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INVESTIGATING HOW MINDFULNESS PROMOTES THE RESTORATIVE EFFECTS OF
NATURE EXPOSURE IN VIRTUAL REALITY

BY

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THESIS

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ABSTRACT

Over the last century, the number of people living in urban areas has been increasing and the general health and happiness of the public has been decreasing (Emfield & Neider, 2014). As more people move into urban environments, the negative consequences of reduced connection with nature are becoming more apparent. One promising way to reverse this trend is by reconnecting humans with the natural world. Natural environments have been shown to exert beneficial influences on mental health; however, to effectively develop therapeutic interventions, there is a strong need to understand the mechanisms of action by which natural environments support positive mental health outcomes. This thesis investigated potential mechanisms of action for therapeutic nature exposure as well as the preliminary efficacy of nature exposure therapy in virtual reality. Research subjects completed a survey measure assessing previous visits to nature and self-reported mental health symptoms. They subsequently completed an in situ experimental session in which they received one of three treatments (real nature, virtual nature or no nature) and then completed a laboratory stress task. Levels of mindfulness during the stressor and changes in self-reported levels of state positive and negative affect before and after the stressor were assessed. Results showed nature visitation indirectly correlated with psychopathology and emotional responses to nature. Additionally, mindfulness covaried with nature treatment type (real nature or virtual nature) for positive affect. These results elucidate the relationship between nature and mental health and demonstrate the potential for virtual restorative environments to be used in the treatment of mental health disorders.

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To my father,

For his wisdom, guidance, endless encouragement, and perfect attendance

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INTRODUCTION

Over the last century, the number of people living in urban areas has been increasing and the general health and happiness of the public has been decreasing (Emfield & Neider, 2014). As more people move into urban environments, the negative consequences of reduced connection with nature are becoming more apparent. The physiological responses to stress that evolved as survival mechanisms for our ancestors, who lived at the mercy of predators and other dangers in the natural world, is less frequently needed now that humans predominantly live in urban environments. Subsequently, maladaptive physiological excitation from exposure to chronic daily stressors frequently results in dysregulation of the stress response system and the development of physical illnesses including heart disease, immunologic dysfunction and inflammatory disorders, as well as psychological ailments including anxiety, depression and addiction (McEwen, 2007). Mental illness is predicted to be the primary cause of disability worldwide by the year 2020 (Murray & Lopez, 1997) with a resulting global healthcare cost expected to reach \$6 trillion USD by 2030 (Jha, Nugent, Verguet, Bloom, & Hum, 2013). Thus, the harmful effects from decreased connection with the natural world and increased morbidity of psychopathology has been declared a global health crisis. Responses to these impacts will be one of the most important health concerns of the coming decades (Bauer, Quas, & Boyce, 2002; Benatar & Poland, 2015).

Previous research indicates an effective pathway for reversing this trend is by reconnecting humans with the natural world (Annerstedt & Wahrborg, 2011; Brymer, Cuddihy, & Sharma-Brymer, 2010; Kamitsis & Simmonds, 2017; Wolsko & Hoyt, 2012). Natural environments have been shown to beneficially influence mental health; however, to develop nature-based therapeutic interventions, there is a strong need to understand how people interact

with nature and manifest positive mental health outcomes (Mantler & Logan, 2015). Indeed, research on the impacts that natural environments have on mental health has uncovered evidence of positive effects on memory, attention, mood, cognitive processing, self-esteem, life satisfaction, and overall well-being (Berto, 2014; Bratman, Hamilton, & Daily, 2012; Pearson & Craig, 2014). Though these benefits are understood in broad ways, the extent of influence, mechanisms of action and clinical implications for the impact that nature has on psychological well-being are particularly pressing gaps in current knowledge (Bratman et al., 2012; Mantler & Logan, 2015). Understanding the relationship between natural environments and psychological well-being, the mechanisms that natural environments deploy to promote adaptive responses to adversity and the ways in which we can utilize nature and technology in clinical applications will allow us to develop therapeutic applications for restorative natural environments so that all people, especially those who cannot access nature, can be resilient against stress and live healthy and fulfilling lives.

Overview and Objectives

Building on previous research that investigated the relationship between nature and mental health, I conducted a study of the relationship between previous experiences in nature and levels of psychopathological disorder symptoms, namely anhedonic depression, anxious arousal and anxious apprehension or trait characteristics which play a key role in the etiology of mental health disorders, namely positive and negative affect. Understanding these relationships is important for determining how nature impacts health and well-being in a more holistic way. Furthermore, my research elucidates an overlooked mechanism for therapeutic outcomes: mindfulness. Building on previous work examining relationships between connection to nature

and mindfulness, I examined whether mindfulness was implicated in the relationship between natural environments and the measurable psychophysiological benefits that resulted from exposure to them.

My thesis was guided by three objectives:

1.) Examine whether people's past visitation to natural areas is tied to their mental health.

H1: I hypothesize that past visitation to natural areas will be correlated with positive affect and inversely correlated with anxious arousal, anxious apprehension, anhedonic depression, negative affect, and disgust.

2.) Examine how visitation to natural areas affects people's mindfulness levels and ability to cope with stressful experiences.

H2: I hypothesize that subjects with more frequent past nature visitation or subjects that were exposed to either outdoor nature or virtual nature treatments will experience higher levels of state mindfulness during a stress task as compared to the control group.

3.) Examine how recent visitation to natural areas affects people's mood and ability to cope with stressful experiences.

H3: I hypothesize that exposure to an outdoor nature environment or a virtual nature environment will predict a smaller change in affect as a result of a laboratory stress task as compared with the control group, indicating a stress-buffering effect from exposure to a natural environment.

This thesis investigated the relationships between natural environments and key components of mental health, mechanisms by which nature influences mental health and

applications for virtual reality to improve mental health with nature. The background section defines the constructs of affect, mood and emotion from a neuropsychological perspective. Depression and anxiety, mindfulness and the research on relationships with natural environments are explored. The use of virtual reality and virtual restorative environments in scientific research are summarized. Next, a methods section describes an innovative experimental design for testing a direct comparison of the effects from a virtual natural environment with in situ exposure to the same real natural environment from which it was created on psychophysiological responses to stress. The results section summarizes empirical data from a pilot test using this novel design and explores correlations between the psychological constructs distinguished in the literature review and previous exposure to natural environments, as well as whether a field site exposure to either real nature or virtual nature predicted changes in affect or levels of state mindfulness. The discussion and conclusion sections explore results from a pilot study and identify strengths and weaknesses in this research. Finally, implications for future research are presented.

BACKGROUND

Theoretical Foundations

Biophilia

There are several theories regarding human connections with nature and how this relationship can lead to positive mental and physical health outcomes. One of the first, the Prospect-Refuge Theory posed by Appleton in 1975, hypothesized that humans evolved in natural settings that provide protection (refuge) and the ability to see approaching predators (prospect). Balling and Falk (1982) posited that success evolving and thriving in these places created an innate human desire to seek out similar environments, which was titled the Biophilia Hypothesis by E.O. Wilson in 1984. Kaplan & Kaplan (1989) subsequently theorized that certain aspects of nature have the ability to restore focus and concentration, known as the Attention Restoration Theory (ART). Extending this line of research, Ulrich (1993) postulated that people experience an unconscious physiological response that facilitates recovery from unpleasant stimuli in these settings, which he called the Stress Reduction Theory (SRT). Together, these theories have become key components to scientific understanding of the restorative mental and physical health benefits from interaction with natural environments (Markevych et al., 2017).

Restoration

Theoretical support for research on the health benefits of nature comes from the integrative framework on restoration proposed by Kaplan (1995), which bridged the gap between the SRT and the ART. Kaplan described two distinct attentional resources, directed attention and involuntary attention. He described directed attention as purposeful mental focus on an activity that requires exerted suppression of distractors through inhibition. Involuntary attention, on the

other hand, was defined as the alternative state of attending that does not require effort and therefore cannot be exhausted. Kaplan argued that stress experienced by an organism could be the result of pressure due to insufficient attentional resources to meet performance demands, resulting in fatigue and failure. He went on to describe how effectiveness could be regained through restorative experiences that assisted in the recovery of directed attention capacities. Restorative experiences rebuild attentional capacities by eliciting involuntary attention (which he calls fascination) through their inherent qualities of providing escape from the mundane (being away), creating the sensation of novelty (extent) and allowing for purposes and inclinations to be fulfilled in a comfortable manner (compatibility). Kaplan concluded that natural environments were restorative because they provided the sensations of fascination, being away, extent and compatibility. Empirical research has provided support for this theory (for review, see: Ohly et al., 2016). For example, natural environments improve measures of directed attention (Sahlin et al., 2016) and fascinating natural environments can assist in the recovery from attentional fatigue (Joye, Pals, Steg, & Evans, 2013). However, other studies have discovered that certain environments can have the opposite effect, with areas that limit the ability to see the horizon or provide few places to hide (aspects that would have threatened survival) increasing stress and adding to attentional fatigue (Gatersleben & Andrews, 2013).

Biophobia

In juxtaposition to biophilia and restoration are the diametric yet complimentary theories of biophobia and evolutionary psychopathology, respectively. Humans evolved an innate appreciation for items in the natural world that supported their survival, but they also evolved an innate fear of dangers in the natural world that threatened it (Ulrich, 1993). Being able to respond

quickly to the threat posed by predators would have conferred an advantage to early humans at the mercy of dangers in the natural world such as spiders and snakes (Öhman, 1986). As human beings have lived in hunter-gatherer tribes for nearly 99% of our evolutionary history, and only very recently come to spend a majority of our lives inside man-made structures, it would not be surprising to find that this biological predisposition would persist until the present day (Gullone, 2000). Unsurprisingly, a study involving identical twins supported the notion of genetic predisposition to specific phobias and found that fear of threats related to the natural world (animals and blood-injury-injection) demonstrated the highest levels of heritability of those investigated (Van Houtem et al., 2013). Moreover, Öhman and colleagues conducted classical conditioning experiments on learned and unlearned fear responses to items that might have posed a threat to evolutionary survival (Esteves, Parra, Dimberg, & Öhman, 1994; Öhman & Soares, 1998) and found that physiological responses to survival-relevant (spiders, snakes, angry faces) stimuli persisted longer after conditioning than responses to survival-irrelevant stimuli (flowers, mushrooms, happy faces), further supporting the hypothesis that evolutionary fears resist extinction (for further discussion, see: McNally, 2016). In addition to fear, previous research has indicated that disgust also plays an important role in our biophobic relationship with nature, hypothesized to have evolved as a protective mechanism stimulating the avoidance of contaminants and vectors for disease (Olatunji, Cisler, McKay, & Phillips, 2010).

Evolutionary Psychopathology

Having the proclivity to respond quickly to dangers in the natural world would have served a beneficial purpose for *Homo sapiens* (Öhman & Mineka, 2001). It is easy to imagine how a few extra seconds to escape could mean the difference between life and death when facing

down a hungry predator. Heightened awareness of distractors present in the environment and the immediate activation of physiological mechanisms, like the fight-or-flight response, would have assisted in survival (Gilbert, 1998). Similarly, in the context of the bands of hunter-gatherers that relied on each other to hunt, reproduce and subsist in the harsh realities of the natural world, certain social traits and behaviors would have ensured survival by maintaining the social bonds required to remain a member of the group (Gilbert, 1993). Now that the realities of everyday life for human beings are quite different, certain genetically selected traits have become maladaptive (Baron-Cohen, 1997). Arguments for depression (Nesse, 2000) and anxiety (Marks & Nesse, 1994) as the modern day maladaptive manifestations of evolutionarily adaptive traits provide a context for understanding why psychopathological disorders are globally ubiquitous and prevalent (Gullone, 2000). Disgust has also been implicated in evolutionary psychopathology for its role in the etiology of anxiety disorders (Olatunji et al., 2010).

Nature and Mental Health

The theories on the benefits of nature have received significant empirical support. Contact with natural environments can provide a wide array of health and wellness benefits, including relieved stress, reduced pain, shortened hospital stays, enhanced mood, increased mental alertness, enhanced cognitive performance, improved immune function, lowered blood pressure, decreased anxiety and reduced depression (for review, see: Haluza, Schönbauer, & Cervinka, 2014). Though the mechanisms by which nature can improve general health and wellness are understood in terms of the impact of individual elements (i.e., organic compounds released by plants reduce blood pressure and alter autonomic activity), the pathways through which this occurs are still being explored (Hartig, Mitchell, de Vries, & Frumkin, 2014).

Markevych and colleagues (2017) theorized that potential pathways linking nature and health function through three domains: first in reducing exposure to stressors and toxins, second through mental and physical restoration and third by promoting beneficial capacities such as exercise and social bonding. Additionally, the enhancement of immune function has strong evidence to support its role as a central pathway through which nature promotes human health (Kuo, 2015). Immune function may also play an important role in how nature effects mental health, given that physically ill patients and physically healthy but depressed patients exhibit the same features of inflammation including elevated levels of proinflammatory cytokines (Dowlati et al., 2010; Miller, Maletic, & Raison, 2009).

Of the health benefits that nature provides, its effects on mental health are particularly noteworthy (Triguero-Mas et al., 2017). Positive emotional well-being is critical to maintaining general health across the lifespan and has been shown to be an important factor in overcoming illness and trauma (Q. Huynh, Craig, Janssen, & Pickett, 2013). Nature can reduce mental fatigue, lower physiological arousal and decrease stress by improving mood, self-esteem and positive affect (Berto, 2014). For example, previous research has linked emotional well-being and proximity to greenspace in Canadian youth living in small cities (Q. Huynh et al., 2013), and better mental health and vitality with time spent visiting greenspace near the home for people in four cities in Europe (van den Berg et al., 2016). In large sample studies from the United Kingdom, visits to natural environments elicited feelings of restoration (White, Pahl, Ashbullby, Herbert, & Depledge, 2013) and greater frequency and duration of time spent in nature close to home was associated with lower levels of depression and better social health (Cox et al., 2017). Greater amounts and closer distances to greenspace were also linked to decreased levels of anxiety and mood disorder treatments in New Zealand (Nutsford, Pearson, & Kingham, 2013)

and walks in nature decreased anxiety in the United States (Bratman, Hamilton, Hahn, Daily, & Gross, 2015). Thus, the mental health benefits of natural environments are numerous and transcend culture or geographic location. However, there is much that we still do not know about the mechanisms through which natural environments exert their influence. Given the trend of increasing morbidity of psychopathology and decreasing connection with the natural world, it is important that a deeper investigation into how the specific constructs underlying mood and mental health relate to natural environments so that we can better utilize nature in supporting well-being.

Affect and Emotions

The first step in understanding the relationship between mental health and nature must be to establish clear definitions for the constructs specific to mental health. Delineating and quantifying human emotion is a difficult task; individual experiences and perceptions vary greatly, in that an individual's interpretation of their own emotions is guided by intuition, and even a simple definition for the term emotion may not be easily agreed upon (Russell, 2003). However, researchers in the field of psychology have reached some consensus on the structure of mood, which should be clearly defined and understood from an empirical standpoint to avoid confusion with layman's terms (Barrett & Russell, 1999). Therefore, this thesis defines "mood" – hereafter referred to as affect – and makes a distinction between affect and emotions.

Core Affect

The circumplex model of affect posits that core affect, or the neurophysiological state that underlies a feeling, is the linear combination of two distinct systems with bipolar

dimensions, pleasantness (valence) and activation (arousal). Thus, each individual affective state lies at the nexus between its relative location on the scale from pleasant to unpleasant as well as the scale from activation to deactivation (see Figure 1), a reflection of neurophysiological changes in the valence and arousal systems, respectively, arising in the nervous system and subcortical brain areas (Russell, 2009). Core affect is “primitive, universal, and simple (irreducible on the mental plane). It can exist without being labeled, interpreted, or attributed to any cause. As an analogy, consider felt body temperature. You can note it whenever you want. Extremes can become very salient. Felt temperature exists prior to such words as hot or cold, prior to the concept of temperature, either in folk or scientific theory, and prior to any attribution about what is making you hot or cold” (Russell, 2003, p. 148).

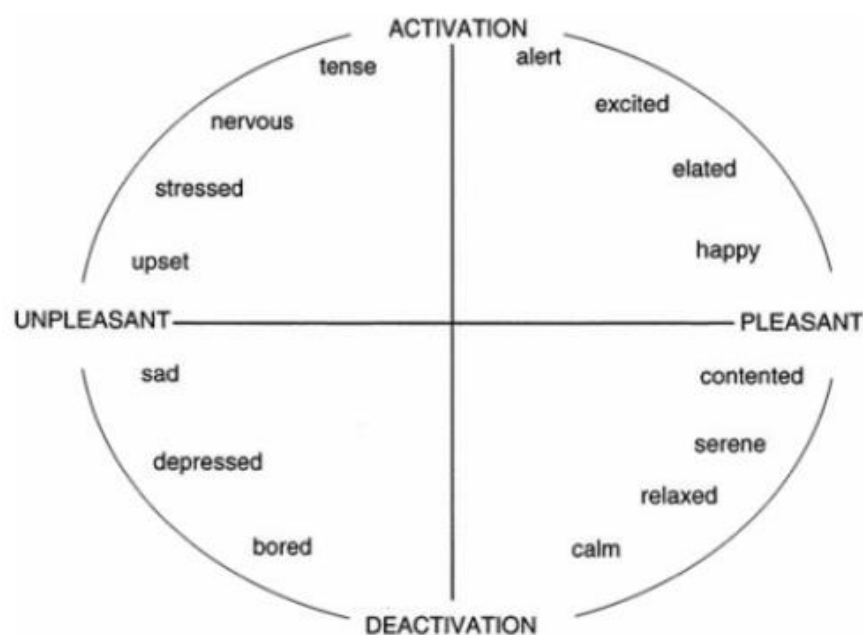


Figure 1 – The Circumplex Model of Affect. Reprinted from “The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology,” by J. Posner, 2005, *Development and Psychopathology*, 17(3), p. 716. Copyright 2005 by the Cambridge University Press.

Cognizance of one's current affective state may fluctuate during periods of change or when higher levels of intensity are reached, though a person experiences core affect at all times, whether or not it is being perceived. Thus, affect more generally can be sampled over varying time courses and assessed in two different ways: as a state quality (what is my current affect right now?) as well as a trait quality (what affect do I generally experience over longer periods of time?) through self-reported measures (Russell, 2009).

State affect and dispositional levels of positive affect or negative affect have a strong impact on our perception of the world as we experience it, influencing how well we are able to adapt to change and cope with situational challenges (Caprara, Eisenberg, & Alessandri, 2017). Though it generally exists below the level of conscious awareness, operating as a backdrop to our daily lives, affect impacts perception through mood congruency, when information similar in emotional valence is more readily accessible to cognitive processing than information which is incongruent (Okon-Singer, Hendler, Pessoa, & Shackman, 2015). Our thoughts and judgements are thus influenced by the affective state in which they are conceived (Russell, 2003).

Positive affect is associated with favorable traits such as self-esteem, extraversion and optimism and has been consistently associated with better health outcomes such as faster recovery from stress and illness and increased longevity (Pressman & Cohen, 2005). Positive affect is theorized to facilitate cognitive functioning and social relationships through the broaden-and-build theory of positive emotions, which posits that positive emotions increase access to physical and intellectual resources, including cognition and attention, that in turn allow us to be creative in achieving our goals (Fredrickson, 2004). Thus, positive affect directly supports good mental health by assisting adaptive coping and reducing maladaptive coping, thereby increasing resilience (Gloria & Steinhardt, 2016). Compared with negative affect, less is

understood regarding the neural mechanisms through which positive affect influences cognition (Chiew & Braver, 2011). However, positive affect has been theorized to function through its association with dopamine (Ashby, Isen, & Turken, 1999). Dopamine is an important neurotransmitter in the central and peripheral nervous systems that plays a key role in motivation, motor function, reward processing and the experience of pleasure and euphoria (J. S. Meyer & Quenzer, 2013). Ashby and colleagues postulated that increased levels of dopamine released during positive affective states augment beneficial cognitive functioning in the anterior cingulate cortex and prefrontal cortex (see Figure 2) facilitating greater creativity and cognitive flexibility in problem solving (Chiew & Braver, 2011).

Negative affect, on the other hand, demonstrates the opposite effects on physical and mental health and has been implicated in increased risk for cardiovascular disease, obesity, addiction, violent behavior and substance abuse (Davidson, Putnam, & Larson, 2000; Mayne, 1999). One of the maladaptive outcomes associated with higher levels of trait negative affect is a difficulty in coping with stressful life experiences, which exacerbates the unpleasantness of experiencing chronic negative affect and increases the risk for developing psychopathology in the form of anxiety and depression (Hofmann, Sawyer, Fang, & Asnaani, 2012). Brain imaging studies (see Figure 2) have found that individuals high in trait negative affect have difficulty ignoring emotionally-valenced stimuli, as evidenced by hypoactivity in specific regions of the dorsolateral prefrontal cortex and anterior cingulate cortex (Crocker et al., 2012), and that state negative affect is associated with increased activation in the orbital prefrontal cortex, indicating preferential attendance for emotion processing at the expense of task performance (Hur et al., 2014). Behaviorally, the tendency to over-attend to emotions or be excessively distracted by them would deplete cognitive and attentional resources and reduce resilience (Rutter, 2013).

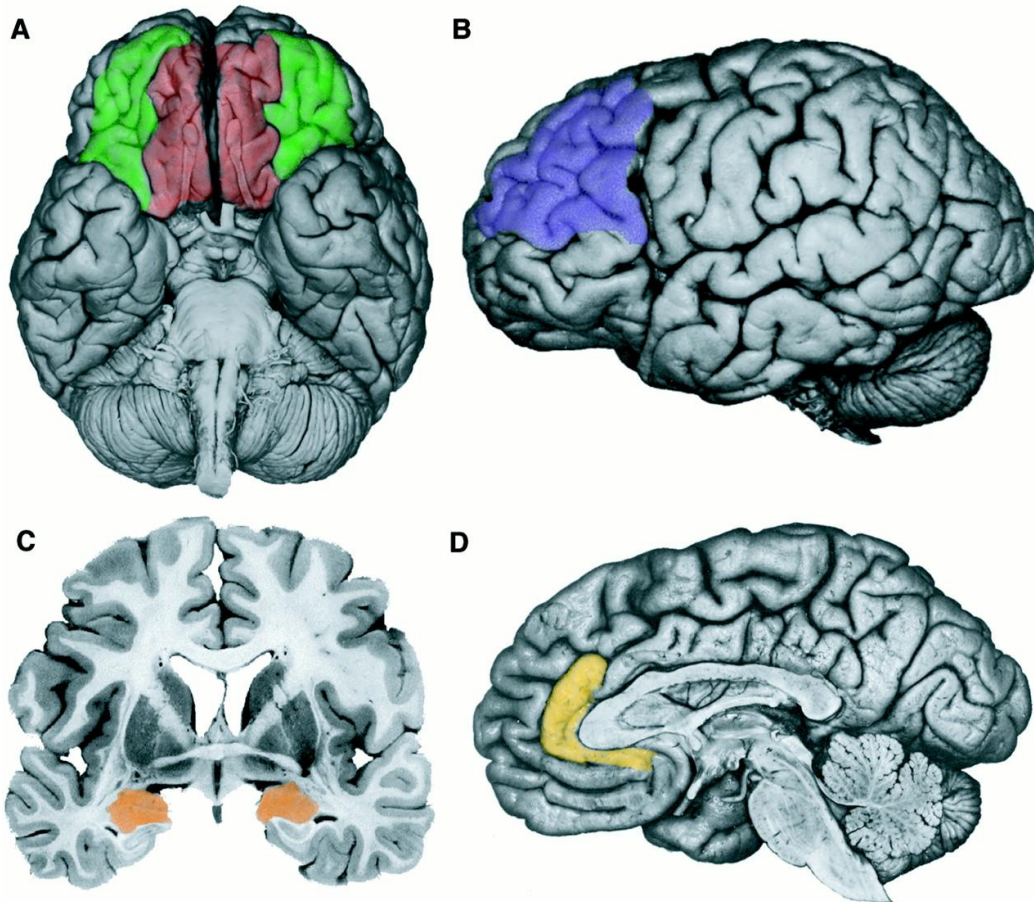


Figure 2 – Emotion regulation processing areas of the brain. Frontal lobe structures include the prefrontal cortex, which can be subdivided into the [A] orbital prefrontal cortex (in green), ventromedial prefrontal cortex (in red) and the [B] dorsolateral prefrontal cortex (in purple). The temporal lobe houses the [C] amygdala (in orange) and the limbic lobe contains the [D] anterior cingulate cortex (in yellow). Reprinted from “Dysfunction in the neural circuitry of emotion regulation – A possible prelude to violence,” by R. Davidson, 2000, *Science*, 289(5479), p. 592. Copyright 2000 by the American Association for the Advancement of Science. Reprinted with permission.

Emotion

Whereas affect is the outcome of primitive pre-cognitive processes involved in the production of a feeling, emotion is the higher-level human cognitive perception of that feeling (Posner, Russell, & Peterson, 2005). Said another way, affect is simply a neurophysiological state and emotions are cognitive appraisals of the neural sensations arising from affective states

combined with information from neocortical brain structures in the form of memories, prior experiences and cultural conceptualizations of emotions (Barrett, 2009). Broadly, emotion (as well as motivation, which interacts with emotion in important ways) can be broken down into two basic orientations: approach and avoidance/withdrawal (Roth & Cohen, 1986). Approach, or the movement towards biological needs desires and goals, is associated with positive affect (Chiew & Braver, 2011). Avoidance or withdrawal, the movement away from unpleasant or aversive stimuli, is associated with negative affect, fear and disgust (Öhman & Mineka, 2001). Furthermore, the construct of emotion can be subdivided into three distinct neurobiological processes: the perception of emotion, the production of emotion, and the regulation of emotion (Phillips, Drevets, Rauch, & Lane, 2003). Okon-Singer and colleagues (2015) provide a helpful review of these concepts and illuminate distinctions that are important to understanding the neurological and psychophysiological nuances of human emotion.

Research studies utilizing functional magnetic resonance imaging have identified brain regions that encode and produce emotional responses, processes and behaviors (for review, see: Davidson & Irwin, 1999; Okon-Singer et al., 2015). Figure 2 highlights some neural structures crucial to emotion regulation in particular. The orbital prefrontal cortex (or orbitofrontal cortex), dorsolateral prefrontal cortex and ventromedial prefrontal cortex play important roles in producing and regulating emotions and have been shown to mediate autonomic responses to affective states and emotional behavior (Phillips et al., 2003; Zilverstand, Parvaz, & Goldstein, 2017). The amygdala has been implicated in perceiving and encoding affective stimuli (especially for negative emotions), and is particularly important in detecting threatening stimuli in the environment and producing fear and disgust in response (Ochsner, Silvers, & Buhle, 2012). The anterior cingulate cortex is of particular importance in attentional processing,

especially when attending to emotional information or avoiding emotional distractors (Crocker et al., 2012; Davidson & Irwin, 1999). All of these areas are involved in reappraisal, a cognitive process in which a person reinterprets an stimulus to distance themselves from their response to it, thereby reducing their experienced emotional reactivity (Ochsner & Gross, 2005; Zilverstand et al., 2017). Reappraisal is of particular importance to salutary mental health as it is known that the brain can regulate emotion automatically without conscious effort or voluntarily with conscious effort (Gyurak, Gross, & Etkin, 2011) and that individuals with mental health disorders experience abnormalities in the neural processing of both automatic and voluntary emotion regulation (Rive et al., 2013). In particular, depression and anxiety have been shown to be a high risk factor resulting from the reduced ability to regulate emotional responses (Joormann & Stanton, 2016; Sharp, Miller, & Heller, 2015; Zilverstand et al., 2017).

Depression and Anxiety

Though they share some common symptoms and arise from the same vulnerability factors, anhedonic depression, anxious arousal and anxious apprehension are three distinct, but frequently co-occurring, clinical conditions that manifest in distinct brain areas (Engels et al., 2007, 2010; Siltan et al., 2011). Anhedonic depression is characterized by as a loss of interest in things that used to be found pleasurable (anhedonia) and low positive affect. Anxious apprehension is characterized by general worry and rumination and anxious arousal is characterized by physiological manifestations typically associated with panic attacks such as racing heartbeat and difficulty breathing (Nitschke, Heller, Imig, McDonald, & Miller, 2001). Brain imaging studies have demonstrated that the two types of anxiety differ not only in experienced manifestations, but furthermore that they can be distinguished by differential

patterns of neuronal activation (Engels et al., 2007). Anxious apprehension, characterized by excessive worry or rumination and frequent negative self-talk, is associated with greater activation in the inferior frontal gyrus of the left hemisphere, a region known as Broca's area which is involved in speech production and language processing, in response to negative emotional stimuli (Silton et al., 2011). Anxious arousal, on the other hand, is associated with greater activation in the inferior temporal gyrus of the right hemisphere, an area involved in threat detection, object identification and physiological arousal of the sympathetic nervous system threat response (Engels et al., 2007). Furthermore, anxious apprehension, but not anxious arousal, has been shown to be associated with increased activation of the dorsolateral anterior cingulate cortex responses during emotion word task performance, indicating an increased cognitive control recruitment from a brain area involved in adaptive conflict resolution (Silton et al., 2011) for one type of anxiety but not the other.

Research has shown that depression and anxiety are associated with cognitive disparities in affective and attentional processing. Anhedonic depression is associated with impairments in emotional processing and attention control (Levin, Heller, Mohanty, Herrington, & Miller, 2007), and patterns of altered activity and time course in the network of brain regions associated with attention have been found for depression and anxiety (Sass et al., 2010; Silton et al., 2011). Deficits in executive function related to inhibition and working memory predict increases in depressive symptoms (Letkiewicz et al., 2014). The convergence of these and other findings regarding neural activation abnormalities in psychopathology paint a grim picture in which everyday life functions are negatively affected by changes in brain activity that reduce capacities to adaptively cope with stressors (Hofmann et al., 2012). As these disorders have been hypothesized to be the modern day fallout from the persistence of evolutionarily advantageous

adaptations, the idea that natural environments can be utilized for restoration of the depleted cognitive resources (not coincidentally in the areas of affect and attention) associated with the transition to urban lifestyles is a logical conclusion (Gilbert, 1998).

It is therefore unsurprising to find empirical evidence of the direct therapeutic impacts that natural environments exert on depression. For example, Berman and colleagues (2012) conducted a study investigating the impacts of a nature walk on the cognition and affect of 19 subjects (mean age 26) that met the criteria for moderate to severe clinical depression. A majority of the subjects also had comorbid diagnoses, though the authors did not indicate if any were anxiety-related disorders. Subjects completed pre-treatment and post-treatment assessments of positive and negative affect. They also completed pre-treatment and post-treatment assessments of short-term (also called working) memory. The treatment involved a 50 minute walk through an arboretum or a walk for the same amount of time through downtown Ann Arbor. Given concerns regarding the potential for increased rumination (anxious apprehension) on these solitary walks, which has been shown to increase and prolong depressive episodes (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008), experimenters primed subjects to ruminate by having them recall and analyze their feelings regarding an intense and unresolved negative experience in their life right before they went on the walk. The researchers wanted to know if nature walks could improve cognitive deficits (working memory) and poor mood (affect) for these depressed individuals and indeed they found a significantly greater improvement in positive affect after the walk through the natural environment compared with the urban environment. Negative affect decreased after the walks through both environments, but there was no significant difference due to the type of environment. Furthermore, there was an extremely strong effect on improvements in working memory after the nature walk as compared with the

urban walk. Finally, there was no significant difference between the two environments in reported levels of thoughts regarding the negative autobiographical memory during the walk, indicating that the nature walk did not increase anxiety-related ruminations. These results demonstrate significant support for natural environment exposure as a treatment for clinical depression.

Natural environments also exert direct therapeutic impacts on anxiety. Bratman and colleagues (2015) investigated the impact of a nature walk on levels of anxiety and found decreased activity in areas of the prefrontal cortex implicated in withdrawal behavior linked to anxiety and depression, as well as reduced levels of rumination in subjects that walked through natural, but not urban, environments (Bratman et al., 2015). In a different study, Martyn and Brymer (2014) queried 305 Australian university students on their relationship with nature and levels of state and trait anxiety. Qualitatively, participants reported experiencing restoration, relaxation and feelings of peace and calm from nature. Quantitatively, connection to nature was associated with lower levels of cognitive state and trait anxiety. In sum, the evidence of the therapeutic impact of nature on depression and anxiety is clear. However, the mechanism by which these therapeutic impacts occur is still uncertain (Mantler & Logan, 2015). In order to best utilize natural environments to improve mental health through restoration of depleted cognitive processes, further investigation on these potential mechanisms must be conducted. One potential mechanism that has been overlooked in the literature regards the construct of mindfulness.

Mindfulness

Positive mental health states are constructed not only from the presence of beneficial attributes and a lack of diagnoses, but also importantly are built upon an individual's ability to

cope with stress and overcome challenges and difficulties in a robust way (Hofmann et al., 2012). Responding to stress through salutary mechanisms (e.g., adaptive coping) builds resilience, thereby preventing the dysregulation fundamental in the etiology of psychopathology (Gloria & Steinhardt, 2016). Mindfulness is an adaptive coping mechanism that facilitates resilience in the face of unpleasant emotions and stress through metacognitive techniques that reduce emotional reactivity, has been shown to be effective in the treatment for anxiety and depression (Goyal et al., 2014).

Mindfulness can be defined as “a tendency to engage a state of consciousness characterized by awareness and non-judgmental acceptance of present-moment experiences. This conscious attentive process uses meta-cognitions to consider one’s thoughts, sensations, and emotions in an accepting, non-judgmental, and non-reactive way” (Harrington, Loffredo, & Perz, 2014, p. 15). The act of cultivating mindfulness has been central to meditation techniques used for centuries; however, research on clinical mindfulness-based therapies for improving mental health has only become widely empirically investigated over the last three decades.

A multitude of studies that have found mindfulness to have beneficial impacts on mental and physical health (Creswell & Lindsay, 2014; Gu, Strauss, Bond, & Cavanagh, 2015; Khoury, Sharma, Rush, & Fournier, 2015). Improvements in self-esteem and wellbeing, facilitation of social relationships and reduction of chronic pain and stress are a few of the many beneficial impacts that have been found (K. W. Brown, Ryan, & Creswell, 2007; Hofmann, Sawyer, Witt, & Oh, 2010; van der Velden et al., 2015). It has been theorized that mindfulness improves emotion regulation through reappraisal (Garland, Farb, R. Goldin, & Fredrickson, 2015) and empirical work has demonstrated that mindfulness training reduces emotional reactivity to stress (Britton, Shahar, Szepsenwol, & Jacobs, 2012; Laurent, Laurent, Nelson, Wright, & De Araujo

Sanchez, 2015). This relationship may be reciprocal as emotional reactivity mediates the clinical effects of trait mindfulness on chronic anxiety (Ostafin, Brooks, & Laitem, 2014).

Therapeutically, mindfulness interventions have been shown to reduce rumination, anxiety, depression and trait negative affect as well as to increase trait positive affect (Hofmann et al., 2010; Kemeny et al., 2012). Brain imaging studies on mindfulness have found higher levels of trait mindfulness were associated with beneficially modulated activity in areas of the brain associated with emotion regulation (dorsolateral prefrontal cortex, anterior cingulate cortex and amygdala) when completing emotionally-valenced tasks (Doll et al., 2016; Laurent, Wright, & Finnegan, 2018; Wheeler, Arnkoff, & Glass, 2017). Opposite effects have been found for individuals with higher levels of trait negative affect, suggesting that dispositional mindfulness and mindfulness practices affect the experience and cognitive processing of emotional events, thereby facilitating resilience against stress and affect dysregulation associated with the development of psychopathology (Crocker et al., 2012; Wheeler et al., 2017).

Studies investigating relationships between natural environments and mindfulness are limited (Schutte & Malouff, 2018). Natural environments have been shown to augment reductions in blood pressure and heart rate from meditation (Sahlin et al., 2016) and levels of attention from mindfulness can enhance restoration effects from outdoor activities (Wolsko & Lindberg, 2013). Connectedness to nature, as opposed to direct contact with nature, has typically been the focus of previous examination (e.g., Barbaro & Pickett, 2016; T. N. Huynh, 2017; Stewart, 2016). For example, one study found nature connectedness was associated with higher levels of mindfulness and greater well-being (Howell, Dopko, Passmore, & Buro, 2011). One meta-analysis of the available literature found a relatively small effect size ($r = 0.25$) between greater levels of connection to nature and higher levels of mindfulness and noted there were

stronger associations for community and older adults as compared with students (Schutte & Malouff, 2018).

There are many similarities in the bodies of literature on the benefits found from mindfulness and those found from exposure to nature, most strikingly in the areas of stress buffering and attention restoration. For example, meta-analyses and reviews on the salutary effects from exposure to nature and mindfulness-based training techniques propose analogous biological pathways and mechanisms of actions (Berto, 2014; Creswell & Lindsay, 2014; Keng, Shian-Ling; Smoski, M & Robins, Keng, Smoski, & Robins, 2011; Kuo, 2015). Stephen Kaplan, who proposed the ART, has argued that research on meditation can provide valuable insights to the body of literature on attention and restoration from natural environments (Kaplan, 2001). Research has found that exposure to elements of the natural environment in the workplace has some relationship with less rumination (Beute & de Kort, 2018) and that clinically depressed subjects had improvements in affect and did not ruminate during a nature walk even when primed to do so (Berman et al., 2012), possibly indicating that nature may exert influence on mental health through the promotion of adaptive self-reflection or reduction of maladaptive rumination. Given these findings, it is interesting that there haven't been direct studies on the potential role of mindfulness as a mechanism that mediates stress reduction and attention restoration from natural environments. Mantler & Logan (2015) noted in their review on nature and mental health that mindfulness practices possess the potential to facilitate outcomes from nature-based therapies and propose that clinicians incorporate contemplative approaches in behavioral treatment regimens. In order to best serve the needs of patients, a deeper understanding of the nature–mindfulness relationship is urgently needed.

Virtual Restorative Environments

Individuals with depression and anxiety experience significant difficulties in performing everyday activities that are required to seek treatment (Hammen, 1991). Social anxiety in particular can make getting to therapy particularly difficult in the face of overwhelming discomfort from being out in public (Marks & Nesse, 1994). Fortunately, benefits from exposure to natural environments can be obtained without the need to be outdoors. The same year that Wilson wrote *Biophilia*, Roger Ulrich (1984) published a seminal study in which he found that patients with views of natural environments from their hospital windows had shorter recovery times, required less pain medication and had fewer complications after surgery. Shortly after, natural environments were shown to have positive psychological effects; people with views of trees from their homes reported significantly more feelings of relaxation and ability to focus than participants without tree views (Kaplan, 2001). Work by Friedman and colleagues discovered that these benefits can even be replicated with “virtual windows.” They installed high-definition TV’s displaying real-time video of an outside area into the windowless offices of university employees, who experienced increased levels of concentration and relaxation (Friedman, Freier, Kahn, Lin, & Sodeman, 2008). Studies of the physiological effects of natural environment views have revealed augmented stress restoration when subjects observed natural environment while doing light physical activity (Engell, 2013), that viewing videos of natural environments accelerated recovery in skin conductance and salivary cortisol levels after a social stress task for men (Jiang, Chang, & Sullivan, 2014), and that people who viewed scenes of natural environments from the road during a simulated driving task had better recovery after a mental stress test (R. Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998).

There is additional evidence that exposure to pleasant and serene natural environments in virtual reality, or virtual restorative environments (VRE's) can be used to benefit the elderly, hospital or trauma patients and even astronauts or submariners who have no possibility of accessing outdoor natural environments by counteracting the deleterious psychological and physiological effects of stress and by improving mental health and wellness (Depledge, Stone, & Bird, 2011; North & North, 2016; Stone, Small, Knight, Qian, & Shingari, 2014). Indeed, virtual environments used in medical applications have been effective in treating psychological ailments including anxiety, depression and phobia; in overcoming trauma-related illnesses such as post-traumatic stress disorder and in restoring motor control during physical rehabilitation (Ma, Jain, & Anderson, 2014). VRE's specifically have been shown to attenuate or completely relieve pain for cancer patients and people undergoing surgery or treatments for severe burns (Gold, Belmont, & Thomas, 2007; Small, Stone, Pilsbury, Bowden, & Bion, 2015).

Previously, research with VRE's was limited to room-sized environments (Annerstedt et al., 2013), large-screen high-definition televisions (Friedman et al., 2008), or three-dimensional displays (Jiang et al., 2014). Stone and colleagues (2014) noted that it would be important for virtual reality technology to be less cumbersome, more affordable and easier to use before it could be readily deployed in medical settings. Fortunately, there are now commercially available low-cost and wireless head-mounted displays (HMD's) that provide levels of realism, or immersion, not previously possible. Despite the enormous potential of this technology, it is only beginning to be utilized in scientific research and this may be the first empirical study to have used the new generation of head-mounted displays to investigate potential positive mental health impacts from exposure to virtual natural environments.

METHODS

Recruitment and Subject Criteria

The study took place over two separate sessions from April to June, 2017. The first session took place at the University of Illinois in the Virtual Reality and Nature lab on campus and required that participants complete a survey questionnaire (hereon “campus questionnaire session”). The second session included an experimental protocol conducted off-campus (hereon the “field site session”).

The campus questionnaire session was primarily designed to determine eligibility and prepare subjects for the second session, and an introduction to the study was provided in the process of determining eligibility. Subjects completed a five-page questionnaire and were asked to put on a virtual reality headset (i.e., the Samsung Gear VR first consumer edition) to screen for difficulties using the head-mounted display (HMD). A complete list of qualifications can be viewed in Table 1 and Appendix A. Subjects were made aware of the screening criteria before signing up for the study. As a result of the screening processes two subjects were excluded from the study due to psychoactive medication use and mental health history.

Table 1
Inclusion and Exclusion Criteria for Participation in the Study

Exclusion Criteria	Justification
- Included approximately equal numbers of male and female individuals between the ages of 18 and 29	- To control for age and sex-related differences in responses to stress (Umetani, Singer, McCraty, & Atkinson, 1998)
- Excluded if history of mental health disorders, if on daily psychoactive medications, if currently being treated for anxiety, ADHD, autism, social phobia or post-traumatic stress disorder or if currently experiencing high levels depressive symptoms (as measured by a score of 21 or above on the Beck Depression Inventory)	- To control for variability due to mental health or any potential negative interactions between mental health and the tasks to be completed (specifically, the stress task and the use of the virtual reality headset; Hofmann, Sawyer, Fang, & Asnaani, 2012), - as well as to preclude complications from a current depressive episode (see BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961)

Table 1, continued

Exclusion Criteria	Justification
<ul style="list-style-type: none"> - Excluded if history of high blood pressure, seizures or cardiovascular diseases 	<ul style="list-style-type: none"> - To control for variability due to physical health (Gladwell, Kuoppa, Tarvainen, & Rogerson, 2016)
<ul style="list-style-type: none"> - Excluded if any adverse reaction to previous virtual reality headset use or any symptoms during or after using the HMD in the lab 	<ul style="list-style-type: none"> - To preclude confounding results from physiological responses to VR sickness from virtual reality headset use (Bruck & Watters, 2011; Lavalle, 2016)

Location and Treatments

The second session took place at the Anita Purves Nature Center, located at Busey Woods in Urbana, Illinois (<https://www.urbanaparks.org/facilities/anita-purves-nature-center/>). The field site session included an experiment room in the basement of the nature center where the initial orientation, setup for the subjects, and administration of the stress task took place (Figure 3).

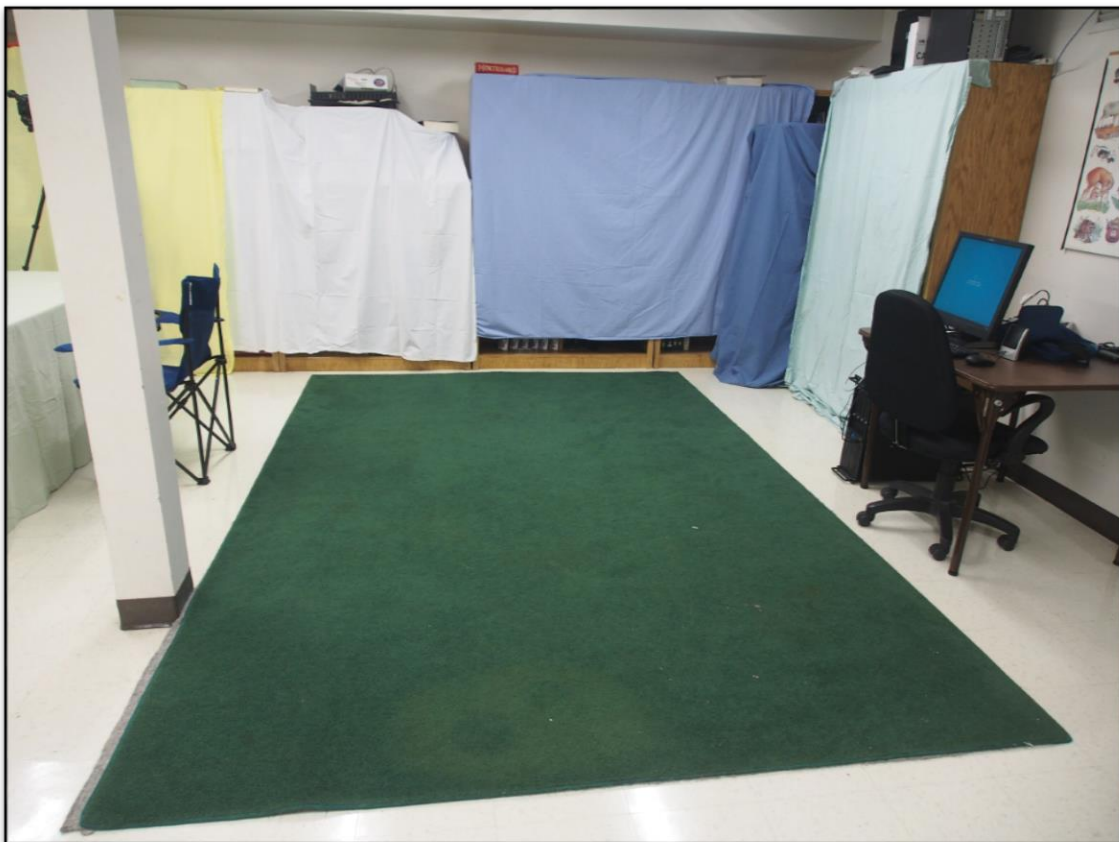


Figure 3 – Basement room in the Anita Purves Nature Center where the field session was run.

Subjects were randomly assigned to one of the three treatments: an outdoor natural environment, a virtual natural environment or the control group (no intervention). The outdoor environment was located in a clearing overlooking a river. To reach the site, outdoor treatment subjects walked down a wooded path and over a bridge to the treatment location, which was approximately three minutes walking distance from the nature center. The control treatment and virtual nature treatment groups completed their treatment sessions inside the nature center, in a corner with a view of a blank wall. A video and audio recording of the outdoor treatment location was recorded and shown to the virtual natural environment subjects for their treatment.

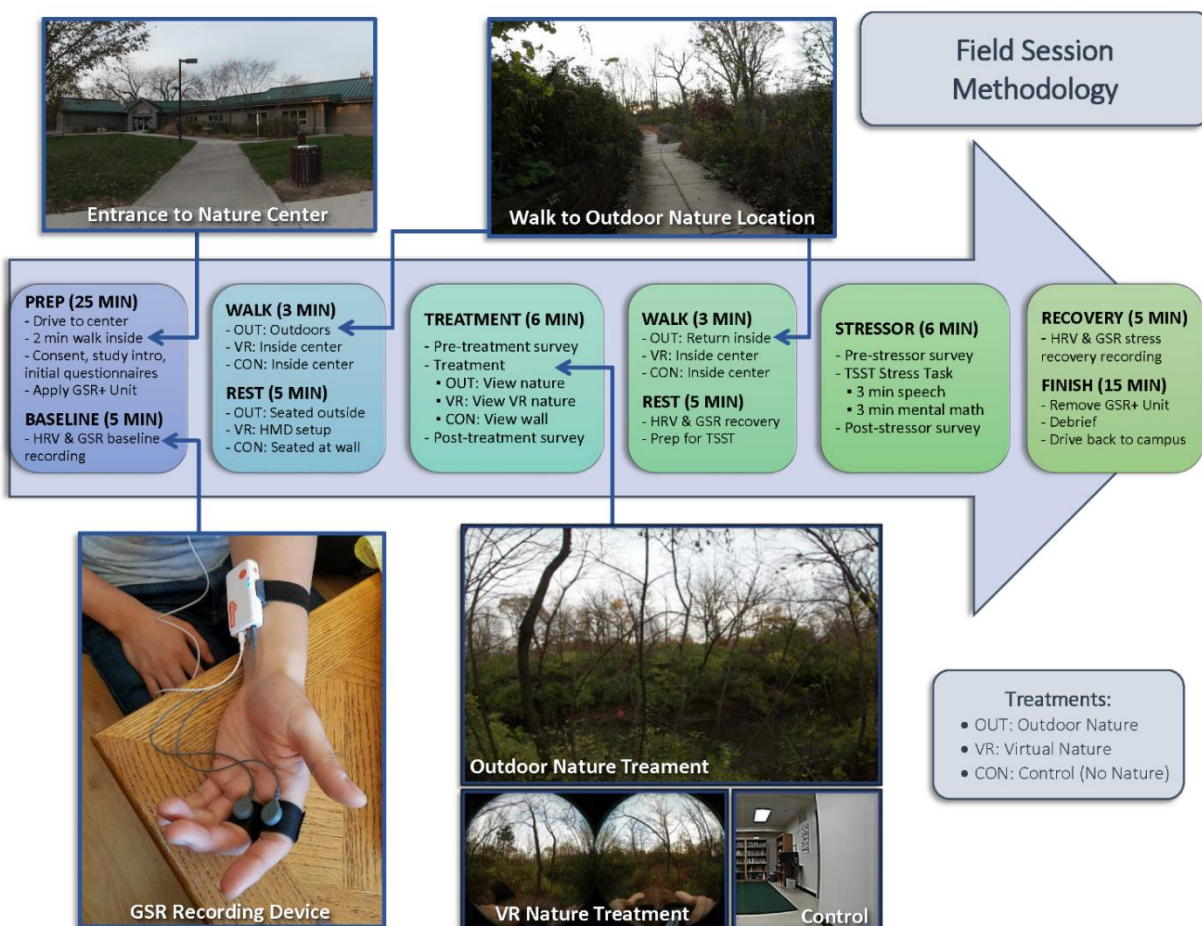


Figure 4 – Research design for the field site session

Field Site Experimental Design

If subjects met all the criteria for inclusion in the study during the first session, they were invited back to complete a second field site experimental session, which was designed to evaluate if laboratory-controlled exposure to natural environments affected responses to stress (Figure 4). For the field site session, subjects met with a research assistant on campus, were given an explanation of the procedures and asked to sign a consent form. Then they completed a screening questionnaire to make sure they had not engaged in any vigorous exercise in the past 48 hours, ingested any medications, non-prescription drugs, alcohol or tobacco in the past 24 hours, or consumed caffeine in the past six hours, as these would have affected their stress response.

Once consent was given and screening complete, they were driven approximately four miles to the Anita Purves Nature Center, which took about 12 minutes. Subjects were instructed to view the seat in front of them or the floor of the car during the ride past Busey Woods and dropped off at the front door with instructions to look only at the sidewalk in front of them while they were escorted inside to minimize any outdoor exposure that could confound the reactivity to the stressor. Once inside, subjects were provided with the opportunity to use the restroom and then led to the experiment room. They were given a short explanation of the experimental procedure, and the GSR+ unit was attached to their left wrist and fingers. Skin conductance and heart rate variability were measured continuously during the entire study. If the subject was in the virtual nature treatment, they were fitted with the headset to adjust it in preparation for the treatment and instructed on its use. Once setup was complete, the subjects either walked outside to the outdoor natural environment setting or remained in the building for the virtual treatment or control treatment setting. All

participants were asked to remain silent during the walks so as not to interfere with the relaxation.



Figure 5—Subject completing pre-treatment questionnaire at the outdoor nature treatment location

All subjects were exposed to a treatment for six minutes, which has been found in previous research to be sufficient for natural environment exposure to elicit autonomic stress buffering (Brown et al., 2013). Subjects that received the outdoor nature treatment walked through a basement door and down a path for approximately three minutes until they reached the treatment setting. The location was secluded from areas open to the public and nearby access was briefly restricted while research recordings took place (Figure 5). Once subjects reached the site, they were seated in a chair with a view of the natural environment

and administered a survey about their current mood. Once this was complete, they were instructed to sit upright but comfortably in the chair, to look straight ahead and to view the scene before them. After six minutes, subjects were administered another survey about their current mood and then led back into the nature center where they completed additional questions evaluating the restorativeness of the nature environment and their levels of mindfulness during the treatment. To replicate the physical activity required to reach the outdoor location, subjects in the two other treatments walked in circles on a green carpet inside the nature center experiment room for three minutes. Next, they were seated in a chair oriented towards a blank wall and given a questionnaire about their current mood. Once the questionnaire was complete, subjects were instructed to sit upright but comfortably in the chair, to look straight ahead and to view the scene before them. If the subject was in the virtual treatment group, they then put on the VR headset and noise-canceling headphones and viewed the nature video. Control subjects remained resting in their chair and viewed the blank wall. After six minutes, subjects removed the headset if they were wearing one and everyone completed another questionnaire about their current mood and two additional questionnaires evaluating the restorativeness of the nature environment and their levels of mindfulness during the treatment. Finally, they walked in circles for three more minutes on the green carpet indoors.

After the treatment was complete, subjects then immediately began the Trier Social Stress Test (TSST). The TSST is one of the most widely used and consistently successful methods in laboratory settings to trigger physiological responses in both the autonomic and somatic nervous systems (Kirschbaum, Pirke, & Hellhammer, 1993). Subjects were seated at a table and given a questionnaire on their current mood, which was administered via

pencil-and-paper to reduce the potential for response biases (Cook, 2010). Then, they were played an audio clip with instructions on completing the stress task and given a pen and notepad to prepare a speech explaining why they should be hired for their dream job. After three minutes of speech preparation, they were played a second instruction audio clip, their notes were taken away and an experimenter turned on the video camera. During the three-minute public speaking task, two research assistants posed as mock job interviewers that provided prompts to continue and appeared to take notes on the subject's performance (Figure 6). After three minutes, the third audio clip was played that gave instructions on completing the mental math tasks. Subjects were told to subtract the number 13 from 6,233 and to keep subtracting 13 from the remainder until three minutes had elapsed. Upon completion of the stress task, post-stressor questions on their current mood and level of mindfulness during the stressor were filled out. Finally, subjects were debriefed about the TSST and study as a whole, the GSR+ module was removed and they were driven back to campus.



Figure 6 - Subject completing the public speaking task during the TSST.

Equipment

The virtual reality nature treatment video of the on-site nature treatment environment was recorded at Busey Woods in May 2017 with a Samsung Gear 360 camera that filmed a 360-degree video in high-definition (4k resolution) using two 180-degree fish-eye lenses. The video was stitched using the Gear 360 ActionDirector Software (Samsung Electronics Co., 2017) and shown to the virtual environment treatment group in the Samsung Gear VR wireless head mounted display (HMD) using the Oculus Video app and a Samsung Galaxy S7 phone (Figure 7). The nature treatment video can be viewed online at <https://youtu.be/KRYZKRdg-RU>.



Figure 7 - Subject completing virtual nature treatment inside the nature center, oriented towards the blank wall viewed by control subjects, and wearing the GSR+ module and virtual reality headset.

Physiological recordings of skin conductance and heart rate variability were collected during subject running, though these data were not evaluated in this thesis. A wireless

Shimmer GSR+ unit (Shimmer GSR, 2015) measured heart rate variability using an optical pulse sensor as well as galvanic skin response using two silver/silver chloride electrodes mounted in a finger cuff and attached to the palmar surfaces of the distal and medial phalanges of the left hand.

Measures

Campus questionnaire session measures

Subjects completed a survey questionnaire administered in two parts. A series of questions about general physical and mental health (created by experimenters, see Appendix C) and the Beck Depression Inventory were asked via pen-and-paper. Additionally, a measure of familiarity with virtual reality technology and frequency of video game use (see Appendix D) was evaluated.

The second part of the survey included a battery of questions that were administered using Qualtrics (www.qualtrics.com). This battery assessed nature visit frequency (Browning, Stern, Ardoin, & Heimlich, 2016), personality (Costa & McCrae, 1992), trait affect (Watson, Clark, & Tellegen, 1988), two types of anxiety (T. J. Meyer, Miller, Metzger, & Borkovec, 1990), depression (Beck et al., 1961), engagement with nature's beauty (Diessner, Solom, Frost, Parsons, & Davidson, 2008), and feelings of disgust with things encountered in nature (Bixler & Floyd, 1999). Trait levels of positive and negative affect were measured with the Positive and Negative Affective Scale (Watson et al., 1988), which consists of a list of feelings (e.g., enthusiastic, inspired and jittery, upset) that were rated on a five-point Likert scale from "very slightly or not all" to "extremely" with higher numbers signifying greater endorsement of that feeling. Trait affect was queried as the extent to which respondents experienced a list of affective

states over the past few weeks. A score for trait affect was calculated by summing their numeric responses for 10 items ($\alpha = .925$) of positive affect and 10 items ($\alpha = .826$) of negative affect.

Additional self-reported measures of psychopathological symptoms included assessments of anxiety and depression. Levels of worry-type anxiety, or anxious apprehension, were calculated from responses to a 16-item scale ($\alpha = .457$) that was drawn from the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990). Levels of panic-type anxiety, or anxious arousal, were calculated from responses to the 17-item MASQ-AA subscale ($\alpha = .362$) of the Mood and Anxiety Symptoms Questionnaire (Watson et al., 1995). Levels of depressive symptoms, or anhedonia, were calculated from responses to the 22-item MASQ-AD subscale ($\alpha = .810$) of the Mood and Anxiety Symptoms Questionnaire (Watson et al., 1995).

Individual variation in disgust response was measured with the Disgust Sensitivity Scale (Bixler & Floyd, 1999). Subjects rated the extent to which they felt disgusted by experiences encountered in the natural world (e.g., getting itchy from dust and sweat on my skin, having to sit on the grounds in the woods, finding a tick crawling up my leg) on a five-point scale from “not at all disgusting” to “very disgusting.” A total disgust score was calculated from the sum of their responses to the 15 items ($\alpha = .933$), with higher scores indicating greater levels of disgust.

Frequency of nature visits was also assessed (Schreyer, Lime, & Williams, 1984). Though experience use history is typically assessed on two dimensions, following Browning et al. (2016), a single item question asking how frequently in the last year subjects had visited a nature-based park (see Appendix B). Responses were indicated on a 9-point scale, with the lowest score signifying “0 times in the last 12 months,” a median score signifying “10-14 times in the last 12 months” and a high score signifying “5 or more times per week - for most weeks in the last year.” Thus, higher scores on this measure indicated more frequent nature visits.

Additional measures were evaluated in this thesis but not included in the present analysis. The personality traits of extraversion, openness to experience, conscientiousness, agreeableness, and neuroticism were assessed via the NEO Five-Factor Inventory (Costa & McCrae, 1992). Also, appreciation of nature's aesthetic beauty and self-reported physiological response to perceiving it were assessed via the 4-item ($\alpha = .675$) natural beauty subscale of the Engagement with Beauty Scale (EBS; Diessner, Solom, Frost, Parsons, & Davidson, 2008). The EBS was ranked with a 7-point Likert scale from "very unlike me" to "very much like me" and a total score was calculated from the sum of all responses. Finally, two open-ended questions asked subjects to provide their definition of nature (responses included: "An outside environment filled with plants, animals, and forests where all living things flourish") and to describe their relationship with nature (responses included: "Nature is something I turn to when I feel alone or depressed or need motivation for [sic]. It is my one stop shop for happiness").

Field site session measures

During the field site session, subjects were first given a screening questionnaire that asked about their recent physical activity, sleep, alcohol use, drug ingestion, and caffeine consumption (see Appendix C). State measures of positive and negative affect were assessed before and after the treatment as well as before and after the stressor. State levels of positive and negative affect were measured with the Positive and Negative Affective Scale (Watson et al., 1988), which consisted of a list of feelings (e.g., enthusiastic, inspired and jittery, upset) that were rated on a five-point Likert scale from "very slightly or not all" to "extremely" with higher numbers signifying greater endorsement of that feeling or emotion. In contrast with trait affect, state affect was measured as the subject's response to indicate the extent they had been feeling

each emotion right at the moment in which they were being assessed. A score for state affect before the stressor was calculated by summing their numeric responses for 10 items ($\alpha = .906$) of positive affect and 10 items ($\alpha = .794$) of negative affect and after the stressor for the 10 items ($\alpha = .905$) of positive affect and 10 items ($\alpha = .846$) of negative affect.

State levels of mindfulness, the extent to which the subject was able to “decenter” or observe their own emotions and “curiosity” or the inclination to investigate those emotions as they were being experienced, were measured with the Toronto Mindfulness Scale (Lau et al., 2006), which was administered immediately after the treatment and again immediately after the stressor. Subjects were asked to indicate the extent to which they agreed with a list of statements about what they just experienced, using a 5-point Likert scale from “not at all” to “very much.” A total mindfulness score was calculated from the sum of the responses to 13 items ($\alpha = .816$), with higher numbers indicating higher levels of state mindfulness during the treatment or stressor. Finally, ratings of subject’s perception of restorativeness of the treatment environment were collected, though those scores were not investigated for this thesis.

RESULTS

Socio-demographics

Our sample consisted of 26 healthy undergraduate students and employees from the University of Illinois that were recruited through campus postings, collaborator emails and online newsletters. The group was divided nearly evenly among men (n=14) and women (n=12). Ages ranged from 18 to 28, with the mean age of 21.6 years. Subjects were typical of the population in a University community, with all subjects either currently working towards a Bachelor's degree or having completed a Bachelor's degree or higher (n=8). The sample consisted of individuals that identified as Caucasian (50%), Asian (26.9%), Black or African American (15.4%), American Indian or Alaskan Native (3.8%) and Multiracial (3.8%) with two people identifying as Hispanic or Latino (7%). Two of those subjects were excluded from the study due to a previous history of mental health disorder diagnoses.

A subset of these subjects (n=17) returned for the field site session, though one subject was excluded for missing data. Due to restrictions in conditions suitable for outdoor running (temperature between 68 degrees and 80 degrees Fahrenheit with sunny conditions) and unfortunate timing of participants, the group of subjects that received the outdoor nature treatment (n=5) consisted of more males (n=4) and the group of subjects that received the virtual nature treatment (n=7) consisted of more females (n=5). The control group (n=5) was more evenly split between males (n=3) and females (n=2).

Descriptive Findings

For the first objective, I investigated whether people's past visitation to natural areas was related to certain measures of mental health. Specifically, I looked at individual's levels of

worry-type anxiety (anxious apprehension), panic-type anxiety (anxious arousal), depression (anhedonia), and general positive or negative disposition (trait positive affect and trait negative affect). The independent variable, nature visit frequency, was within the standard ranges for skewedness (.547) and kurtosis (-1.420) and was distributed approximately normally.

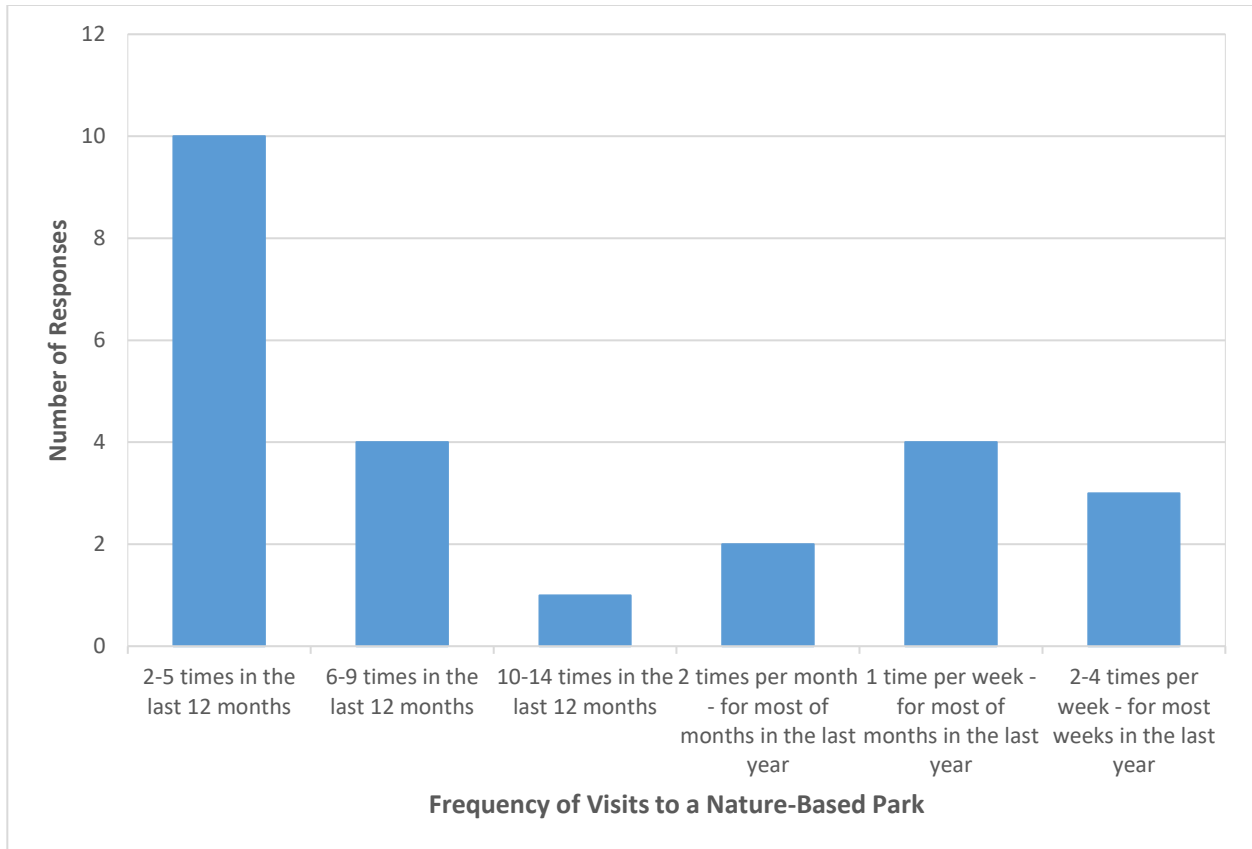


Figure 8 – Response Distribution of Nature Visit Frequency

Correlations between nature visit frequency and anxious apprehension ($r = -.21, p = .32$), anxious arousal ($r = -.10, p = .65$), anhedonic depression ($r = -.08, p = .70$), trait positive affect ($r = .21, p = .33$) and trait negative affect ($r = -.20, p = .36$) were examined, though none of those relationships were found to be significant at alpha level = 0.05. However, the measures of mental health did demonstrate strong significant relationships that would be expected, with both types of

anxiety positively correlated with each other ($r = .56, p < .01$), higher levels of worry correlated with more symptoms of depression ($r = .52, p < .01$) and trait positivity inversely correlated with anhedonia ($r = -.841, p < .01$). Trait negativity was correlated with both types of anxiety, anxious apprehension ($r = .60, p < .01$) and anxious arousal ($r = .55, p < .01$), as well as depression ($p = .53, p < .01$).

Although the mental health measures were not found to be directly related to nature visit frequency, the relationship between individual differences in levels of disgust with items in the natural world and nature visit frequency was negatively correlated to a near-significant level ($r = -.38, p = .067$). Additionally, disgust sensitivity was found to be strongly significantly correlated with trait negativity ($r = .56, p < .01$) as well as significantly correlated with higher levels of negative mental health in the form of both worry-type ($r = .49, p < .05$) and panic-type ($r = .44, p < .05$) anxiety.

Analytic Findings

For the second objective, an initial investigation of any correlation between nature visit frequency and state mindfulness during the stress task was not significant ($r = .419, p = .106$).

Table 2

Results from Regression Analysis of Nature Visit Frequency on State Mindfulness during the Stress Task

	<i>B</i>	<i>SE B</i>	β	t
Nature Visit Frequency	2.156	1.250	.419	.106

A simple linear regression to see if nature visit frequency would predict state level of mindfulness during the stress task was not significant ($R^2 = .175$, $F(1, 14) = 2.978$, $p = .106$).

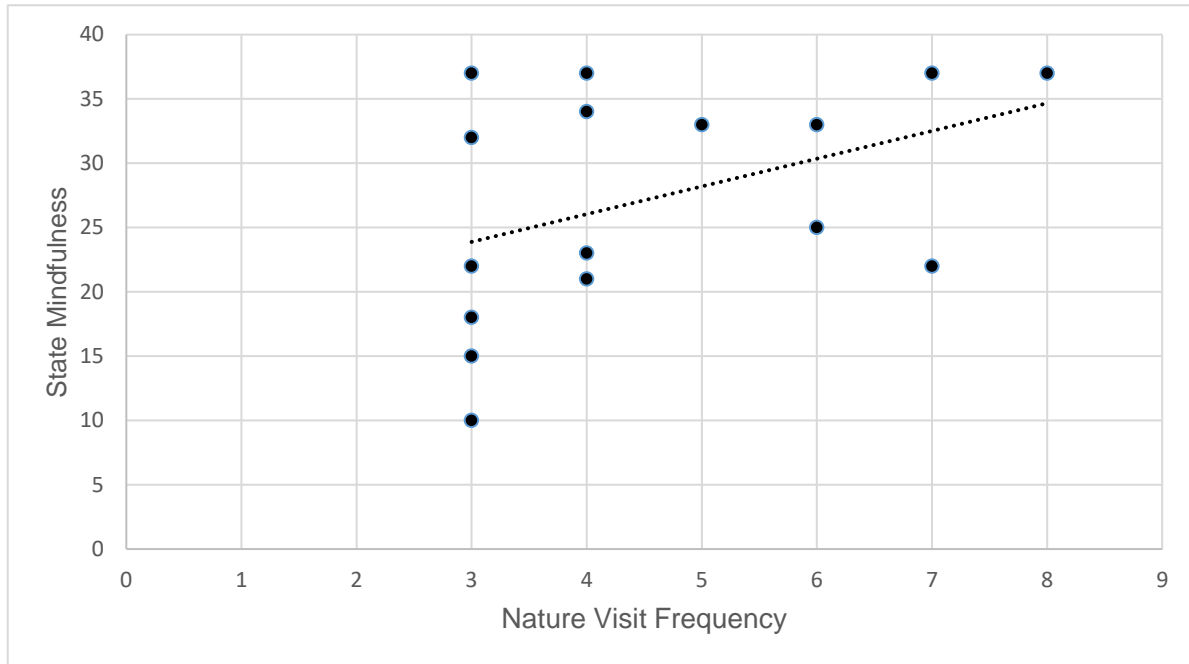


Figure 9 – The Relationship between nature visit frequency and state mindfulness during the stress task

A one-way ANOVA found no significant effect for nature treatment type on state mindfulness scores ($F(2, 13) = .175$, $p = .841$) across the control treatment ($M = 28.25$, $SD = 5.620$), virtual nature treatment ($M = 28.14$, $SD = 10.463$) or outdoor nature treatment ($M = 25.20$, $SD = 9.783$). Next, a simple linear regression to see if nature treatment type predicted state mindfulness scores during the stress task was calculated. A predictor variable was coded with a 1 if a subject was exposed to the outdoor treatment or virtual nature treatment and 0 if they were exposed to the control treatment. Z-scores were computed for the raw state mindfulness scores ($M = 27.25$, $SD = 8.813$). A non-significant relationship was found ($R^2 = .005$, $F(1, 14) = 0.064$, $p = .803$).

Table 3

Results from Regression Analysis of the Nature Treatments on State Mindfulness during the Stress Task Scores

	<i>B</i>	<i>SE B</i>	β	t
Outdoor or Virtual Nature Treatment	-.151	.596	-.068	-.254

Finally, simple linear regression analyses were run to see if the treatment type (virtual nature or outdoor nature) would predict the change in positive and negative affect scores from before versus after the stress task. The change in affect was calculated as a variable by subtracting the state affect score before the stress task from the state affect score after the stress task. The outdoor and virtual nature predictor variables were dummy coded with a 1 if a subject was exposed to that treatment and 0 if they were exposed to the control or other type of nature treatment. Mindfulness was added as a covariate to the model.

For the change in positive affect, a non-significant regression was found ($R^2 = .369$, $F(3, 11) = 2.145$, $p = .152$).

Table 4

Results from Regression Analysis of the Treatment Type on the Change in Positive Affect Scores

	<i>B</i>	<i>SE B</i>	β	t
Mindfulness	.415	.185	.544	2.244*
Outdoor Treatment	3.009	4.498	.214	.669
Virtual Reality Treatment	-2.470	4.251	-.186	-.581

* $p\text{-value} \leq 0.05$

For the change in negative affect, a non-significant regression was also found ($R^2 = .253$, $F(3, 11) = 1.242$, $p = .341$).

Table 5

Results from Regression Analysis of the Treatment Type on the Change in Negative Affect Scores

	<i>B</i>	<i>SE B</i>	β	<i>t</i>
Mindfulness	-.182	.142	-.336	-1.276
Outdoor Treatment	2.400	3.461	.241	.693
Virtual Reality Treatment	4.935	3.271	.525	1.508

DISCUSSION

There is much that is known about how physiological adaptations that were evolutionarily advantageous have persisted to become maladaptive in present day society, where humans live separated from the natural world (Boyce & Ellis, 2005). However, much less is known about psychological adaptations that once supported survival but now detract from it (Pearson & Craig, 2014). In order to best utilize natural environments to ameliorate the effects of this dysregulation, the mechanisms through which nature can reverse or buffer against the etiology or maintenance of mental health disorders must first be uncovered (Mantler & Logan, 2015). Additionally, the question of how visitation to natural environments are associated with maladaptive affect orientations and mood disorder symptoms must be answered.

In order to address this problem, I first examined how previous visits to natural areas associated with trait affect and psychopathological symptoms in a clinically healthy population. Biophilic theories have been supported by a significant body of literature linking the positive impacts of nature with better mental health (for reviews, see: Kuo, 2015; Mantler & Logan, 2015; Pearson & Craig, 2014). Despite evidence suggesting that visitation to natural environments improves mental health and wellness outcomes, frequency of nature visits did not correlate with any of the mood or mental health measures assessed in this study. Other studies have also failed to find these effects. For example, van den Bosch and colleagues (2015) examined a public health survey in Sweden and did not find any evidence that moving into an area with more greenspace improved mental health. In another study of nearly 4,000 individuals in Spain, the Netherlands, Lithuania and the United Kingdom, no association between purposeful visits to natural environments and better mental health was found (van den Berg et al., 2017).

Associations between previous nature visits and levels of trait affect, depression or anxiety were not identified for a number of reasons. First, this was a pilot study for future data collection with novel technology and, as such, was small in sample size. Second, we investigated these symptoms in a student population that was screened for previous mental health diagnoses and thus only included psychologically healthy individuals. This served to remove confounding factors related to current psychopathology; however, this may have impacted our findings in other ways. One study found that beneficial affective effects from exposure to elements of nature were more pronounced for individuals with higher levels of depressive symptoms than those with lower levels, which the authors attributed to a greater effect size in people with higher need for restoration (Beute & de Kort, 2018). Other studies have found improvements in affect and cognition from a nature walk for individuals diagnosed with major depressive disorder but not for subclinical populations investigated in a previous study (Berman et al., 2012). There is also the possibility that the subject selection procedures adopted for this research limited the external validity of the project given that one study found over half of college students that were surveyed reported suffering from depression and there is evidence to suggest that this is common across college campuses (Furr, McConnell, Westefeld, & Jenkins, 2001).

Another limitation of this research was related to the measurement of frequency of nature visits and the two types of anxiety. Frequency of nature visits was only assessed via a single question that asked about visitation over the last year, which may have been too long of a time scale to elucidate underlying connections. The measure was not assessed via a continuous measure, which creates a limitation to the conclusions that can be drawn from the discrete variable. There is a long-standing body of work on experience use history that suggests that items of this nature should be assessed with at least two items (Hammitt, Knauf, & Noe, 1989;

Williams & Vaske, 2003). The measure asked subjects specifically how often they had visited a “nature-based park.” Individuals, and the scientific community as a whole, lack a unanimous definition for nature or clear boundaries between what is considered “nature,” “natural,” “wilderness” or “green space,” so responses to the single item measure may not reflect the true extent of how often natural environments were visited (Lachowycz & Jones, 2013). Since there is empirical evidence that just living in an area in close proximity to more green space is associated with better mental health (McEachan et al., 2016; Nutsford et al., 2013), perhaps investigating nature exposure as only the frequency of visits to nature-based parks is insufficient. Additionally, anxious arousal and anxious apprehension both showed low scale reliability, despite being from questionnaires that have been established as reliable in non-clinical samples (van Rijsoort, Emmelkamp, & Vervaeke, 1999; Watson, Clark, et al., 1995), so the implications for effects on anxiety in this context are limited.

Supporting theories on biophobia, we uncovered an interesting finding from the first objective on the role of disgust. Disgust for items in the natural world likely improved fitness as it would have motivated our ancestors to avoid contact with contaminants and disease-spreading vectors including invertebrates like spiders and ticks (Bixler & Floyd, 1999). In the current study, the correlation between disgust elicited by items in the natural world and frequency of nature visits was nearly significant ($p = .067$). This is consistent with evidence that higher disgust sensitivity is related to lower preference for outdoor environments and activities and a higher preference for indoor environments and activities in children (Bixler & Floyd, 1997), as well as an avoidance from engaging in outdoor recreation activities in adults (Bixler & Powell, 2003). Moreover, I found that disgust was strongly correlated with trait negative affect and significantly correlated with anxious arousal and anxious apprehension. This is also consistent

with findings highlighting the role of disgust in the etiology of psychopathology, specifically in regards to anxiety-related disorders (Muris, 2006; Olatunji et al., 2010; Vernon & Berenbaum, 2002). Given our preliminary findings, further investigation of the role of disgust in avoidance of restorative environments and the development or maintenance of anxiety disorders is merited. If higher levels of disgust for items found in nature provokes avoidance of natural environments, which might ameliorate anxiety associated with innate disgust sensitivity, then some method, such as exposure therapy, to combat avoidance or assist in overcoming nature phobias must be incorporated in the treatment of mental health with natural environments to achieve the best clinical outcomes.

Investigations into the relationship between mindfulness and natural environments has been called for given the similarities in restorative effects that they both provide (S. Kaplan, 2001). The integrative framework for restoration posits that the ART and SRT are related through the cognitive resource of attention. If attentional control impairments, especially to emotional stimuli, distinguish deficits in anxiety and depression (Crocker et al., 2013; Warren et al., 2013), perhaps through mindfulness one can abate the tendency to become overwhelmed by emotions or fall into rumination, which bolsters negative affective states (Nakajima, Takano, & Tanno, 2017). Mindfulness could do this in two ways: by replenishing depleted attentional resources, thereby reducing the salience of emotional distractors and/or by facilitating de-centering from reactivity to attention-grabbing emotional stimuli thus increasing adaptive coping through resilience (Brewer et al., 2011; Doll et al., 2016; Garland et al., 2015; Garland, Froeliger, & Howard, 2014; Vago & Silbersweig, 2012; Wheeler et al., 2017). These mechanisms have been supported in the literature by findings suggesting that top-down attentional control in the anterior cingulate cortex is modulated negatively by psychopathology

and positively by mindfulness, indicating a potential mechanism through which depletion due to disorder or restoration due to metacognitive adaptive processes may function (Crocker et al., 2012; Wheeler et al., 2017). Therapeutic effects conferred via reductions in emotional reactivity have also been demonstrated in behavioral studies as well as differential processing in the amygdala and prefrontal cortex as a result of mindfulness (Crocker et al., 2013; Doll et al., 2016). Finally, study comparing identical twins demonstrated that positive affect can buffer reactivity to stressors and posited that mindfulness may be able to do the same by boosting the ability to remain positive despite pressure from negative stimuli (Wichers et al., 2007). Together, this work supports the proposition that mindfulness may play a mechanistic role linking the ART & SRT to facilitate the salutary impacts of restoration.

To empirically investigate this proposition, I examined the hypotheses in the second objective of the current study. Though past nature visitation did not correlate statistically with state mindfulness during the stress task, a moderate effect size ($r = .419$) was found. Given the small sample size, this result are likely be replicated with a larger sample. Meta-analyses of previous research investigating mindfulness interventions on a number of clinical outcomes (Hofmann et al., 2010), as well as an empirical study of meditation on state levels of mindfulness and changes in affect on the PANAS scale (Thompson & Waltz, 2007), have revealed moderate effect sizes of mindfulness treatments as well. Further exploration of the nature treatment exposure effects on state levels of mindfulness did not find any predictive relationship between the two, which may have been related to the sample size or may have been effected by dispositional mindfulness, which was not measured.

Mindfulness was a significant covariant in the regression model for positive, but not negative affect. This finding is supported by previous research across a variety of contexts that

has found the connection between mindfulness and affect to yield different results between the two types of affect (Brown et al., 2007; Keng, Shian-Ling; Smoski & Robins et al., 2011). For example, previous study found that trait levels of mindfulness attenuated cortisol and affective responses to the TSST stress task, which supports the idea that mindfulness acts as a stress buffer. This study also found that dispositional mindfulness was associated with lower negative affective responses to the TSST (Brown, Weinstein, & Creswell, 2012). Laurent, Wright, & Finnegan (2018) found that mothers higher in mindfulness had lower activation in areas of the brain associated with emotional reactivity when engaging with their infants in negative as opposed to positive emotional contexts, suggesting that dispositional mindfulness may help overcome the emotional impact of negative experiences better by responding to unpleasant experiences less and pleasant experiences more. As we did not measure trait mindfulness in our study, we cannot examine the effect that dispositional mindfulness had on the differences in positive and negative affective responses of subjects, though this may provide some explanation for variation we observed with state levels. It is clear that mindfulness plays some role in affective processing associated with the development of or the avoidance from psychopathology, though further research is merited.

It is important to distinguish between mindfulness practices (e.g., meditation, mindfulness-based stress reduction or cognitive therapies), state mindfulness (i.e., how much you are able to engage in non-judgmental awareness of your present state at a specific point in time) and trait or dispositional mindfulness (i.e., your ability to engage in mindful states in a more stable and consistent way over time) (Chiesa, 2013). Research has indicated that state mindfulness may not operate in a linear way with the construct of dispositional mindfulness; that is, how mindful a person generally may not predict how mindful they are able to be at a given

moment. Thompson & Waltz (2007) found no significant relationship between trait levels of mindfulness and state levels of mindfulness during meditation in the same individual, though the study consisted of subjects that were naïve to meditation and did not include intensive formal meditation training as part of the methodology. There are several issues inherent to the complexities in semantics and measurement around the construct of mindfulness (Van Dam et al., 2018), and other studies have found that mindfulness-based therapies increased state levels of mindfulness (Lau et al., 2006). A meta-analysis found several studies in which mindfulness therapy increased individuals' trait levels of mindfulness as well (Khoury et al., 2013). So, it does seem that engaging in mindfulness practices can impact one's ability to be mindful and that mindfulness effects on an individual can be present in both the long and short term. In this study we measured state levels of mindfulness and did not examine trait mindfulness, which can differentially impact the beneficial effects from exposure to experiences such as being out in nature (Laurent et al., 2015). Future work should measure trait levels of mindfulness as well as state levels of mindfulness to understand the relationships between natural environments and this construct in a deeper way.

My third hypothesis, which posited that either the real nature treatment or virtual nature treatment would predict changes in affect, was not supported. This contradicted previous work that found enhanced stress recovery from exposure to natural environments and sounds in room-scale virtual environment (Annerstedt et al., 2013) and other work demonstrating an increase in positive affect and decrease in autonomic skin-conductance response to stress from exploration of a virtual nature environment displayed in an HMD and navigated through by walking on a rumble platform (Valtchanov, Barton, & Ellard, 2010). Though our study included six minutes of physical activity (i.e., either the walk to and from the outdoor location or the walk indoors on the

carpet), the natural environment that we presented in the head-mounted display was not navigable or interactive in any way. Meta-analyses of nature exposure studies have found small effect sizes of nature treatments (Bowler, Buyung-Ali, Knight, & Pullin, 2010; Hartig et al., 2014). Given these estimates, power analyses calculations indicate that at least three to four times as many subjects would need to be run in a subsequent full study to accurately detect effects from the design of this pilot study (Cohen, 1992). Berman et al. (2012) found a large effect size on changes in working memory capacity in their study of 19 individuals with depression who walked through either a natural environment as compared with subjects who walked through an urban environment, and it is interesting to note that this effect was nearly five times larger than the effect they found in a previous study with non-clinically depressed subjects. Therefore, given the strong mental health of subjects in this study and small sample size it was not surprising that the regression analyses for the third objective were non-significant. Another consideration was the distractions present outdoors; a water park, busy road and children's play area were all within an audible range for subjects. Subjects were given unscented mosquito repellent, though it was only somewhat effective at reducing the distraction from them for outdoor subjects. The video of the virtual nature treatment included a brief ambulance siren, which was reported as distracting by one subject as well. Future work investigating longer nature treatment exposure or interactive natural environments is merited.

Implications for Future Research

A significant strength of this study was in the creation of this innovative design. My study incorporated the newest generation of virtual reality head mounted displays, wireless biosensors for continuous recording of physiological data, a manipulation before treatment

design to test for autonomic stress buffering and a direct comparison of the same environment in real life and in virtual reality. The design of this study was used for subsequent data collection with a larger sample size that will provide further elucidation on the relationships proposed here.

The decision to immerse subjects in a nature video as opposed to an interactive nature environment was made for three reasons that merit discussion for future studies. First, changes in the scene displayed on the human retina that occur when a subject moves through a virtual environment are interpreted as physical movement by visual cortex, which conflicts with incoming information from the vestibular organ in the human ear responsible for determining the orientation of your body in space. The physiological result from receiving incompatible bodily stimuli is the sensation of nausea, similar to car or sea sickness, which is called simulator sickness in the context of virtual environments (Lavelle, 2016). As I was recording autonomic measures, a sympathetic response to simulation sickness would have been a source of measurement error (as well as a concern for the Institutional Review Board). Second, the virtual reality headset that was used for the study did not permit positional tracking and only afforded three degrees of freedom in the movement allowed by the user. Third, the high definition video used for the treatment was recorded in the exact location where the outdoor nature subjects were exposed to the treatment. This provided a higher level of ecological validity in the comparisons than would have been afforded by a computer-generated scene.

Although the virtual nature treatment was not associated with affective changes resulting from exposure to the restorative environment, this may have been due to the limited sample size and the potential for therapeutic results with a larger group should not be overlooked. Given the significant reductions in negative symptoms and incredible improvements in quality of life from exposure to natural environments (Pálsdóttir, Persson, Persson, & Grahn, 2014; Wolsko & Hoyt,

2012), it is critical to find ways to connect individuals that suffer from depression and anxiety with nature in an accessible way. Currently, virtual environments are interesting to research participants as a function of novelty, which creates the possibility that a virtual experience might elicit awe, fascination, extent, compatibility and a sense of being away (Kjellgren & Buhrkall, 2010). According to the restoration theory posited previously, these characteristics could confer some restoration to the subject, regardless of the stimulus environment. This consideration should be taken into account when investigating virtual environments. Exciting work on therapeutic applications for improving mental and physical health with virtual reality have begun to highlight some of the myriad of applications for this technology (Annerstedt et al., 2013; Gold et al., 2007; Owens & Beidel, 2015; S. Parsons, 2016; Riva et al., 2007). However, the importance of the natural environments in particular in restoring cognitive capacities and building metacognitive resilience makes the importance of investigation on virtual restorative environments in particular critical for future research (Depledge et al., 2011; Riva, Banos, Botella, Mantovani, & Gaggioli, 2016; Small et al., 2015; Stone et al., 2014).

CONCLUSION

This study is the first step in an important direction for the scientific literature on nature, mental health and mindfulness. First, by uniting the literature on the psychology and neuroscience of psychopathology with work on the benefits of restoration from natural environments, a transdisciplinary investigation of mindfulness in the relationship between nature and its beneficial effects on health and wellbeing adds to bodies of work in both fields. The impact of natural environments in promoting mindfulness for cognitive reappraisal of emotional responses to distress and the subsequent benefits to resilience and positive mental health outcomes merits further investigation. Second, the design of the study provides a useful mechanism for future work investigating the use of virtual reality technology to study affective and physiological stress buffering impacts from virtual natural environment exposure and proposes mindfulness as an important mechanism for investigation. New technological advances create exciting possibilities for providing therapeutic nature exposure to a broad audiences. This study lays the groundwork for future research on the use of virtual reality technology for personal and clinical applications to improve the mental health and well-being for all people, especially individuals who cannot access nature-based settings that would benefit most from alleviation of the suffering resulting from mental health struggles. Given the findings that virtual reality can help transform our emotional responses and create change in the way that we perceive and interact with the world, the potential for building emotional resilience through mindful restoration from nature in virtual settings provides an exciting direction for future work to restore the human connection with nature and improve human health and wellbeing.

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APPENDIX A –STUDY QUALIFICATION CHECKLIST

Please check that each subject meets the following criteria (answers given by subs are assumed to be true):

General Health and Demographics

- Age is 18 to 29 inclusive** (ages under 18 or 30 and above are **EXCLUDED**)
- Person is currently affiliated with the university** (they must have an active @illinois.edu email)
- Person has normal color vision and no other eye issues** (it is okay if they don't have perfect vision, as long as they don't have any congenital or current eye issues and no partial or complete blindness in one or both eyes)
- Person has normal hearing and no other ear issues** (it is okay if they don't have perfect hearing, as long as they don't have a hearing aid or hearing loss in one or both ears)
- Person is right-handed** (only the hand they use to write with matters)
- Person is a native English speaker** (must have learned to speak English as first language)
- Person does NOT have a history of cardiovascular diseases** (heart issues), **stroke**, **high blood pressure**, **epilepsy** or **seizures**
- Person is not currently taking psychoactive medications** (consult psychoactive meds list)
- Person does NOT have a history of diagnosed mental health disorders** (including: depression, anxiety, ADHD, autism, social phobia or posttraumatic stress disorder)
- Person is NOT currently being treated for depression, anxiety, ADHD, autism, social phobia or posttraumatic stress disorder**

BDI Questionnaire

- Total score is less than or equal to 20** (scores of 21 and above are **EXCLUDED**)
Add up the score for each of the twenty-one questions by counting the number to the right of each question. The highest possible total for the whole test would be sixty-three and the lowest possible score for the test would be zero.

VR Headset

- No issues putting on or testing the headset** (it is okay if they have a small astigmatism as long as they have no issue with the demo)
- No history of sensitivity to motion sickness** (you'll ask them about this during the demo)

APPENDIX B – FREQUENCY OF NATURE VISITS QUESTIONNAIRE

Directions:

In the past year, how many time did you visit a nature-based park? This might be someplace local like Busey Woods, Crystal Lake, Homer Lake, Meadowbrook, or a private woodland, or it might be someplace farther away like a State Park or National Park.

- 0 times in the last 12 months (1)
- 1 time in the last 12 months (2)
- 2-5 times in the last 12 months (3)
- 6-9 times in the last 12 months (4)
- 10-14 times in the last 12 months (5)
- 2 times per month - for most of months in the last year (6)
- 1 time per week - for most of months in the last year (7)
- 2-4 times per week - for most weeks in the last year (8)
- 5 or more times per week - for most weeks in the last year (9)

APPENDIX C – GENERAL HEALTH AND DEMOGRAPHICS QUESTIONNAIRE

Gender: _____ Age: _____ Birthdate: _____

Highest Level of Education Completed: _____

Ethnicity (please circle one): Hispanic/Latino Not Hispanic/Latino Decline to Report

Race (please circle one): American Indian/Alaska Native Asian Caucasian
Black/African American Hawaiian/Pacific Islander
Multiracial Decline to Report

Questions (TO BE KEPT CONFIDENTIAL):

1. Are you currently a student, faculty member, staff or other University employee? NO YES
2. Do you currently smoke and/or use any recreational or street drugs? NO YES
3. Do you wear glasses or contact lenses? No Contacts Glasses Both
4. Is your normal or corrected vision perfect, or 20/20? NO YES
Are you, in any way, color blind? NO YES
Please describe any problems with your vision: _____
5. Do you use a hearing aid? NO YES
Have you ever been diagnosed with (or noticed) a hearing problem? NO YES
If YES, please describe _____
6. Do you consider yourself right or left-handed? RIGHT LEFT AMBIDEXTROUS
7. What is your native language? English Other (specify): _____
8. Have you ever been diagnosed with a neurological disorder (e.g., seizures, stroke, tremor)? NO YES
(_____)
9. Have you ever been diagnosed with a psychiatric disorder (e.g., depression, anxiety, bipolar, PTSD)?
NO YES (_____)
10. Have you had any major operations (e.g., bypass surgery)? NO YES
If YES, please describe what and when: _____
11. Are you currently taking any prescription or nonprescription medications? NO YES
If YES, which ones? _____
12. Do you have any other current or recurring medical problems? NO YES
If YES, please describe: _____
13. On a regular day, when do you typically drink caffeine? Please check all that apply
 - 1:00 – 5:59 AM
 - 6:00 – 7:59 AM
 - 8:00 – 9:59 AM
 - 10:00 – 11:59 AM
 - 12:00 – 1:59 PM
 - 2:00 – 3:59 PM
 - 4:00 – 5:59 PM
 - 6:00 – 7:59 PM
 - 8:00 – 9:59 PM
 - 10:00 PM – 12:59 AM

14. How much sleep do you regularly get? _____ hours

15. During your free time in an average week, how many times do you engage in the following kinds of exercise for more than 15 minutes?

Strenuous exercise during which your heart beats rapidly (e.g., running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, and vigorous long distance bicycling)

____ times per week

Moderate exercise which is not exhausting (e.g., fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, and popular or folk dancing)

____ times per week

Mild exercise which requires minimal effort (e.g., yoga, archery, fishing from river bank, bowling, playing horseshoes, golfing, snow-mobiling, and easy walking)

____ times per week

16. During a typical DAY, how much time do you spend sitting while at work, at home, and during your leisure time? This may include time spent sitting at a desk, and reading or sitting or lying down to watch television or use your phone/tablet.

- Less than 2 hours
- 2-4 hours
- 5-7 hours
- 8-10 hours
- More than 10 hours

17. How often have you felt stressed during the last two weeks (14 days)?

- Never
- Seldom
- Sometime
- Often
- Regularly

18. How often have you felt depressed during the last two weeks (14 days)?

- Never
- Seldom
- Sometime
- Often
- Regularly

