affect Negative Affect Scale (PANAS), could identify underlying emotions that positively correlate with the findings of FAA within this study.

Limitations and Future Study

Several limitations for this study are noteworthy including the finite amount of time and budget that established a relatively small sample size of participants. In addition, the experimental setting was indoors and attempted to remove any additional sensory stimulus, such as noise, for participants. There was also limited participant diversity, since all participants were University of Maryland students, and due to convenience sampling, many participants were students within the Landscape Architecture Department. Finally, this study only considered one psychological and one psychophysiological metric during the experimental study; however, there are a myriad of physiological and psychological metrics that deserve exploration but were outside of this scope of work.

This study is just a first step and provides methodology and previous research for a wide variety of future studies. Specifically, further research could create multiple design alternatives in virtual reality to explore participant preference and perceived restorativeness through surveys. The percentage and structure of nature within these multiple design alternatives could also be quantified, using the Visible Green Index identified in Zhu et al. (2021), to understand preference in the degree of environmental greening. In addition, future research could utilize a larger sample size of participants to further assess the existing trends presented in this study regarding perceived restorativeness, brain frequencies, and FAA, potentially including participants living in the community of the actual site. Also, the incorporation of outdoor immersion could examine the influence of a multi-sensory experimental setting on brain activity. Finally, the inclusion of a survey quantifying emotional response could determine if there is a predictive emotional response that correlates to FAA and approach-withdrawal motivation.

Chapter 6: Conclusion

The comparative study presented in this thesis illustrates an opportunity to explore how design and vegetation in virtual reality impacts a human's feelings of restorativeness and brain activities. However, this thesis also speaks to a broader commitment that landscape architects must engage with, a commitment to create contextually rooted greenspace for everyone, regardless of income, race, or ethnicity. This research adds to evidence-based literature that investigates psychological and physiological trends associated with human interactions with environments, specifically urban spaces. As research in virtual reality, psychophysiology, and landscape continues to evolve, this research may provide additional leverage for policy makers and residents advocating for greenspace equity in their communities. We all deserve access to greenspace, and as landscape architects we can help design those spaces through community-led initiatives, collaboratively researching those spaces, through disciplines including Neurourbanism, and encourage revisioning of urban spaces through sharing knowledge in inclusive, far-reaching capacities. Here is a start, but there is still so much to learn and understand, so let us keep moving forward and explore together!

Appendices

Appendix I: IRB Application Approval

UNIVERSITY OF MARYLAND

INSTITUTIONAL REVIEW BOARD

1204 Marie Mount Hall
College Park, MD 20742-5125
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DATE:	August 30, 2022
TO:	Audrey Seiz
FROM:	University of Maryland College Park (UMCP) IRB
PROJECT TITLE:	[1929610-1] The Brain Does Not Lie: A Case Study of Psychophysiology and Landscape in Broadway East
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	August 30, 2022
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *4 & 7*

Thank you for your submission of New Project materials for this project. The University of Maryland College Park (UMCP) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

Prior to final approval of this project scientific review was completed by the IRB Member reviewer.

This submission has received Expedited Review based on the applicable federal regulations.

This project has been determined to be a MINIMAL RISK project.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Unless a consent waiver or alteration has been approved, Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate Amendment forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

Please note that all research records must be retained for a minimum of seven years after the completion of the project.

If you have any questions, please contact the IRB Office at 301-405-4212 or irb@umd.edu. Please include your project title and reference number in all correspondence with this committee.

- 1 -

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This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Maryland College Park (UMCP) IRB's records.

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MARYLAND
INSTITUTIONAL REVIEW BOARD

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DATE:	November 4, 2022
TO:	Audrey Seiz
FROM:	University of Maryland College Park (UMCP) IRB
PROJECT TITLE:	[1929610-2] The Brain Does Not Lie: A Case Study of Psychophysiology and Landscape in South Clifton Park
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	November 4, 2022
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *4 & 7*

Thank you for your submission of Amendment/Modification materials for this project. The University of Maryland College Park (UMCP) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

Prior to final approval of this project scientific review was completed by the IRB Member reviewer.

This submission has received Expedited Review based on the applicable federal regulations.

This project has been determined to be a MINIMAL RISK project.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Unless a consent waiver or alteration has been approved, Federal regulations require that each participant receives a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate Amendment forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed. All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

Please note that all research records must be retained for a minimum of seven years after the completion of the project.

If you have any questions, please contact the IRB Office at 301-405-4212 or irb@umd.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Maryland College Park (UMCP) IRB's records.

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DATE: December 2, 2022

TO: Audrey Seiz
FROM: University of Maryland College Park (UMCP) IRB

PROJECT TITLE: [1929610-3] The Brain Does Not Lie: A Case Study of Psychophysiology and Landscape in South Clifton Park
REFERENCE #:
SUBMISSION TYPE: Amendment/Modification

ACTION: ACKNOWLEDGED
EFFECTIVE DATE: December 2, 2022
EXPIRATION DATE:

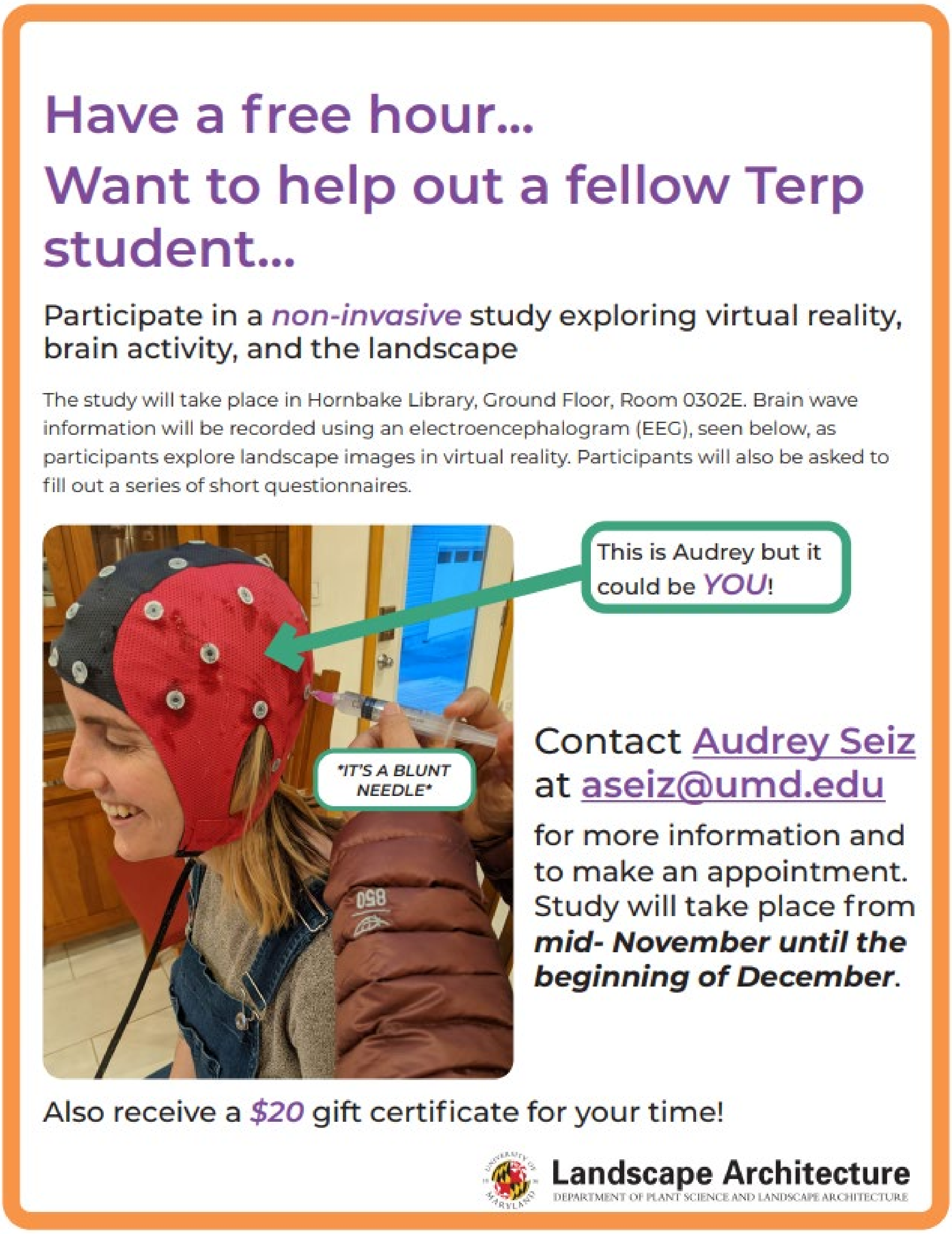
Thank you for submitting the Amendment/Modification materials for this project. The University of Maryland College Park (UMCP) IRB has ACKNOWLEDGED your submission. No further action on submission 1929610-3 is required at this time.

The following items are acknowledged in this submission:

- Amendment/Modification - To add graduate student, Kyle Pietro, and Assistant Research Professor, Dr. Hyuk Oh, in the Department of Kinesiology, to the project. They will help in processing the unidentifiable EEG data for this project.

If you have any questions, please contact the IRB Office at 301-405-4212 or irb@umd.edu. Please include your project title and reference number in all correspondence with this committee.

Appendix II: Flyer for Study Participation



Appendix III: Consent Form

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Informed Consent

The Brain Does Not Lie: A Case Study of Psychophysiology and Landscape in Broadway East

This research is being conducted by **Audrey Seiz** at the University of Maryland, College Park in the PSLA Critique Hall 0104. We are inviting you to participate in this research project because you answered our advertisement and expressed interest in the study. The purpose of this research project is a comparative study exploring how 3D virtual reality visualization impacts participants' brain wave activity as well as the restorative quality of the landscape.

This study is expected to take approximately an hour and is not invasive. The procedure involves placing a cap with electrodes on your head, gelling up the electrodes, and measuring brainwave activity through electroencephalogram (EEG). In addition, a virtual reality headset will show images in three-dimensions. Finally, you will be asked to complete three surveys throughout the session. The first questionnaire asks about age, gender, and previous experience with virtual reality. The additional two questionnaires ask about the current experience with virtual reality as well as the perceived restorativeness of the images displayed in virtual reality.

There may be some risks from participating in this research study. Potential risks from wearing the virtual reality headset include nausea, discomfort, disorientation, and visual fatigue associated with VR sickness. Should a participant feel any VR sickness symptoms during the study, then the virtual reality headset will immediately be removed. Participants will have an opportunity to recover and will be asked if they would like to continue with the study. Before the study begins, the researcher will confirm that the participant is comfortable participating in the study even if they have experienced VR sickness in the past. Potential risks from the EEG include discomfort from EEG cap tightness and minor skin irritation from the electrode gel. To mitigate those risks, participants will try on the caps and confirm tightness before gel is applied. In addition, participants will receive a towel to remove gel after the session is complete.

There are no direct benefits from participating in this research. However, possible benefits include expanding the body of research exploring the impact of nature, specifically virtual nature, on the brain and the body.

Any potential loss of confidentiality will be minimized by storing all data in UMD Qualtrics, which is password-protected. Identifiable information (i.e. consent forms) will be destroyed after three years. The only people that will have access to identifiable information (questionnaires, consent forms, and compensation forms) will be Audrey Seiz and Dr. Byoung- Suk Kweon. Unidentifiable EEG data will be shared via UMD Box, which is password-protected, to a graduate student who will complete EEG data processing. If we write a report or article about this research project, your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.

You will receive physical $20 gift certificate for your participation at the end of the study process. You will be responsible for any taxes assessed on the compensation. If you do not earn over $100 only your name and address will be collected to receive compensation.

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

If you are an employee or student at the University of Maryland, your academic standing as a student or employability at UMD will not be affected by your participation or non-participation in this study.

If you decide to stop taking part in the study, if you have questions, concerns, or complaints, or if you need to report an injury related to the research, please contact the investigator:

Audrey Seiz
2711 N. Howard Street, Baltimore, MD 21218
Email: aseiz@umd.edu
Telephone: 207-210-7782

If you have questions about your rights as a research participant or wish to report a research-related injury, please contact:

University of Maryland College Park Institutional Review Board Office
1204 Marie Mount Hall College Park, Maryland, 20742
E-mail: irb@umd.edu
Telephone: 301-405-0678
IRBNet Package Number: 1929610-1

For more information regarding participant rights, please visit: https://research.umd.edu/research-resources/research-compliance/institutional-review-board-irb/research-participants. This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.

Your signature indicates that you are at least 18 years of age; you have read this consent form or have had it read to you; your questions have been answered to your satisfaction and you voluntarily agree to participate in this research study. You will receive a copy of this signed consent form.

If you agree to participate, please sign your name below.

Name of Participant:

Signature of Participant:

SIGN HERE

clear

Email (for a copy of the consent form):

Today's Date:

Powered by Qualtrics

Appendix IV: Questionnaire 1

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Default Question Block

Today's Date:

Age:

Gender:

- ○ Male
- ○ Female
- ○ Non-binary / third gender
- ○ Prefer not to say

Have you used a virtual reality headset before?

- ○ Yes
- ○ No
- ○ Not sure

If yes, how much did you enjoy using the virtual reality headed on a scale from 0 (none at all) to 6 (completely)?

	0 (none at all)	1	2	3 (moderate)	4	5	6 (completely)	N/A
I enjoyed the virtual reality headset	○	○	○	○	○	○	○	○

If yes, did you experience any virtual reality sickness symptoms?

- ☐ Nausea
- ☐ Discomfort
- ☐ Disorientation
- ☐ Visual fatigue
- ☐ Other
- ☐ None
- ☐ N/A

Appendix V: Questionnaire 2 & 3

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Default Question Block

Today's Date:

How much did you enjoy using the virtual reality headset on a scale from 0 (none at all) to 6 (completely)?

	0 (none at all)	1	2	3 (moderate)	4	5	6 (completely)
I enjoyed the virtual reality headset	○	○	○	○	○	○	○

Are you experiencing any virtual reality sickness symptoms?

- ☐ Nausea
- ☐ Discomfort
- ☐ Disorientation
- ☐ Visual fatigue
- ☐ Other
- ☐ None

Please respond to the following questions about the landscape you were shown on a scale from 0 (none at all) to 6 (completely):

	0 (none at all)	1	2	3 (moderate)	4	5	6 (completely)
It is an escape experience.	○	○	○	○	○	○	○
Spending time here gives me a good break from my day-to-day routine.	○	○	○	○	○	○	○
The setting has fascinating qualities.	○	○	○	○	○	○	○
My attention is drawn to many interesting things.	○	○	○	○	○	○	○
I would like to get to know this place better.	○	○	○	○	○	○	○
There is much to explore and discover here.	○	○	○	○	○	○	○

	0 (none at all)	1	2	3 (moderate)	4	5	6 (completely)
I would like to spend more time looking at the surroundings.	○	○	○	○	○	○	○
There is too much going on.	○	○	○	○	○	○	○
It is a confusing place.	○	○	○	○	○	○	○
There is a great deal of distraction.	○	○	○	○	○	○	○
It is chaotic here.	○	○	○	○	○	○	○
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 VI: Compensation Form

UNIVERSITY OF MARYLAND

First Name

Full Name:
(first and last)

Full Address:
(please include street number and name, state, zip code)

Powered by Qualtrics

Appendix VII: EEG Data Processing Methodology

EEG data were processed using EEGLAB v2022.1 (Delorme & Makeig, 2004) and MATLAB (R2022b, The MathWorks, Inc.). Specifically, EEG data were imported using the EEGLAB plugin, Anteepimport (version 1.13, ANT Neuro). EEG data were inspected to identify bad EEG channels with the EEGLAB plugin, clean_rawdata (version 2.7; Delorme & Makeig, 2004), which were replaced with spherically interpolated channels. These EEG data were re-referenced to a common-average of all EEG channels, excluding M1 and M2, and filtered with a hamming window-based finite impulse response (FIR) filter from 1 to 30 Hz. EEG data were first downsampled to 128 Hz and then subjected to the extended Infomax Independent Component Analysis (ICA; Lee et al., 1999). Decomposition matrices were applied to the non-downsampled EEG data, through which the quality of ICA decomposition could be improved. Independent components that had more than 80% probability of task-irrelevant activities, including blinks, eye movements, heart, muscle, line noise, and channel noise, were removed using the EEGLAB plugin, ICLabel (version 1.4; Pion-Tonachini et al., 2019). A current source density (CSD) transformation was applied to these denoised EEG data using the CSD Toolbox (version 1.1; Kayser, 2009; Kayser & Tenke, 2006a, 2006b) with the spherical spline flexibility factor (*m*) of 4 and the smoothing factor (λ) of 1.0×10^{-5}, respectively. The transformed EEG data were baseline corrected using the mean of each eyes open condition. Power spectral densities were computed for each of the four, 60 second photo-realistic immersive 3D views using Welch's method (Welch, 1967) utilizing a periodic hamming window of 4 s with 50% overlap and 4096 fast Fourier transform (FFT) points. Power spectra were approximated by applying the trapezoidal rule to each of six EEG frequency bands, including broadband alpha (8-13 Hz), alpha I (8-10 Hz), alpha II (10-13 Hz), broadband beta (13-30 Hz), beta I (13-20 Hz), and beta II (20-30 Hz).

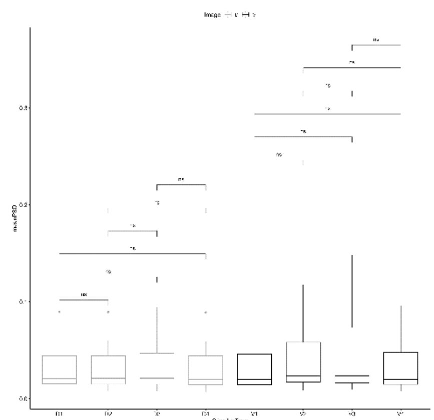

Figure 1: Box plot of mean power spectral density by image

A group of pairwise t-tests were computed to evaluate simple mean differences within the four photo-realistic immersive 3D views for each location. To detect statistical significance within location, α was set at 0.05 and a Bonferroni correction was utilized to correct for multiple comparisons (i.e., $\alpha = \frac{0.05}{8}$). The result of this preliminary statistical testing was that there were no significant differences within the four photo-realistic immersive 3D views for either location (Figure 1 and Table 1).

Table 1: P-values for pairwise t-test

Group 1	Group 2	P-value
D1	D2	1
D1	D3	0.41
D1	D4	1
D2	D3	0.63
D2	D4	0.08
D3	D4	0.21
V1	V2	0.31
V1	V3	0.54
V1	V4	1
V2	V3	0.82
V2	V4	0.25
V3	V4	0.52

Since there were no significant differences between the four photo-realistic immersive 3D views for either location, group means were calculated to compare differences between each stimulus environment.

References

Abhang, P. A., Gawali, B. W., & Mehrotra, S. C. (2016). Chapter 2—Technological Basics of EEG Recording and Operation of Apparatus. In P. A. Abhang, B. W. Gawali, & S. C. Mehrotra (Eds.), *Introduction to EEG- and Speech-Based Emotion Recognition* (pp. 19–50). Academic Press. https://doi.org/10.1016/B978-0-12-804490-2.00002-6

Adli, M., Berger, M., Brakemeier, E.-L., Engel, L., Fingerhut, J., Gomez-Carrillo, A., Hehl, R., Heinz, A., H, J. M., Mehran, N., Tolaas, S., Walter, H., Weiland, U., & Stollmann, J. (2017). Neurourbanism: Towards a new discipline. *The Lancet Psychiatry*, *4*(3), 183–185. https://doi.org/10.1016/S2215-0366(16)30371-6

Al-barrak, L., Kanjo, E., & Younis, E. M. G. (2017). NeuroPlace: Categorizing urban places according to mental states. *PLOS ONE*, *12*(9), e0183890. https://doi.org/10.1371/journal.pone.0183890

Allen, J. J. B., Coan, J. A., & Nazarian, M. (2004). Issues and assumptions on the road from raw signals to metrics of frontal EEG asymmetry in emotion. *Biological Psychology*, *67*(1), 183–218. https://doi.org/10.1016/j.biopsycho.2004.03.007

Aspinall, P., Mavros, P., Coyne, R., & Roe, J. (2015). The urban brain: Analysing outdoor physical activity with mobile EEG. *British Journal of Sports Medicine*, *49*(4), 272–276. https://doi.org/10.1136/bjsports-2012-091877

Badger, E. (2016). 'White flight' began a lot earlier than we think. *Washington Post*. https://www.washingtonpost.com/news/wonk/wp/2016/03/17/white-flight-began-a-lot-earlier-than-we-think/

Bailey, A., Allen, G., Herndon, J., & Demastus, C. (2018). Cognitive benefits of walking in natural versus built environments. *World Leisure Journal*, 1–13. https://doi.org/10.1080/16078055.2018.1445025

Baltimore City Commission for Historical and Architectural Preservation. (2002). *Baltimore East/South Clifton Park Historic District (B-5077)*.

Baltimore City Department of Housing & Community Development. (n.d.). *CoDeMap*. Retrieved March 21, 2023, from https://cels.baltimorehousing.org/codemapv2ext/

Baltimore City Department of Legislative Reference. (2022). *Article 32- Zoning.* Retrieved March 21, 2023, from https://legislativereference.baltimorecity.gov/sites/default/files/Art%2032%20-%20Zoning_(rev%2004-13-22).pdf

Baltimore City Department of Planning. (2006). *City of Baltimore Comprehensive Master Plan*.

Baltimore City Department of Planning. (2020). *2020 Census Redistricting Demographics Data Explorer*. Retrieved March 21, 2023, from https://baltplanning.maps.arcgis.com/apps/dashboards/5f2cb611572640b3beca2f295e1bc229

Baltimore Police Department. (n.d.). *Crime Stats*. Retrieved March 21, 2023, from https://www.baltimorepolice.org/crime-stats

Berlucchi, G., & Vallar, G. (2018). Chapter 1—The history of the neurophysiology and neurology of the parietal lobe. In G. Vallar & H. B. Coslett (Eds.), *Handbook of Clinical Neurology* (Vol. 151, pp. 3–30). Elsevier. https://doi.org/10.1016/B978-0-444-63622-5.00001-2

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology*, *25*(3), 249–259. https://doi.org/10.1016/j.jenvp.2005.07.001

Berto, R. (2014). The Role of Nature in Coping with Psycho-Physiological Stress: A Literature Review on Restorativeness. *Behavioral Sciences*, *4*(4), 394–409. https://doi.org/10.3390/bs4040394

Borden, N. M., Forseen, S. E., Stefan, C., & Moore, A. J. E. (2015). *Imaging Anatomy of the Human Brain*. Springer Publishing Company. https://doi.org/10.1891/9781617051258

Broadway East Community & CDC. (2022). *Community Partners*. https://www.broadwayeast-cdc.org/our-partners

Browning, M. H. E. M., Mimnaugh, K. J., van Riper, C. J., Laurent, H. K., & LaValle, S. M. (2020). Can Simulated Nature Support Mental Health? Comparing Short, Single-Doses of 360-Degree Nature Videos in Virtual Reality With the Outdoors. *Frontiers in Psychology*, *10*. https://www.frontiersin.org/articles/10.3389/fpsyg.2019.02667

Bullard, R. D. (1983). Solid Waste Sites and the Black Houston Community*. *Sociological Inquiry*, *53*(2–3), 273–288. https://doi.org/10.1111/j.1475-682X.1983.tb00037.x

Bullard, R. D., & Wright, B. H. (1990). The Quest for Environmental Equity: Mobilizing the Black Community for Social Change. *Race, Poverty & the Environment*, *1*(2), 3–17.

Buttazzoni, A., Parker, A., & Minaker, L. (2021). Investigating the mental health implications of urban environments with neuroscientific methods and mobile technologies: A systematic literature review. *Health & Place*, *70*, 102597. https://doi.org/10.1016/j.healthplace.2021.102597

Buttazzoni, A., Doherty, S., & Minaker, L. (2022). How Do Urban Environments Affect Young People's Mental Health? A Novel Conceptual Framework to Bridge Public Health, Planning, and Neurourbanism. *Public Health Reports (Washington, D.C.: 1974)*, *137*(1), 48–61. https://doi.org/10.1177/0033354920982088

Chang, C.-Y., Hammitt, W. E., Chen, P.-K., Machnik, L., & Su, W.-C. (2008). Psychophysiological responses and restorative values of natural environments in Taiwan. *Landscape and Urban Planning*, *85*(2), 79–84. https://doi.org/10.1016/j.landurbplan.2007.09.010

Chang, E., Kim, H. T., & Yoo, B. (2020). Virtual Reality Sickness: A Review of Causes and Measurements. *International Journal of Human–Computer Interaction*, *36*(17), 1658–1682. https://doi.org/10.1080/10447318.2020.1778351

Chiang, Y.-C., Li, D., & Jane, H.-A. (2017). Wild or tended nature? The effects of landscape location and vegetation density on physiological and psychological responses. *Landscape and Urban Planning*, *167*, 72–83. https://doi.org/10.1016/j.landurbplan.2017.06.001

Coan, J. A., & Allen, J. J. B. (2003). The state and trait nature of frontal EEG asymmetry in emotion. In K. Hugdahl & R. J. Davidson (Eds.), *The asymmetrical brain* (pp. 565–615). Boston Review.

Coan, J. A., & Allen, J. J. B. (2004). Frontal EEG asymmetry as a moderator and mediator of emotion. *Biological Psychology*, *67*(1–2), 7–49. https://doi.org/10.1016/j.biopsycho.2004.03.002

The Cultural Landscape Foundation. (n.d.). *Clifton Park.* Retrieved March 21, 2023, from https://www.tclf.org/clifton-park

Data USA. (n.d.). *Baltimore city, MD.* Retrieved March 21, 2023, from https://datausa.io/profile/geo/baltimore-city-md

Davidson, R. J. (1993). Cerebral asymmetry and emotion: Conceptual and methodological conundrums. *Cognition and Emotion*, *7*(1), 115–138. https://doi.org/10.1080/02699939308409180

Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods, 134*(1), 9-21. https://doi.org/10.1016/j.jneumeth.2003.10.009

Deng, L., Li, X., Luo, H., Fu, E.-K., Ma, J., Sun, L.-X., Huang, Z., Cai, S.-Z., & Jia, Y. (2020). Empirical study of landscape types, landscape elements and landscape components of the urban park promoting physiological and psychological restoration. *Urban Forestry & Urban Greening*, *48*, 126488. https://doi.org/10.1016/j.ufug.2019.126488

Department of Planning Maryland Historical Trust. (1984). *Eastern High* School. Retrieved March 21, 2023, from https://mht.maryland.gov/nr/NRDetail.aspx?NRID=888

Department of Public Works. (1977). *Historical Growth Map of the City of Baltimore*.

Elsadek, M., Liu, B., & Lian, Z. (2019). Green façades: Their contribution to stress recovery and well-being in high-density cities. *Urban Forestry & Urban Greening*, *46*, 126446. https://doi.org/10.1016/j.ufug.2019.126446

Elsadek, M., Liu, B., & Xie, J. (2020). Window view and relaxation: Viewing green space from a high-rise estate improves urban dwellers' wellbeing. *Urban Forestry & Urban Greening*, *55*, 126846. https://doi.org/10.1016/j.ufug.2020.126846

Elsadek, M., Shao, Y., & Liu, B. (2021). Benefits of Indirect Contact With Nature on the Physiopsychological Well-Being of Elderly People. *HERD*, *14*(4), 227–241. https://doi.org/10.1177/19375867211006654

The Equality Equation. (2021). *About* Us. Retrieved March 21, 2023, from https://e2equation.com/aboutus/

Firat, R. B. (2019). Opening the “Black Box”: Functions of the Frontal Lobes and Their Implications for Sociology. *Frontiers in Sociology*, *4*. https://www.frontiersin.org/articles/10.3389/fsoc.2019.00003

Fryer, J. (2010). Ailanthus altissima. *In: Fire Effects Information System*. Retrieved March 21, 2023, from https://www.fs.usda.gov/database/feis/plants/tree/ailalt/all.html#GeneralDistribution

Gao, T., Zhang, T., Zhu, L., Gao, Y., & Qiu, L. (2019). Exploring Psychophysiological Restoration and Individual Preference in the Different Environments Based on Virtual Reality. *International Journal of Environmental Research and Public Health*, *16*(17), 3102. https://doi.org/10.3390/ijerph16173102

Gidlow, C. J., Jones, M. V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M. P., Smith, G., & Nieuwenhuijsen, M. (2016). Where to put your best foot forward: Psycho-physiological responses to walking in natural and urban environments. *Journal of Environmental Psychology*, *45*, 22–29. https://doi.org/10.1016/j.jenvp.2015.11.003

Gladwell, V. F., Brown, D. K., Barton, J. L., Tarvainen, M. P., Kuoppa, P., Pretty, J., Suddaby, J. M., & Sandercock, G. R. H. (2012). The effects of views of nature on autonomic control. *European Journal of Applied Physiology*, *112*(9), 3379–3386. https://doi.org/10.1007/s00421-012-2318-8

Grassini, S., Revonsuo, A., Castellotti, S., Petrizzo, I., Benedetti, V., & Koivisto, M. (2019). Processing of natural scenery is associated with lower attentional and cognitive load compared with urban ones. *Journal of Environmental Psychology*, *62*, 1–11. https://doi.org/10.1016/j.jenvp.2019.01.007

Grassini, S., Segurini, G. V., & Koivisto, M. (2022). Watching Nature Videos Promotes Physiological Restoration: Evidence From the Modulation of Alpha Waves in Electroencephalography. *Frontiers in Psychology*, *13*. https://www.frontiersin.org/articles/10.3389/fpsyg.2022.871143

Harmon-Jones, E. (2003). Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology*, *40*(6), 838–848. https://doi.org/10.1111/1469-8986.00121

Hartig, T., Mang, M., & Evans, G. W. (1991). Restorative Effects of Natural Environment Experiences. *Environment and Behavior*, *23*(1), 3–26. https://doi.org/10.1177/0013916591231001

Hartig, T., Korpela, K., & Evans, G. (1996). *Validation of a measure of perceived environmental restorativeness.* https://www.semanticscholar.org/paper/Validation-of-a-measure-of-perceived-environmental-Hartig-Korpela/ed18eae35bf5b6f80f163324818aa1aea8a890f2

Hartig, T., Kaiser, F., & Bowler, P. (1997a). *Further Development of a Measure of Perceived Environmental Restorativeness (Working Paper #5)*.

Hartig, T., Korpela, K., Evans, G., & Gärling, T. (1997b). A Measure of restorative quality in environments. *Housing Theory and Society - HOUS THEORY SOC*, *14*, 175–194. https://doi.org/10.1080/02815739708730435

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology*, *23*(2), 109–123. https://doi.org/10.1016/S0272-4944(02)00109-3

Hassan, A., Tao, J., Li, G., Jiang, M., Aii, L., Zhihui, J., Zongfang, L., & Qibing, C. (2018). Effects of Walking in Bamboo Forest and City Environments on Brainwave Activity in Young Adults. *Evidence-Based Complementary and Alternative Medicine: ECAM*, *2018*, 9653857. https://doi.org/10.1155/2018/9653857

Herman, K., Ciechanowski, L., & Przegalinska, A. (2021). Emotional Well-Being in Urban Wilderness: Assessing States of Calmness and Alertness in Informal Green Spaces (IGSs) with Muse-Portable EEG Headband. *Sustainability*, *13*. https://doi.org/10.3390/su13042212

Hernández, B., & Hidalgo, M. (2005). Effect of Urban Vegetation on Psychological Restorativeness. *Psychological Reports*, *96*, 1025–1028. https://doi.org/10.2466/PR0.96.3.1025-1028

Hill, D. (2019). How Virtual Reality Impacts the Landscape Architecture Design Process at Various Scales. *All Graduate Theses and Dissertations*. https://doi.org/10.26076/9r1z-nh57

Hopman, R. J., LoTemplio, S. B., Scott, E. E., McKinney, T. L., & Strayer, D. L. (2020). Resting-state posterior alpha power changes with prolonged exposure in a natural environment. *Cognitive Research: Principles and Implications*, *5*(1), 51. https://doi.org/10.1186/s41235-020-00247-0

Hu, M., & Roberts, J. (2020). Built Environment Evaluation in Virtual Reality Environments-A Cognitive Neuroscience Approach. *Urban Science*, *4*, 48. https://doi.org/10.3390/urbansci4040048

Huang, Q., Yang, M., Jane, H., Li, S., & Bauer, N. (2020). Trees, grass, or concrete? The effects of different types of environments on stress reduction. *Landscape and Urban Planning*, *193*, 103654. https://doi.org/10.1016/j.landurbplan.2019.103654

Interdisciplinary Forum Neurourbanism. (n.d.). Introduction. Retrieved March 21, 2023, from https://neurourbanistik.de/en/

James, W. (1892). *Psychology*. H. Holt.

Jennings, V., Johnson Gaither, C., & Gragg, R. S. (2012). Promoting Environmental Justice Through Urban Green Space Access: A Synopsis. *Environmental Justice*, *5*(1), 1–7. https://doi.org/10.1089/env.2011.0007

Jiang, B., Chang, C.-Y., & Sullivan, W. C. (2014). A dose of nature: Tree cover, stress reduction, and gender differences. *Landscape and Urban Planning*, *132*, 26–36. https://doi.org/10.1016/j.landurbplan.2014.08.005

Jiang, M., Hassan, D., Chen, Q., & Liu, Y. (2019). Effects of different landscape visual stimuli on psychophysiological responses in Chinese students. *Indoor and Built Environment*, *29*, 1420326X1987057. https://doi.org/10.1177/1420326X19870578

Jo, S.-H., Park, J.-S., & Yeon, P.-S. (2021). The Effect of Forest Video Using Virtual Reality on the Stress Reduction of University Students Focused on C University in Korea. *International Journal of Environmental Research and Public Health*, *18*(23), 12805. https://doi.org/10.3390/ijerph182312805

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective* (pp. xii, 340). Cambridge University Press.

Kardong-Edgren, S. S., Farra, S. L., Alinier, G., & Young, H. M. (2019). A Call to Unify Definitions of Virtual Reality. *Clinical Simulation in Nursing*. https://doi.org/10.1016/j.ecns.2019.02.006

Karmanov, D., & Hamel, R. (2008). Assessing the restorative potential of contemporary urban environment(s): Beyond the nature versus urban dichotomy. *Landscape and Urban Planning*, *86*(2), 115–125. https://doi.org/10.1016/j.landurbplan.2008.01.004

Kayser, J. (2009). *Current source density (CSD) interpolation using spherical splines - CSD Toolbox (Version 1.1)*. http://psychophysiology.cpmc.columbia.edu/Software/CSDtoolbox

Kayser, J., & Tenke, C. E. (2006a). Principal components analysis of Laplacian waveforms as a generic method for identifying ERP generator patterns: I. Evaluation with auditory oddball tasks. *Clinical Neurophysiology, 117*(2), 348-368. https://doi.org/https://doi.org/10.1016/j.clinph.2005.08.034

Kayser, J., & Tenke, C. E. (2006b). Principal components analysis of Laplacian waveforms as a generic method for identifying ERP generator patterns: II. Adequacy of low-density estimates. *Clinical Neurophysiology, 117*(2), 369-380. https://doi.org/https://doi.org/10.1016/j.clinph.2005.08.033

Kellert, S., & Wilson, E. (2013). *The Biophilia Hypothesis*. Island Press.

Kephart, L. (2022). How Racial Residential Segregation Structures Access and Exposure to Greenness and Green Space: A Review. *Environmental Justice*, *15*(4), 204–213. https://doi.org/10.1089/env.2021.0039

Khosla, A., Khandnor, P., & Chand, T. (2020). A comparative analysis of signal processing and classification methods for different applications based on EEG signals. *Biocybernetics and Biomedical Engineering*, *40*(2), 649–690. https://doi.org/10.1016/j.bbe.2020.02.002

Kiernan, J. A. (2012). Anatomy of the Temporal Lobe. *Epilepsy Research and Treatment*, *2012*, 176157. https://doi.org/10.1155/2012/176157

Knaust, T., Felnhofer, A., Kothgassner, O. D., Höllmer, H., Gorzka, R.-J., & Schulz, H. (2022). Exposure to virtual nature: The impact of different immersion levels on skin conductance level, heart rate, and perceived relaxation. *Virtual Reality*, *26*(3), 925–938. https://doi.org/10.1007/s10055-021-00595-2

Korpela, K. M. (2013). Perceived Restorativeness of Urban and Natural Scenes—Photographic Illustrations. *Journal of Architectural and Planning Research*, *30*(1), 23–38.

Kourtesis, P., Collina, S., Doumas, L. A. A., & MacPherson, S. E. (2019). Validation of the Virtual Reality Neuroscience Questionnaire: Maximum Duration of Immersive Virtual Reality Sessions Without the Presence of Pertinent Adverse Symptomatology. *Frontiers in Human Neuroscience*, *13*. https://www.frontiersin.org/articles/10.3389/fnhum.2019.00417

Küçük, S., & Yüceer, H. (2022). Neuroscience and the Cities: Neurourbanism. *Gazi University Journal of Science*, *10*, 287–301.

Kuehn, Robert R., "A Taxonomy of Environmental Justice" (2000). *Aboriginal Policy Research Consortium International (APRCi)*. *307*. https://ir.lib.uwo.ca/aprci/307

Lanki, T., Siponen, T., Ojala, A., Korpela, K., Pennanen, A., Tiittanen, P., Tsunetsugu, Y., Kagawa, T., & Tyrväinen, L. (2017). Acute effects of visits to urban green environments on cardiovascular physiology in women: A field experiment. *Environmental Research*, *159*, 176–185. https://doi.org/10.1016/j.envres.2017.07.039

Lee, T.-W., Girolami, M., & Sejnowski, T. J. (1999). Independent Component Analysis Using an Extended Infomax Algorithm for Mixed Subgaussian and Supergaussian Sources. *Neural Computation, 11*(2), 417-441. https://doi.org/10.1162/089976699300016719

Lee, J., Park, B.-J., Tsunetsugu, Y., Kagawa, T., & Miyazaki, Y. (2009). Restorative effects of viewing real forest landscapes, based on a comparison with urban landscapes. *Scandinavian Journal of Forest Research*, *24*(3), 227–234. https://doi.org/10.1080/02827580902903341

Lee, J., Park, B.-J., Tsunetsugu, Y., Ohira, T., Kagawa, T., & Miyazaki, Y. (2011). Effect of forest bathing on physiological and psychological responses in young Japanese male subjects. *Public Health*, *125*(2), 93–100. https://doi.org/10.1016/j.puhe.2010.09.005

Lee, K. E., Williams, K. J. H., Sargent, L. D., Williams, N. S. G., & Johnson, K. A. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *Journal of Environmental Psychology*, *42*, 182–189. https://doi.org/10.1016/j.jenvp.2015.04.003

Lin, W., Chen, Q., Jiang, M., Tao, J., Liu, Z., Zhang, X., Wu, L., Xu, S., Kang, Y., & Zeng, Q. (2020). Sitting or Walking? Analyzing the Neural Emotional Indicators of Urban Green Space Behavior with Mobile EEG. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, *97*(2), 191–203. https://doi.org/10.1007/s11524-019-00407-8

Liu, Q., Wang, X., Liu, J., Zhang, G., An, C., Liu, Y., Fan, X., Hu, Y., & Zhang, H. (2021). The Relationship between the Restorative Perception of the Environment and the Physiological and Psychological Effects of Different Types of Forests on University Students. *International Journal of Environmental Research and Public Health*, *18*(22), 12224. https://doi.org/10.3390/ijerph182212224

Lovinger, D. M. (2008). Communication Networks in the Brain. *Alcohol Research & Health*, *31*(3), 196–214.

Mahamane, S., Wan, N., Porter, A., Hancock, A. S., Campbell, J., Lyon, T. E., & Jordan, K. E. (2020). Natural Categorization: Electrophysiological Responses to Viewing Natural Versus Built Environments. *Frontiers in Psychology*, *11*. https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00990

Maryland Transit Administration. (n.d.). *BaltimoreLink Routes.* Retrieved March 21, 2023, from https://www.mta.maryland.gov/

Milgram, P., & Kishino, F. (1994). A Taxonomy of Mixed Reality Visual Displays. *IEICE Trans. Information Systems*, *E77-D, no. 12*, 1321–1329.

Ndaguba, E., Cilliers, J., Mbanga, S., Brown, K., & Ghosh, S. (2022). Re-Imaging the Future in Urban Studies and Built Environment Discourse: A Neurourbanism Perspective. *Buildings*, *12*(12), Article 12. https://doi.org/10.3390/buildings12122056

Neale, C., Aspinall, P., Roe, J., Tilley, S., Mavros, P., Cinderby, S., Coyne, R., Thin, N., & Ward Thompson, C. (2020). The impact of walking in different urban environments on brain activity in older people. *Cities & Health*, *4*(1), 94–106. https://doi.org/10.1080/23748834.2019.1619893

Nehmad, O. D., Leon. (1998). The end in sight: A look at the occipital lobe. *Clinical Eye and Vision Care*, *10*(3), 125–133. https://doi.org/10.1016/S0953-4431(98)00013-7

Nelson, R., Winling, L., Marciano, R., & Connolly, N. (2012). *Mapping Inequality*. (n.d.). Retrieved March 21, 2023, from https://dsl.richmond.edu/panorama/redlining/

Olszewska-Guizzo, A., Paiva, T., & Barbosa, F. (2018). Effects of 3D Contemplative Landscape Videos on Brain Activity in a Passive Exposure EEG Experiment. *Frontiers in Psychiatry*, *9*. https://doi.org/10.3389/fpsyt.2018.00317

Olszewska-Guizzo, A., Sia, A., Fogel, A., & Ho, R. (2020). Can Exposure to Certain Urban Green Spaces Trigger Frontal Alpha Asymmetry in the Brain?—Preliminary Findings from a Passive Task EEG Study. *International Journal of Environmental Research and Public Health*, *17*(2), 394. https://doi.org/10.3390/ijerph17020394

Olszewska-Guizzo, A., Fogel, A., Escoffier, N., & Ho, R. (2021). Effects of COVID-19-related stay-at-home order on neuropsychophysiological response to urban spaces: Beneficial role of exposure to nature? *Journal of Environmental Psychology*, *75*, 101590. https://doi.org/10.1016/j.jenvp.2021.101590

Ottosson, J., & Grahn, P. (2005). A Comparison of Leisure Time Spent in a Garden with Leisure Time Spent Indoors: On Measures of Restoration in Residents in Geriatric Care. *Landscape Research*, *30*(1), 23–55. https://doi.org/10.1080/0142639042000324758

Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine*, *15*(1), Article 1. https://doi.org/10.1007/s12199-009-0086-9

Parke, C. S. (2013). *Module 5: Identifying and addressing outliers*. SAGE Publications, Inc., https://doi.org/10.4135/9781506335148

Pasini, M., Berto, R., Brondino, M., Hall, R., & Ortner, C. (2014). How to Measure the Restorative Quality of Environments: The PRS-11. *Procedia - Social and Behavioral Sciences*, *159*, 293–297. https://doi.org/10.1016/j.sbspro.2014.12.375

Pion-Tonachini, L., Kreutz-Delgado, K., & Makeig, S. (2019). ICLabel: An automated electroencephalographic independent component classifier, dataset, and website. *Neuroimage, 198*, 181-197. https://doi.org/10.1016/j.neuroimage.2019.05.026

Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. *Computers, Environment and Urban Systems*, *54*, 376–384. https://doi.org/10.1016/j.compenvurbsys.2015.05.001

Purcell, T., Peron, E., & Berto, R. (2001). Why do Preferences Differ between Scene Types? *Environment and Behavior*, *33*(1), 93–106. https://doi.org/10.1177/00139160121972882

Reeves, J. P., Knight, A. T., Strong, E. A., Heng, V., Neale, C., Cromie, R., & Vercammen, A. (2019). The Application of Wearable Technology to Quantify Health and Wellbeing Co-benefits From Urban Wetlands. *Frontiers in Psychology*, *10*. https://www.frontiersin.org/articles/10.3389/fpsyg.2019.01840

Rounds, J. D., Cruz-Garza, J. G., & Kalantari, S. (2020). Using Posterior EEG Theta Band to Assess the Effects of Architectural Designs on Landmark Recognition in an Urban Setting. *Frontiers in Human Neuroscience*, *14*. https://www.frontiersin.org/articles/10.3389/fnhum.2020.584385

Schomer, D. L., & Lopes da Silva, F. H. (Eds.). (2018). *Niedermeyer's electroencephalography: Basic principles, clinical applications, and related fields* (7th ed.). Oxford University Press.

Schutte, N. S., Bhullar, N., Stilinović, E. J., & Richardson, K. (2017). The Impact of Virtual Environments on Restorativeness and Affect. *Ecopsychology*, *9*(1), 1–7. https://doi.org/10.1089/eco.2016.0042

Sillman, D., Rigolon, A., Browning, M. H. E. M., Yoon, H. (Violet), & McAnirlin, O. (2022). Do sex and gender modify the association between green space and physical health? A systematic review. *Environmental Research*, *209*, 112869. https://doi.org/10.1016/j.envres.2022.112869

Smith, E. E., Reznik, S. J., Stewart, J. L., & Allen, J. J. B. (2017). Assessing and conceptualizing frontal EEG asymmetry: An updated primer on recording, processing, analyzing, and interpreting frontal alpha asymmetry. *International Journal of Psychophysiology*, *111*, 98–114. https://doi.org/10.1016/j.ijpsycho.2016.11.005

Song, C., Ikei, H., Igarashi, M., Miwa, M., Takagaki, M., & Miyazaki, Y. (2014). Physiological and psychological responses of young males during spring-time walks in urban parks. *Journal of Physiological Anthropology*, *33*(1), 8. https://doi.org/10.1186/1880-6805-33-8

Sonntag-Öström, E., Nordin, M., Lundell, Y., Dolling, A., Wiklund, U., Karlsson, M., Carlberg, B., & Slunga Järvholm, L. (2014). Restorative effects of visits to urban and forest environments in patients with exhaustion disorder. *Urban Forestry & Urban Greening*, *13*(2), 344–354. https://doi.org/10.1016/j.ufug.2013.12.007

Souchet, A. D., Lourdeaux, D., Pagani, A., & Rebenitsch, L. (2023). A narrative review of immersive virtual reality's ergonomics and risks at the workplace: Cybersickness, visual fatigue, muscular fatigue, acute stress, and mental overload. *Virtual Reality*, *27*(1), 19–50. https://doi.org/10.1007/s10055-022-00672-0

Stigsdotter, U. K., Corazon, S. S., Sidenius, U., Kristiansen, J., & Grahn, P. (2017). It is not all bad for the grey city – A crossover study on physiological and psychological restoration in a forest and an urban environment. *Health & Place*, *46*, 145–154. https://doi.org/10.1016/j.healthplace.2017.05.007

Tennessen, C. M., & Cimprich, B. (1995). Views to nature: Effects on attention. *Journal of Environmental Psychology*, *15*(1), 77–85. https://doi.org/10.1016/0272-4944(95)90016-0

Teo, W.-P., Muthalib, M., Yamin, S., Hendy, A. M., Bramstedt, K., Kotsopoulos, E., Perrey, S., & Ayaz, H. (2016). Does a Combination of Virtual Reality, Neuromodulation and Neuroimaging Provide a Comprehensive Platform for Neurorehabilitation? – A Narrative Review of the Literature. *Frontiers in Human Neuroscience*, *10*, 284. https://doi.org/10.3389/fnhum.2016.00284

TreeBaltimore. (2007). *Baltimore's Tree Planting Partnership*. Retrieved March 21, 2023, from https://www.treebaltimore.org/

Triguero-Mas, M., Gidlow, C. J., Martínez, D., de Bont, J., Carrasco-Turigas, G., Martínez-Íñiguez, T., Hurst, G., Masterson, D., Donaire-Gonzalez, D., Seto, E., Jones, M. V., & Nieuwenhuijsen, M. J. (2017). The effect of randomised exposure to different types of natural outdoor environments compared to exposure to an urban environment on people with indications of psychological distress in Catalonia. *PloS One*, *12*(3), e0172200. https://doi.org/10.1371/journal.pone.0172200

Tsunetsugu, Y., Lee, J., Park, B.-J., Tyrväinen, L., Kagawa, T., & Miyazaki, Y. (2013). Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements. *Landscape and Urban Planning*, *113*, 90–93. https://doi.org/10.1016/j.landurbplan.2013.01.014

Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology*, *38*, 1–9. https://doi.org/10.1016/j.jenvp.2013.12.005

Ulrich, R. S. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the Natural Environment* (pp. 85–125). Springer US. https://doi.org/10.1007/978-1-4613-3539-9_4

Ulrich, R. S. (1991). Natural Versus Urban Scenes: Some Psychophysiological Effects. *Environment and Behavior*, *13*(5), 523–556. https://doi.org/10.1177/0013916581135001

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

United States Department of Agriculture National Resource Conservation Service. (n.d.). *Web Soil Survey*. Retrieved March 21, 2023, from https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

U.S. Census Bureau. (2019). *South Clifton Park*. Retrieved March 21, 2023, from https://planning.baltimorecity.gov/sites/default/files/SOUTHCLIFTONPARK.PDF

Vachha, B. A., Massoud, T. F., & Huang, S. Y. (2022). Anatomy of the Cerebral Cortex, Lobes, and Cerebellum. *Neuroimaging Clinics of North America*, *32*(3), 463–473. https://doi.org/10.1016/j.nic.2022.04.008

Valtchanov, D., Barton, K. R., & Ellard, C. (2010). Restorative effects of virtual nature settings. *Cyberpsychology, Behavior and Social Networking*, *13*(5), 503–512. https://doi.org/10.1089/cyber.2009.0308

Wang, J., Korczykowski, M., Rao, H., Fan, Y., Pluta, J., Gur, R. C., McEwen, B. S., & Detre, J. A. (2007). Gender difference in neural response to psychological stress. *Social Cognitive and Affective Neuroscience*, *2*(3), 227–239. https://doi.org/10.1093/scan/nsm018

Wang, X., Rodiek, S., Wu, C., Chen, Y., & Li, Y. (2016). Stress recovery and restorative effects of viewing different urban park scenes in Shanghai, China. *Urban Forestry & Urban Greening*, *15*, 112–122. https://doi.org/10.1016/j.ufug.2015.12.003

Wang, Y., Jiang, M., Huang, Y., Sheng, Z., Huang, X., Lin, W., Chen, Q., Li, X., Luo, Z., & Lv, B. (2020a). Physiological and Psychological Effects of Watching Videos of Different Durations Showing Urban Bamboo Forests with Varied Structures. *International Journal of Environmental Research and Public Health*, *17*(10), 3434. https://doi.org/10.3390/ijerph17103434

Wang, T.-C., Sit, C. H.-P., Tang, T.-W., & Tsai, C.-L. (2020b). Psychological and Physiological Responses in Patients with Generalized Anxiety Disorder: The Use of Acute Exercise and Virtual Reality Environment. *International Journal of Environmental Research and Public Health*, *17*(13), 4855. https://doi.org/10.3390/ijerph17134855

Welch, P. (1967). The use of fast Fourier transform for the estimation of power spectra: A method based on time averaging over short, modified periodograms. *IEEE Transactions on Audio and Electroacoustics, 15*(2), 70-73. https://doi.org/10.1109/tau.1967.1161901

Wilkie, S., & Clouston, L. (2015). Environment preference and environment type congruence: Effects on perceived restoration potential and restoration outcomes. *Urban Forestry & Urban Greening*, *14*(2), 368–376. https://doi.org/10.1016/j.ufug.2015.03.002

Wilson, E. O. (1984). *Biophilia*. Harvard University Press. https://doi.org/10.2307/j.ctvk12s6h

Wohlgenannt, I., Simons, A., & Stieglitz, S. (2020). Virtual Reality. *Business & Information Systems Engineering*, *62*(5), 455–461. https://doi.org/10.1007/s12599-020-00658-9

Yi, J., Kim, S. G., Khil, T., Shin, M., You, J.-H., Jeon, S., Park, G. H., Jeong, A. Y., Lim, Y., Kim, K., Kim, J., Kang, B., Lee, J., Park, J. H., Ku, B., Choi, J., Cha, W., Lee, H.-J., Shin, C., Kim, J. U. (2021). Psycho-Electrophysiological Benefits of Forest Therapies Focused on Qigong and Walking with Elderly Individuals. *International Journal of Environmental Research and Public Health*, *18*(6), 3004. https://doi.org/10.3390/ijerph18063004

Yu, C.-P., Lee, H.-Y., & Luo, X.-Y. (2018). The effect of virtual reality forest and urban environments on physiological and psychological responses. *Urban Forestry & Urban Greening*, *35*, 106–114. https://doi.org/10.1016/j.ufug.2018.08.013

Zhu, H., Yang, F., Bao, Z., & Nan, X. (2021). A study on the impact of Visible Green Index and vegetation structures on brain wave change in residential landscape. *Urban Forestry & Urban Greening*, *64*, 127299. https://doi.org/10.1016/j.ufug.2021.127299