Perceived Restorativeness and Restorative Outcomes: A Comparative Study of Diverse Environments in Urban and Natural Settings

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

Natural environments are generally considered more restorative than urban ones, with various elements contributing to their restorative potential. This research investigates restoration in urban and natural environments using virtual reality and field studies. In particular, I examined urban and natural environments with both high and low restorative potential. Additionally, this research explores if participants can effectively evaluate an environment's restorativeness based solely on the environment's visual aspects. Across studies, restoration was assessed using subjective and objective measures of stress, attention, and affect. Results demonstrated that the natural environments did not consistently outperform the urban environments on restorative outcomes. Indeed, there were some indications that urban environments could also be restorative. Finally, participants' predictions of restorative potential did not align with the restorative measures, indicating a gap between perceived restorative potential and actual restorative outcomes. Overall, the findings indicate that environmental restorativeness is complex, and not all urban or natural environments offer the same level of restoration. Further research is needed to understand the specific elements that contribute to an environment's restorative potential.

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Chapter 1 Introduction

Social and Scholarly Context

With over 50% of the world's population currently living in cities (United Nations, 2018), and a predicted increase to 70% by 2050 (United Nations, 2014), we are facing increased urgency to ensure that human-designed, urban environments support the health and well-being of all individuals. Urban inhabitants may increasingly endure negative health effects, especially those who face socioeconomic disadvantages (Bashir, 2002). This need is especially true as many cities look to densification options to deal with the influx of urban dwellers (Beatley, 1999).

Urban living is often associated with chronic stress, anthropogenic environmental hazards, and other health issues (Braubach et al., 2017; Peen et al., 2010). Research in environmental psychology suggests that the illness experienced by those living in urban areas could be a result of the physical and symbolic environment affecting psychological well-being (Roe & McCay, 2021). Specifically, environmental psychologists have suggested that chronic stress can increase negative moods (Lazarus & Lazarus, 1994), and reduce well-being (Hartig et al., 1996; Laumann et al., 2003), while inducing significant detriments to cardiovascular, gastroenterological, immunological, neurological, endocrine and mental and emotional health status (Association. A. P, 2019; Dye, 2008; Larzelere & Jones, 2008). Additionally, it has been shown that people living in poorly designed urban spaces, such as apartment blocks without views of nature, experience higher mental fatigue with a reduced ability to deal with major life issues (Kuo, 2001). Finally, many individuals are exposed to urban environments through their work in office settings, particularly in centralized urban areas like financial districts. While some people may not reside in poorly designed urban spaces, a significant number of them encounter such environments

daily due to their job requirements. This highlights the importance of considering the impact of urban environments on individuals, regardless of their residential setting. Finally, elevated stress can have negative economic consequences (Degenhardt et al., 2011; Michie, 2002). For example, poor mental health and reduced well-being have been linked to increased work absenteeism, decreased productivity, and poorer decision-making (Boyd, 1997). These findings emphasize the importance of providing accessible resources for stress recovery to mitigate the detrimental effects of work and everyday environment-related stressors in order to promote overall well-being among various populations.

Given the potential negative impacts of urban environments, it is essential to provide individuals with restorative spaces that can help reduce stress, enhance cognitive abilities, and alleviate negative emotions associated with their work and home settings. These spaces can play a crucial role in promoting overall well-being and resilience for those who reside in urban areas or experience chronic stress in their professional lives. Studies have shown that nature and specifically greenspaces have significant restorative benefits (stress reduction, attention restoration, and emotion restoration), compared to the harmful effects of urban environments (high levels of stress and reduced health and well-being) (e.g., Antonelli et al., 2019; Berto, 2014; Kaplan & Kaplan, 1989; Maas et al., 2006; Ulrich et al., 1991).

While literature supports the benefits of natural environments, this dissertation investigates which patterns of both nature and urban environments can efficiently induce a restorative effect. As densification continues and places pressures on available land, the provision of natural spaces in urban environments will become difficult to justify without strong evidence that supports its restorative potential (e.g., Tyrväinen et al., 2005). Velarde et al. (2007) and Corazon et al. (2019), among others, note the inadequacy of the current restorative literature to address

densification of urban environments; the current literature has provided general guidance for the importance of nature areas, but offers relatively little guidance for specific environmental design measures outside of greenspaces. Additionally, I wanted to investigate whether certain aspects of the urban environment might be restorative, as Kaplan and Berman (2010) theorized the existence of restorative urban spaces, challenging the oversimplification of an urban-nature dichotomy and Weber and Trojan (2018) and Bornioli et al. (2018) suggest the restorative potential of historic and low traffic urban environments. The WHO suggests that a healthy city is "one that continually creates and improves its physical and social environments and expands the community resources that enable people to mutually support each other in performing all the functions of life and developing to their maximum potential" (WHO, 2022). This dissertation will provide evidence of crucial areas in cities that might offer a restorative experience and help attenuate stress for individuals who have insufficient recovery options or lack accessible greenspace for restoration. In my dissertation, I provide a systematic examination of the restorative effects of nature and urban environments.

Overview of Dissertation Direction

This dissertation examines the restorative potential of natural and urban environments by assessing changes in restorative measures related to stress, attention, and affect. Its primary objective is to bridge the knowledge gap in restorative experiences within these environments. Following Valtchanov and Ellard's (2015) advice, I used novel paradigms and stimuli to extend the current findings on restorative environments. The methods used include immersive virtual reality (VR) environments as well as field studies to confirm the results of the VR studies using subjective and objective measures of restoration. This will allow me to determine which elements are consistently present in restorative environments and produce a more robust

restorative experience, while also performing a conceptual replication of the research currently in the literature. Employing a combination of computer-generated environments, 360-degree videos, and field studies, the research highlights the importance of various exposure mediums and diverse natural and urban settings with differing restorative capacities. By investigating multiple versions of each natural and urban settings, this dissertation addresses the oversimplification of natural environments as positive restorative spaces and urban environments as a negative and draining space. Ultimately, this research contributes to a more comprehensive understanding of restorative experiences available in different environments, considering the variety of factors influencing restorative potential.

Theoretical Perspectives from the Restorative Literature

Theorists have proposed two different explanations of the path to restoration: Attention Restoration Theory and Stress Reduction Theory. These theories draw upon an evolutionary perspective (Weber & Trojan, 2018) first proposed by E. O. Wilson (1984) who suggests natural environments are restorative because humans have evolved in these environments and are thus more adept at processing them (Kaplan & Kaplan, 1989; Ulrich, 1993).

The Attention Restoration Theory (ART), developed by Kaplan and Kaplan (1989) suggests that restorative environments lead to the restoration of focused attention which leads to an increased ability to accomplish goals, reducing work stress and increasing positive moods from the accomplishment of goals. They note that our modern world (where work and recreation take place in urban areas) requires a lot of directed attention to complete increasingly demanding workloads while blocking out competing stimuli or thoughts (Kaplan & Kaplan, 1989). Over the course of a day, the intense need for inhibitory control and capacity for directed attention can become depleted, thereby requiring restoration for optimal human functioning (Hartig et al.,

1991). Kaplan and Kaplan (1989) posit four ART criteria which help make an environment restorative: first, *Being Away*: the environment must allow the individual to feel as though they are away from their everyday life and stresses (either by physically being in another environment, or psychologically by experiencing it through a window or image); second, *Fascination*: it must be fascinating and capture involuntary attention through interest, curiosity (mystery) and possible explorations in the environment (Kaplan, 1995). This fascination criteria ensures that demands on depleted voluntary attention can recover through the *involuntary* capturing of our attention (Hartig et al., 1991). The third criteria of a restorative environment is, *Extent*: in which, the environment must feel as though it is part of a larger place, suggesting more information can be obtained from further exploration (Hartig et al., 1991). The final criteria is, *Compatibility*: the environment must support people's needs and inclinations (Bornioli & Subiza-Pérez, 2023).

In contrast to ART's focus on attention deficits from everyday fatigue, Roger Ulrich proposed the Stress Reduction Theory (SRT), which focuses more on the emotional and physiological impacts that arise when people encounter a stressful situation. Ulrich suggests that restorative environments lead to a reduction in stress (neurophysiological arousal) from the calming effect of nontaxing natural stimuli and its ability to increase positively toned emotional states and impeding negatively toned emotions, alleviating stress and allowing individuals to focus and pay attention to tasks and goals requiring focused attention (Hartig et al., 1991; Ulrich, 1981; 1993; Ulrich et al., 1991). Ulrich's (1993) psychoevolutionary perspective posits that our emotional responses to natural environments are genetically determined and linked to survival advantages. According to this theory, individuals are more likely to approach environments abundant in survival resources if they also elicit positive emotions. This inclination ultimately

contributes to the passing down of these genetic preferences. Within this framework, natural environments are viewed as more conducive to human survival because they offer essential resources such as food, shelter, and water. The presence of these resources in natural settings triggers positive emotions and reduces stress, enhancing the chances of survival. Conversely, urban environments often evoke negative emotions due to the absence of these survival-related features. Since urban environments are relatively recent developments, our emotional responses to them have not yet evolved to match the positivity associated with natural environments (Ulrich, 1993). Supporting this theory, McMahan and Estes (2015) conducted a meta-analysis on the effect of nature interventions on positive and negative affect. They found that nature exposure was highly positively correlated with positive emotions and negatively correlated with negative emotions.

Theoretical Integration of the SRT and ART

As evidence for the SRT theory Ulrich (1993) cites people's universal willingness to pay more for access to water or greenspaces in parks or golf courses around the world– as these properties tend to be more desired and thus expensive, suggesting that regardless of culture these environments are preferred. Ulrich (1983) further suggested that people gain a lot of positive benefits from being in environments they prefer because preference is likely tied to individual needs as humans experience positive emotions in environments that are aesthetically appealing. Kaplan and Kaplan (1989) have also argued that preferences should not be considered a luxury, as preferences are tied to the needs of organisms. Despite theoretical differences in the path to recovery between ART and SRT, research in this field usually integrates both perspectives (Subiza-Pérez et al., 2019). That said, when measuring restoration, all studies measure subjective emotions and usually an objective measure of either stress (psychophysiological measures) or

attention (attention tasks). They then propose that their findings apply to the restorative literature in general, which encompasses both SRT and ART, even though they focus on studying either stress or attention and often with mixed results (e.g., Bowler et al., 2010; Ohly et al., 2016). I thus incorporated measures of emotion, stress, and attention in each study to ensure I could apply the findings to both theories and reduce the heterogeneity of the restorative literature results.

The Research Methodology of the Restorative Literature

Over the past 30 years, nature, specifically greenspace has been studied and found to be a restorative beneficial environment for health and well-being outcomes (e.g., De Vries et al.,2003; Bowler et al., 2010; Stevenson et al., 2018; Velarde et al., 2007). It has been predominantly studied using a comparison between two conditions: nature vs. urban (e.g., Nordh et al., 2011; Pearson & Craig, 2014; Stigsdotter et al., 2017). The issue with the extant research is that the conclusions from field studies (nature is more restorative than urban environments; (e.g., Kaplan & Kaplan, 1989)) has been established based on a methodology that uses just two dichotomous environments. One environment is usually a romanticised positive natural green setting (generally beautiful, tranquil, and aesthetically pleasing; (Bornioli & Subiza-Pérez, 2023)) and the other environment is usually a negative outdoor urban space commonly unattractive and commercial with motor traffic (ugly, busy, noisy, and not built for recreation purposes) and lacking natural elements (e.g., Bornioli & Subiza-Pérez, 2023; Hartig et al., 2003; Hartig et al., 1997; Hartig & Staats, 2006; Laumann et al., 2001; Ulrich et al., 1991).

The notion that there might not be sharp and easily identified distinction between “natural” and “urban” environments in terms of their restorative potential has been considered by other authors. For example, Kaplan (1993) notes the possibility of other restorative environments (e.g., museums) and White et al. (2010) found that researchers report less on the positive impact of

urban environments, thus identifying a large gap in the restorative literature. Additionally, Pearson and Craig (2014) have noted that the field of restorative environments tends to compare natural scenes against urban scenes, and "that there is a tendency to treat the categories of "natural" and "urban/built" as being more clearly defined and identifiable than may be the case in every-day judgement" (pp. 2). Interestingly, Herzog et al. (2003) found differences in ratings of restorative potential between different urban and natural environments (using photos in lab). Some urban environments were actually rated as more potentially restorative than some natural environments (e.g., Herzog et al., 2003; Nordh et al., 2011; Staats et al., 2016).

My aim is to investigate the potential benefits across a spectrum of natural and urban environments, moving beyond the traditional binary comparison. I intend to employ immersive environmental experiences to achieve more ecologically valid results. While some studies have examined natural and urban environments on a continuum, those that have, primarily utilize subjective measures, in-lab protocols, and images or imagined scenarios to determine restorative potential (e.g., Herzog et al., 2003). My research seeks to build upon these findings by determining whether restorative potential leads to measurable restorative outcomes through the use of immersive experiences with the environments. Such research will provide a more comprehensive understanding of the benefits and limitations of subjective predictions of restorative potential.

In this dissertation, I define 'nature' as the non-threatening, vegetation-rich outdoor spaces commonly studied in restorative research (White et al., 2020), while 'urban environments' refer to artificial, human-made spaces with little or no natural elements (Hartig et al., 2011). By examining the restorative potential of both nature and urban environments, I aim to better understand the benefits and limitations of each setting for the well-being of urban dwellers.

Studying Restorative Environments on a Continuum

Bornioli and Subiza-Pérez (2023) suggest restorative environments can be categorized based on the level of restoration they provide. The most fundamental aspect of a restorative environment is the absence of negative or taxing features, referred to as Containment. This is the basis for an environment to be considered restorative. Building on this, if restorative elements are introduced to a Containment environment, Passive Restoration can occur. Passive Restoration involves the viewer achieving a restorative experience from the environment characteristics without effort (Bornioli & Subiza-Pérez, 2023). Thus, in this dissertation, restorative environments were subdivided and categorized as either being low in restorative potential or high in restorative potential based on their capacity to provide restorative experiences. Environments that do not afford a Containment experience are classified as having low restorative potential. While environments that provide restorative features facilitating Passive Restoration are considered to have high restorative potential. To achieve this, it is crucial to understand which specific aspects of nature and urban environments provide restorative opportunities and which do not.

Preliminary studies have identified elements perceived to contribute to restorative experiences, such as greenery, biodiversity, and aesthetic appeal. Nordh et al. (2009, 2011) found that urban parks with greater grass coverage, more trees, and larger green areas were associated with higher restorative potential. Wang et al. (2019) reported increased restorative potential with more trees, flowers, or water in images. Aesthetic quality and biodiversity have also been linked to restorative potential (Hands & Brown, 2002; Lee et al., 2014; Parsons & Daniel, 2002; Wang et al., 2019), but none of these features have been field tested for their restorativeness or how much they restore people's attention, affect, and reduce stress. In a study conducted by Janeczko

et al. (2021), it was discovered that an increase in environmental diversity, particularly in areas with natural slow decay, led to significant improvements in mood. Consequently, the researchers concluded that environments exhibiting greater diversity possessed enhanced restorative qualities, but it is unclear whether environmental diversity will impact other aspects of restoration including stress and attention. Additional evidence for the link between biodiversity and well-being can be found in the studies conducted by Southon et al. (2018) and Dallimer et al. (2012). These studies evaluated visual perceptions of diverse natural environments, ultimately concluding that individuals perceive greater well-being benefits from environments characterized by higher levels of biodiversity.

Regarding urban environments, restorative features of urban environments have received less attention than natural settings (Joye & van den Berg, 2018). However, certain elements can be manipulated to study the restorative potential of urban environments. Key aspects include the impact of tall buildings on stress levels (Asgarzadeh et al., 2012) and the potential restorative effects of shop fronts in malls and cafés (Staats et al., 2016). Additionally, historic urban environments and museums have demonstrated comparable restorative potential to urban parks (Fornara & Troffa, 2009; Hartig & Staats, 2003). By altering these variables in diverse urban settings, I hope to further investigate and confirm their restorative capacity.

Methodological Approach in Studying Restoration

To advance the understanding of restorative outcomes, this research will evaluate restorative potential using a combination of virtual reality technology and field studies. Additionally, restoration will be measured using subjective measures and more importantly objective measures of restoration, such as psychophysiological indicators for a more detailed evaluation of the restorative experience. Building upon previous studies that have confirmed the

positive impact of nature on affect (e.g., McMahan & Estes, 2015), this approach will contribute to a more comprehensive understanding of restorative experiences in various environments. Employing immersive experiences will enhance ecological validity in these studies (Bornioli & Subiza-Pérez, 2023), providing valuable insights to both the scientific and urban planning communities. By extending this research beyond traditional lab-based protocols using self-reports, I can further confirm the real-world impacts of various environments and perceived restorative features, contributing to the field of restorative environments. Additionally, the use of VR allows for complete control over the content of the environments, while also controlling many confounding factors of real-world environments (travel time to location, noise, light, weather, etc.) (Mattila et al., 2020). Furthermore, Huang et al. (2005) notes "the great usefulness of computer simulation is its ability to create highly realistic landscapes before the real design or planning projects are implemented" (p.207).

Finally, this dissertation endeavors to provide further evidence corroborating the findings from Menardo et al.'s (2021) meta-analysis on restoration in urban and natural environments, which found that nature was consistently perceived as more restorative than urban environments; as they put it, this perception "confirm[s] from an empirical point of view what is typically now considered a given in environmental psychology (Gifford, 2014; Staats, 2012)" (pp. 427). I will expand on the reviewed work by using more robust methodologies from cognitive neuroscience, including using psychophysiological measures of restoration, attention, and affect using field studies or immersive environments to confirm what is already a "given".

Research Purpose, Hypothesis, and Study Overview

The dissertation will examine restorativeness across a variety of natural and urban environments using a diverse set of outcome variables and methods. In this dissertation, I

focused all studies (1, 2, 3, and 4) on the restorative effects of natural and urban environments; assessed using subjective affective measures (as they have been found to measure restoration successfully; (McMahan & Estes, 2015)), objective measure of stress (physiological measures) and measures of attention (both subjective measures of attention and tasks measuring working memory, cognitive flexibility, and attentional control). This allows the results to contribute to our understanding of restorative effectiveness as it relates to the SRT and ART.

To replicate previous work, I will utilize urban and natural environments; however, in Studies 2, 3, and 4 I will also manipulate the restorative potential of different types of urban and natural environments. In order to study the environments as a continuum, I blurred distinctions between restorative/not restorative natural and urban environments. I also wanted to determine if some urban environments can be restorative (Bornioli & Subiza-Pérez, 2023). Finally, I used different stimuli (manufactured VR environments, immersive VR videos, and real-world environments) to evaluate and compare methods that measure restorative effects of environments.

My first hypothesis is that restorative potential will vary across different natural and urban environments, with natural environments inducing greater restorative outcomes compared to urban environments, as demonstrated by previous research. I also expect certain urban environments to induce a restorative effect, supporting the notion that restorativeness is not exclusive to natural environments. Finally, I predict participants can accurately gauge the restorative potential of an environment based on its visual characteristics, indicating alignment between participants subjective perceptions of restorative potential and the objective restorative capacity of diverse environments.

There is some debate regarding participant's ability to accurately estimate how they might behave/feel in the environment under investigation due to insufficient metacognition (Pearson & Craig, 2014), but previous studies have relied on these subjective ratings to provide suggestions of restorative environments. To test this theory, I have incorporated previously assumed restorative features into environments and I will investigate the impact the environment with the restorative features has on a number of measures of restoration. Additionally, I will use the Perceived Restorativeness Scale (Hartig et al., 1997) and correlational analysis between the PRS and measures of restoration to further test this hypothesis. Thus, helping other researchers better understand which environments are objectively restorative and which elements are consistently present in restorative environments, urban or natural.

Overview of Studies

Study 1

This study used VR environments to compare the restorative effects of one nature and one urban environment. The use of only two environments was to use the same approach as the literature for the first study to determine whether the urban and natural environments created provided similar restorative effects as those found in the literature.

Study 2

Due to the lack of a significant difference between the urban and natural environments in Study 1, I created two new VR environments that were more extreme examples of restorative nature and depleting urban environments. The primary objective of this study is to investigate whether the environments utilized in Study 1 contributed to the lack of expected results. Additionally, I incorporated a new variable in this study called Restorative Potential which is the expected ability of the environment to restore individuals. Thus, I could examine both urban and

natural environments and environments that differ in restorative potential (i.e., Nature-High Restorative Potential; Natural-Low Restorative Potential; Urban-High Restorative Potential; Urban-Low Restorative Potential).

Study 3

This study was conducted to conceptually replicate Studies 1 and 2, but using similar real-world environments.

Study 4

This study was designed to better test the hypothesis that individuals can accurately assess the restorative potential of different environments and elements of environments. It employed immersive VR technology and YouTube 360° videos. The study used nature and urban environments that varied in restorative potential. To assess participants ability to accurately predict restorative potential, the restorative potential of each environment was assessed using the Perceived Restorativeness Scale and these scores were then compared to restorative measures to identify if the scores correlated with the perceived restorativeness of the environment.

Chapter 2 Literature Review

This section offers a comprehensive review of research on the restorative effects of nature and urban environments. Nature has been studied using a diverse array of stimuli, including field studies using real nature, as well as lab-based studies using symbolic nature such as images or video. The diverse findings collectively emphasize the advantages of natural settings, forming the basis of my main hypotheses. Additionally, I provide context on the methodologies employed in past studies on nature, which inform my approach to investigating both natural and urban environments in this dissertation. I begin by examining the literature on nature, focusing on studies involving participants living in close proximity to natural settings. I then explore studies on nature interventions and the various methodologies used to measure the restorative effect.

Proximity to Greenspaces

Proximity to greenspaces in residential environments has been consistently found to benefit health and well-being. For example, Kuo (2001) conducted quasi-experiments on residents of apartment blocks who either had a view of trees/greenspace or did not. Kuo (2001) found that residents who were exposed to views of greenspace felt better able to manage stressful life events and experienced reduced mental fatigue, compared to those that did not have views of nature. Additionally, Maas et al. (2006) found higher perceived health ratings in areas that had a higher amount of greenspace surrounding residence homes. In addition, a Dutch study of over 10,000 people found a positive relationship between living in green environments and three global health indicators 1) number of symptoms experienced in the last 14 days, 2) perceived general health, and 3) scores on the Dutch version of the General Health Questionnaire, which indicates one's propensity to psychiatric morbidity (de Vries et al., 2003). These health benefits have also been found by Mitchell and Popham (2008) who note that greenspace decreased

circulatory disease-related mortality in income deprived communities. Finally, a systematic review of mortality and residential greenspace found that the majority of these studies show a reduction in risk for cardiovascular disease mortality in areas with more residential greenness (Gascon et al., 2015). Clearly, positive health benefits exist from living near greenspace. However, studies show that if a person does not have access to greenspace in the immediate vicinity of their residence, they can still experience consistent psychological and physiological benefits through short term exposure, including exposure for days (e.g., Hartig et al., 1991), hours (e.g., Park et al., 2007), and even minutes (e.g., de Bloom et al., 2017; Berman et al., 2008; Zelenski & Nisbet 2014).

Exploring the Holistic Effects of Nature Exposure (Field Studies)

Roger Ulrich proposed the SRT to explain why even short-term exposure to natural environments restores affect by reducing negative moods, increasing positive moods and reducing stress, which in turn helps increase attention (Ulrich, 1983; Ulrich, 1993; Ulrich et al., 1991). Meta-analysis and systematic reviews on the restorative effect of nature (e.g., Bowler et al., 2010; Corazon et al., 2019; Ohly et al., 2016) have found consistently that exposure to non-threatening natural settings that support survival have a calming effect with an immediate unconscious and spontaneous emotional experience of positive emotions and reduced levels of arousal for most people (Jiang et al., 2021). The next section highlights some of the studies supporting the psychophysiological, affective, and attentional effects nature has on a restorative experience.

Forest Bathing (Shinrin-yoku)

A large amount of evidence for the SRT comes from the Shinrin-yoku literature which focuses on psychophysiological and affective measures to understand the effects of nature

interventions. Shinrin-yoku is the practice of forest bathing in which participants walk slowly or sit in forests for short periods of time (30 minutes to an hour) and take in the atmosphere of their surroundings for health benefits (Tsunetsugu et al., 2010). Many medical researchers in Japan have studied the experience of Shinrin-yoku and have consistently shown positive effects on measures of emotion and physiological indicators of stress (e.g., Tsunetsugu et al., 2010). For example, Hansen et al. (2017) conducted a literature review on Shinrin-yoku, finding many studies demonstrated a positive correlation between Shinrin-yoku and positive physiological and psychological outcomes.

Tsunetsugu et al. (2010) studied the trends emerging from the Shinrin-yoku research and found numerous benefits of forest bathing, such as significant positive changes in measures of autonomic nervous system activity, including heart rate variability (HRV), blood pressure, and pulse rate. Park et al (2007a), focused on salivary cortisol (a hormone released during the stress response) and cerebral activity, finding that those exposed to a forest–compared to a city–environment had significantly lower cerebral activity in the prefrontal cortex. Additionally, Park et al. (2007a) found that salivary cortisol was significantly lower for those exposed to the forest compared to the city group, thereby suggesting that Shinrin-yoku can induce relaxation for the body and mind.

In a study conducted at 24 field sites across Japan, Park et al. (2007b) discovered that visiting a forest environment led to reduced salivary cortisol levels compared to spending time in an urban setting. Additionally, Park et al. (2007b) found enhanced parasympathetic nervous system activity and a lowering of sympathetic nervous system activity, compared to those exposed to a city environment. Morita et al. (2007) assessed the psychological effects of a forest intervention, finding hostility and depression reduced significantly while liveliness increased

significantly, after the forest visit, compared to the control day when participants did not visit a forest. They also found that respondents' psychological stress impacted the degree to which the mood changed after the forest environment. The results suggested that the more stressed the individual felt, the greater the beneficial effect (Morita et al., 2007). Additionally, Miyazaki and Motohashi (1995) found that after 40 minutes of walking in an ancient cedar forest, tension, depression, anger, fatigue, and confusion scores lowered while scores for vigor increased. Finally, they found that salivary cortisol was lower after the forest walk compared to a 40 minute walk in a laboratory.

In a meta-analysis of Shinrin-yoku research, Antonelli et al. (2019) found that while heart rate and blood pressure did not lower consistently, and heart rate variability (HRV) did not increase consistently after forest bathing across all Shinrin-yoku studies, they did find a consistent trend in cortisol levels to be lower after exposure to forest environments. This research supports the SRT, providing evidence that exposure to forests through Shinrin-yoku, positively improves psychology and physiological indicators of stress. Other limitations of the Shinrin-yoku literature that support continuing this research comes from a review by Hansen et al. (2017) who identified a number of limitations from the Shinrin-yoku studies such as small sample sizes, lack of diversity, and geographical constraints in existing studies. Tyrväinen et al. (2014) also highlighted the need for additional research on Shinrin-yoku due to the limited number of studies and potential psychological and physiological effects on different populations outside of Asia. Additionally, Tsunetsugu et al. (2010) and Antonelli et al. (2019) emphasized the importance of gathering more physiological measures when studying Shinrin-yoku, considering the inconsistencies in existing psychophysiological data. To address these gaps, further studies with

diverse populations should be conducted outside of Asia using both psychological and physiological measures.

Holistic Nature Interventions in Western Studies

Numerous field studies beyond the Shinrin-yoku literature have demonstrated the positive effects of nature exposure on attention and emotional well-being. For instance, Hartig et al. (2003) discovered that viewing trees and walking in greenspaces reduced blood pressure and feelings of anger while increasing positive affect, whereas urban environments yielded opposite emotional effects. Moreover, participants performed better on attention tasks in nature compared to urban settings (Hartig et al., 2003). Similarly, Hartig et al. (1991) found that participants who went on a multi-day wilderness vacation exhibited higher attention levels based on a proofreading task and reported increased happiness scores during a one-month follow-up, suggesting that restorative experiences like wilderness vacations may protect individuals from daily life stressors. Finally, Berman et al. (2008) also reported improvements in emotion and attention after a 50-minute nature walk, as opposed to an urban walk. Collectively, these field studies highlight the significant positive impact of nature exposure on human cognition and emotional well-being. This evidence emphasizes the importance of integrating natural elements into daily life as an effective strategy to improve attention, alleviate stress, and improve affect.

Exploring the Benefits of a Visual Connection to Nature

While authentic natural environments have been shown to provide stronger restorative effects (Stevenson et al., 2018), the use of images and videos presents a more accessible and resource-efficient alternative (García et al., 2006). This is particularly important to consider when acknowledging that direct access to natural environments may be limited for certain individuals. Consequently, exploring alternative media and methods that can induce restorative

experiences in the absence of direct access to nature becomes crucial. The following section will delve into various effective approaches used to induce restorative outcomes when natural environments are not reliably available.

Simulated Nature and Restoration

Restorative Effect of Images

Extensive research has been conducted on the restorative effects of symbolic representations of nature, such as images and videos, in controlled laboratory settings. These studies have contributed to the understanding of how even indirect exposure to nature can positively impact human well-being and stress reduction. Ulrich (1979) for example used 50 images of nature and urban environments and found that positive affect increased after viewing nature images while also reducing fear arousal. In another study, Ulrich (1981) exposed participants to nature and urban scenes. Results indicated that nature scenes alone had a positive impact on psychophysiological measures of stress (Ulrich, 1991). In later research, Berman et al. (2008) and Berto (2005) found that directed attention can be improved after participants are exposed to nature images.

Restorative Effect of Videos

Researchers have employed videos as a tool to investigate nature's restorative qualities, revealing notable positive outcomes. These studies suggest that the use of video as a medium can provide restorative benefits similar to those experienced in actual natural environments. For example, Ulrich et al.'s (1991) landmark study used videos and found that not only did positive affect increase after participants watched a video of nature, as opposed to a video of urban environments, but anger/aggression also decreased. Furthermore, Ulrich et al. (1991) measured heart rate and skin conductance and found that the nature videos lowered each of these

physiological measures. These results suggested that the parasympathetic nervous system was most active during nature videos. After inducing stress in their participants, De Kort et al. (2006) found that heart rate was significantly slower after 1 minute of an immersive nature video, suggesting that participants were more relaxed after viewing this short symbolic version of nature. Finally, Mayer et al. (2009) filmed a walk in an arboretum and had participants either watch the recording or walk through the arboretum themselves. They specifically wanted to test if simulated nature can induce the same beneficial effects as real nature exposure. In their study 2, they found that positive affect and ability to reflect was equally experienced in the simulated nature (video) and the real nature condition, suggesting that simply viewing videos of nature can have similar if not the same impact on emotion restoration. That said, they found no differences for attention measures in either of the simulated or real nature conditions. They reflect that perhaps there may not have been enough statistical power to find a statistically significant difference between the simulated nature and the real nature (as no difference was found) when also including an urban video for comparison. In a third study, they replicated their second study with natural environments only (in lab video and field experiment). They found that real nature had a significantly stronger impact, with participants reporting significantly more positive emotions and a greater ability to reflect after the real nature experience compared to the nature video (Mayer et al., 2009).

Restorative effects of Virtual Reality

Virtual reality (VR), which provides the immersive experiences of entering an environment, could be more beneficial than movies and images. Virtual experiences bypass constraints in field studies, such as weather, and brightness effects, which can impact participants (Chen et al., 2016). As Hartig et al. (2011) note, when we substitute pictures and video for real

nature, our participants may not have experiences similar to a real environment because they could not enter the environment or interact with it. As such, VR might offer an opportunity for high levels of control and more realism. Several studies have used VR and immersive media to assess the restorative effects of nature. For example, Valtchanov et al. (2010) found that when participants explored a virtual forest, their positive affect increased, while stress, which was induced pre-environmental exposure, decreased. More specifically, skin conductance was significantly lower for those exposed to the virtual forest condition compared to an abstract art slideshow. In another study, Mattila et al. (2020) found that a 5-minute virtual forest experience improved positive affect as measured by the Positive Affect Negative Affect Schedule (PANAS) scale and the Vitality scale. Additionally, they found that the VR forest was perceived to be as restorative as a real forest, but more fascinating and coherent. In another VR study, Alyan et al. (2021) had participants experience either a realistic virtual forest or a dream-like virtual forest. They found that heart rate and skin conductance decreased significantly more after the realistic virtual forest compared to the dream-like forest environment. They argued that this result indicates that realistic virtual environments can reduce sympathetic nervous system activity, which may result in quicker recovery from stress (Alyan et al., 2021). Additionally, participants in the realistic virtual forest had lower depression and confusion scores on the Profile of Moods Scale (Alyan et al., 2021). Finally, Valtchanov and Ellard (2010) found that a 10-minute walk in a virtual nature environment was enough to improve affect and reduce stress levels (measured using skin conductance), compared to a virtual urban cityscape walk or a neutral environment composed of large geometric shapes. These results demonstrate that VR nature experiences can have a similar effect to real nature stimuli increasing parasympathetic activity and reducing

sympathetic nervous system activity as Park et al. (2007b) and Park et al (2010) found in their field studies on Shinrin-yoku.

The Impact of Natural Environments on Stress Recovery and Affect

Berto (2014) conducted a literature review of how nature helps people coping with psycho-physiological stress, noting that the physical settings people are in can play a substantial role in how the individual will be able to cope with and recover from stress. Berto (2014) specifically focuses on how natural environments aid in the recovery from physiological stress and mental fatigue. In her literature review, Berto (2014) reinforced the claim that, "in fact, exposure to natural environments protects people against the impact of environmental stressors and offers physiological, emotional, and attention restoration more so than urban environments" (pp. 394). She notes that simple visual access to natural environments can reduce physiological symptoms of stress, mitigate the negative effects of stress, and reduce negative moods while enhancing positive emotions. Additionally, nature can help restore declines in cognitive performance associated with stress (Berto, 2014). Velarde et al. (2007) also note that the visible landscape may affect humans in different ways, such as inciting an aesthetic appreciation for the environment and impacting people's health and well-being. Velarde et al. (2007) conducted a literature review on the health effects of viewing landscapes and how different types of landscapes may differentially impact people. They found that natural environments consistently had a positive effect on health, whereas urban environments did not induce the same level of positive outcome and in some cases, even lead to negative health effects (Velarde et al., 2007). However, they note a lack of diversity among landscape classifications and found that the literature generally categorizes environments as either natural or urban. Essentially, few studies used subcategories within these natural and urban group classification.

The Impact of Natural Environments on Attention Restoration

While there are many studies focused on the emotional and psychophysiological benefits of interacting with nature there has been some debate regarding how attention is restored from nature interventions. Ohly et al. (2016) performed a systematic review and meta-analysis of the attention restoration potential of natural environments, finding the review process difficult due to the small number of investigators, small samples, heterogeneity of reporting of study quality indicators, and heterogeneity of outcomes. Ohly et al. (2016) found that researchers are still uncertain about which aspects of attention are affected by nature, largely because many studies have not clearly identified operational definitions of "directed attention" as conceptualized by Kaplan and Kaplan (1989) and Kaplan (1995). Stevenson et al. (2018) performed a systematic review of the ART literature to clarify the attention process affected by nature stimuli. They found that working memory, cognitive flexibility, and attentional control are improved with nature interventions. Interestingly they also found that exposure to real environments enhanced the restorative effect compared to virtual exposure.

Uncertainties in the Restorative Literature

Up until this point, I have discussed how living near nature can be beneficial to health and well-being and how nature interventions can be restorative. However, uncertainties still exist with respect to the restorative experiences of nature. For example, Bowler et al. (2010) conducted a systematic review of 25 studies that focused on mostly short-term exposure to nature while walking or running. The most often reported result was a change in subjective emotions, which is only one measure of restoration according to SRT and ART. It would have been more promising for this field of research to find consistent positive effects on objective measures of stress (psychophysiological measures) and attention throughout the literature. They also

conducted a meta-analysis and found generally positive outcomes from walking or running in nature, compared to an indoor or outdoor urban environment; however, attention scores did not significantly improve after adjusting effect size for pretest differences, with even less evidence supporting changes in blood pressure and cortisol. Stevenson et al. (2018) also found only low to moderate effect sizes of attention improving after nature exposure from their meta-analysis on ART. Bowler et al. (2010) concluded their review by suggesting that natural environments have a positive impact on well-being, but more research is needed to further understand the relationship.

More recently, Corazon et al. (2019) conducted a systematic review of the past 8 years in research related to outdoor nature-based interventions on psycho-physiological stress recovery. They found that outdoor nature interventions have a positive effect on emotional parameters related to stress relief. However, studies using physiological (objective) measures of stress showed more ambiguous results (Corazon et al., 2019). They conclude, as Bowler et al (2010) had, that a solid base exists for our understanding of how outdoor nature-based experiences impact psychology and emotions, but physiological results were very heterogeneous.

Twohig-Bennett and Jones (2018) also conducted a systematic review and meta-analysis on health outcomes from greenspace exposure, which included literature from both the Bowler et al. (2010) and Corazon et al. (2019) review period. The review results align with previous reviews, finding that greenspaces have multiple health benefits. However, researchers are still unable to pinpoint the exact elements of nature responsible for these positive effects, the specific health outcomes linked to distinct environmental patterns (e.g., tree density, manicured parks, pathways), or how to prescribe nature recommendations for particular health outcomes. They also note that the meta-analysis was hampered by poor study quality and high levels of

heterogeneity (Twohig-Bennett & Jones, 2018). This heterogeneity in methods makes it difficult to replicate the best practices to study restorative environments.

Assessing the Perceived Restorative Potential of Diverse Environments and Their Distinctive Features

I have reviewed how nature exposure is more beneficial than exposure to urban environments. However, I have not yet discussed the literature investigating diverse versions of nature and urban environments, and the different restorative or nonrestorative characteristics of these spaces. Kaplan and Kaplan (1989) and Kaplan (1995) posited four factors (extent, fascination, being away, and compatibility) that help make a restorative environment according to the ART. The SRT, differs in its approach, concentrating on the importance of particular stimuli that enhance survival, such as vegetation and water, which are regarded as vital components in fostering restorative environments (Ulrich, 1993). In order to effectively assess the restorative potential of urban environments, which often lack survival-related stimuli, it is crucial to investigate studies that do not use the SRT to understand restorative potential. Notably, studies verifying ART based assessment tools are unique in investigating both natural and urban environments for restorative potential, making ART an indispensable tool for studying restorative urban conditions. Consequently, when studying the restorative effects of various environments, it is crucial to utilizing both SRT and ART components to study restorative potential. This approach enables a more comprehensive understanding of restorative potential across diverse settings.

Restorative Elements

Prior research has investigated elements that contribute to restorative environments, such as trees and bushes (Nordh et al., 2011; White et al., 2010), relying on participants' predictions of

emotional responses to these elements in images rather than actual experiences. Although Nordh et al. (2011) assert that fatigue scenarios and participants' ability to imagine familiar environments are appropriate in restorative environment research, these studies do not validate their findings with follow-up field studies. Despite this limitation in understanding the true restorative potential of these features, the available literature on restorative environment elements has been included in this dissertation due to the scarcity of research in this area.

The Influence of Natural Elements on Restoration

Nordh et al. (2011) specifically studied the restorative components of pocket parks (accessible nature) that were no bigger than a city block. In their study, they identified that the amount of grass, trees, and people were important for a restorative experience. This is consistent with Nordh et al's (2009) conclusions that the number of trees, bushes, and flower beds and the amount of grass correlated positively with the likelihood of restoration. Additionally, Kaplan's (2007) research supports these results, as it also found a positive correlation between the number of trees and preference for the environment. More trees in a space increases the biodiversity and scenic beauty (Hands & Brown, 2002; Parson & Daniel, 2002; Wang et al., 2019) which can also help provide the restorative experience of fascination through attracting attention (Wang et al., 2019). Wang et al (2019) specifically found that restorative potential ratings increased due to an increased number of trees, flowers, and clear water in images, suggesting that adding these elements to urban environments could increase restoration in terms of mental stress. Kaplan (1995) explains that the number of trees can lead to the feeling of being away, as the number of trees restructure the environment to be more complex and rich, taking people's attention into this new fascinating environment that takes them away from their routine life. Wang et al. (2019) also contend that with more trees there is a potential to conceal information which may

encourage rich imagination and the desire to explore more due to a feeling of extent. Moreover, Fuller et al. (2007) discovered that increased biodiversity is associated with enhanced perceived well-being. Their findings revealed that the elements within a greenspace, rather than its size, can influence perceived well-being. For instance, a large grass field may provide a similar level of well-being as a smaller area with greater biodiversity (Fuller et al., 2007).

Restorative Urban Elements

Research investigating restorative urban environments is limited, but some studies suggest that museums (Kaplan et al., 1993), art galleries (Clow & Fredhoi, 2006), and monasteries (Ouellette et al., 2005) may possess restorative qualities. However, the primary focus of this dissertation is on the exploration of outdoor nature and outdoor urban environments. Consequently, these indoor urban areas will not be considered further in the context of this study.

Weber and Trojan (2018) conducted a systematic review on studies focused on the restorative value of urban environments finding architectural elements, cultural, and leisure areas had perceived restorative value, whereas streets and residential areas were not perceived as restorative. Other urban environments that may hold restorative potential, as perceived by participants are as follows. Of streetscapes, buildings and industrial zones Hernández and Hidalgo (2005) found participants rated images of streetscapes as the most restorative setting and this was especially true when natural elements were present. Similarly, Staats et al. (2016) found that when participants imagined being in either an urban park, a café, a shopping mall, or a busy street, participants indicated the most restorative environments in descending order were urban park, the café, the shopping mall, and then the walk beside a busy street was deemed least restorative. Interestingly Lindal and Hartig (2013) discovered that architectural variation and lower building heights contributed to higher perceived restoration likelihood. Finally, Galindo

and Hidalgo (2005) found that of four categories of urban environments, cultural-historic places and recreation areas were rated as most restorative, compared to housing areas and panoramic areas. Interestingly participants rated residential areas as least restorative and least liked. Finally, Fornara and Troffa (2009) observed that visitors perceived a historical site as equally restorative as an urban park, compared to a shopping mall and a panoramic site, emphasizing the potential for historical sites to provide restorative benefits.

Restorative research highlights that specific elements in natural environments, such as trees, flowers, bushes, and biodiversity, can be modified to influence an environment's restorative potential positively or negatively. In contrast, urban environments frequently contain stress-inducing stimuli like crowds, traffic, and tall buildings (Asgarzadeh et al., 2014; Staat et al., 2016; Ulrich et al., 1991). Urban settings, however, also encompass restorative elements, including cultural-historic sites, recreation areas, shopping malls, and cafés. These elements can likewise be manipulated to increase or decrease the restorative potential of such environments.

Assessing Restoration

Affective/Emotion Measures

In line with the SRT, which emphasizes the role of instantaneous, instinctual affective states in guiding human behavior and stress responses, this dissertation employs affect as a means to measure emotional changes. Affective valence, is a critical component of emotion, categorizing emotional experiences on a continuum from positive to negative based on their pleasantness or unpleasantness (Watson et al., 1988). This concept has been extensively studied and recognized as a fundamental dimension of emotion (Russell, 2003). Positively valanced emotions, like joy and excitement, are characterized by pleasant feelings, while negatively valanced emotions, such as sadness and anger, are considered unpleasant (Ekman, 1992).

Additionally, emotion has been assessed based on individual emotions such as fear, awe, and sadness (Shiota et al., 2007; Ulrich et al., 1991; Van Cappellen & Saroglou, 2012).

Positive affect plays a crucial role in fostering overall well-being, as it positively impacts various factors that contribute to mental and physical health. Cultivating positive emotions allows individuals to experience improvements in multiple areas of their lives and enhances their ability to cope with adverse situations effectively (Isen, 2009; Taylor & Aspinwall, 1996). For example, research indicates that individuals with high levels of optimism and hope manage stress more effectively (Armor & Taylor, 1998; Taylor & Aspinwall, 1996). Additionally, research on the choice overload effect has revealed that positive affect helps people manage and enjoy a variety of options despite potential stress (Dhar, 1997; Isen, 2009; Iyengar & Lepper, 2000). Consequently, urban environments that evoke positive affect may aid in reducing the negative impacts of choice overload. Additionally, natural environments capable of inducing positive affect could potentially alleviate the choice overload experienced by urban dwellers, thereby enhancing their overall well-being. These findings suggest that environments eliciting positive affective responses may contribute to greater improvements in stress reduction and overall well-being.

Looking for changes in affect can be used to determine how an environment is impacting the participants either positively or negatively. Most of our emotional responses happen instantaneously via the autonomic nervous system which either activates the sympathetic nervous system for dangerous stimuli or the parasympathetic nervous system for stimuli that promote relaxation (Myers, 2010). Thus, even short exposure to environments can induce a measurable response that can be mapped onto physiological measures to better understand how the environment impacts participants. Additionally, psychological distress activates the

hypothalamic-pituitary-adrenal (HPA) axis and cardiovascular responses, as sensory information is processed by the prefrontal cortex to evaluate potential threats and available coping mechanisms (Campbell & Ehlert, 2012). This process induces emotional responses via limbic connections and triggers physiological systems such as the HPA axis. Consequently, both psychological and physiological measures of stress can be employed to monitor restoration, despite limited research on the direct correspondence between these measures (Campbell & Ehlert, 2012).

Although the psychology-to-physiology trigger theory has been assumed for decades (Mauss et al., 2005), limited research explicitly examines the correspondence between physiology and emotional stress responses (Campbell & Ehlert, 2012). Some studies have found covariation between perceived stress and HPA/autonomic nervous system activity (Oldenhinkel et al., 2011) and a strong covariance between psychoendocrine responses following a stressor (Schlotz et al., 2008). However, a meta-analysis by Dickerson and Kemeny (2004) showed no consistent relation between cortisol responses and subjective distress.

Despite this theoretical inconclusiveness, my studies will assess affective responses alongside physiological stress changes, as this dissertation is guided by the SRT and ART, both of which posit a relationship between emotion and the stress response. This relationship is commonly evaluated using psychophysiological measures in cognitive neuroscience, and strong evidence supports physiological changes in response to emotions (Berto, 2014; Potter & Bolls, 2012).

Physiological Indicators of Stress

Exposure to natural scenes has been shown to elicit positive emotions, activating the parasympathetic nervous system, which in turn lowers heart rate, blood pressure, skin

conductance, and reduces negative emotions (Ulrich et al., 1991). The prefrontal cortex controls the adaptive stress response, suppressing areas like the amygdala when an individual feels safe (Grupe & Nitschke, 2013; Maier, 2015; Motzkin et al., 2015). However, when safety is compromised, the amygdala reactivates the stress response, increasing heart activity and blood pressure for heightened access to energy and oxygen (Brosschot et al., 2018).

Cardiovascular measures have been widely used in restorative environment research (e.g., Laumann et al., 2003; Park et al., 2007; Tsunetsugu et al., 2013; Ulrich, 1979; Ulrich 1981; Ulrich et al., 1991; Vrijkotte et al., 2000). Blood pressure has also been employed to measure the restorative effects of natural environments (Hartig et al., 2003; Ulrich et al., 1991), while heart rate has been used to track restoration in natural and urban environments (Laumann et al., 2003; Pretty et al., 2005). Employing these measurements in stress response studies enables comparison with previous research and further exploration of the connection between natural environments and restoration. Ideally, the psychological and physiological measures will align, providing convergent and valid results that instill greater confidence in findings.

Assessing Attentional Responses to Nature Stimuli

Alongside measuring affect and stress, assessing attention is crucial as both the SRT and the ART propose that attention is significantly influenced by exposure to nature and can be restored through exposure to restorative environments. Specifically, the use of nature interventions has been found to improve working memory, cognitive flexibility, and attentional control (Stevenson et al., 2018). To effectively measure attention restoration, it is essential to assess one's ability to inhibit distractions, as suggested by James (1892) and reaffirmed by Kaplan (1995). Specifically, Kaplan (1995) proposes that nature provides relief compared to urban environments due to the latter's depletion of attentional resources caused by competing

stimuli. While heterogeneity exists in attention measures within the restorative literature (Ohly et al., 2016), the n-back task, frequently used in neuroimaging research, is generally considered a working memory task (Miller et al., 2009). However, a key limitation of this tool and other attention assessments is its susceptibility to stress, as selective attention has been shown to improve under stress (Chajut & Algom, 2003), rendering attention measurement tools that require selective attention less reliable in stress-inducing studies. Thus, studies that induce stress should not use attention measurement tools that require selective attention.

Chapter 3 Study 1

Introduction

This study used Virtual Reality (VR) to compare the restorative effect of a natural environment with an urban environment. Traditionally, restorative effects have been studied using dichotomous environments (i.e., natural vs. urban; Pearson & Craig, 2014), so for the first study I used the same approach as the literature, creating two virtual environments: one natural and one urban. My goal was to ensure these environments provide restorative effects similar to those found in previous studies. By then building upon these established methods, I aim to further incorporate various stimuli to deepen our understanding of the factors contributing to the restorative potential of both natural and urban environments.

I modeled the VR environments after environments that were around the University of Waterloo, which meant that the stimuli sampled commonly experienced environments familiar to the participants. This ensured that I can test the results of this study in similar real-world environments to confirm the findings of this VR study. However, this meant that the environments were not as spectacular in their representation of nature and urban environments as previously studied (Bornioli & Subiza-Pérez, 2023). However, Herzog et al. (1976) and Milligan and Bingley (2007) found that people prefer familiar environments. Such environments can impact restoration outcomes (Purcell et al., 2001). Additionally, many of the studies focused on restorative environments focus on familiar environments (e.g., Nordh et al., 2009; 2010). Finally, many studies on restorative environments use urban landscapes that do not resemble the urban spaces most residents experience in their everyday life (Zhao et al., 2020), so I thought I would study the effects of a familiar everyday urban environment (moderate building height, shopping area) with that of an everyday nature environment (urban forest in a park). By using these types

of environments, the research focused on everyday environments that are likely to be encountered by a large proportion of city dwellers. I hypothesize that the forest/greenspace will be more restorative, than an urban environment that lacks natural elements.

Methods

The primary objective of this study is to investigate the restorative capacity of everyday urban and natural environments using Virtual Reality (VR) technology. Participants were outfitted with heart rate and blood pressure monitoring devices to measure psychophysiological changes, and answered questions related to their stress, attention levels and affect.

All studies reported in this dissertation received approval from the University of Waterloo ethics committee.

Participants

Participants were all University of Waterloo undergraduate students who were recruited through the SONA website for students in psychology courses. University students are a good participant pool because they frequently deal with significant levels of stress, anxiety and or depression (Regehr et al., 2013) with substantial health risk factors of irregular sleep, personal relationship changes, over-drinking, and academic pressure (Eisenberg et al., 2007). Many studies have found that participants who experience more stress also experience greater restoration (Morita et al., 2007). Additionally, Menardo et al. (2021) suggests that undergraduates are a good representative sample of the general population when the aim is to investigate perceptions of restoration in different environments. Participants received a course credit of .5 for every half hour of participation. Both male and females were recruited for this study. This study was conducted with 46 participants. I removed 9 participants due to simulator

sickness or equipment malfunctioning. I had 26 participants identify as female and 11 participants identify as male with participants aged between 17-32 (M = 20.4, SD = 2.46).

Virtual Reality Display

The two environments were displayed using an nVisor SX60 head-mounted display (HMD). The nVisor SX60 HMD is PC powered VR which provides 44° horizontal FoV, 35° vertical FoV, and 60° diagonal FoV, with 2xLCoS binocular display and a resolution of 1280x1024 per-eye. This HMD does not come with controllers and uses 3 DoF tracking, meaning it had 3 axis orientation tracking, so the participants could move their head in the 3 axes an object can rotate in: Yaw (vertical axis), Pitch (transverse axis), and Roll (longitudinal axis). To allow for exploration using the HMD I had the participants use a mouse and hold down the left button to move forward in the environments.

The HMD was a wired video DVI SXGA connection and because the HMD was wired, the participants could only walk a short distance in the lab. This device helped limit the participants' movement, reducing movement artifacts in the physiological measures. The researcher was in the room watching the participant to ensure no adverse events occurred, such as bumping into tables and getting pulled by the wire from the HMD. In addition, they could assess participants for motion sickness, so the participant never became overly impacted by the symptoms of cybersickness.

Stress Induction

To study the relation between restoration and environment type, there needs to be depleted psychophysiological resources. To cultivate restorative needs, studies have reduced participants adaptive resources through stress and/or fatigue induction, guided by the two restoration theories (Han, 2021). Some studies use a stress induction to elevate baseline stress which helps to

facilitate the measurement of stress recovery especially when measuring physiological responses (Beil & Hanes, 2013), while others use an imagined stressful scenario to increase psychophysiological stress (Han, 2021). To assess changes in restoration, this study employed the Trier Social Stress Test (TSST) as a stress induction method. The TSST has been shown to significantly impact physiological indicators of stress, making it an appropriate choice given my use of physiological measures in this research.

Trier Social Stress Test (TSST)

The TSST was used in this study because it is relatively easy to administer and proven reliable for the induction of acute psychosocial stress (Campbell & Ehlert, 2012). It involves a speech regarding a job interview and an arithmetic task requiring subtraction (Campbell & Ehlert, 2012). The combination of social-evaluative threat from negative judgement by others and uncontrollable outcomes in performance have been associated with the largest and most reliable cortisol response compared to other laboratory stressors (Dickerson & Kemeny, 2004). The social and cognitive stress the TSST induces are experienced everyday and can lead to chronic stress if not mitigated.

Measuring Stress

To study the SRT I will study stress with a holistic approach by collecting subjective psychological and objective physiological data. Ulrich et al (1991) suggested that even the most basic natural scene activates positively-toned emotions, which can induce a parasympathetic nervous system response. This response can result in several behavioral changes, such as lower heart rate, blood pressure, and skin conductance (Ulrich et al.,1991). Holistic approaches are useful, because psychophysiological pathways of stress are complex, which makes them impossible to measure with one tool (Beil & Hanes, 2013).

Psychological Measures

Examining psychological activity during stress is essential, as emotional and cognitive processes primarily trigger arousal, leading to adverse physiological states (Campbell & Ehlert, 2012). These states contribute to long-term health issues (Campbell & Ehlert, 2012). Additionally, it is important to determine the direction of the arousal as either a positive happy, elated, excited affective state or negative fear and panic (Myers, 2010). Campbell and Ehlert (2012) hypothesised that the integration of sensory information by the prefrontal cortex, provides cognitive evaluations of the significance of a stimulus and the available coping strategies. This then initiates the emotional response via limbic connections and ultimately activating physiological systems like the HPA, suggesting an association between the physiological arousal and subjective emotional stress experienced (Campbell & Ehlert, 2012).

The Zuckerman Inventory of Personal Reactions Scale

I selected the Zuckerman Inventory of Personal Reactions Scale (ZIPERS; Zuckerman, 1977) to evaluate psychological well-being. This tool evaluates positive affect and negative affect among other key psychological states. My choice was influenced by its usage in several other studies, including Hartig et al. (1991), Hartig et al. (2003), Ulrich (1981), Ulrich et al. (1991), and Valtchanov and Ellard (2010), which examined the restorative effects of nature. Notably, Ulrich et al. (1991) employed this scale to assess the restorative potential of diverse urban and natural environments, extending its application to everyday settings such as a mall and a busy street among other urban environments. By using ZIPERS, I can more readily compare the results of this dissertation to those of other influential studies on the restorative effects of nature and urban environments.

The ZIPERS assesses affective states according to five factors of emotion: fear, positive affect, anger/aggression, attentiveness/interest, and sadness such as “I feel like acting friendly or affectionate” or “I feel like hurting or ‘telling off’ someone”. However, it also has questions related to subjective attentiveness, such as “I feel attentive or focused”. Participants indicate the degree to which each item describes the way they feel at that exact moment using a 5-point Likert scale.

I did not analyze the questions from the ZIPERS scale that ask the participant how fast they felt their heart was beating or how fast they were breathing because I had objective measures of heart rate. Furthermore, I utilized the question "I feel attentive or focused," to gain insight into participants' Subjective Attention. The reason for measuring subjective attention in this way was because acute stress has been demonstrated to enhance vigilance, capturing an individual's attention (Allen et al., 2016; Chajut & Algom, 2003; McEwen, 2007). However, Rojas-Thomas et al. (2023) found that while social-evaluative threat increased basal activity of the coeruleus-norepinenphrine system, enhancing alertness, it decreased voluntary attentional resources. This suggests that social-evaluative threat impacts attention similar to urban environments. As a result, the stress induction may have a mitigating effect on objective attention-based measures, but if I measure subjective attention, I should get more naturalistic results of how restorative environments can reduce everyday attention fatigue. Consequently, in this study, which incorporated a stress induction, I opted for a subjective measure of attention, as an attention task might be influenced by the presence of stress.

Subjective Stress

Incorporating the perceptual aspect of stress was crucial, as focusing solely on physiological measures without considering psychological reactivity would yield an incomplete

understanding of stress exposure (Campbell & Ehlert, 2012). I evaluated subjective stress using the following question: "How stressed do you feel right now on a scale from 1 to 5, 1 being not stressed at all to 5 very stressed?" This question enabled me to gauge subjective stress levels and further corroborate the physiological stress response measures. The ZIPERS scale does not include a question assessing subjective stress, making this additional question essential for a comprehensive assessment.

Physiological Measures

Blood Pressure and heart rate were used as measures of stress. They have been used to measure physiological signs of stress and well-being in several studies that compared participants' exposure to urban and forest environments (e.g., Horiuchi et al., 2013; Park, et al., 2008; Park et al., 2011; Tsunetsugu et al., 2013; Ulrich et al., 1991). An additional advantage of measuring heart rate and blood pressure is they are controlled by the autonomic nervous system, which can show unconscious changes in stress levels based on how high or low both physiological measures are (Potter & Bolls, 2012). Additionally, researchers have found that, when using pre-post test measurements in controlled field studies on forest therapy, cardiovascular outcomes such as blood pressure and heart rate are robust and positive for health and well-being (Zeng et al., 2020).

Blood Pressure

Blood Pressure was assessed using a digital blood pressure cuff placed on the participant's upper arm, a method also employed by Horiuchi et al. (2014). In this study, I specifically utilized the OMRON 5 series arm automatic blood pressure monitor, model: BP710CAN (HEM-773-CAN). This device is equipped with an automatically inflating and deflating arm band cuff. The cuff is connected to a monitor that controls the cuff as well as takes and displays the readings of

the blood pressure and heart rate. The OMRON 5 series has been clinically validated at the National Opinion Research Center at the University of Chicago and it has been formally placed on the US Blood Pressure Validated Device Listings (Clinical Validation, 2022).

A digital blood pressure cuff is advantageous due to its ease of use and minimal training requirements for accurate measurement. Participants were asked to sit quietly and remain motionless during blood pressure collection. A 10 mm Hg difference in blood pressure signifies a meaningful change in health risks (Agarwal et al., 2008), however, Potter and Bolls (2012) assert that small effect sizes associated with physiological measures do not diminish the practical or theoretical significance of results. They argue that images of environments seldom elicit the same physiological changes as real-world experiences. Thus, I also consider small changes in blood pressure as important when examining VR environments.

Heart Rate

Heart rate was measured each time blood pressure was taken using the digital blood pressure cuff. Field studies were planned, so it was decided that it was more advantageous to compromise some of the accuracy of the heart signal in favor of a device that is removed when not in use, allowing for more natural behaviors of the user and ultimately increasing ecological validity.

Body Temperature

Body temperature was also monitored using the Empatica while participants were in VR to assess signs of simulator sickness, because body temperature would continually increase with increased feelings of sickness. In addition, body temperature was monitored for declines during field studies in the fall, as participants could become cold and stressed due to inappropriate clothing. In both cases, when the researcher noticed continuous changes in temperature and signs

of temperature stress, the researcher would intervene and ask about the condition of the participant to stop any adverse events and stop participation if necessary. The Empatica device is worn as a watch.

Simulator Sickness Questionnaire

The simulator sickness questionnaire (SSQ) was used to determine how sick an individual became after exposure to the virtual environment because many of the symptoms from simulator sickness impact physiology, it was important to monitor. The SSQ is the most popular way to assess simulator sickness after the fact (Balk et al., 2013). This method was developed 20 years ago by Kennedy et al. (1993). There are many ways to assess simulator sickness (e.g., Gianaros et al., 2001) as it is similar to motion sickness and results in feelings of nausea, dizziness, vertigo and sweating (among other symptoms; Balk et al., 2013). I used the SSQ to determine whether to include participant data based on how sick the individual felt post VR. Balk et al. (2013) compared 9 studies that used the SSQ and removed any participant data that resulted in a score of 55 or higher, "as it was assumed these individuals chose to 'stick it out' despite obvious simulator sickness symptoms" (pp. 259). However, the current study took a more conservative approach and excluded anyone who scored higher than half of the 96 total points available which would be a score of 48.

Environments

I meticulously designed the present study to validate that the two everyday urban and natural environments under investigation align with the previously established restorative outcomes. By doing so, I aim to pave the way for subsequent studies in which various features of these two environments will be systematically manipulated to test other hypotheses related to

urban and natural settings, ultimately deepening our understanding of the restorative potential within the broader context of urban and natural environments.

Urban Environment

The urban environment depicted in Figure 3.1 was designed after the shopping area of the city in which the study was conducted. It had three-story high, colourful buildings, shopfronts, and different architectural features, such as a diverse array of windows, streetlights, benches, and other common urban characteristics.

Figure 3.1. Urban Environment



Natural Environment

The natural environment depicted in Figure 3.2 was designed to replicate an urban forest near the university, with diverse plant life, small young trees, larger mature trees, and a manicured appearance. To facilitate a forest walk experience (the common way individuals experience forests), a path was incorporated into the design. Ensuring a well-groomed appearance prevents the forest from appearing wild and overgrown, which may evoke feelings of unease in some individuals (Milligan & Bingley, 2007). Prioritizing safety is crucial, as concerns

about it can hinder the restorative process (Staats et al., 2016). Kaplan and Kaplan (1989) found that overgrown parklands were perceived as less safe and more threatening, highlighting the importance of maintaining an inviting atmosphere in the design of restorative urban forests.

Figure 3.2. Nature Environment



Procedure

Upon arrival at the psychology department, participants were guided to a designated lab room. The study began with participants reading and completing the information and consent forms. Subsequently, participants filled out Survey 1 which included demographics questions, the ZIPERS scale, and a subjective stress question. Following this, participants were equipped with the Empatica and asked to sit quietly for 5 minutes. This rest period allowed participants' heart rate and blood pressure to return to baseline levels, in case participants had experienced elevated physiology due to unforeseen circumstances prior to the study. Once the rest period was complete blood pressure was taken.

After establishing baseline physiological and psychological levels, participants were guided through a 15-minute stress induction. Post-induction physiological measures were recorded, and participants were asked to complete Survey 2 which included the ZIPERS scale

and the subjective stress question once more to assess the impact of the stress induction on participants.

Upon concluding the questionnaire, participants received instructions on using the Virtual Reality (VR) headset. They were then equipped with the VR headset and encouraged to interact with the VR environment at their own pace for 15 minutes. Following the environment intervention, final physiological measures were taken, and the recording devices were removed. Participants completed the final Survey 3 which included the ZIPERS scale, along with the subjective stress question, for the final time. The study concluded after the survey was submitted.

Results

The first analysis conducted was the assessment of the Simulator Sickness Questionnaire (SSQ) scores to eliminate anyone who despite feeling sick in the VR environment "stuck it out" and had a SSQ score of 48 or more. My results for this study were based on 37 participants in total (Nature N = 19, Urban N = 18). Four participants were eliminated due to equipment malfunction and five were eliminated due to simulator sickness. Simulator sickness overall was (M = 9.31, SD = 6.35). I ran a one-way ANOVA on the SSQ scores between the urban and natural condition, finding no significant difference in simulator sickness between conditions F (1, 34) = .506, p =.482. The urban condition SSQ mean score was (M = 9.88, SD = 7.69), while the nature condition had an SSQ score of (M = 8.84, SD = 4.96). The following results were derived from the mixed factorial ANOVAs performed on the measures of restoration (dependent variable).

To analyze the restorative effects of the environments I first assessed whether the groups differed before exposure to the respective environments and whether there was an influence of the stress induction. This was done by analyzing the dependent measure using a mixed ANOVA with Time (Time 1-baseline vs. Time 2-after stress induction) as the within-participant factor, and Naturalness (Urban, Nature) as a between-participant factor. I then conducted another mixed ANOVA for each dependent measure to assess the influence of the exposure to the respective environments. This ANOVA included Time (Time 2-after stress induction vs. Time 3-after environment exposure) as the within-participant factor, and again Naturalness (Urban, Nature) as the between-participant factors. Additionally, I used a Bonferroni correction at the .05 level to evaluate the simple main effects.

The results are presented in three tables for each dependent variable (DV). The first table contains mean scores for the DV with standard deviations as a function of condition. The following two tables provide the ANOVA results. The header for each DV indicates the associated table numbers for the descriptives and the two ANOVAs.

It is important to note that not all the data sets were completed for each DV, as participants occasionally missed questions either inadvertently due to inattention or intentionally chose to skip certain questions they felt uncomfortable answering.

Positive Affect (PA; Table 3.1; 3.2; 3.3)

The results from the Time1/Time2 ANOVA revealed a significant main effect of Time. The means indicate PA decreased from Time 1 (M = 11.10, SE = .53) to Time 2 (M = 9.53, SE = .63). This result is consistent with the notion that the stress induction lowered PA.

The Time 2/Time 3 ANOVA indicated there were no significant main effects or interactions.

Table 3.1

Positive Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

		Condition	
Measure		Nature	Urban
Positive Affect	Time 1	11.58 (3.13)	10.61 (3.35)
	Time 2	10.11 (3.70)	8.94 (4.00)
	Time 3	11.00 (4.59)	8.94 (3.49)

Table 3.2

Mixed ANOVA on Positive Affect by Time 1 and Time 2, by Naturalness

Predictor	df	F	p	η^2_g
Time	1	12.72	.001	.267
Naturalness	1	.97	.332	.027
Naturalness x Time	1	.05	.828	.001
Error	35			

Table 3.3

Mixed ANOVA on Positive Affect by Time 2 and Time 3, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	.64	.430	.02
Naturalness	1	1.86	.181	.05
Naturalness x Time	1	.64	.430	.02
Error	35			

Negative Affect (NA; Table 3.4; 3.5; 3.6)

Results from the Time 1/Time 2 ANOVA revealed there was a significant main effect of Time. The means indicate NA increased from Time 1 (M = 4.94, SE = .28) to Time 2 (M = 6.72, SE = .58). These results are consistent with the interpretation that the stress induction increased NA.

Table 3.4

Negative Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

		Condition	
Measure		Nature	Urban
Negative Affect	Time 1	5.00 (1.56)	4.83 (1.72)
	Time 2	7.28 (4.10)	6.17 (2.67)
	Time 3	5.26 (1.97)	5.11 (1.71)

Table 3.5

Mixed ANOVA on Negative Affect by Time 1 and Time 2, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	14.70	<.001	.30
Naturalness	1	.74	.396	.021
Naturalness x Time	1	.92	.345	.026
Error	34			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time. The means indicate NA decreased from Time 2 (M =6.72, SE = .58) to Time 3 (M = 5.22, SE = .31).

Although NA improved after exposure to the various environments, no specific environment proved to be significantly more restorative than the others.

Table 3.6

Mixed ANOVA on Negative Affect by Time 2 and Time 3, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	9.77	.004	.22
Naturalness	1	.71	.405	.02
Naturalness x Time	1	.86	.361	.03
Error	34			

Subjective Attention (Table 3.7; 3.8; 3.9)

The Time 1/Time 2 ANOVA indicated there were no significant main effects or interactions on Subjective Attention. This suggests that the stress induction did not have a notable influence on participants' Subjective Attention, inconsistent with my expectation.

Table 3.7

Subjective Attention, Means and Standard Deviations (in Brackets) from Each Condition Across Time

		Condition	
Measure		Nature	Urban
Subjective Attention	Time 1	3.32 (1.00)	3.22 (.65)
	Time 2	3.11 (1.20)	3.33 (1.03)
	Time 3	2.90 (.94)	2.28 (.96)

Table 3.8

Mixed ANOVA on Subjective Attention by Time 1 and Time 2, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	.06	.804	.002
Naturalness	1	.07	.797	.002
Naturalness x Time	1	.66	.423	.018
Error	35			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time and a significant interaction between Time and Naturalness. The means suggest Subjective Attention decreased from Time 2 (M = 3.22, SE = .18) to Time 3 (M = 2.59, SE = .16). The post hoc pairwise comparison on simple main effects with Bonferroni correction demonstrated that the Urban conditions significantly (p<.001) decreased Subjective Attention from Time 2 (M = 3.33, SE = .26) to Time 3 (M = 2.28, SE = .22). There was no significant effect of the Nature condition on Subjective Attention (p = .408). These findings are inconsistent with the hypothesis that the natural environment would be more restorative. However, they do suggest that the urban environment was more likely to cause attention fatigue, indicating a potential negative impact of urban settings on cognitive processes.

Table 3.9

Mixed ANOVA on Subjective Attention by Time 2 and Time 3, by Naturalness

Predictor	df	F	p	η^2_g
Time	1	12.32	.001	.26
Naturalness	1	.45	.506	.013
Naturalness x Time	1	5.49	.025	.136
Error	35			

Subjective Stress (Table 3.10; 3.11; 3.12)

The Time 1/Time 2 ANOVA revealed a significant main effect of Time. The means indicate Subjective Stress increased from Time 1 (M = 2.22, SE = .12) to Time 2 (M = 2.88, SE = .18). These results are consistent with the notion that the stress induction was effective.

Table 3.10

Subjective Stress, Means and Standard Deviations (in Brackets) from Each Condition Across Time

		Condition	
Measure		Nature	Urban
Subjective Stress	Time 1	2.37 (.76)	2.00 (.69)
	Time 2	3.06 (1.06)	2.71 (1.11)
	Time 3	1.84 (.96)	1.83 (.99)

Table 3.11

Mixed ANOVA on Subjective Stress by Time 1 and Time 2, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	13.14	<.001	.285
Naturalness	1	1.81	.187	.052
Naturalness x Time	1	.00	.957	.000
Error	33			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time with the means indicating Subjective Stress reduced from Time 2 (M = 2.88, SE = .18) to Time 3 (M = 1.80, SE = .15). A general decrease in stress levels as can be seen here indicates that no single environment outperformed the other on restorative potential.

Table 3.12

Mixed ANOVA on Subjective Stress by Time 2 and Time 3, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	27.69	<.001	.456
Naturalness	1	.13	.726	.00
Naturalness x Time	1	1.55	.222	.045
Error	33			

Diastolic Blood Pressure (DBP; Table 3.13; 3.14; 3.15)

The ANOVA indicated no significant main effects or interactions at Time 1/Time2 or at Time 2/Time 3. The lack of a main effect of Time suggests that the stress induction did not significantly affect participants' DBP.

Table 3.13

Diastolic Blood Pressure, Means and Standard Deviations (in Brackets) from Each Condition Across Time

		Condition	
Measure		Nature	Urban
Diastolic	Time 1	74.35 (8.06)	75.59 (15.85)
Blood	Time 2	78.82 (10.67)	76.35 (9.67)
Pressure	Time 3	80.35 (5.69)	79.00 (7.12)

Table 3.14

Mixed ANOVA on Diastolic Blood Pressure by Time 1 and Time 2, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	1.24	.273	.037
Naturalness	1	.04	.846	.001
Naturalness x Time	1	.62	.436	.019
Error	32			

Table 3.15

Mixed ANOVA on Diastolic Blood Pressure by Time 2 and Time 3, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	1.83	.186	.054
Naturalness	1	.594	.447	.018
Naturalness x Time	1	.131	.720	.004
Error	32			

Systolic Blood Pressure (SBP; Table 3.16; 3.17; 3.18)

The ANOVA indicated no significant main effects or interactions at Time 1/Time2 or at Time 2/Time 3. The lack of a main effect of Time suggests that the stress induction did not significantly effect participants' SBP.

Table 3.16

Systolic Blood Pressure, Means and Standard Deviations (in Brackets) from Each Condition Across Time

		Condition	
Measure		Nature	Urban
Systolic Blood Pressure	Time 1	113.77 (12.39)	116.76 (12.11)
	Time 2	117.18 (14.73)	120.88 (10.48)
	Time 3	117.29 (10.73)	120.18 (10.26)

Table 3.17

Mixed ANOVA on Systolic Blood Pressure by Time 1 and Time 2, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	3.79	.061	.106
Naturalness	1	.77	.388	.023
Naturalness x Time	1	.03	.856	.001
Error	32			

Table 3.18

Mixed ANOVA on Systolic Blood Pressure by Time 2 and Time 3, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	.03	.869	.00
Naturalness	1	.84	.367	.03
Naturalness x Time	1	.05	.817	.00
Error	32			

Heart Rate (Table 3.19; 3.20; 3.21)

The Time 1/Time 2 ANOVA indicated that there were no significant main effects or interactions on Heart Rate. The lack of a main effect of Time suggests that the stress induction did not significantly affect participants' Heart Rate.

Table 3.19

Heart Rate, Means and Standard Deviations (in Brackets) from Each Condition Across Time

		Condition	
Measure		Nature	Urban
Heart Rate	Time 1	79.00 (10.85)	70.71 (12.07)
	Time 2	80.47 (11.23)	70.59 (11.84)
	Time 3	76.47 (9.10)	68.47 (12.02)

Table 3.20

Mixed ANOVA on Heart Rate by Time 1 and Time 2, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	.36	.554	.011
Naturalness	1	.77	.388	.023
Naturalness x Time	1	.49	.488	.015
Error	32			

The Time 2/Time 3 ANOVA revealed a significant main effect of Naturalness on Heart Rate, whereby the participants in the Natural conditions had significantly higher Heart Rate (M = 78.47, SE = .2.45) than those in the Urban conditions (M = 69.53, SE = 2.45). These results contradict my initial hypothesis, which predicted that natural environments would lead to a reduction in Heart Rate compared to urban settings.

Table 3.21

Mixed ANOVA on Heart Rate by Time 2 and Time 3, by Naturalness

Predictor	df	F	*p*	η^2_g
Time	1	3.71	.063	.10
Naturalness	1	6.66	.015	.17
Naturalness x Time	1	.35	.56	.01
Error	32			

Discussion

I first analyzed how the stress induction impacted participants, analyzing the change in dependent measures at Time 1 and Time 2. The stress induction consistently influenced the restorative measures by decreasing PA and Subjective Attention, and increasing NA, Subjective Stress, and SBP. However, when I analyzed the intervention's effect on the measures of restoration, I found limited significant effects, with only Subjective Attention being affected by the intervention. While the Natural condition did not improve Subjective Attention, the Urban condition significantly reduced Subjective Attention aligning with Kaplan (1995) who suggests people did not evolve in urban environments and are thus less adept at processing these environments. These results suggest that urban environments can be detrimental to attentional resources. Notably, the detrimental impact on attention should be attributed to the visual aspects of the environment alone, as other stimuli (noise, crowds, and traffic) were consistent across conditions. This highlights the significant role that visual elements play in the restorative effects of different environments on attentional capacities, despite the absence of a clear restorative effect of nature.

The literature suggests that the participants in the nature condition should have experienced some restorative outcomes shown in variables such as higher PA after the nature intervention or reduced physiological measures (e.g., Berto, 2014); however, this was not the case. There could be several reasons for this outcome. One potential explanation for the results is that the study may be underpowered. I assumed the well-established restorative effect of nature would significantly impact participants, as shown by previous studies, many of which had smaller sample sizes. For instance, Hansen et al. (2017) noted that small sample sizes were a limitation in Shinrin-yoku studies, yet they consistently found significant differences between natural and

urban environments. Similarly, Igarashi et al. (2018), Beil and Hanes (2013), and Tsunetsugu et al. (2007) found significant physiological and psychological effects of nature exposure using sample sizes of 18, 15, and 12 participants, respectively. These findings led me to expect similar results in the study.

Another possible explanation for the limited significant findings between the environments is that this study did not employ environments that were sufficiently different. Previous research has employed environments with stark contrasts, such as comparing a quiet rural forest to a bustling city environment. For example, Park et al. (2007b) found that forest bathing was more restorative than similar experiences in urban settings like a busy, highly stimulating city street or an underground parking lot with traffic and people. The dramatic contrast between the environments in such studies may explain why they observed differences in restorative measures between urban and natural settings.

To better understand these results, further investigation is needed. One approach involves increasing the study's power by involving more participants. Another approach could be adjusting the restorative potential of both urban and natural environments and examining the resulting effects on the restorative measures. Thus, Study 2 will incorporate more participants and was developed to analyze two new environments based on those in the literature, with the aim of determining if the lack of significant effects was due to the use of moderately restorative urban and natural environments.

Chapter 4 Study 2

Introduction

In Study 1 I investigated whether a restorative effect could be found using a standard urban and a natural environment. The primary variation between the environments involved vegetation and buildings. Efforts were made to exclude other stress-inducing factors such as noise, people, and traffic, across all conditions. I hypothesised that the nature effect was strong enough to carry across diverse mediums of stimuli, as various studies have consistently shown (e.g., Berto, 2014; Velarde et al., 2007). However, I found no statistically significant differences across environments in most of the measures of restoration.

One reason I might have failed to find effects of exposure to natural vs. urban environments is that the environments were not sufficiently extreme exemplars of restorative nature and depleting urban environments. Indeed, prior studies have used much more disparate and extreme exemplars of urban and nature settings. Pearson and Craig (2014) criticize the literature by suggesting that "there is a tendency to treat the category of 'natural' and 'urban/built' as being more clearly defined and identifiable than may actually be the case in everyday-judgement" (p. 2). In addition, Stigsdotter et al. (2017) also critiques the use of a clear dichotomy between "serene natural forest environments … [and] urban environments located in urbanized zones, often along major traffic roads around the main train station" (146).

To address potential issues with Study 1's environments, I designed two additional environments that fall on either side of the restorative continuum. These new environments, when compared to Study 1's everyday environments, more closely resemble the more disparate dichotomous urban and natural environments commonly used in the restorative literature. The newly created forest and urban conditions were as follows. The new forest environment features

densely packed, large, mature trees, reflecting a pristine forest that has been shown to increase people's enjoyment of a natural space (Kaplan & Kaplan, 1989). Research suggests that more trees and vegetation enhance stress reduction (Jiang et al., 2014; Roe et al., 2013; Ward Thompson et al., 2012), so I included a greater number of plants and trees to increase the complexity and richness of the environment (Chiang et al., 2017; Wang et al., 2019). Additionally, I incorporated more mature trees in the new nature environment to create a more spectacular setting. Simkin et al. (2020) found that old-growth and mature commercial forests are more restorative than urban recreation areas. Conversely, the new urban space was characterized by densely built-up, tall, gray skyscrapers surrounding the participant-navigated road. This environment more accurately represents a "typical" urban setting studied in the restorative literature, featuring a complete lack of nature, uninteresting architecture, and elements similar to industrial areas, parking garages, or underpass tunnels (e.g., Bodin & Hartig, 2003; Nisbet et al., 2011; Park et al., 2007b).

Overview

The primary objective of this study is to investigate whether the environments utilized in Study 1 contributed to the lack of expected results. To address this, I have incorporated the two environments from Study 1 and I also added two new environments that more closely resemble the nature, and urban settings described in the literature. The addition of the two new environments introduces another factor I refer to as Restorative Potential. Restorative Potential is the expected ability of an environment to reduce stress, improve attention, and enhance affect, determined by factors like trees, biodiversity, and architectural features. These elements can either promote relaxation and restoration or contribute to stress and attention fatigue. Introducing this concept allows me to categorize environments, such as urban and natural, into subcategories, addressing the oversimplification of merely classifying them as either urban or natural. Based on Bornioli and Subiza-Pérez's (2023), this classification is

determined by the existence or absence of stress-inducing stimuli, and the presence of restorative stimuli. If an environment contains stress inducing stimuli, then it is considered to have Low Restorative Potential, while environments that do not contain stress inducing stimuli and do contain restorative stimuli will be considered High Restorative Potential environments. The stimuli used to adjust the Restorative Potential have been predominantly identified through subjective assessments and remain untested in field studies. This study aims to investigate these stimuli in various urban and natural environments using immersive experiences. The findings will help determine if these stimuli impact the restorative potential of urban and natural environments, offering an understanding of restorative environments beyond the urban-nature dichotomy and enabling further exploration and understanding of environments on a continuum.

Based on the categorization of restorative environments, the following classifications have been assigned to the environments used in this study: 1) the new natural environment featuring large, mature trees, and biodiversity is considered to have High Restorative Potential, 2) the natural environment from Study 1 is categorized as Low Restorative Potential, as it lacks the restorative features described in the High Restorative Potential natural environment, 3) the urban environment from Study 1 is regarded as High Restorative Potential due to the absence of stress-inducing stimuli and the presence of perceived restorative urban features such as shops and interesting architectural elements, and finally 4) the new urban condition is classified as Low Restorative Potential because it lacks restorative features and includes tall buildings and an industrial feel, which are predicted to be less restorative and potentially stress-inducing.

My investigation will focus on the same measures used in Study 1. The aim is to identify which environments promote restoration most effectively and to assess whether this restoration occurs at a psychological, physiological, or combined level.

I anticipate, as in Study 1, that the stress induction would significantly impact participants. Thus, I will first analyze the impact of the stress induction on the restorative measures

anticipating a decrease in PA and Subjective Attention, while expecting NA, Subjective Stress, Blood Pressure, and Heart Rate to increase due to an increase in stress. Subsequently, I will examine the effects of different environmental conditions on restorative outcomes. It is hypothesized that the Nature condition will promote greater restoration, as measured by multiple restorative indicators, compared to the Urban conditions. Additionally, I expect the Highly Restorative conditions to yield larger restorative effects than the Low Restorative conditions. However, it remains unclear whether the Highly Restorative Urban condition will provide more restorative benefits than the Low Restorative Nature condition.

Methods

Participants

Participants were all University of Waterloo undergraduate students who were recruited through the SONA website for students in psychology courses. The study included 130 participants in total (80 female, 50 male).

Virtual Reality Display, Stress Induction, and Measures

The VR headset, Stress Induction, and measures described in Study 1 are the same as the ones used in this study.

Stimuli

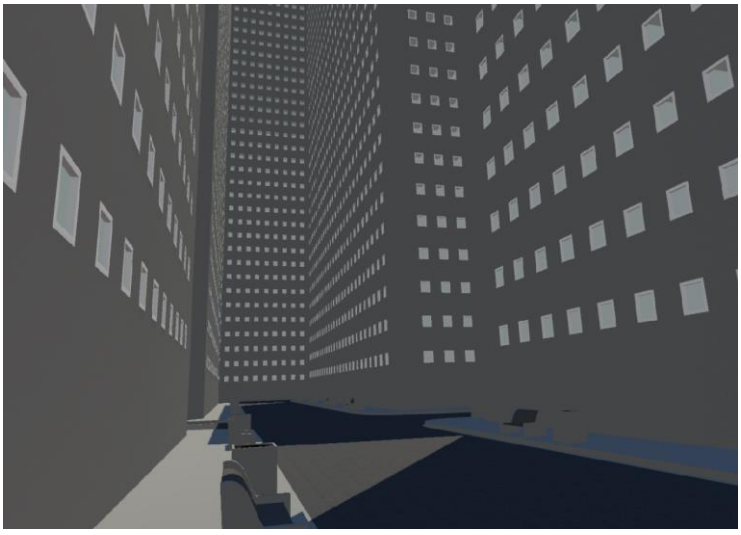
I compared four environments including the two from Study 1 as well as a High Restorative Potential (HRP) Natural environment (HRP-nature; Figure 4.1) and a Low Restorative Potential (LRP) Urban environment (LRP-urban; Figure 4.2). Figure 3.1 depicts the HRP-urban environment and Figure 3.2 depicts the LRP-natural environment.

Environments

Figure 4.1. HRP-nature



Figure 4.2. LRP-urban



Procedure

The procedures from this study are the same as Study 1.

Results

For each dependent measure, I first assessed whether the groups differed before exposure to the respective environments and whether there was an influence of the stress induction. This was done by analyzing the dependent measure using a mixed ANOVA with Time (Time 1-baseline vs. Time 2-after stress induction) as the within-participant factor, and Naturalness (Urban, Nature) and Restorative Potential (High, Low) as between-participant factors. I then conducted another mixed ANOVA for each dependent measure to assess the influence of the exposure to the respective environments. This ANOVA included Time (Time 2-after stress induction vs. Time 3-after environment exposure) as the within-participant factor, and again Naturalness (Urban, Nature) and Restorative Potential (High, Low) as between-participant factors. Additionally, I used a Bonferroni correction at the .05 level to evaluate the simple main effects. The results are presented in three tables for each dependent variable (DV). The first table contains mean scores for the DV with standard deviations as a function of condition. The following two tables provide the ANOVA results comparing Time 1/Time 2 and Time 2/Time 3 (within-participant) respectively, using Naturalness (Nature, Urban) and Restorative Potential (High, Low) as the between-subjects factors. The header for each DV indicates the associated table numbers for the descriptives and the two ANOVAs respectively.

It is important to note that not all the data sets were completed for each DV, as participants occasionally missed questions either inadvertently due to inattention or intentionally chose to skip certain questions they felt uncomfortable answering.

Positive Affect (PA; Table 4.1; 4.2; 4.3)

The Time 1/Time 2 ANOVA revealed a significant main effect of Time. The means indicated PA decreased from Time 1 (M = 10.88, SE = .27) to Time 2 (M = 9.17, SE = .40) This result is consistent with the notion that the stress induction lowered PA.

Table 4.1

Positive Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	11.32 (2.92)	10.71 (3.1)	11.14 (2.82)	10.34 (3.16)
Time 2	10.25 (3.09)	9.44 (6.28)	9.5 (3.47)	7.48 (2.62)
Time 3	10.96 (3.66)	10.29 (4.08)	9.22 (3.17)	8.16 (3.06)

Table 4.2

Mixed ANOVA on Positive Affect by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2g
Time	1	28.39	< .001	.19
Naturalness	1	1.82	.179	.02
Restorative Potential	1	3.09	.080	.03
Naturalness x Restorative Potential	1	.33	.560	.00
Naturalness x Time	1	2.83	.100	.02
Restorative Potential x Time	1	1.22	.270	.01
Naturalness x Restorative Potential x Time	1	.63	.427	.01
Error	122			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time, with the means indicating participants' PA increased from Time 2 (M = 9.15, SE = .39) to Time 3 (M = 9.97, SE = .32). Though PA increased, no environment emerged as distinctly more restorative than the others.

Table 4.3

Mixed ANOVA on Positive Affect by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	28.39	<.001	.19
Naturalness	1	1.82	.179	.02
Restorative Potential	1	3.09	.080	.02
Naturalness x Restorative Potential	1	.33	.560	.00
Naturalness x Time	1	2.83	.100	.02
Restorative Potential x Time	1	1.22	.270	.01
Naturalness x Restorative Potential x Time	1	.33	.560	.00
Error	122			

Negative Affect (NA; Table 4.4; 4.5; 4.6)

The Time 1/Time 2 ANOVA revealed a significant main effect of Time. The means indicate an increase in NA from Time 1 (*M* = 4.99, *SE* = .12) to Time 2 (*M* = 6.53, *SE* = .24). These results are consistent with the interpretation that the stress induction increased NA.

There was also a significant Time by Restorative Potential interaction. Pairwise comparisons on the simple main effects with Bonferroni correction revealed that both the HRP and LRP condition participants experienced an increase in NA. Those in the HRP conditions (p<.001) felt an increase in NA from Time 1 (*M* = 4.96, *SE* = .17) to Time 2 (*M* = 6.03, *SE* = .37), and those in the LRP conditions (p<.001) experienced an increase in NA from Time 1 (*M* = 5.02, *SE* = .17) to Time 2 (*M* = 7.03, *SE* = .36). Interestingly the LRP condition participants experienced a larger decrease in NA than those in the HRP condition, though the difference was not significant.

Table 4.4

Negative Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	5.18 (1.28)	5.00 (1.47)	4.75 (1.39)	5.40 (1.06)
Time 2	5.89 (5.89)	6.85 (6.85)	6.16 (6.16)	7.20 (7.2)
Time 3	5.46 (1.88)	5.13 (1.73)	5.34 (1.96)	5.96 (1.95)

Table 4.5

Mixed ANOVA on Negative Affect by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	48.41	<.001	.29
Naturalness	1	.03	.868	.00
Restorative Potential	1	2.43	.121	.02
Naturalness x Restorative Potential	1	.17	.680	.00
Naturalness x Time	1	1.29	.258	.01
Restorative Potential x Time	1	4.60	.034	.04
Naturalness x Restorative Potential x Time	1	.19	.67	.00
Error	121			

The Time 2/Time3 ANOVA revealed a significant main effect of Time. An analysis of the means suggests participants' NA decreased from Time 2 (M =6.56, SE = .26) to Time 3 (M =5.44, SE = .17). Additionally, there was a significant interaction between Time and Restorative Potential. Pairwise comparisons with Bonferroni correction revealed a significant decline in NA from Time 2 (M = 7.02, SE = .36) to Time 3 (M = 5.01, SE = .24) for those in the LRP conditions (p<.001). While NA did not significantly decrease for those in the HRP conditions (p = .052). This suggests that the LRP conditions were more restorative than the HRP conditions as the stress induction increased NA for all participants pre intervention.

Table 4.6

Mixed ANOVA on Negative Affect by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	26.14	<.001	.175
Naturalness	1	.78	.379	.01
Restorative Potential	1	2.74	.100	.02
Naturalness x Restorative Potential	1	.7	.405	.01
Naturalness x Time	1	.024	.877	.00
Restorative Potential x Time	1	5.35	.022	.04
Naturalness x Restorative Potential x Time	1	.452	.502	.00
Error	123			

Subjective Attention (Table 4.7; 4.8; 4.9)

The Time 1/Time 2 ANOVA indicated there were no significant main effects or interactions. Thus, the stress induction did not impact participant's Subjective Attention.

Table 4.7

Subjective Attention, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	3.25 (.75)	3.17 (.92)	3.31 (.73)	3.15 (.83)
Time 2	3.21 (.88)	3.15 (1.15)	3.24 (1.06)	2.96 (1.04)
Time 3	2.46 (1)	2.76 (.92)	2.33 (.92)	2.08 (1.02)

Table 4.8

Mixed ANOVA on Subjective Attention by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	.62	.434	.00
Naturalness	1	.05	.832	.00
Restorative Potential	1	1.16	.285	.01
Naturalness x Restorative Potential	1	.28	.600	.00
Naturalness x Time	1	.24	.626	.00
Restorative Potential x Time	1	.08	.780	.04
Naturalness x Restorative Potential x Time	1	.12	.730	.00
Error	124			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time. Specifically, subjective levels of Attention decreased from Time 2 ($M = 3.14$, $SE = .09$) to Time 3 ($M = 2.41$, $SE = .09$). These results indicate no environment was significantly more restorative than others.

Table 4.9

Mixed ANOVA on Subjective Attention by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	48.61	<.001	.282
Naturalness	1	2.72	.102	.02
Restorative Potential	1	.29	.594	.00
Naturalness x Restorative Potential	1	1.69	.197	.01
Naturalness x Time	1	2.41	.123	.02
Restorative Potential x Time	1	.834	.363	.01
Naturalness x Restorative Potential x Time	1	.635	.427	.01
Error	124			

Subjective Stress (Table 4.10; 4.11; 4.12)

The Time 1/Time 2 ANOVA revealed a significant main effect of Time, indicating an increase in Subjective Stress from Time 1 (M = 2.27, SE = .08) to Time 2 (M = 3.08, SE = .09). These results are consistent with the notion that the stress induction was effective.

There was also a main effect of Restorative Potential, with the means indicating participants in the HRP conditions had lower Subjective Stress (M = 2.54, SE = .10) than those in the LRP conditions (M = 2.82, SE = .10). There was also a significant interaction between Naturalness and Restorative Potential. Pairwise comparison with Bonferroni correction indicated Subjective Stress was significantly different between the Urban conditions (p = .005) while there was no difference for those in the Nature conditions (p = .940). Participants had higher Subjective Stress in the LRP-urban condition (M = 2.94, SE = .15) than those in the HRP-urban condition (M = 2.36, SE = .14). It is important to keep in mind that the environment exposure had not yet occurred, suggesting there were group differences with regards to Subjective Stress.

Table 4.10

Subjective Stress, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	2.39 (.79)	2.28 (.82)	1.97 (.75)	2.46 (.95)
Time 2	3.04 (.92)	3.13 (.97)	2.74 (1.13)	3.42 (.99)
Time 3	1.82 (.82)	1.68 (.73)	1.81 (.98)	1.96 (1.83)

Table 4.11

Mixed ANOVA on Subjective Stress by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	78.72	< .001	.39
Naturalness	1	.18	.680	.00
Restorative Potential	1	4.24	.042	.03
Naturalness x Restorative Potential	1	4.67	.033	.04
Naturalness x Time	1	.45	.510	.00
Restorative Potential x Time	1	1.18	.280	.01
Naturalness x Restorative Potential x Time	1	.00	.960	.00
Error	121			

The Time2/Time3 ANOVA revealed only a significant main effect of Time, whereby Subjective Stress decreased from Time 2 (M = 3.08, SE = .09) to Time 3 (M = 1.82, SE = .08). The results indicate no particular environment was more influential on the restorative experience.

Table 4.12

Mixed ANOVA on Subjective Stress by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	150.26	< .001	.55
Naturalness	1	.24	.625	.00
Restorative Potential	1	1.92	.169	.02
Naturalness x Restorative Potential	1	2.52	.115	.02
Naturalness x Time	1	.419	.519	.00
Restorative Potential x Time	1	3.4	.067	.03
Naturalness x Restorative Potential x Time	1	.483	.494	.00
Error	121			

Diastolic Blood Pressure (DBP; Table 4.13; 4.14; 4.15)

The Time 1/ Time 2 ANOVA revealed only a significant main effect of Time. The means indicate DBP increased from Time 1 (M =74.61, SE = 1.00) to Time 2 (M = 77.52, SE = 1.05). These results are consistent with the interpretation that the stress induction increased DBP.

Table 4.13

Diastolic Blood Pressure, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	73.39 (9.44)	75.57 (7.79)	77.43 (15.88)	72.04 (6.44)
Time 2	78.58 (10.01)	80.46 (13.07)	75.70 (10.13)	75.35 (9.93)
Time 3	79.69 (6.78)	80.00 (5.64)	78.47 (8.34)	78.35 (6.53)

Table 4.14

Mixed ANOVA on Diastolic Blood Pressure by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	7.05	.009	.06
Naturalness	1	1.16	.283	.01
Restorative Potential	1	.059	.809	.00
Naturalness x Restorative Potential	1	2.01	.159	.02
Naturalness x Time	1	3.76	.055	.032
Restorative Potential x Time	1	1.16	.283	.01
Naturalness x Restorative Potential x Time	1	1.48	.227	.013
Error	112			

The Time 2/Time 3 ANOVA revealed a significant main effect of Naturalness. Participants in the Natural conditions had higher DBP (M = 79.6, SE = .98) than those in the Urban conditions (M = 76.54, SE = 1.04). These results indicate the conditions had no impact on DBP.

Table 4.15

Mixed ANOVA on Diastolic Blood Pressure by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	2.65	.107	.02
Naturalness	1	4.59	.034	.038
Restorative Potential	1	.049	.825	.00
Naturalness x Restorative Potential	1	.443	.507	.004
Naturalness x Time	1	1.72	.193	.015
Restorative Potential x Time	1	.17	.683	.00
Naturalness x Restorative Potential x Time	1	.17	.682	.00
Error	116			

Systolic Blood Pressure (SBP; Table 4.16; 4.17; 4.18)

The Time 1/Time 2 ANOVA revealed a main effect of Time. The means indicate SBP increased from Time 1 (M = 117.32, SE = 1.28) to Time 2 (M = 122.58, SE = 1.39). These findings are in line with the idea that the stress induction increased blood pressure.

Table 4.16

Systolic Blood Pressure, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	119.85 (15.05)	116.62 (13.11)	115.77 (14.31)	117.04 (11.44)
Time 2	123.31 (11.65)	122.89 (18.29)	122.93 (12.63)	121.17 (13.84)
Time 3	123.23 (11.65)	116.87 (21.04)	118.27 (10.47)	118.48 (10.84)

Table 4.17

Mixed ANOVA on Systolic Blood Pressure by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	21.21	< .001	.16
Naturalness	1	.35	.553	.00
Restorative Potential	1	.18	.670	.00
Naturalness x Restorative Potential	1	.11	.744	.00
Naturalness x Time	1	.12	.732	.00
Restorative Potential x Time	1	.00	.960	.00
Naturalness x Restorative Potential x Time	1	1.64	.203	.01
Error	112			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time. SBP decreased from Time 2 (M = 122.29, SE = 1.35) to Time 3 (M = 118.9, SE = 1.37). Though SBP decreased, no environment emerged as distinctly more restorative than others.

Table 4.18

Mixed ANOVA on Systolic Blood Pressure by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	7.03	.009	.06
Naturalness	1	.57	.450	.01
Restorative Potential	1	1.22	.272	.01
Naturalness x Restorative Potential	1	.06	.803	.00
Naturalness x Time	1	.05	.828	.00
Restorative Potential x Time	1	.58	.450	.01
Naturalness x Restorative Potential x Time	1	2.34	.129	.02
Error	116			

Heart Rate (Table 4.19; 4.20; 4.21)

The Time 1/Time 2 ANOVA indicated there was a significant main effect of Naturalness. The means indicate participants assigned to the Nature conditions had significantly higher Heart Rate (M = 76.94, SE = 1.52) compared to those assigned to the Urban conditions (M = 72.35, SE = 1.52). These measures were taken before the intervention thus, the results indicate a pre-existing difference between groups.

Table 4.19

Heart Rate, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	75.96 (14.56)	77.89 (11.03)	71.97 (10.57)	71.87 (10.49)
Time 2	76.19 (16.06)	77.70 (12.84)	73.83 (12.56)	71.74 (11.99)
Time 3	72.46 (12.27)	73.08 (10.49)	67.50 (10.79)	66.26 (11.3)

Table 4.20

Mixed ANOVA on Heart Rate by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	.31	.580	.00
Naturalness	1	4.21	.042	.04
Restorative Potential	1	.02	.889	.00
Naturalness x Restorative Potential	1	.40	.530	.00
Naturalness x Time	1	.28	.600	.00
Restorative Potential x Time	1	.57	.450	.01
Naturalness x Restorative Potential x Time	1	.24	.620	.00
Error	112			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time. The means suggest Heart Rate decreased from Time 2 (M = 74.81, SE = 1.23) to Time 3 (M = 69.78, SE = 1.02). There was also a significant main effect of Naturalness, whereby Heart Rate was higher for those in the Natural conditions (M = 74.63, SE = 1.42) compared to those in the Urban conditions (M = 69.96, SE = 1.51). These results indicate no condition impacted Heart Rate.

Table 4.21

Mixed ANOVA on Heart Rate by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2g
Time	1	31.18	< .001	.212
Naturalness	1	5.11	.026	.04
Restorative Potential	1	.01	.929	.00
Naturalness x Restorative Potential	1	.42	.520	.00
Naturalness x Time	1	.89	.347	.01
Restorative Potential x Time	1	.04	.844	.00
Naturalness x Restorative Potential x Time	1	.09	.770	.00
Error	116			

Discussion

Study 2 focused on the impact of urban and natural environments that each varied in degree of Restorative Potential. I first analyzed how the stress induction impacted participants by analyzing the change in dependent measures across Time 1 and Time 2. The stress induction influenced the restorative measures by decreasing PA, increasing NA, increasing Subjective Stress, and increasing blood pressure. I then analyzed how exposure to the various environments impacted participants after the stress induction by comparing measures across Time 2 and Time 3. In this regard I either found no effects of environment exposure or the differences between Time 2 and Time 3 could be attributed to pre-intervention group differences (at Time 2). Thus, even though I increased the variety of natural and urban environments to include more extreme versions, I failed to observe robust influences of environment exposure on the measures of restoration.

I expected that the presence of infrastructure would negatively impact participants by raising blood pressure (Dye, 2008) and stress levels (Asgarzadi, 2014), while virtual nature would offer benefits such as stress reduction (e.g., Berto, 2014; Ulrich et al., 1991), attention restoration (e.g., Berto, 2005; Kaplan & Kaplan, 1989; Stevenson et al., 2018), and positive changes in affect (e.g., McMahan & Estes, 2015). These expectations were based on previous research, however, the findings of the study were not consistent with these expectations. There are a number of potential reasons why I might have failed to find a significant effect of nature on restoration. Nature has been studied using a diverse array of stimuli, including field studies using real nature, as well as lab-based studies using symbolic nature such as images or video (e.g., Ulrich et al., 1991; Ulrich, 1983; Ulrich, 1981). The utilization of VR environments may have contributed to the lack of significant findings. The Attention Restoration Theory (Kaplan, 1995)

suggests that simulated environments might require more directed attention to focus on the simulation while filtering out distracting scenery. The increased directed attention required in VR environments could potentially diminish the restorative benefits of nature exposure (Kjellgren & Buhrkall, 2010). As a result, VR might have reduced the potential of the environmental stimuli to be restorative.

Another possible reason for not observing environmental exposure impacts might be related to sample sizes. By increasing the sample size, it may be possible to better approximate the population mean reported in other studies investigating the restorative effects of nature.

To gain a better understanding of the restorative differences between urban and natural environments, my next study involved a field study.

Chapter 5 Study 3

Introduction

This field study aimed to extend Studies 1 and 2 using similar but real-world environments instead of virtual reality (VR) environments, facilitating comparisons with other restorative literature studies. Although simulations, like that in VR, can provide an immersive experience, it likely does not capture all aspects of real-world settings. Indeed, research suggests that simulated nature is less impactful than real-world environments (e.g., Kjellgren & Buhrkall, 2010). Kahn et al. (2008) observed greater heart rate recovery in participants viewing nature through a window compared to a plasma screen. Mayer et al. (2009) also found that being in nature as opposed to seeing it in a video increased positive emotions. Additionally, Horiuchi et al. (2014) studied participants seated in a forest with either an obscured or unobscured view. They found that blood pressure decreased after 15 minutes for all, however, those with a forest view reported improved moods, indicating that a holistic environmental experience may yield diverse effects.

Multisensory Factors Impacting Restoration

Emerging studies have demonstrated the diverse effects of auditory and olfactory elements on restorative measures. Research has shown that various sounds and aromas can influence mood, physiology, and behavior, potentially enhancing the sense of "being there" and improving focus and involvement within an environment. These findings collectively suggest that multisensory exposure to environmental elements can have significant impacts on restoration measures. For example, Benfield et al. (2015) induced negative moods prior to having participants listen to either no sound, nature sounds (birds and leaves rustling in the wind), motorized noise (vehicle sounds added to nature sounds), or voices added to nature sound. The results demonstrated that nature sounds improved feelings of pleasantness and positive mood

while the other sounds showed no change except for the motorized condition, which caused a further increase in negative moods following the sound exposure. Additionally, aromas have also been shown to influence mood, physiology, and behavior (Herz, 2009). For example, they can trigger specific emotions through the connection between the olfactory and limbic systems, which are also linked to the autonomic system governing fight-or-flight responses and various emotions including hate, aggression, love and more (Joseph & Cordozo, 2004). Riecke and Schulte-Pelkum (2015) and Smyth et al. (2015) suggest that increased immersion should heighten the sense of "being there" with improved focus and involvement with the environment. Taken together this suggests that having all senses exposed to all elements of an environment can have additional impacts on measures of restoration. Building upon these findings, this study sought to identify stronger physiological differences between conditions that were not observed in the earlier VR-based studies.

Vitality as a Measure in Dynamic Environments

Given the dynamic nature of field sites, and the strong connection between nature exposure and increases in vitality (e.g., Tyrväinen et al., 2014), I included a measure of Vitality to assess participants' energy levels. Vitality is defined as the feeling of vigor, alertness, and liveliness, a general energy for life, colloquially described as a manifesting of excitement and energy (Bostic et al., 2000; Ryan & Frederick, 1997). Vitality is different than non-active states of positive emotions such as happiness, satisfaction and contentment (McNair et al., 1971; Nix et al., 1999). Additionally, reducing stress and tension positively influences an individual's vitality, as high stress levels can impact calm energy (Thayer, 1987). Stewart et al. (1992) note that this energy feeling state is related to mental health and is associated with many well-being indicators (Nisbet et al., 2011; Ryan & Frederick, 1997) and specifically eudaimonic well-being (Nix et al., 1999).

Subjective vitality has been empirically associated with behavioral and health outcomes, and positive stress response mechanisms (e.g., Barrett et al., 2004; Rozanski et al., 2005). More specifically, people with more vitality were found to report greater health and well-being and better stress coping ability (Ryan & Frederick, 1997). Additionally, results on forest bathers consistently find elevated vigor levels in natural versus urban settings (e.g., Ochiai et al., 2015). As previous research has demonstrated significant links between vitality, stress reduction, and various health outcomes, this study's focus on subjective vitality in diverse environments contributes to the understanding of restorative experiences and emphasizes the need for further investigation in this area.

Overview

This study seeks to expand upon the existing body of restorative research by examining the holistic psychological and physiological impacts of real-world environments, broadening the restorative literature. Although not an exact replication, the main measures and fundamental procedures remain consistent with Study 1 and 2. Specifically, I collected the same restorative measures at the same three time points, baseline, post stress induction, and post exposure (15 minutes in environment) as I had in Study 1 and 2, with the addition of the vitality measure. Given that the study occurred in the field, I had to use a modified stress induction. Implementing the TSST was deemed unsuitable for this study, as the lab-induced stress would likely dissipate during the 10-15 minute walk to the location. As such, I incorporated the stress induction into the walk to the field site. This involved a 10-15 minute walk along a busy, four-lane arterial road with constant traffic, including cars, buses, and trucks. Participants walked on a crowded sidewalk, exposing them to urban conditions known to impair optimal functioning due to noise, pollution, crowding, and increased directed attention demands from traffic hazards. This

approach aimed to effectively induce stress by immersing participants in a challenging and stimulating urban environment.

A review by Ising and Braun (2000) found significant increases in cortisol levels when noise exposure during sleep exceeded Leq 30 dB and Lmax 55 dB, with chronic cortisol elevation resulting from continuous noise exposure, such as traffic. This finding indicates that a heavily trafficked roadway can effectively induce a stress response. Furthermore, a walk beside the road occurred on a busy sidewalk, potentially enhancing stress induction through a sense of crowding (Schmidt & Keating, 1979). This approach ensured that the stress induction occurred immediately before the intervention. Urban environments are known to induce stress due to factors such as noise, crowding, and air pollution (Ulrich et al., 1991; Ising & Braun, 2000; Ndrepepa & Twardella, 2011). Moreover, urban settings can distract individuals from their thoughts, hindering goal accomplishment and leading to stress and diminished mood and attention (Kaplan, 1995). Therefore, a walk in an urban environment could serve as a naturalistic stress induction method.

Additionally, I continued the examination of restorative potential by selecting four environments that cross nature and urban locales with higher and lower restorative potential (see methods for details for each environment). As such, each participant was exposed to one of four environments (High Restorative Potential Nature, Low Restorative Potential Nature, High Restorative Potential Urban, and Low Restorative Potential Urban). Detailed descriptions of environments are provided in the method section.

The hypotheses are similar to Study 1 and 2, 1) the natural environments collapsed together will exhibit greater restoration than the urban environments combined, with High Restorative Potential (HRP) conditions significantly outperforming Low Restorative Potential (LRP)

conditions in terms of restoration. 2) The HRP-urban condition may prove as restorative as the LRP-natural environments, reflecting observations from earlier studies with similar conditions. 3) the LRP-urban condition, an oppressive urban environment characterized by towering buildings will be the least restorative condition due to its overwhelming nature and lack of restorative stimuli.

Methods

Participants

There were 110 University of Waterloo student participants from the SONA system described in Study 1 and 2. In total there were 88 females and 22 males with participants ranging in age from 17-31 (M =19.92, SD = 4.6).

Measures

Subjective Vitality Scale

We included a new measure of a restorative experience, Vitality, which was assessed using the Subjective Vitality Scale (SVS; Ryan & Frederick, 1997). Bostic et al. (2000) validated the scale, confirming it specifically measures vitality. They removed one item, resulting in a revised 6-item SVS that demonstrated better goodness of fit indices. The SVS is a self-report measure assessing individuals' perceived vitality and energy levels, focusing on feelings of energy, aliveness, and alertness rather than physical activity or fatigue. Participants rate agreement with statements reflecting their feelings on a Likert-type scale from 1 (strongly disagree) to 7 (strongly agree). Higher scores indicate higher vitality. The scale demonstrates strong internal consistency, with coefficient alpha values ranging from .87 to .89 (Ryan & Frederick, 1997).

Environment

This field study controlled potential confounding variables such as stress levels and mood by ensuring all locations were situated near the same four-lane artery road. This ensured consistent traffic noise exposure for all participants, as traffic noise has been shown to induce stress (Babisch, 2006). Furthermore, each location was within a 10-15 minute walk from the University of Waterloo's Lab location to maintain consistent physical activity levels among

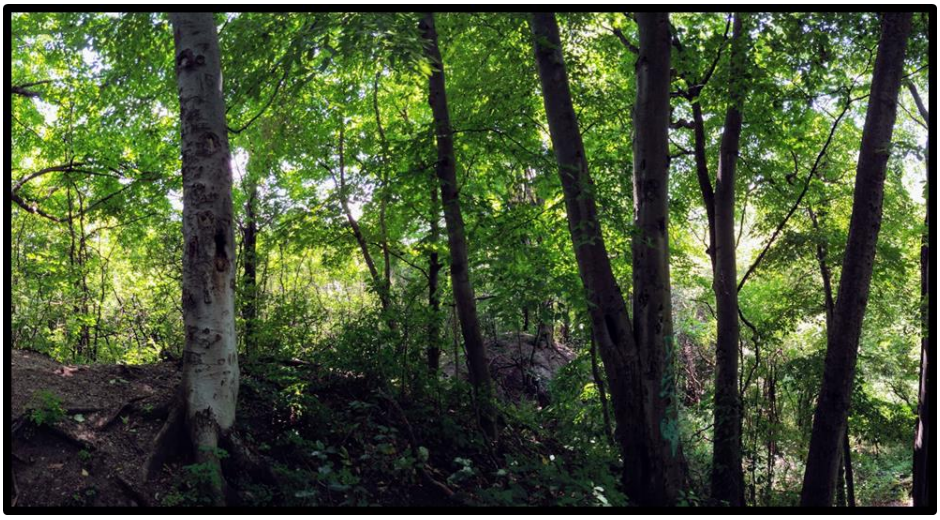
participants, as physical activity has been shown to reduce stress and enhance mood (Hamer et al., 2012).

High Restorative Potential Nature

The location for this environment (modified replication of Study 2's HRP-nature, shown in Figure 5.1) aimed to immerse participants in a tranquil and serene nature environment by surrounding them with lush green vegetation, large mature trees, and diverse vegetation. Research has shown that such elements can reduce stress and enhance well-being in a dose-dependent manner (Kaplan & Kaplan, 1989; Lee et al., 2009; Roe et al., 2013; Ulrich et al., 1991; Ward et al., 2012).

The environment was situated next to a walking trail, ensuring a sense of safety (Milligan & Bingley, 2007; Kaplan & Kaplan, 1989), crucial for the restorative process (Staats et al., 2016). Additionally, the 111-acre park in which the environment was located had ample vegetation and trees that helped reduce traffic noise from a nearby busy road. Other restorative aspects included minimal visual access to the urban surroundings (van der Jagt et al., 2014) and the presence of a small forest clearing for prospect and refuge sightlines. To create an optimal restorative environment, I emphasized restorative features like trees and vegetation and minimized potential stress-inducing stimuli such as unkempt overgrowth, urban features, and traffic noise.

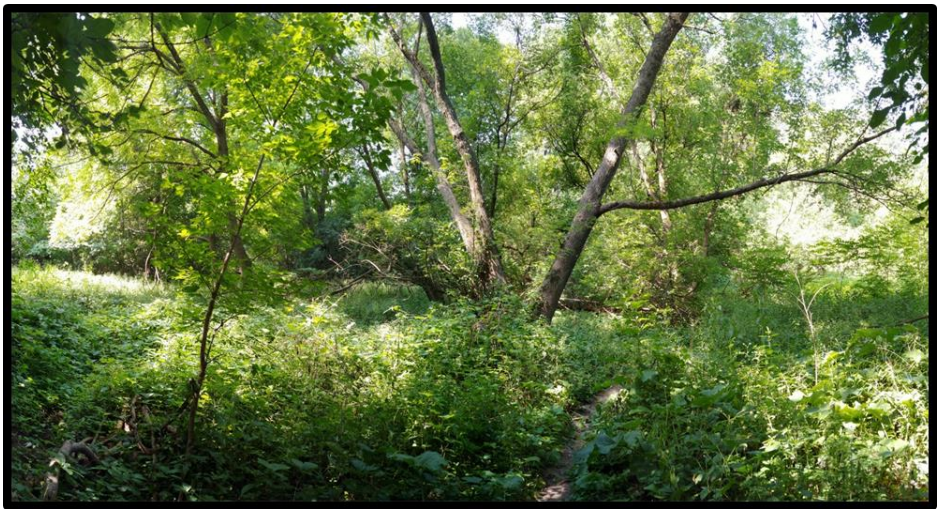
Figure 5.1. HRP-nature



Low Restorative Natural Environment

The location in Figure 5.2 was selected to approximately replicate the LRP-nature environment from Study 1. It featured no infrastructure and surrounded participants with green vegetation. Participants were seated at the edge of the park used in the HRP-nature condition, with a view of an overgrown area containing few small, widely spaced trees. The wild overgrowth helped to buffer the park from a busy road running parallel to it. However, traffic noise was noticeably louder than in the HRP-nature environment due to the close proximity to the road. Despite being enveloped in biodiverse vegetation, this natural environment had limited tree presence and contained stress-inducing stimuli such as unkempt overgrowth, bushes, and traffic noise.

Figure 5.2. LRP-nature



High Restorative Potential Urban

The site depicted in Figure 5.3 is an approximate replication of the HRP-urban environment from Study 1. Participants were situated in a small outdoor mall with appealing one-story buildings and shopfronts, along with natural elements like trees lining the road.

The architectural diversity and low building height contribute to the environment's restorative potential (Herández & Hidalgo, 2005). Streetscapes, shopping malls, and recreational areas are considered more restorative than residential areas, densely built areas, and industrial zones, which are perceived as less restorative (Galindo & Hidalgo, 2005; Herández & Hidalgo, 2005). This environment also minimized stress by reducing overstimulating urban features like crowds, distracting stimuli, and heavy traffic, known to cause attention fatigue (Kaplan, 1995). Benches were available for mall visitors and participants, decreasing the likelihood of awkward social experiences and stress from social evaluation threats (Dickerson & Kemeny, 2004; Allen et al., 2017). Participants were seated in front of a closed store, reducing pedestrian traffic and crowding within the mall area to alleviate stress (Ulrich et al., 1991). Thus, this environment has

high restorative potential due to its size, the fact that is a mall and recreation areas, diverse architecture, natural elements, and it contained few stress-inducing stimuli, promoting relaxation and alleviating stress for participants.

Figure 5.3. HRP-urban



Low Restorative Potential Urban

Figure 5.4, Figure 5.5, and Figure 5.6 depict the LRP-urban environment selected to approximately replicate the LRP-urban condition from Study 2. It was selected as it emulates a dense, industrial cityscape with minimal architectural variation, featuring tall residential buildings, as seen in Study 2. Participants were seated along a walking path leading to a student commons area, ensuring a constant flow of pedestrians and inducing a sense of crowding, which can be a stress-inducing factor (Ulrich et al., 1991). The tall concrete buildings are also known to induce stress (Asgarzadeh et al., 2012), and residential areas with numerous buildings have been predicted to be the least restorative urban environments (Galindo & Hidalgo, 2005; Herández & Hidalgo, 2005).

Despite efforts to remove restorative elements, the area retained an open grassy field with a few small trees. Since the HRP-urban environment also contained some natural elements, the comparable presence of nature in both urban settings made it suitable for studying urban stimuli, as few urban environments are entirely devoid of natural elements. I ensured that stress-inducing urban features, such as tall buildings, residential areas, and crowding, were present. As a result, this environment lacked urban elements predicted to be restorative and contained stress-inducing elements commonly found in urban settings.

Figure 5.4. LRP-urban (Forward Facing View)



Figure 5.5. LRP-urban Environment (Left Side View)

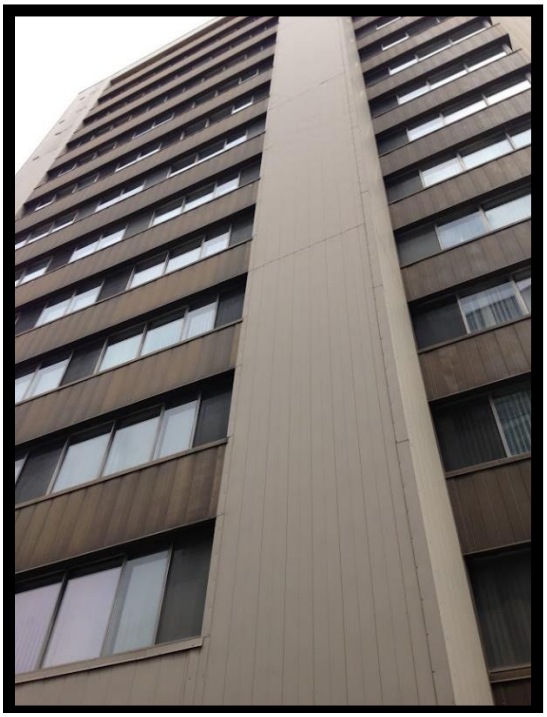


Figure 5.6. LRP-urban Environment (Right Side View)



Noise of Each Environment

One important and consistent feature of the environments was the noise level. To provide some context, Downtown Waterloo, the city where the study was conducted, has an average decibel of 80dB along the street and 65dB in public spaces, both these levels of decibels are considered irritating (Pan, 2018). Thus, to understand the impact of noise on participants in each environment, I measured decibels over the course of a week in the morning, midday, and afternoon (during study times) using the phone application Sound Meter, an app created by Abc Apps that measures sound level using an android devices microphone (Google Play, 2023). The app suggests that most android devices are aligned to human voice (which the device used was), so the maximum values are limited by the android device and thus does not record volume over ~90dB. The app shows a decibel value by measuring the environmental noise (Google Play, 2023). As can be seen in Table 5.1 the dB of each area was roughly similar and thus was not expected to have had a substantial impact on participants.

Table 5.1.

Decibels of Each Location

Environment	Average dB	High dB	Low dB
HRP-nature	59.7	80	53
LRP-nature	61.4	80	55
HRP-urban	64	80	57
LRP-urban	60	80	50

Note: dB= Decibels

Procedure

Naturalistic Stress Induction

A key difference between this study and Studies 1 and 2 is the stress induction method. While Studies 1 and 2 were conducted as in-lab experiments using the TSST, this study employed exposure to stress-inducing stimuli. Participants were required to walk for 10-15

minutes to their study location, accompanied by a researcher. The route included busy roads with heavy traffic, increasing participants' sense of danger and introducing pollution and loud traffic noise. The researchers maintained relative silence during the walk, speaking only to provide necessary instructions. The duration of each walk to the study locations was kept consistent and the sidewalks were intentionally chosen to have pedestrians to evoke a feeling of crowding. To ensure consistent levels of traffic and pedestrian activity during the walks, all studies were carried out during regular business hours, from 9:00 am to 5:00 pm. The proximity of the study locations to the university contributed to a steady flow of pedestrian traffic as students traveled between their residential areas and the university for classes.

Procedural Overview

The study's methodology largely follows that of previous studies with data collection conducted at three time points, with a 15 minute stress induction, and a 15 minute intervention experience. However, this study was a field study, so there are some deviations from the procedures of Study 1 and 2.

Upon arrival at the psychology department, participants were guided to a designated lab room. The study began with participants reading and completing the information and consent forms. They were then asked to sit quietly for 5 minutes to allow their physiology to return to baseline. Following the 5 minutes of relaxation, blood pressure was then taken and the Empatica was placed on the participant's wrist to monitor body temperature. Once participants were equipped with the measurement device, participants were then directed to complete the first survey with demographic questions, the ZIPERS scale, and a measure of Subjective Stress and Attention. Following this, participants were guided to their study location with the researcher, along the busy road for the stress induction. Once participants arrived at the study location, they

were instructed to sit in the seat provided and blood pressure measures were taken. Participants were then asked to fill out the second survey which included the ZIPERS scale and the Subjective Stress and Attention questions. Following this, participants were instructed to sit quietly and observe their surroundings taking in the atmosphere of their location including the sights, sounds, and smells of the location for 15 minutes. The researcher sat beside the participant during the 15 minutes and also observed the surroundings to model the expected behaviour of the participant. Once the 15 minutes finished, the Empatica was removed from the participant and blood pressure was collected. Finally, the participant was asked to complete the final survey which included the ZIPERS scale and the Subjective Stress and Attention question. The study concluded following this with the researcher walking the participant back to the university and providing a debrief.

Experimental Design

The design was a 2x2x2 mixed factorial design with measures taken at Time 1 (baseline), Time 2 (post stress induction) and Time 3 (post exposure) as within-subjects factors, and Naturalness (Nature & Urban) and Restorative Potential (High & Low) as between-subjects factors. Each participant was randomly assigned to one of the four environments (HRP-nature, LRP-nature, HRP-urban, and LRP-urban.

Analysis

The analysis for this study is the same as the one used in Study 1 and 2. I ran a mixed factorial ANOVA on Time 1/Time 2 and on Time 2/Time 3 (within-subjects) with Naturalness (Urban and Nature) and Restorative Potential (High and Low) as between-subjects factors. With post hoc analysis conducted on interactions assessing the simple main effects with Bonferroni correction at the .05 levels.

Results

The results are presented in three tables for each dependent variable (DV). The first table contains mean scores for the DV with standard deviations as a function of condition. The following two tables provide the Mixed ANOVA results comparing Time 1/Time 2 and Time 2/Time 3 (within-participant) respectively, using Naturalness (Nature, Urban) and Restorative Potential (High, Low) as the between-subjects factor. The header for each DV indicates the associated Table numbers for the descriptives and the two Mixed ANOVAs respectively.

It is important to note that not all the data sets were completed for each DV, as participants occasionally missed questions either inadvertently due to inattention or intentionally chose to skip certain questions they felt uncomfortable answering.

Positive Affect (PA; Table 5.2; 5.3; 5.4)

The Time 1/Time 2 ANOVA analysis revealed a significant main effect of Time. The means indicate an increase in PA from Time 1 (M = 11.15, SE = .4) to Time 2 (M =12, SE = .31). This is inconsistent with the stress induction working.

Table 5.2

Positive Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	11.82 (2.80)	11.50 (2.80)	10.24 (3.65)	11.04 (2.86)
Time 2	12. 7 (3.20)	12.04 (3.00)	11.55 (3.50)	11.70 (3.28)
Time 3	12.82 (3.51)	13.85 (3.75)	11.07 (3.37)	12.85 (3.70)

Table 5.3

Mixed ANOVA on Positive Affect by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	17.56	<.001	.14
Naturalness	1	2.38	.126	.02
Restorative Potential	1	.00	.989	.00
Naturalness x Restorative Potential	1	.71	.401	.01
Naturalness x Time	1	.46	.500	.00
Restorative Potential x Time	1	1.50	.224	.01
Naturalness x Restorative Potential x Time	1	.13	.719	.00
Error	105			

The results of the Time 2/Time 3 ANOVA revealed a main effect of Time. The means indicate PA increased from Time 2 (M = 12, SE = .31) to Time 3 (M = 12.65, SE = .34). Additionally, there was a significant two-way interaction between Time and Restorative Potential. Pairwise comparisons were made with a Bonferroni correction on the simple main effects at the .05 level, indicating PA was significantly impacted by the LRP conditions (p = <.001) compared to the HRP conditions (p = .495). The means indicate that PA significantly increased from Time 2 (M = 11.87, SE = .45) to Time 3 (M = 13.35, SE = .49). This is inconsistent with what was predicted as I had expected the HRP conditions to increase PA.

Table 5.4

Mixed ANOVA on Positive Affect by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	11.01	.001	.10
Naturalness	1	2.84	.095	.03
Restorative Potential	1	.84	.361	.01
Naturalness x Restorative Potential	1	.39	.533	.00
Naturalness x Time	1	2.59	.111	.02
Restorative Potential x Time	1	18.25	<.001	.15
Naturalness x Restorative Potential x Time	1	.01	.930	.00
Error	105			

Negative Affect (NA; Table 5.5; 5.6; 5.7)

The Time 1/Time 2 ANOVA revealed a significant main effect of Time. The means indicate NA decreased from Time 1 (M = 4.94, SE = .14) to Time 2 (M = 4.41, SE = .08). The reduction in NA across all environments, conflicts with the intended effectiveness of the stress induction.

Table 5.5

Negative Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	4.85 (1.41)	5.33 (1.75)	5.04 (1.50)	4.56 (.85)
Time 2	4.30 (.72)	4.63 (1.08)	4.38 (.86)	4.33 (.73)
Time 3	4.30 (.82)	4.37 (.74)	4.14 (.35)	4.33 (.88)

Table 5.6

Mixed ANOVA on Negative Affect by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	26.91	<.001	.20
Naturalness	1	1.03	.311	.01
Restorative Potential	1	.13	.716	.00
Naturalness x Restorative Potential	1	2.84	.095	.03
Naturalness x Time	1	.86	.356	.01
Restorative Potential x Time	1	.48	.491	.00
Naturalness x Restorative Potential x Time	1	1.99	.161	.02
Error	106			

The Time 2/Time 3 ANOVA revealed no significant main effects or interactions on NA. This lack of significant findings may have been due to the stress induction reducing NA across all conditions. This inconsistency may have impeded the ability to observe significant decreases in NA that could help determine the most restorative environment for NA reduction.

Table 5.7

Mixed ANOVA on Negative Affect by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	2.59	.111	.02
Naturalness	1	.62	.435	.01
Restorative Potential	1	1.14	.290	.01
Naturalness x Restorative Potential	1	.25	.622	.00
Naturalness x Time	1	.00	.954	.00
Restorative Potential x Time	1	.00	.954	.00
Naturalness x Restorative Potential x Time	1	2.59	.111	.02
Error	106			

Vitality (Table 5.8; 5.9; 5.10)

The results from the Time 1/Time 2 ANOVA revealed a main effect of Time, indicating Vitality increased from Time 1 (M = 18.49, SE = .41) to Time 2 (M = 19.79, SE = .43). The results are surprising, as I had expected a decrease in Vitality levels due to the stressful experience induced by the stress induction procedure.

Table 5.8

Vitality, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	19.00 (3.64)	18.74 (4.23)	17.52 (4.81)	18.70 (4.53)
Time 2	20.70 (4.27)	19.26 (4.52)	19.17 (4.60)	20.04 (4.56)
Time 3	20.37 (4.40)	20.82 (4.50)	17.76 (4.55)	20.11 (4.82)

Table 5.9

Mixed ANOVA on Vitality by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	24.93	<.001	.19
Naturalness	1	.50	.480	.01
Restorative Potential	1	.01	.914	.00
Naturalness x Restorative Potential	1	1.38	.244	.01
Naturalness x Time	1	.54	.464	.01
Restorative Potential x Time	1	2.09	.152	.02
Naturalness x Restorative Potential x Time	1	.68	.410	.01
Error	106			

The Time 2/Time 3 ANOVA analysis revealed a significant two-way interaction between Time and Naturalness. To further investigate this interaction, planned pairwise comparisons were conducted with a Bonferroni correction, comparing Natural and Urban environments across

Time. There was no significant difference in Vitality levels for those exposed to the Natural conditions (p = .090), however, there was a marginally significant difference in Vitality between Time 2 and Time 3 for those in the Urban conditions (p = .059). The means indicate that Vitality decreased from Time 2 (M = 19.61, SE = .60) to Time 3 (M = 18.94, SE = .61). Thus, it appears the urban environments used in this study had a negative effect on energy levels.

Additionally, the two-way interaction between Time and Restorative Potential was significant. Post-hoc analyses using a Bonferroni correction revealed that participants in the HRP conditions experienced a significant decrease in Vitality (p = .014) from Time 2 (M = 19.94, SE = .60) to Time 3 (M = 19.06, SE = .61). Conversely, those in LRP conditions experienced a significant increase in Vitality (p = .025) between Time 2 (M = 19.65, SE = .61) and Time 3 (M = 20.46, SE = .62). This finding implies that differences in restorative capacity can influence Vitality outcomes. However, these outcomes were unexpected as it was hypothesized that the HRP conditions would increase Vitality and the LRP conditions would reduce Vitality.

Table 5.10

Mixed ANOVA on Vitality by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	.01	.907	.00
Naturalness	1	1.51	.222	.14
Restorative Potential	1	.45	.505	.00
Naturalness x Restorative Potential	1	1.62	.206	.02
Naturalness x Time	1	6.53	.012	.06
Restorative Potential x Time	1	11.35	.001	.10
Naturalness x Restorative Potential x Time	1	.16	.690	.00
Error	106			

Subjective Attention (Table 5.11; 5.12; 5.13)

The Time 1/Time 2 ANOVA revealed a significant main effect of Time. The means indicate a decrease in Subjective Attention from Time 1 (M = 3.57, SE = .07) to Time 2 (M = 3.41, SE = .09). There was also a significant interaction between Time and Restorativeness. Planned pairwise comparisons revealed a significant difference between those in the HRP conditions (p =.005), while no significant difference was observed for those in the LRP conditions (p = 1.00). The means of the HRP participants suggest Subjective Attention decreased from Time 1 (M = 3.67, SE = .10) to Time 2 (M = 3.34, SE = .13). Since this occurred prior to participants' exposure to their respective Restorative Potential conditions, it suggests that there were preexisting group differences in Subjective Attention.

Table 5.11

Subjective Attention, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	3.78 (.70)	3.44 (.85)	3.55 (.74)	3.52 (.80)
Time 2	3.33 (1.00)	3.33 (.92)	3.34 (1.08)	3.63 (.93)
Time 3	3.56 (.97)	3.36 (.97)	3.24 (1.02)	3.67 (1.04)

Table 5.12

Mixed ANOVA on Subjective Attention by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	4.13	.045	.04
Naturalness	1	.07	.790	.00
Restorative Potential	1	.02	.891	.00
Naturalness x Restorative Potential	1	.97	.330	.01
Naturalness x Time	1	2.06	.154	.02
Restorative Potential x Time	1	4.13	.045	.04
Naturalness x Restorative Potential x Time	1	.00	.960	.00
Error	106			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time. The means suggest participants Subjective Attention increased from Time 2 (M = 3.41, SE = .09) to Time 3 (M = 3.52, SE = .10). The results align with my expectations following the stress induction, as Subjective Attention declined due to the walk in a highly stimulating environment with distracting stimuli that depleted attentional resources. Although Subjective Attention improved after exposure to the various environments, no specific environment proved to be significantly more restorative than the others.

Table 5.13

Mixed ANOVA on Subjective Attention by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	623.26	<.001	.86
Naturalness	1	.58	.450	.01
Restorative Potential	1	.51	.480	.01
Naturalness x Restorative Potential	1	.81	.370	.01
Naturalness x Time	1	.68	.413	.01
Restorative Potential x Time	1	.56	.456	.01
Naturalness x Restorative Potential x Time	1	.30	.582	.00
Error	106			

Subjective Stress (Table 5.14; 5.15; 5.16)

The Time 1/Time 2 ANOVA analysis revealed a significant main effect of Time. The means suggest Subjective Stress decreased from Time 1 (M = 2.38, SE = .09) to Time 2 (M = 1.76, SE = .08) indicating the stress induction was ineffective.

Table 5.14

Subjective Stress, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	2.63 (.97)	2.19 (.92)	2.46 (1.10)	2.26 (.53)
Time 2	1.85 (.72)	1.85 (.91)	1.72 (.81)	1.61 (.74)
Time 3	1.52 (.70)	1.48 (.70)	1.78 (.85)	1.37 (.63)

Table 5.15

Mixed ANOVA on Subjective Stress by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	70.83	<.001	.42
Naturalness	1	.63	.430	.01
Restorative Potential	1	1.58	.212	.02
Naturalness x Restorative Potential	1	.06	.81	.00
Naturalness x Time	1	.87	.354	.01
Restorative Potential x Time	1	3.25	.074	.03
Naturalness x Restorative Potential x Time	1	1.42	.237	.01
Error	100			

The Time 2/Time 3 ANOVA indicated that there was a main effect of Time. The means indicate Subjective Stress decreased from Time 2 (M = 1.76, SE = .08) to Time 3 (M = 1.54, SE = .07). The two-way interaction between Time and Naturalness was also significant. Pairwise comparisons with Bonferroni correction revealed a significant reduction in Subjective Stress for participants in the Natural conditions (p<.001), with mean Subjective Stress decreasing from Time 2 (M = 1.85, SE = .11) to Time 3 (M = 1.5, SE = .10). In contrast, no significant difference was observed for the Urban condition participants (p = .349) between Time 2 and Time 3. These findings provide evidence that natural environments are more effective than urban settings in reducing stress, as the urban condition did not demonstrate any restorative impact on stress levels.

Table 5.16

Mixed ANOVA on Subjective Stress by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	13.40	<.001	.11
Naturalness	1	.19	.67	.00
Restorative Potential	1	1.16	.285	.01
Naturalness x Restorative Potential	1	.87	.35	.01
Naturalness x Time	1	5.49	.021	.05
Restorative Potential x Time	1	2.41	.124	.02
Naturalness x Restorative Potential x Time	1	1.53	.22	.01
Error	106			

Diastolic Blood Pressure (DBP; Table 5.17; 5.18; 5.19)

The Time 1/Time 2 ANOVA analysis revealed a significant main effect of Time, and there was also a significant three-way interaction between Time, Naturalness, and Restorative Potential. The means suggest DBP increased from Time 1 (M = 70.15, SE = .80) to Time 2 (M = 78.71, SE = .83), which was not surprising as the participants had just walked to the field site. There was also a significant two-way interaction between Time and Restorative Potential, however, because there is a significant three-way interaction I performed the post-hoc analysis only on the three-way interaction. The pairwise comparisons with Bonferroni correction revealed a significant difference in DBP between the LRP-natural and LRP-urban conditions at Time 2 (p = .018). The means indicate participants who walked to the LRP-urban environment experienced significantly higher DBP after the walk (M = 80.27, SE = 1.69) compared to those who walked to the LRP-natural environment (M = 74.59, SE = 1.66). While no other environments were found to significantly impact DBP between Time 1 and Time 2 (HRP-nature vs HRP-urban at Time 1

(p = .881), HRP-nature vs HRP-urban at Time 2 (p = .206), LRP-nature vs LRP-urban at Time 1 (p = .962)). It is important to keep in mind that the environment exposure had not yet occurred, which suggests the walk to the LRP conditions had significantly different effects on participants DBP.

Table 5.17

Diastolic Blood Pressure, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	70.65 (7.68)	70.15 (9.58)	70.03 (8.09)	70.04 (7.93)
Time 2	81.46 (8.41)	74.59 (7.89)	78.52 (10.46)	80.27 (7.27)
Time 3	77.50 (9.19)	73.30 (9.54)	75.48 (8.03)	79.58 (12.68)

Table 5.18

Mixed ANOVA on Diastolic Blood Pressure by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	243.12	<.001	.70
Naturalness	1	.14	.707	.00
Restorative Potential	1	.76	.387	.01
Naturalness x Restorative Potential	1	2.08	.152	.02
Naturalness x Time	1	2.12	.149	.02
Restorative Potential x Time	1	4.94	.028	.05
Naturalness x Restorative Potential x Time	1	14.56	<.001	.12
Error	105			

The analysis of the Time 2/Time 3 ANOVA revealed a significant main effect of Time. The means suggest DBP decreased from Time 2 (M = 78.71, SE = .83) to Time 3 (M = 76.46, SE

= .96), congruent with expectations, considering the participants sat for 15 minutes after their walk to the study site. There was also a significant two-way interaction between Naturalness and Restorative Potential. The pairwise comparisons with Bonferroni correction suggest that there was a significant difference (p = .01) between the LRP-urban and LRP-natural conditions, while no differences were found between the HRP conditions (p =.273). The means suggest that the LRP-urban condition participants had significantly higher DBP (M =79.92, SE = 1.64) in general compared to the LRP-natural condition participants (M = 73.94, SE = 1.61). Due to group differences before the intervention, it is difficult to interpret these findings in relation to how the intervention impacted participants' DBP.

Table 5.19

Mixed ANOVA on Diastolic Blood Pressure by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	7.88	.006	.07
Naturalness	1	1.18	.279	.01
Restorative Potential	1	.66	.418	.01
Naturalness x Restorative Potential	1	6.93	.010	.06
Naturalness x Time	1	.23	.633	.00
Restorative Potential x Time	1	2.45	.121	.02
Naturalness x Restorative Potential x Time	1	.01	.920	.00
Error	104			

Systolic Blood Pressure (SBP; Table 5.20; 5.21; 5.22)

The analysis of the Time 1/Time 2 ANOVA revealed a significant main effect of Time with the means indicating SBP increased from Time 1 (M = 112.15, SE = 1.06) to Time 2 (M = 127.47, SE = 1.22). There was also a significant three-way interaction between Time,

Naturalness, and Restorativeness. The pairwise comparisons with Bonferroni correction suggest that each condition was significantly affected by the stress induction, but no condition was significantly differentially impacted at either Time 1 or Time 2 to discuss the interaction effect. For example, at Time 1 there was no difference between the Restorative Potential of the Urban conditions (p = .423), as well as at Time 2 (p = .182). This also occurred with the difference in Restorative Potential for the Natural conditions at Time 1 (p = .694) and at Time 2 (p = .678). However, the effect of Time proved significant for all conditions with the HRP-nature condition participants experienced a significant increase in SBP (p<.001), with the means suggesting SBP increased from Time 1 (M = 111.70, SE = 2.13) to Time 2 (M = 127.89, SE = 2.46). The LRP-nature condition participants experienced a significant increase in SBP (p<.001) with the means suggesting SBP increased from Time 1 (M = 112.89, SE = 2.13) to Time 2 (M = 126.44, SE = 2.46). The HRP-urban condition participants also experienced a significant increase in SBP (p<.001) with the means suggesting SBP increased from Time 1 (M = 113.21, SE = 2.05) to Time 2 (M = 125.45, SE = 2.37). Finally, the LRP-urban condition participants experienced a significant increase in SBP (p<.001) with the means suggesting SBP increased from Time 1 (M = 110.81, SE = 2.17) to Time 2 (M = 130.08, SE = 2.50). These results suggest that the stress-inducing walk elevated SBP for all conditions; however, the psychological measures suggest that this increase in SBP was likely due to the physical activity of the walk itself rather than stress-related factors.

Table 5.20

Systolic Blood Pressure, Means and Standard Deviations (in Brackets) from each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	112.19 (8.76)	112.89 (10.78)	113.21 (14.14)	110.81 (9.22)
Time 2	128.04 (10.57)	126.44 (12.64)	125.45 (14.40)	130.08 (13.19)
Time 3	115.19 (10.05)	114.85 (9.17)	117.21 (12.95)	116.73 (12.76)

Table 5.21

Mixed ANOVA on Systolic Blood Pressure by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	321.54	<.001	.75
Naturalness	1	.01	.943	.00
Restorative Potential	1	.05	.817	.00
Naturalness x Restorative Potential	1	.09	.770	.00
Naturalness x Time	1	.27	.605	.00
Restorative Potential x Time	1	1.70	.201	.02
Naturalness x Restorative Potential x Time	1	8.00	.006	.07
Error	105			

The analysis of the Time 2/Time 3 ANOVA revealed a significant main effect of Time. The means suggest SBP decreased from Time 2 (*M* = 127.44, *SE* = 1.24) to Time 3 (*M* = 116.02, *SE* = 1.10). These results align with the notion that the stress induction led to increased blood pressure (Time1/Time2 results), which then decreased following exposure to various environments (Time 2/Time 3 results). However, the lack of significant interactions between

Time and Naturalness or Restorative Potential suggests that none of the environments substantially impact the observed changes in SBP.

Table 5.22

Mixed ANOVA on Systolic Blood Pressure by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	144.61	<.001	.58
Naturalness	1	.34	.564	.00
Restorative Potential	1	.07	.795	.00
Naturalness x Restorative Potential	1	.51	.480	.01
Naturalness x Time	1	.56	.458	.01
Restorative Potential x Time	1	1.01	.317	.01
Naturalness x Restorative Potential x Time	1	2.76	.100	.03
Error	104			

Heart Rate (Table 5.23; 5.24; 5.25)

The analysis of the Time 1/Time 2 ANOVA revealed a significant main effect of Time. The means indicate Heart Rate increased from Time 1 (M = 73.48, SE = 1.04) to Time 2 (M = 82.84, SE = 1.50). A significant three-way interaction between Time, Naturalness, and Restorative Potential was also observed. Post-hoc analysis with Bonferroni correction revealed there was a significant difference in Heart Rate between the HRP and LRP urban conditions at Time 2 (p = .039). The means indicating that the LRP-urban condition participants experienced significantly higher Heart Rate (M = 86.46, SE = 3.06) at Time 2 compared to those in the HRP-urban condition (M = 77.65, SE = 2.90). Due to the fact that the intervention had not yet occurred we can interpret this as the LRP-urban condition participants were more effected by the walk to the study location than the other conditions, as there were no difference between the (HRP-urban

vs LRP urban at Time 1 (p = .203), HRP-nature vs LRP-nature at Time 1 (p =.900), HRP-nature vs LRP-nature at Time 2 (p =.435)). Thus, there were group differences in Heart Rate due to the walk to the study sites before the intervention.

Table 5.23

Heart Rate, Means and Standard Deviations (in Brackets) from each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	74.81 (9.00)	74.81 (10.32)	70.45 (11.36)	74.19 (12.32)
Time 2	81.96 (13.77)	83.60 (14.97)	77.66 (15.67)	86.46 (17.00)
Time 3	78.92 (10.93)	70.89 (11.98)	70.34 (10.24)	76.42 (10.21)

Table 5.24

Mixed ANOVA on Heart Rate by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	p	η^2_g
Time	1	86.23	<.001	.45
Naturalness	1	.67	.415	.01
Restorative Potential	1	1.02	.314	.01
Naturalness x Restorative Potential	1	2.68	.105	.03
Naturalness x Time	1	.13	.715	.00
Restorative Potential x Time	1	.11	.737	.00
Naturalness x Restorative Potential x Time	1	4.72	.032	.04
Error	105			

The Time 2/Time 3 ANOVA revealed a significant main effect of Time. The means indicated participants' Heart Rate decreased from Time 2 (M = 82.85, SE = 1.51) to Time 3 (M = 74.15, SE = 1.05). There was also a significant two-way interaction between Naturalness and Restorative Potential. There was a significant difference between the Restorative Potential of the Urban conditions (p = .027) compared to the Restorative Potential of the Natural conditions (p =

.094). The means indicate that participants' Heart Rate was significantly higher for those in the LRP-urban condition (M = 81.44, SE = 2.41) compared to the HRP-urban condition (M = 74.00, SE = 2.28). Clearly the group differences identified at Time 1/Time 2 remained consistent throughout the study.

Table 5.25

Mixed ANOVA on Heart Rate by Time 2 and Time 3, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	64.89	<.001	.38
Naturalness	1	.43	.514	.00
Restorative Potential	1	.137	.712	.00
Naturalness x Restorative Potential	1	7.72	.006	.07
Naturalness x Time	1	.00	.980	.00
Restorative Potential x Time	1	2.95	.089	.03
Naturalness x Restorative Potential x Time	1	.21	.651	.00
Error	105			

Discussion

The purpose of the study was to examine the restorative impact of real-world environments resembling those investigated in Studies 1 and 2, with a focus on analyzing the effects of varying restorative potential in urban and natural settings using field studies. I aimed at achieving similar or even more pronounced restorative results, as the immersive nature of field environments (described by Slater & Wilbur, 1997, as providing an inclusive, extensive, and vivid reality) could potentially enhance the restorative effects observed in previous studies.

Inconsistent Results

Overall, the results were inconsistent. One important point to make is that the stress induction did not yield the expected outcomes. Subjective Stress scores and other subjective restorative measures remained relatively unchanged or resulted in positive outcomes post-stress induction (Time 2). This absence of a successful stress induction, crucial for evaluating stress recovery, may have impeded the detection of differences between baseline and post-intervention measures. For example, NA, Subjective Attention, Blood Pressure and Heart Rate were unchanged by the conditions contrary to previous research finding (e.g., Hansen et al., 2017; Berto, 2014; Kaplan, 1995).

An interesting result regarding the physiological measures and the stress induction was that the stress induction increased all the physiological measures from Time 1 to Time 2. However, this increase in physiology was likely due to the walk to the study locations as PA and Vitality increased, and NA and Subjective Stress decreased indicating a lack of stress from the walk to the study location. Previous studies including those in the review by Penedo and Dahn (2005) on exercise and well-being indicate physical activity interventions can positively impact health-related quality of life, better functional capacity, and better mood states. Thus, it is likely that the

walk outdoors had a significant positive impact on participants superseding the detrimental effects of the stressful street environment.

Additionally, there were differences in the physiological measures pre-intervention. For example, DBP increased for all participants, but DBP was significantly higher after participants walked to the LRP-urban condition compared to those that walked to the LRP-nature condition. Additionally, Heart Rate was significantly higher for those that walked to the LRP-urban condition compared to the HRP-urban condition. Both increases in physiology occurred at Time 2 (post walk), suggesting there was a significantly different impact on physiology for those who walked to the LRP-urban condition.

Recognizing the confounding factors that could impact the participants due to the different walks to the study sites, efforts were made to ensure similar walking distances and traffic volume between study locations. However, clearly there were different effects from the walk to the study sites. The difference could be attributed to differences in restorative stimuli exposure during the walks, as the walk to the nature conditions, and the HRP-urban condition involved slightly more restorative stimuli exposure due to the routes. While the LRP-urban condition walk involved more stressful urban stimuli, such as people, traffic and the industrial buildings that were to surround participants at the study site. Future research should aim to minimize these confounding factors that were present due to the walk to the study site locations.

These inconsistent group differences before the intervention may have impacted the ability to identify significant differences due to the conditions alone. Another potential reason for the lack of significant differences could be the choice of urban environments, particularly in relation to Subjective Attention. To align with the virtual reality environments used in Studies 1 and 2, and to mitigate potential confounding factors related to attention and stress-inducing elements

not found in nature and highly variable in urban environments, I deliberately chose urban environments with reduced stressors like traffic and attention-grabbing stimuli such as advertisements (Kaplan, 1995; Staats et al., 2016). By minimizing these stressful elements in the urban environment, I focused on the impact of imposing infrastructure. This approach allowed me to examine the independent effects of infrastructure on individuals and evaluate the influence of static environmental elements with reduced stress-induced attentional resource depletion. This may explain why the study did not observe significant differences in attention between conditions, as the absence of traditional, highly stimulating urban environments could have mitigated the impact on attention compared to other studies. For example, Kaplan (1995) suggests that stress-inducing factors like traffic, pedestrians, and advertising, typically present in urban spaces can lead to increased stress and depleted attention.

Another factor that might have contributed to maintaining attention capacity in urban environments could be the existence of small pockets of nature within those settings. An inherent limitation of field studies is the challenge of controlling all possible confounding variables, as demonstrated by the unavoidable inclusion of natural elements within the field sites. This may have contributed to mitigating attention depletion as Kaplan (1993) proposed that even minimal exposure to nature, such as a few trees, landscaping elements, or any sign of vegetation, can have beneficial effects on attention, even in the presence of buildings or parking lots. While this hypothesis has not been extensively tested, some research supports the notion that brief exposure to nature can improve attention (Lee et al., 2014).

Additionally, regarding the physiological measures, Bowler et al. (2010) also discovered weak or inconsistent results on nature's impact on blood pressure, and Twohig-Bennett and Jones (2018) found consistent changes only in diastolic blood pressure in relation to greenspace

exposure. The discrepancies in this study suggest that nature's restorative impact may be less pronounced than initially hypothesized, highlighting the importance of continued exploration of restoration using physiological measures and the controlling of confounds in field research. To gain a clearer understanding of nature's impact of physiological restoration, I would recommend evaluating the restorative potential of various environments with more sensitive physiological measures. The findings of this study highlight the importance of a nuanced understanding of the restorative value of different environments. My results, when compared to existing literature, indicate that not all natural settings consistently produce a restorative physiological effect, emphasizing the need for further research and a more detailed evaluation of various environments' restorative potential.

Employing a more sensitive measurement device may help identify differences in blood pressure and heart rate between environments. According to Muntner et al. (2019), multiple measurements, rather than a single measure, can provide more accurate blood pressure results. They recommend taking at least three successive measurements to obtain a reliable mean value, with additional measures offering even more comprehensive information. Future studies should consider incorporating multiple blood pressure and Heart Rate readings for enhanced accuracy.

Reinforcing Nature's Restorative Qualities Compared to Urban Environments

Despite observing several inconsistencies, the findings provided some evidence confirming the hypothesis that natural environments possess greater restorative potential than urban settings, further solidifying nature's role as a restorative environment in comparison to urban environments in general. This is illustrated by the significant two-way interactions between Time and Naturalness for Subjective Stress and Vitality measures. Vitality levels were significantly higher after participants experienced nature conditions compared to urban conditions, while

Subjective Stress decreased following exposure to nature conditions, with no significant change observed for urban conditions.

Assessing Restorative Capacity: A Comparison of High and Low Restorative Conditions

In this study, I also hypothesized that environments with High Restorative Potential would significantly enhance restoration compared to those with Low Restorative Potential. As anticipated, I observed differences in restoration measures based on the restorative potential of the environments. Unexpectedly, conditions initially considered Low in Restorative Potential yielded better results for the restoration measures compared to High Restorative Potential conditions. For example, the two-way interaction at Time 2/Time3 between Time and Restorative Potential was significant for PA and Vitality. PA increased across all conditions but increased significantly more for those in the Low Restorative Potential conditions compared to the High Restorative Potential conditions. Vitality demonstrated a similar pattern to PA, with High Restorative Potential conditions significantly reducing Vitality and Low Restorative Potential conditions significantly increasing it. My initial expectation that High Restorative Potential environments would outperform Low Restorative Potential conditions in terms of restoration was not supported by the findings.

The HRP-urban condition had the least favorable impact on Vitality, contradicting previous studies suggesting that shopping areas with low building height can function as restorative urban environments (Staats et al., 2016; Ulrich et al., 1991). The reduced restorative capacity observed in the HRP-urban condition could be attributed to safety concerns and the presence of noise, traffic, and high densities of people. These elements, challenging to control in urban settings, can adversely impact perceived restorative quality (Staats et al., 2016; Ulrich et al., 1991). Although these factors were limited in the HRP-urban environment, they were still

more prevalent compared to the other environments, potentially explaining the diminished restoration experienced.

One intriguing outcome of this study is the observation that participants were influenced differently than researchers had anticipated by the stimuli present in various environments. Notably, the HRP-urban shopping plaza appeared to be the most oppressive urban environment, contrary to the hypothesis of this study. Future studies might benefit from understanding participants' predictions of each environment's restorative potential. This could provide valuable insights into how perceived restorative environments impact participants based on their own perspectives of the environment experienced.

Chapter 6 Study 4

Introduction

In the present study I continued to explore how ostensibly high and low restorative potential urban and natural environments impact subjective and objective measures of attention, affect and stress. Overall, Study 4 follows the same general pattern as the previous studies, with several notable exceptions that extend the prior studies in several novel ways.

First, in contrast to the previous studies, Study 4 employed immersive virtual reality (VR) technology and YouTube 360° videos to strike a balance between ecological validity and experimental control. This technology provides an immersive experience with real-world environments while maintaining the control of a lab setting. A 360° video provides a more immersive experience than watching a video in lab because they are recorded from every perspective within a scene, allowing viewers to visually explore the environment in any direction. This increased level of viewer control and agency can enhance immersion and presence, enabling participants to better appraise landscapes compared to traditional videos or photographs (Wiederhold et al., 1998; Yuhan et al., 2015). At the same time, this technology allows me to retain experimental control over the characteristics of the environments presented to participants.

Second, the study aimed to include natural and urban environments that highlighted the contrast between low and high restorative potential stimuli. By investigating both established and understudied environments with differing restorative potential, the study expanded upon previous findings. The HRP-nature environment encompassed a lush rainforest and the LRP-urban environment encompassed a bustling city center as these conditions had features previously studied extensively with known outcomes. The study also included less-explored

environments including a LRP-natural environment, characterized by barren and lifeless natural elements, and a HRP-urban environment, distinguished by visually appealing historical architecture with moderate building height. These new environments possess restorative qualities that have been proposed but rarely studied objectively. Specifically, the LRP-nature setting is hypothesized to have low restorative potential due to the absence of living elements and survival advantages, as suggested by the SRT (Ulrich, 1993). Conversely, the HRP-urban environment, with moderate building height and aesthetically pleasing, historic architecture, is believed to be restorative (Bornioli & Subiza-Pérez, 2023).

Third, the stress induction previously used was removed and replaced with an attention task completed pre-environment exposure to index initial levels of attention and to deplete attention (Berto, 2005; Kahneman, 1973) and increase stress. The attention task should invoke stress as simple, repetitive, tasks requiring continuous attention have been found to increase the stress response (Langner & Eickhoff, 2013). Specifically, this study employed the n-back task (Kirchner, 1958) because it has widely been used to assess attentional engagement (Diamond, 2013; Owen et al., 2005) and it is attentionally demanding, and thus should deplete attention (Schmidt et al., 2009) enabling the measurement of restorative differences between the environments based on measures of stress, attention, and affect.

Fourth, after environment exposure, the restorative potential of the environment was assessed using the Perceived Restorativeness Scale (PRS; Hartig et al., 1997). The PRS is a scale that is grounded in the ART and focuses on environmental features expected to promote restorative experiences (Hartig et al., 1997). The addition of the PRS served two goals, namely, 1) to facilitate the collection of perceived restorativeness ratings from non-experts, and 2) provide the opportunity to examine the correlations between people's perceived restorative

potential and my other subjective and objective measures of attention, affect and restoration that were used in previous studies. The later point is important because research has shown that discrepancies may occur between expert and non-expert opinions regarding architectural designs and aesthetic quality assessments (Boumová Půžová & Zdráhalová, 2016; Rosley et al., 2014; Stamps, 1999). These differences in assessment criteria may result in variations in preference and restorative quality perceptions (Herzog et al., 2003; Van den Berg et al., 2003; Wang et al., 2019). To better understand restorative environments, it is essential to gather perspectives beyond expert opinions, as expert researchers may overlook or underestimate certain aspects of restorative settings (Van den Berg et al., 2003).

Finally, in the present study a shorter environment exposure duration was used than in the previous studies in this thesis. Specifically, participants were exposed to their respective environment for 6 minutes in this study. This decision was based on the understanding that psychological and physiological responses can rapidly change within a short period of time. For example, Ulrich et al. (1991) found that after 4 minutes of exposure to either urban or natural scenes in lab, physiological measures were shown to change significantly including skin conductance and heart period. Jiang et al. (2014) found reductions in stress (as measured by cortisol) for males after 6 minutes of exposure to a digital greenspace. Additionally, Wang et al. (2016) found that 8 minutes of viewing videos shot in nature-based urban parks relieved stress and restored attention levels. Additionally, Berto (2005) conducted three studies on attention capacity and restorative environments and found that, after just over 6 minutes, participants performed better on an attention task. Mishima et al. (2004) also found that listening to the sound of a stream for 60-90 seconds after being exposed to a dental turbine reduced heart rate to levels lower than baseline and, lastly, Lee et al. (2014) found that 40 seconds of viewing a computer

simulation of a green roof caused participants to make significantly less omission errors on an attention task and showed more consistent responding. Thus, it is expected that 6 minutes in the environments will be enough time to see significant changes in measures of physiology and psychology.

Overview

The hypotheses of this study are that the HRP-nature condition will be the most restorative, while the LRP-urban condition will be the least restorative. The restorative potential of the LRP-nature condition is unclear, as it has been suggested to be less restorative than the HRP-nature condition due to a lack of restorative features. Similarly, the restorative potential of the HRP-urban condition is uncertain, since the supposedly restorative features have not been empirically tested in the field, despite suggestions of their restorative qualities.

Methods

Participants

The results are based on a sample of 127 University of Waterloo participants acquired through the SONA system described in Study 1 with a mean age of 20.39 (*SD* 1.66). There were 51 males and 76 females in the study. No participants were excluded due to simulator sickness as the short VR intervention did not cause any sickness among the participants.

Measures

The Positive Affect Negative Affect Scale (PANAS)

Affect was assessed using the PANAS, developed by Bradburn (1969) to measure the balance between positive and negative affect. A systematic review by Nguyen et al. (2021) supported its use in greenspace quality and health research. A meta-analysis by McMahan and Estes (2015) found the PANAS was widely used in nature intervention studies, alongside the ZIPER scale. Consequently, I chose the PANAS for this study for its consistent application in greenspace research similar to the ZIPERS scale (Berman et al., 2008; Mayer et al., 2009; Nisbet & Zelenski, 2011). Additionally, due to inconclusive findings from previous studies employing the ZIPERS scale, I selected the PANAS for this research to determine if it is more sensitive to changes in Affect. I anticipate comparable results to the ZIPERS scale, but hypothesize that the PANAS, being specifically designed for affect measurement, may provide more sensitive and detailed data on emotional responses.

The PANAS consists of two short 10-item scales and was designed to be easy to administer (Watson et al., 1988): “The scales are shown to be highly internally consistent, largely uncorrelated (ranges of -.12 to -.23), and stable at appropriate levels over a 2-month time period” (Watson et at., 1988. p. 1063). The Chronbach’s alphas were .86 (positive affect), and .87

(negative affect). Item responses are based on a Likert scale ranging from 1 (very slightly or not at all) to 5 (extremely). The participants rate their emotions using the descriptive words provided such as “excited and interested” (positive affect) and “distressed and upset” (negative affect).

Additionally, single-item measures from the PANAS were used to assess Vitality and Subjective Attention, helping to keep the survey brief and minimize participant fatigue, which can increase error variance (Gravetter & Forzano, 2012). While single-item measures are generally less reliable than multi-item scales, they can be justified when the construct is narrow and clearly defined. As Wanous et al. (1997) note, single items demonstrate acceptable validity when assessing unambiguous, well-specified concepts. I also selected single items from the PANAS scale because the scale is designed to capture momentary emotional states, making it well-suited for assessing immediate, transient changes in Vitality and Subjective Attention. This aligns with the goal of measuring participants’ real-time experiences rather than stable trait levels. Thus, in this study, constructs were intentionally focused: for example, “Attentiveness” reflects the specific capacity to respond to discrete stimuli (Sohlberg & Mateer, 1989), not broader attentional functioning, which would require a more complex measurement (Allen et al., 2022). The targeted aspects of Vitality and Subjective Attention are clearly defined in this methods section, ensuring alignment between the construct and the measure.

Vitality

Instead of utilizing the Subjective Vitality Scale, I employed a single item from the PANAS scale that inquired about participants' perceived level of activity. Question 19 of the PANAS scale (how Active due you feel currently?) was selected to measure Vitality, as it captures participants' self-reported feelings of energy, alertness, and liveliness – key characteristics of vitality as described by Ryan and Frederick (1997) and Bostic et al. (2000).

Subjective Attention

Subjective Attention was assessed using two components from the PANAS scale. This was done because Ohly et al. (2016) highlighted how environment exposure can affect various forms of attention, necessitating the use of different attention assessment methods. The measures used in this study were Attentiveness measuring focused attention, which is the capacity to discretely respond to stimuli (Sohlberg & Mateer, 1989). This dimension was measured using question 17 from the PANAS (how Attentive due you currently feel?). Alertness (question 12 from the PANAS) was the other measure of Subjective Attention that indicates sustained attention, involves maintaining awareness and vigilance across tasks (Sohlberg & Mateer, 1989). Collectively, these components provided a thorough evaluation of Subjective Attention, addressing both focused and sustained aspects.

Objective Measure of Attention: The N-back

The N-back task was used to assess Attention restoration objectively. It requires participants to maintain and update an ever-changing set of stimuli, in this case letters that need to be constantly updated with each letter presentation, while also responding to each item (Kane et al., 2007). The task requires participants to inhibit the distraction of the upcoming letters while keeping the past letters in working memory. Commonly 3-back tasks are used (Meule, 2017), so I used a 3-back in this study.

As per Kane et al. (2007), I manipulated 2 factors: the stimulus type (target vs. non-target) and sequence type (lure vs. non-lure) in the 3-back. Targets were letters that match the letter presented three items back, whereas non-targets were letters that did not match the letter presented three items back. For example, in this example (A, H, L, A, G), A is the target, while all other letters are non-targets. For the 3-back, the lures consisted mostly of 2-back lures (e.g. G,

H, A, L, A). Non-lure sequences for targets were when the target was not preceded by a lure (1-back or 2-back lure).

Participants completed four blocks of 48 trials for the 3-back. Stimuli consisted of eight phonologically distinct letters: B, F, K, H, M, Q, R, and X. Each block of 48 trials contained eight targets (16.6%) and 40 non-targets. Six of these targets were non-lure targets and two of these targets were lure targets. Of the 40 non-target trials, 34 were non-lures and six were lures. All participants completed a practice block after they were given the instructions. During the practice block, there were 16 practice trials with 2 targets. If participants were not hitting the spacebar on the target, the observing researcher would say when a target was coming up and indicate when to hit the spacebar, so the participant had an example of what to look for when completing the task.

Physiological Measurement and Devices

Blood Pressure & Heart Rate (Continuous Non-Invasive Arterial Blood Pressure Monitor 500; (CNAP)).

Blood pressure and heart rate were monitored using the CNAP blood pressure monitor, a non-invasive, continuous arterial pressure monitoring system. Participants had their non-dominant arm fitted with finger cuffs and an arm cuff for calibration purposes. They were instructed to rest their arm on the chair's armrest to minimize movement-related measurement inconsistencies. The CNAP device utilizes finger cuffs placed on the index and middle fingers to provide continuous blood pressure readings after initial calibration with the arm cuff. This system allowed for the collection of real-time blood pressure and heart rate data throughout the intervention.

Measuring Restorative Potential with the Perceived Restorativeness Scale (PRS)

To measure how restorative participants perceived their environment would be, I used the Perceived Restorativeness Scale (PRS). The PRS is a validated 16-item scale that measures how restorative an environment is perceived to be related to ART criteria (Hartig et al., 1997). For this study, the 11-item version of the PRS was used. The PRS-11 was validated by Pasini et al. (2014), which was found to be invariant across nationality and gender. The PRS-11 can effectively differentiate subjective restorative outcomes across various environmental categories, with the highest scores associated with images featuring hills and lakes, followed by housing and city streets, while industrial zones received the lowest scores (Pasini et al., 2014).

Virtual Reality Headset

The virtual reality headset worn by participants was the HTC VIVE-virtual reality system. The headset has an accelerometer, gyroscope, and the Lighthouse Laser tracking system sensors (Kyoto, 2016). The headset has two 3.6 inch screens with a resolution of 2160 x 1200px which is split into two displays with resolutions 1200 x 1080 px per eye. The screen refreshes at a rate of 90 Hz and the field of view is 110 degrees (Kyoto, 2016).

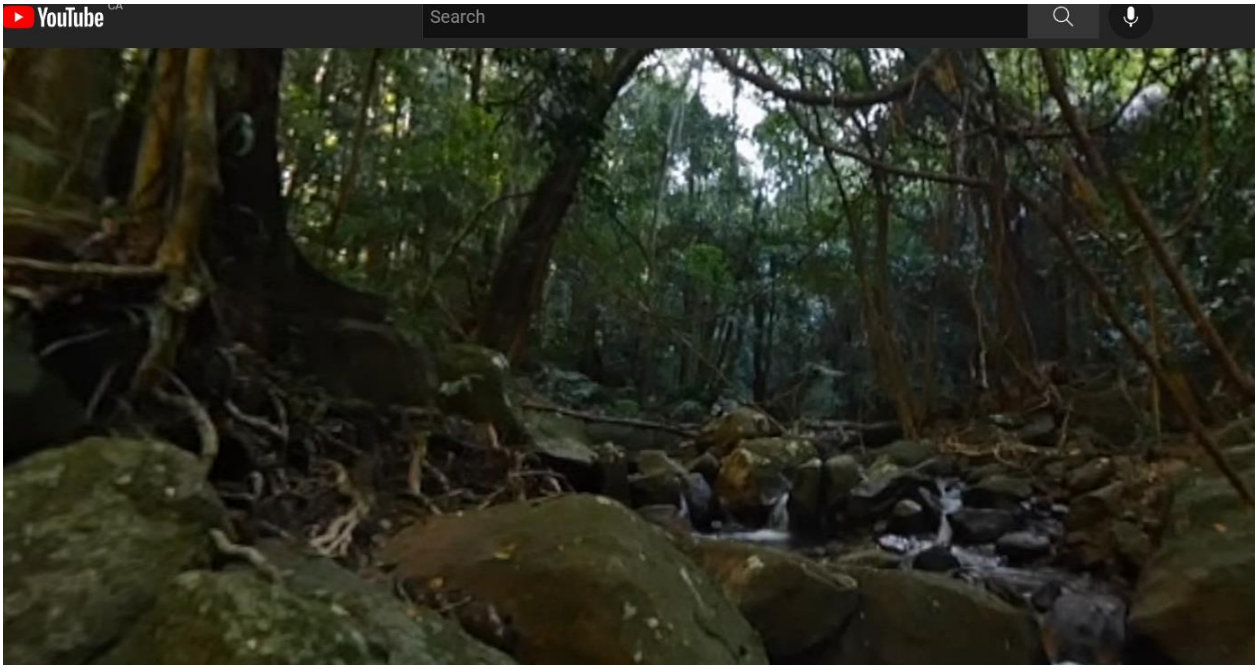
Environments

Each environment was selected from the YouTube 360 video database.

The HRP-nature condition (Figure 6.1) was chosen as a natural environment due to its absence of urban features and its setting within a tranquil, open rainforest. The environment surrounded participants with lush green vegetation, a consistently proven restorative feature (Kaplan & Kaplan, 1889; Pearson & Craig, 2014; Tsunetsugu et al., 2010). Restorative elements included plant and tree diversity (Southon et al., 2018; Janeczko et al., 2021) and the presence of water, promoting stress reduction and mood enhancement as per Ulrich's (1993) survival

advantage theory. Moreover, I ensured the vegetation did not encroach on participants, preventing potential unease (Milligan & Bingley, 2007) and fear-induced stress (Staats et al., 2016). The selected video positioned participants beside a stream, with rocks and boulders maintaining a comfortable distance from the vegetation, further reducing potential stressors in the environment.

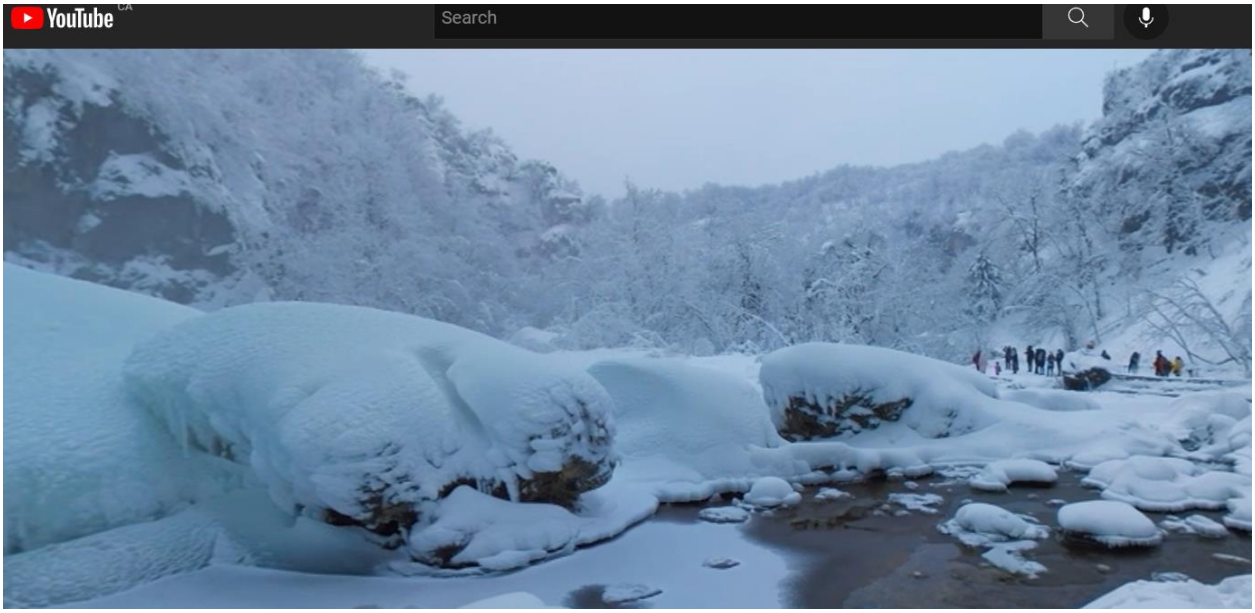
Figure 6.1. HRP-natural Environment



Note. Screenshot of the VR HRP-natural environment from the YouTube 360 video by Immersion Imagery (2016). Back to Nature 2 - Rainforest (Stereoscopic 360° VR Video). Retrieved from https://www.youtube.com/watch?v=iPwlNh48eYk

The LRP-nature condition (Figure 6.2) was chosen as a nature setting due to its lack of urban features and its placement of participants in a natural broad-leaved winter forest, sharing similarities with other forested areas in this dissertation. The environment lacked many stress-reducing stimuli typically found in restorative settings, such as resources essential for survival like food and shelter. In accordance with Ulrich's SRT (1993), this environment may not be considered restorative due to the harsh climate and absence of survival advantages, which could evoke inherent negative feelings in individuals. Additionally, the presence of groups of people disrupted the typically tranquil atmosphere found in natural environments, and the setting lacked other restorative qualities, such as biodiversity and lush vegetation.

Figure 6.2. LRP-natural Environment

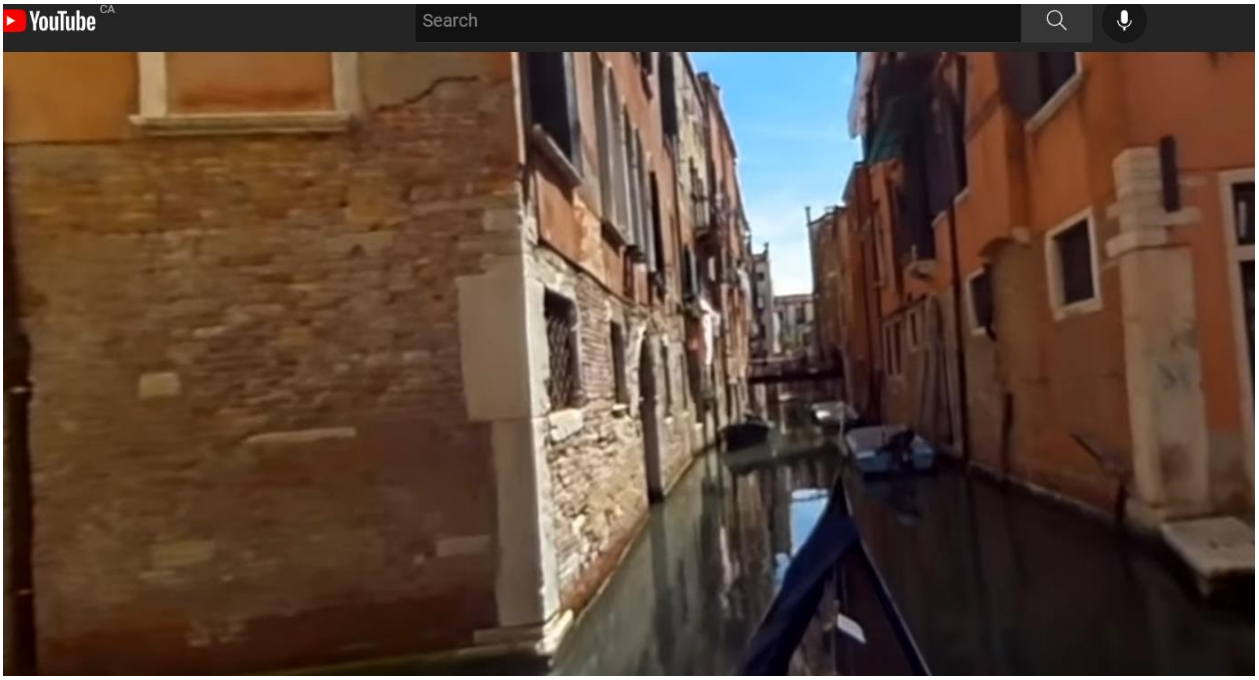


Note. Screenshot of the VR LRP-natural environment from the YouTube 360 video by AirPano VR. (2018). Plitvice Lakes in Winter, Croatia. 8K aerial video. Retrieved https://www.youtube.com/watch?v=A5ubcGt8Gfo

The HRP-urban condition featured in Figure 6.3 was selected as an urban environment due to its absence of vegetation and presence of buildings and infrastructure. Participants explored the Venetian canals in the video, providing an experience characterized by beauty and tranquility—qualities often found in restorative greenspaces (Bornioli & Subiza-Pérez, 2023). Additionally, the unfamiliar environment could help induce a sense of Being Away (Kaplan, 1995), while the historical and cultural significance contributed to its high restorative potential (Weber & Trojan, 2018). Finally, there was a great deal of architectural diversity and low building height enhancing the restorative potential of the condition (Herández & Hidalgo, 2005). Stress-inducing stimuli, such as crowds (Ulrich et al., 1991), traffic (Staats et al., 2016), and tall buildings (Asgarzadeh et al., 2012; Kaplan, 1995; Lipfert & Wyzga, 2008), were minimized to

prevent sensory overload and facilitate a comfortable information processing experience (Milgram, 1970).

Figure 6.3. HRP-urban Environment



Note. Screenshot of the VR HRP-urban environment from the YouTube 360 video by Geneeo (2016). 360 VR video experience in Venice. Retrieved https://www.youtube.com/watch?v=8gt2E8ewUKE

The LRP-urban condition featured in Figure 6.4, was selected as an urban environment as it did not contain any natural components and lots of infrastructure. Participants experienced NY Times Square which was deemed low in restorative potential because it consisted of stress inducing stimuli such as crowding from pedestrians and traffic (e.g., Ulrich et al., 1991; Schmidt & Keating, 1979), skyscrapers (Asgarzadeh et al., 2012), and eye-catching urban stimuli such as billboards which increases attention fatigue (Berman et al., 2008) and no restorative elements.

Figure 6.4. LRP-urban Environment



Note. Screenshot of the VR LRP-urban environment from the YouTube 360 video by J Utah (2016) Driving Downtown VR 360 - New York City 4K – USA. Retrieved https://www.youtube.com/watch?v=2fDhCPRnndM

Participants experienced the designated environments using a VIVE virtual reality headset. All videos were viewed without sound to ensure that any observed restorative effects could be attributed to the visual characteristics of the environments alone.

Procedure

The study's methodology largely follows that of previous studies, except data collection was limited to two time points: Time 1 for baseline measures and Time 2 for post-environment exposure measures.

Upon arrival at the psychology department, participants were guided to a designated lab room. The study began with participants reading and completing the information and consent forms. Then they were directed to complete the demographic questions and the PANAS scale for

our baseline subjective measures. Once complete participants were equipped with the Empatica to measure electrodermal activity (which was not analyzed due to insufficient data) and the CNAP to measure blood pressure and heart rate continuously. Following this, participants had the VR VIVE headset placed on their head, so they could view the environment they were to experience in the intervention and rate how restorative the environment would be using the PRS. Participants viewed the environment for 30 seconds after which they were given the PRS to complete. Once completed the participant was given instructions on the 3-back task and were given a trial run to ensure they understood how the task worked. Each trial had two targets and if the participant missed the first target, the researcher would interrupt the trial and inform the participant when the next target was to occur, ensuring the participant knew what to look for. Once the participant was confident in the task, they were asked to complete the full 3-back which was 8 minutes long. Following the 3-back, participants had the VIVE headset placed back on their head to experience the VR environment for 6 minutes. Once the intervention was complete the headset was removed, and the physiological measurement equipment was removed. Following this, participants were given the PANAS survey again. Once complete participants were asked to complete the 3-back for the final time to assess how the environments restored attention. Once the 3-back was complete participants were debriefed and thanked for their participation, concluding the study.

Analysis

To investigate the influence of the condition on each of the dependent measures, I conducted mixed factorial ANOVAs, utilizing a similar analytical approach as in the previous studies. Additionally, Familiarity, Preference and the PRS data was analyzed using a one-way

ANOVA. Additionally, I ran a correlational analysis to determine if any of the measures of restoration were correlated with the PRS scores across conditions.

To prepare physiological measures for the mixed factorial ANOVA analysis, Time 1 was calculated as the average of the first minute of the intervention, while Time 2 was determined by averaging the last minute of the physiological data during the intervention.

Results

The results are presented in two tables for each dependent variable (DV). The first table contains mean scores for the DV with standard deviations as a function of condition. The following table provides the ANOVA results with Time 1/Time 2 as a within-participant factor and Naturalness (Nature, Urban) and Restorative Potential (High, Low) as between-subjects factors. The header for each DV indicates the associated table numbers for the descriptives and the ANOVA results.

It is important to note that not all the data sets were completed for each DV, as participants occasionally missed questions either inadvertently due to inattention or intentionally chose to skip certain questions they felt uncomfortable answering.

Positive Affect (PA; Table 6.1; 6.2)

The ANOVA revealed a significant main effect of Time. The means suggest that participants had higher PA before the intervention at Time 1 (M = 27.7, SE = .94) than Time 2 (M = 25.55, SE = .89). There was also a significant main effect of Restorative Potential. The HRP condition participants had significantly lower PA (M = 25.27, SE = .94) compared to the LRP condition participants (M = 28.00, SE = .89). The absence of a significant interaction between Time and Restorative Potential indicates that the observed differences in Restorative Potential may be attributed to factors other than the experimental conditions.

Table 6.1

Positive Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	26.14 (6.87)	27.72 (7.62)	26.07 (6.57)	30.88 (8.02)
Time 2	25.11 (8.10)	26.31 (9.48)	23.77 (7.03)	27.00 (7.59)

Table 6.2

Mixed Factorial ANOVA on Positive Affect by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	15.64	<.001	.117
Naturalness	1	.22	.639	.002
Restorative Potential	1	4.39	.038	.036
Naturalness x Restorative Potential	1	1.04	.310	.009
Naturalness x Time	1	2.94	.089	.024
Restorative Potential x Time	1	.80	.374	.007
Naturalness x Restorative Potential x Time	1	.31	.581	.003
Error	118			

Negative Affect (NA; Table 6.3; 6.4)

The ANOVA revealed a significant main effect of Time. The means indicate NA decreased from Time 1 (*M* = 13.52, *SE* = .36) to Time 2 (*M* = 12.43, *SE* = .35). There was also a significant interaction between Time and Naturalness. Pairwise comparisons were made with a Bonferroni correction on simple main effects indicating those in the Natural conditions significantly reduced their NA between Time 1/Time 2 (p<.001) while there was no difference between Time 1/Time 2 for those in the Urban conditions (p=.435). The means suggest the Nature conditions significantly decreased NA from Time 1 (*M* = 13.47, *SE* = .51) to Time 2 (*M* = 11.57, *SE* = .50).

There was also a significant interaction between Time and Restorative Potential. Pairwise comparisons were made with a Bonferroni correction on the simple main effects. Results indicated a significant difference in NA between the HRP conditions (*p*<.001) between Time 1 (*M* = 13.76, *SE* = .51) and Time 2 (*M* = 11.78, *SE* = .50), indicating NA decreased over time for those in the HRP conditions but not for those in the LRP conditions (*p*=.572).

Table 6.3

Negative Affect, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	13.80 (3.86)	13.13 (3.55)	13.71 (4.89)	13.44 (3.43)
Time 2	11.53 (2.68)	11.61 (4.67)	12.03 (3.11)	14.53 (4.77)

Table 6.4

Mixed Factorial ANOVA on Negative Affect by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	16.86	<.001	.123
Naturalness	1	1.91	.170	.016
Restorative Potential	1	.386	.536	.003
Naturalness x Restorative Potential	1	1.15	.287	.009
Naturalness x Time	1	9.05	.003	.07
Restorative Potential x Time	1	10.97	.001	.084
Naturalness x Restorative Potential x Time	1	3.61	.06	.029
Error	120			

Vitality (Active; Table 6.5; 6.6)

The results from the ANOVA revealed a significant main effect of Time. Participants experienced higher Vitality at Time 1 ($M = 2.59$, $SE = .1$) compared to Time 2 ($M = 2.34$, $SE = .10$). There was also a significant main effect of Restorative Potential, with participants in the LRP condition exhibiting higher Vitality ($M = 2.69$, $SE = .12$) compared to those in the HRP conditions ($M = 2.24$, $SE = .13$). A significant two-way interaction between Naturalness and Restorative Potential was also observed. Post-hoc Bonferroni-corrected pairwise comparisons revealed that only participants in the Urban conditions experienced a significant difference in

Vitality between Restorative Potential conditions (p = .001), while no difference was found for the Natural conditions (p=.768). Participants in the LRP-urban condition had higher Vitality (M = 2.94, SE = .17) compared to the HRP-urban condition participants (M = 2.11, SE = .18).

Finally, the three-way interaction between Time, Naturalness, and Restorative Potential was significant. Post-hoc pairwise comparisons with Bonferroni correction revealed that only the LRP-nature condition significantly impacted Vitality (p = .001). The means suggest Vitality significantly decreased from Time 1 (M = 2.76, SE = .19) to Time 2 (M = 2.12, SE = .20) in that condition. No other condition significantly impacted Vitality between Time 1 and Time 2 (HRP-nature (p = .508), HRP-urban (p = .075), and LRP-urban (p = .522). These results suggest that Vitality levels did not increase due to exposure to nature, but actually decreased due to exposure to the LRP-nature condition; a condition that lacked any living organisms due to the nature of the winter environment.

Table 6.5

Vitality, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	2.30 (.99)	2.76 (1.15)	2.29 (1.24)	3.00 (.98)
Time 2	2.43 (.94)	2.12 (1.24)	1.94 (1.18)	2.88 (1.16)

Table 6.6

Mixed Factorial ANOVA on Vitality by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	6.28	.014	.049
Naturalness	1	.50	.483	.004
Restorative Potential	1	6.69	.011	.052
Naturalness x Restorative Potential	1	4.69	.032	.037
Naturalness x Time	1	.00	.953	.000
Restorative Potential x Time	1	1.89	.171	.015
Naturalness x Restorative Potential x Time	1	6.49	.012	.051
Error	122			

Subjective Attention (Attentiveness; Table 6.8; 6.9)

The ANOVA revealed a significant main effect of Time. Participants were more Attentive at Time 1 ($M = 3.20$, $SE = .09$) compared to Time 2 ($M = 2.88$, $SE = .10$). This suggests the study was fatiguing, which is not surprising as I had participants complete an attention tasks between the Time 1 and Time 2 Attentiveness scores. No other effects or interactions reached significance.

Table 6.7

Subjective Attention (Attentive), Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	2.93 (1.07)	3.18 (1.04)	3.32 (.92)	3.47 (1.14)
Time 2	2.72 (1.22)	2.91 (1.16)	2.81 (.79)	3.06 (1.08)

Table 6.8

Mixed Factorial ANOVA on Subjective Attention (Attentive) by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	13.55	<.001	.101
Naturalness	1	1.49	.225	.012
Restorative Potential	1	1.94	.166	1.94
Naturalness x Restorative Potential	1	.01	.925	.000
Naturalness x Time	1	.95	.331	.008
Restorative Potential x Time	1	.02	.882	.000
Naturalness x Restorative Potential x Time	1	.05	.824	.000
Error	121			

Subjective Attention (Alertness; Table 6.10; 6.11)

The ANOVA revealed a significant main effect of Time, indicating higher Alertness at Time 1 ($M = 2.88$, $SE = .10$) compared to Time 2 ($M = 2.57$, $SE = .10$). No other main effects or interactions were statistically significant.

Table 6.9

Subjective Attention (Alert), Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	2.97 (.96)	2.91 (1.07)	2.61 (1.02)	3.03 (1.23)
Time 2	2.50 (1.17)	2.61 (1.22)	2.16 (1.00)	3.00 (1.14)

Table 6.10

Mixed factorial ANOVA on Subjective Attention (Alert) by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	9.58	.002	.073
Naturalness	1	.068	.795	.001
Restorative Potential	1	3.70	.057	.029
Naturalness x Restorative Potential	1	3.17	.077	.025
Naturalness x Time	1	.50	.480	.004
Restorative Potential x Time	1	2.08	.151	.017
Naturalness x Restorative Potential x Time	1	.40	.527	.003
Error	122			

Subjective Stress (Table 6.12; 6.13)

The ANOVA revealed a main effect of Time. The means indicate participants experienced more Subjective Stress when they began the study at Time 1 (M = 2.11, SE = .08) compared to post intervention scores collected at Time 2 (M = 1.85, SE = .08). A significant main effect of Restorative Potential was also observed, indicating that individuals in the LRP conditions experienced higher Subjective Stress (M = 2.14, SE = .09) compared to those in the HRP conditions (M = 1.81, SE = .10).

There was also a significant two-way interaction between Naturalness and Restorative Potential. Pairwise comparisons were made with a Bonferroni correction at the .05 level. Results indicated there was a significant difference between the Urban conditions (p<.001). The means indicate the LRP-urban condition participants had significantly higher Subjective Stress (M = 2.38, SE = .13) than those in the HRP-urban condition (M = 1.62, SE = .14). While there was no difference between the Natural conditions (p = .627). This suggests that Naturalness proved

significant in the relationship between the impact of Restorative Potential and Subjective Stress, whereby the Restorative Potential had a significant impact on stress levels exclusively in the Urban conditions.

Table 6.11

Subjective Stress, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	2.20 (.93)	2.06 (.79)	1.83 (.99)	2.33 (.96)
Time 2	1.80 (.85)	1.76 (.90)	1.40 (.72)	2.42 (1.12)

Table 6.12

Mixed Factorial ANOVA on Subjective Stress by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	7.36	.008	.057
Naturalness	1	.11	.744	.001
Restorative Potential	1	6.49	.012	.05
Naturalness x Restorative Potential	1	10.48	.002	.079
Naturalness x Time	1	.88	.351	.007
Restorative Potential x Time	1	2.60	.109	.012
Naturalness x Restorative Potential x Time	1	1.23	.270	.010
Error	122			

N-Back tasks

Hit Rate (Table 6.14; 6.15)

Results from the ANOVA revealed a significant main effect of Time. The means suggest participants were less accurate on the 3-back at Time 1 (M = 0.70, SE = .02) compared to Time 2 (M = 0.82, SE = .02) The main effect of Restorative Potential was also significant. The means suggest that participants in the LRP conditions were better at the 3-back (M = 0.8, SE = .03) than those in the HRP conditions (M = 0.72, SE = .03). There were no other significant main effects or interactions suggesting none of the conditions significantly increased 3-back performance more than others.

Table 6.13

N-back Hits Rate, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	0.63 (0.19)	0.71 (0.19)	0.69 (0.18)	0.75 (0.15)
Time 2	0.72 (0.28)	0.83 (0.26)	0.82 (0.26)	0.9 (0.21)

Table 6.14

Mixed Factorial ANOVA on N-back Hits by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	44.50	<.001	.294
Naturalness	1	3.23	.075	.029
Restorative Potential	1	4.5	.036	.04
Naturalness x Restorative Potential	1	.072	.789	.001
Naturalness x Time	1	.682	.411	.006
Restorative Potential x Time	1	.635	.427	.006
Naturalness x Restorative Potential x Time	1	.018	.893	.000
Error	107			

False Alarm (Table 6.16; 6.17)

The ANOVA revealed a significant main effect of Time. The means indicated there were more False Alarms the first time participants completed the 3-back at Time 1 (*M* = .11, *SE* = .01) than at Time 2 (*M* = .08, *SE* = .01). A significant main effect of Restorative Potential was also observed, with participants in the HRP condition demonstrating lower False Alarm scores (*M* = .08, *SE* = .01), compared to those in the LRP conditions (*M* = .11, *SE* = .01). These results, combined with the hit rate results suggests that the LRP condition participants used a more liberal strategy to complete the attention task as they had more Hits, but also incorrectly identified more non-target stimuli as targets (i.e., false alarms), while the HRP condition participants employed a more conservative approach with less hits, but also less false alarms.

Table 6.15

N-back False Alarms, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	0.08 (0.05)	0.12 (0.07)	0.11 (0.06)	0.13 (0.09)
Time 2	0.06 (0.06)	0.09 (0.07)	0.08 (0.07)	0.10 (0.09)

Table 6.16

Mixed Factorial ANOVA on 3-back False Alarms by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	29.92	<.001	.219
Naturalness	1	1.38	.242	.013
Restorative Potential	1	4.53	.036	.041
Naturalness x Restorative Potential	1	.21	.650	.002
Naturalness x Time	1	.58	.448	.005
Restorative Potential x Time	1	.01	.910	.00
Naturalness x Restorative Potential x Time	1	.09	.770	.001
Error	107			

Diastolic Blood Pressure (Table 6.20; 6.21)

The ANOVA indicated there were no significant main effects or interactions.

Table 6.17

Diastolic Blood Pressure, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	71.52 (15.79)	73.95 (23.48)	67.64 (20.10)	67.39 (16.91)
Time 2	69.14 (16.26)	77.85 (20.79)	70.05 (20.42)	69.49 (19.12)

Table 6.18

Repeated measures ANOVA Diastolic Blood Pressure by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	2.29	.133	.023
Naturalness	1	1.49	.225	.015
Restorative Potential	1	.498	.482	.005
Naturalness x Restorative Potential	1	.67	.417	.007
Naturalness x Time	1	.57	.454	.006
Restorative Potential x Time	1	2.26	.136	.022
Naturalness x Restorative Potential x Time	1	2.73	.102	.027
Error	99			

Systolic Blood Pressure (SBP; Table 6.22; 6.23)

The ANOVA revealed a significant interaction between Time, Naturalness, and Restorative Potential. Pairwise comparisons with Bonferroni correction indicate there was only a significant difference between Time 1 and Time 2 for those in the LRP-natural environment (p = .032), while no other condition impacted participants SBP including the HRP-nature condition (p = .220), HRP-urban condition (p = .204), and LRP-urban condition (p = .736). The LRP-nature condition increased SBP from Time 1 (M = 105.31, SE = 5.34) to Time 2 (M = 110.49, SE =

5.65). This suggests the LRP-nature condition was significantly more stressful than any of the other conditions.

Table 6.19

Systolic Blood Pressure, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	100.32 (23.33)	105.31 (28.65)	102.31 (28.10)	96.36 (21.94)
Time 2	97.50 (22.15)	110.49 (27.72)	105.07 (31.36)	97.11 (25.91)

Table 6.20

Mixed factorial ANOVA on Systolic Blood Pressure by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	1.69	.197	.017
Naturalness	1	.39	.531	.004
Restorative Potential	1	.04	.842	.000
Naturalness x Restorative Potential	1	2.46	.120	.024
Naturalness x Time	1	.06	.801	.001
Restorative Potential x Time	1	1.76	.188	.017
Naturalness x Restorative Potential x Time	1	4.92	.029	.047
Error	99			

Heart Rate (Table 6.24; 6.25)

The ANOVA revealed a significant main effect of Time, where Heart Rate decreased from Time 1 ($M = 81.60$, $SE = .92$) to Time 2 ($M = 77.24$, $SE = .91$). No other significant main effects or interactions were present.

Table 6.21

Heart Rate, Means and Standard Deviations (in Brackets) from Each Condition Across Time

	Nature		Urban	
	High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
Time 1	84.84 (7.60)	81.62 (9.80)	80.22 (10.18)	79.71 (9.39)
Time 2	80.08 (8.23)	77.94 (10.58)	77.46 (7.96)	73.46 (10.09)

Table 6.22

Mixed ANOVA on Heart Rate by Time 1 and Time 2, Naturalness, and Restorative Potential

Predictor	df	F	*p*	η^2_g
Time	1	38.66	<.001	.281
Naturalness	1	4.04	.047	.039
Restorative Potential	1	2.13	.148	.021
Naturalness x Restorative Potential	1	.016	.900	.00
Naturalness x Time	1	.043	.836	.000
Restorative Potential x Time	1	.74	.392	.007
Naturalness x Restorative Potential x Time	1	2.65	.107	.026
Error	99			

Familiarity

Participants were asked to rate their familiarity with the environment they experienced providing a single score of how familiar they were to the environment. To determine any significant differences in familiarity among conditions, a two-by-two between-subjects ANOVA (Table 6.24) was performed using the Familiarity scores. The results from the ANOVA revealed a significant difference in how familiar participants were to the Naturalness conditions, with the means suggesting participants were considerably more Familiar with the Urban conditions (M = 3.46, SE = .17) compared to the Natural conditions (M = 2.70, SE = .17). There was also a significant interaction between Naturalness and Restorative Potential. Pairwise comparisons

indicated that there was a significant difference between the Urban conditions ($p < .001$) with the means suggesting participants were more Familiar with the LRP-urban condition ($M = 4.12$, $SE = .24$) than the HRP-urban condition ($M = 2.81$, $SE = .25$). Additionally, there was also a significant difference between the Familiarity participants had with the Natural condition ($p < .001$). The means suggest participants were more Familiar with the HRP-nature condition ($M = 3.57$, $SE = 2.18$) than the LRP-nature condition ($M = 2.18$, $SE = .24$). These results indicate participants were more familiar with the urban conditions as a whole but were also more familiar with the conditions used more frequently in the restorative literature (i.e. the HRP-nature and the LRP-urban).

Table 6.23

Familiarity with the Environment, Mean and Standard Deviation (in Brackets) from each Condition

Nature		Urban	
High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
3.57 (1.36)	2.18 (1.26)	2.81 (1.54)	4.12 (1.34)

Table 6.24

Two-way between subjects ANOVA, on Familiarity with the Environment

Predictor	df	F	*p*	η^2_g
Naturalness	1	5.83	.017	.045
Restorative Potential	1	0.02	.886	.000
Naturalness x Restorative Potential	1	30.54	<.001	.199
Error	123			

Univariate analysis (2x2) between subjects

Preferences for the Environments

Participants were asked to rate their preference for the environments they experienced providing a single Preference score. To determine any significant differences in preference

among conditions, a two-by-two between-subjects ANOVA (Table 6.26) was performed using Preference scores. There was a significant main effect of Naturalness (p = .002). The means demonstrated that participants significantly preferred the Natural conditions (M = 5.01, SE = .14) compared to the Urban conditions (M = 4.39, SE = .14). Additionally, there was a significant main effect of Restorative Potential on Preference (p = .03). The means suggest participants preferred the HRP conditions (M = 4.92, SE = .14) more than the LRP conditions (M = 4.49, SE = 14). Finally, there was a significant interaction between Naturalness and Restorative Potential (p = .009). Post hoc pairwise comparisons revealed there was a significant difference between the Urban conditions (p < .001), while there was no difference between the Nature conditions (p = .739). The means suggest the LRP-urban environment was least preferred (M = 3.91, SE = .19) compared to the HRP-urban condition (M = 4.87, SE = .20). Thus, the LRP-urban condition was significantly least preferred compared to all other environments, as can be seen in Table 6.25.

Table 6.25

Preference, Means and Standard Deviations (in Brackets) from Each Condition Across Time

Nature		Urban	
High Restorative Potential (N = 30)	Low Restorative Potential (N = 33)	High Restorative Potential (N = 31)	Low Restorative Potential (N = 33)
4.97 (1.07)	5.06 (1.06)	4.87 (.99)	3.91 (1.31)

Table 6.26

Two-way between subjects ANOVA, on Preference scores between Conditions

Predictor	df	F	p	η^2_g
Naturalness	1	9.91	.002	.075
Restorative Potential	1	4.8	.030	.028
Naturalness x Restorative Potential	1	7.10	.009	.055
Error	123			

Univariate analysis (2x2) between subjects

Perceived Restorativeness Scale

The PRS scale was used to determine how restorative participants thought the condition they were to be exposed to was. The PRS scale questions were added together to generate one score indicating the perceived restorativeness of the environment. A two-by-two between-subjects ANOVA was conducted on PRS scores between Naturalness and Restorative Potential conditions. The results of this analysis are presented in

Table 6.28. There was a significant main effect of Naturalness (p = .035). The means suggest participants perceived the Natural conditions to be more restorative (M = 43.89, SE = 1.03) than the Urban conditions (M = 40.79, SE = 1.02). Additionally, there was a significant interaction between Naturalness and Restorative Potential (p = .024). Participants perceived the HRP-urban condition as significantly more restorative (M = 42.84, SE 1.51) compared to the LRP-urban condition (M = 38.73, SE = 1.38). While there was no difference between the Restorative Potential of the Natural conditions (p = .215). This finding suggests that participants expected greater restorative potential from the HRP-urban condition than the LRP-urban condition. This observation supports the idea that restorative potential can vary within urban environments, emphasizing the importance of further investigating and understanding the restorative qualities of different urban settings.

Table 6.27

Perceived Restorativeness Scale, Means and Standard Deviations (in Brackets) from Each Condition Across Time

Nature		Urban	
High Restorative Potential	Low Restorative Potential	High Restorative Potential	Low Restorative Potential
42.60 (8.55)	45.17 (7.16)	42.84 (7.20)	38.73 (7.37)

Table 6.28

Two-way between subjects ANOVA, Perceived Restorativeness Scale scores by Naturalness and Restorative Potential

Predictor	df	F	*p*	η^2_g
Naturalness	1	4.54	.035	.041
Restorative Potential	1	.28	.599	.003
Naturalness x Restorative Potential	1	5.28	.024	.048
Error	105			

Univariate analysis (2x2) between subjects

In order to assess participants' ability to accurately gauge the restorative capacity of environments, correlational analyses were performed between the PRS scores and various measures of restoration. Difference scores (subtracting Time 1 scores from Time 2 scores) were computed for each DV except Familiarity and Preference as these variables were collected at one time only. Table 6.29 provides the correlations.

The correlation analysis revealed significant relationships between the PRS and PA, Vitality, and Preference scores. The strongest correlation was observed between the PRS and Preference for the environment, $r(125) = 0.71$, $p < .001$, indicating that participants who rated the environment higher in restorative quality also tended to like it more. A significant positive correlation was also found between the PRS scores and PA, $r(120) = 0.29$, $p = .001$, indicating participants could moderately predict which environment would increase their PA. Finally, Vitality was moderately correlated with perceived restorative potential, $r(124) = .22$, $p = 0.016$, indicating participants predicted which environments would restore energy.

Table 6.29

Correlations between PRS scores and Measures of Restoration

				95% CI	
Variable	n	Correlation	Sig (2 tailed)	LL	UL
PA	122	.287*	0.001	0.115	0.442
NA	124	-0.092	0.309	-0.264	0.086
Vitality	126	.215*	0.016	0.042	0.376
Attention	125	0.131	0.144	-0.045	0.3
Alert	126	-0.008	0.929	-0.183	0.167
Stress	126	-0.068	0.448	-0.24	0.108
Familiarity	127	0.063	0.483	-0.113	0.234
Preference	127	.708**	<.001	0.609	0.786
Hit	111	0.069	0.469	-0.119	0.253
False Alarm	111	0.149	0.119	-0.039	0.326
DBP	103	0.069	0.4866	-0.126	0.259
SBP	103	0.108	0.277	-0.087	0.295
HR	103	0.068	0.493	-0.127	0.258

Note. CI = confidence interval; LL = lower limit; UL = upper limit

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

Discussion

Overall, the findings were either non-significant or did not align with the expected outcomes related to nature's restorative effects, illustrated by the inconsistencies among the results. NA was the only measure to indicate a restorative effect while all other measures were non-significant or inconsistent. The inconsistencies observed in the study are exemplified by the contrasting effects of the conditions on NA, Subjective Stress and SBP. While exposure to Nature and the HRP conditions decreased NA as hypothesized, indicating a restorative effect, no such impact was observed on the physiological measures. Contrary to expectations based on Ulrich et al.'s (1991) findings, the positive impact of Nature on Affect did not translate to improved psychophysiological outcomes. Moreover, although SBP increased following exposure to the LRP-nature condition, indicating heightened stress, neither Subjective Stress nor NA significantly increased, indicating a lack of alignment between the subjective and objective measures of restoration. This lack of coherence between subjective and objective measures challenges the predictions made by the SRT. These findings highlight the difficulty of considering multiple measures when assessing restoration.

There was alignment between Vitality and SBP, as participants experienced reduced Vitality following exposure to the LRP-nature condition, which was accompanied by a significant increase in SBP. This finding suggests a relation between physiological demand and perceived energy levels in this environment, as the results suggest lower energy levels might be linked to higher physiological demands. However, in the restorative literature, Vitality has not been associated with physiological restoration or in this case a depletion of energy as a result of higher stress.

One potential reason for the lack of significant results could be due to group differences. For example, there was a main effect of Restorative Potential for both PA and Subjective Stress where the participants in the LRP conditions experienced significantly lower PA and higher Subjective Stress throughout the study, while the HRP condition participants had higher PA in general and lower Subjective Stress. Moreover, the participants in the LRP conditions demonstrated a more liberal response strategy to the 3-back task. They achieved higher Hit Rate percentages than those in the HRP conditions but also committed more False Alarms.

The findings, although challenging to the prevailing SRT and ART, are consistent with meta-analyses conducted on studies used to support these theories. For example, Corazon et al. (2019) found positive effects of outdoor nature on emotional parameters, but ambiguous results for physiological stress measures. A systematic review of the Shinrin-Yoku literature also revealed inconsistencies in physiological measures post nature intervention, except for reductions in cortisol which were consistent with nature exposure (Antonelli et al., 2019). Furthermore, I found no significant differences in subjective and objective attention measures among the various conditions, contrary to my initial expectations. However, the attention results align with recent systematic reviews and meta-analyses exploring the restorative effects of nature, such as those by Bowler et al. (2010) and Stevenson et al. (2018). Bowler et al (2010) found attention scores did not significantly improve after nature interventions and Stevenson et al. (2018) found only low to moderate effect sizes of attention improving after nature exposure from their meta-analysis on ART. With group differences and the modest likelihood of detecting substantial changes in attention, it is unsurprising that this study did not find a significant effect of nature on attention. This study has thus fallen short of confirming the restorative effects of

nature. However, it appears the inconsistencies with the results of this study are inline with previous meta-analysis and systematic reviews of the restorative literature.

Alignment between Perceived Restorative Potential and the Restorative Measures

Another interest of the present experiment was determining if participants perceived (using the PRS) the restorative potential of the environments in the same manner as predicted by the researchers, distinguishing between high and low restorative conditions. The nature conditions were perceived as more restorative based on the PRS scores which aligns with the NA scores as the Nature conditions reduced NA significantly more than the urban conditions, which also aligns with the researcher expectations. Additionally, participants rated the Perceived Restorativeness of the Urban conditions in line with the Restorative Potential expected by the researcher based on the features of the environment that were expected to either increase restorative potential or decrease it. However, unexpectedly this did not occur for the Restorative Potential of the Nature conditions. Participants rated the HRP-urban condition as more restorative than the LRP-urban condition, which aligned with the researcher expectations and features of the environments as the LRP conditions were expected to reduce restorative potential and the HRP conditions were expected to increase restoration. Thus, the PRS scores aligned with the researcher expectations, and this aligns with the NA scores as NA reduced following the HRP conditions, but not the LRP conditions. This suggests participants could evaluate the varying restorative potential of urban conditions. Van den Berg et al. (2014) found no significant differences in restoration among their three nature settings, but found participants had a stronger recovery from emotional stress after the natural conditions compared to an urban street condition. Perhaps natural environments reach a ceiling effect in which all nature is perceived and experienced as similarly restorative, while urban conditions may vary more in restorative

potential. Further research is required to validate this hypothesis and account for the inconsistencies in the current study.

Correlations between the Perceived Restorativeness Scale and Restorative Measures

To examine the connection between predicted restorative potential and empirical restoration, I conducted correlational analyses between restorative measures and the PRS. Significant positive correlations were found between the PRS and PA, as well as the PRS and Vitality.

The PRS-PA correlation aligns with earlier findings connecting highly restorative environments to higher PA scores (Hartig et al., 1997). However, there were no significant PA results except for group differences in this study. If participants could accurately predict which environments were restorative, I would have expected NA to be highly correlated with the PRS scores. Hartig et al. (1997) asserts that the PRS correlates well with positive emotions, however, it is important that it also correlates with negative emotions as well, as a reduction in NA and Subjective Stress indicates restoration as well.

Regarding the PRS-Vitality correlation, it may be valuable to consider Vitality as a potential measure of physiological stress as it closely aligned with SBP. Additionally, high vitality has been linked to increased vigor, alertness, and liveliness (Bostic et al., 2000; Ryan & Frederick, 1997), as well as enhanced productivity (Janeczko et al., 2020), making it a relevant factor in restoring individuals who feel depleted. By taking vitality into account, researchers can broaden their understanding of the energy toll required of certain environments.

The lack of correlation with other restorative measures like subjective stress or attention indicates that accurately predicting restorative potential may not be feasible. However, further research is needed to explore the complex relation between perceived restorative potential and

actual restorative outcomes. Consequently, due to its limitations in identifying environments that effectively alleviate NA the only restorative measure indicating a significant restorative effect from diverse environments, it is suggested that the PRS tool be further researched to determine its effectiveness in identifying restorative environments, especially in terms of urban environments.

Preference and Perceived Restorativeness

This study also found a significant positive correlation between Preference for the environment and the PRS scores. This is consistent with previous research linking higher restorative potential to environments with favorable visual attributes (Pazhouhanfar & Kamal, 2014). These findings indicate that participants' perceptions of restorative potential were strongly associated with the aesthetic qualities of the environments (preference) leading to variations in perceived restorative quality based on preference (Boumová Půžová & Zdráhalová, 2016; Rosley et al., 2014; Stamps, 1999; Herzog et al., 2003; Van den Berg et al., 2003; Wang et al., 2019). These findings imply that visual appeal has a significant impact on individuals' assessments of restorative potential. This highlights the importance of considering visual attractiveness when interpreting individuals' assessments of restorative potential in various environments, as aesthetic appeal may significantly influence these assessments.

Although the study yielded limited significant results, it advances the understanding of the SRT and the ART by "field testing" hypothesized restorative features. By assessing urban and natural environments with various restorative and stress-inducing characteristics, this research sheds light on potential differences in restorative potential across diverse settings. Using multiple objective and subjective measures of restoration, this study provides important insights into the intricate nature of restorative experiences within different environments. Discrepancies between

existing theories and objective stress and attention outcomes highlight the need for further research. This study also highlighted the use of the PRS for identifying restorative environments in urban settings.

Limitation

A limitation of this study was the inability to gather additional data from more participants due to the COVID-19 pandemic. In addition, the pandemic has potentially altered public perceptions of urban spaces, introducing possible bias in participant responses. Furthermore, post-COVID-19 studies may yield different results compared to pre-pandemic research, complicating comparisons between this study and others within the dissertation.

Chapter 7 General Discussion

This dissertation was designed to move the restorative literature past the urban, nature dichotomy and instead investigated a diverse array of everyday environments for their restorative capacity or restorativeness. The European Landscape Convention (Council of Europe, 2000) has recognized the importance of everyday environments such as streets, squares, and buildings and their unrelenting impact on people (United Nations, 2014). However, few everyday environments have been investigated for their restorativeness. What has been found is a consistently more negative experience derived from urban environments compared to natural ones with the implication that urban environments are not restorative. The literature currently has confirmed that positive natural areas (e.g., beautiful, tranquil, and aesthetic recreational forests or parks) are restorative in terms of affective recovery while negative urban built settings (e.g., ugly, busy, noisy non-recreational streets) are not restorative (Bornioli, & Subiza-Pérez, 2023).

This research is especially important because increasingly modern urbanised societies have chronically stressed individuals (WHO, 2016) with little access to natural environments as recovery spaces (Bratman et al., 2015; Twohig-Bennett & Jones, 2018) and, when combined (high stress and few recovery/restorative options), are a significant contributor to long-term health issues (McEwan, 1998; Tyrväinen et al., 2014). Twohig-Bennett and Jones (2018) note how many health care providers are collaborating with local nature partnerships to ensure more people have access to this health resource. However, Twohig-Bennett and Jones (2018) also mention the challenge of ensuring everyone has equitable access to nature, especially for socioeconomically disadvantaged people, such as those who live in low-income neighbourhoods with reduced greenspace availability (Astell-Burt et al., 2014a, 2014b). Jones et al. (2009) identify a compounding issue with residents of lower income communities visiting greenspace

less, while higher income communities live near quality greenspaces and visit these spaces more (Lesli et al., 2010). These studies suggest some populations may not have access to, or want to, access greenspaces in their everyday environments, reducing the likelihood of them restoring their body from stress, attention fatigue, and potential affective difficulties experienced after a long day, leading to chronic stress, ill health, and low productivity (e.g., American Psychological Association, 2012; Larzelere & Jones, 2008; Michie, 2002). Thus, in this dissertation I not only wanted to further define the differences between restoration in a natural and an urban environment, but I also wanted to determine if there are urban environments with high restorative potential, that may be more accessible and safer (Kaplan & Kaplan 1989) for urban dwellers that have little access to nature, or maybe do not feel as comfortable in it due to a lack of familiarity (Bixler & Flod, 1997; Brosschot & Verkuil, 2018; 2016; Jorgensen et al., 2007; Milligan & Bingley, 2007). I conducted an analysis of what constitutes High Restorative Potential (HRP) and Low Restorative Potential (LRP) environments based on measures of stress, attention, and affect. I also looked at what elements continually appear in HRP and LRP environments (such as in Study 3) to further determine what might make a location restorative or stressful.

Dissertation Hypothesis and Findings

The results of my investigations were inconsistent. The initial hypothesis that natural conditions would prove more restorative than urban conditions was only partially supported, as it held true for a limited number of measures and was not consistent across the studies. In fact, the only restorative nature outcomes were a decrease in Subjective Stress following the Nature condition in Study 3 and a decrease in NA in Study 4. The second hypothesis was that urban environments with high restorative potential (HRP) would produce different and better

restorative effects than low restorative potential (LRP) urban environments. However, the findings did not support this hypothesis. While participants rated the HRP-urban environment as having higher restorative potential compared to the LRP-urban environment based on the PRS scores, the restorative measures did not significantly change following exposure to the HRP-urban environment. Interestingly the Restorative Potential of some urban environments did positively impact the restorative measures, but this was always in conjunction with a nature condition with the same restorative potential. For example, in Study 2 the LRP conditions (which included an urban condition) significantly reduced NA while the HRP conditions did not. Additionally, the LRP conditions in Study 3 increased PA and Vitality, meaning the LRP-urban environment had a significant positive restorative effect on participants. Finally, in Study 4 the HRP conditions significantly reduced NA. Thus, there does seem to be urban conditions with restorative effects.

The third hypothesis investigated whether participants could accurately predict their restorative experiences based on an environment's visual aspects, despite concerns about metacognitive constraints (Pearson & Craig, 2014). In line with previous studies identifying restorative elements such as trees, historic places, and biodiversity (Hands & Brown, 2002; Lee et al., 2014; Parsons & Daniel, 2002; Wang et al., 2019; Weber & Trojan, 2018), this dissertation examined the impact of these elements on restorative measures in Studies 2, 3, and 4. The goal was to assess the restorative potential of these environmental features and their effects on participants' restorative experiences. Additionally, Study 4 aimed to determine whether participants' assessments of restorative potential as measured by the PRS, aligned with the restorative outcomes identified by the restorative measures used.

The results showed minimal impact from the HRP conditions containing the elements predicted to be high in restorative potential, with few significant outcomes except for a decrease in NA in Study 4. Study 4 further tested this hypothesis, by investigating the correlations between the PRS score and the restorative measures. However, as noted above, the HRP-urban condition was predicted to be significantly more restorative than the LRP-urban condition in Study 4 based on the PRS scores, but we found no restorative measures specifically corroborating these predictions by participants. That said, in Study 4 the HRP conditions reduced NA suggesting a restorative effect, however, the HRP-urban condition was not independently able to induce a restorative effect without the HRP-nature condition. Additionally, the nature conditions were perceived as more restorative based on the PRS scores which aligned with the reduction in NA in Study 4, following exposure to the Nature conditions. This partially supports the hypothesis, but more research is needed with more significant restorative outcomes to better test the accuracy of the PRS in identifying environments with greater restorative potential.

The correlational analysis indicated that there were significant correlations between the PRS, PA, and Vitality. However, PA and Vitality did not show restorative outcomes in Study 4. PA decreased across all conditions and Vitality significantly decreased due to the LRP-nature condition. This discrepancy suggests that the PRS's perceived restorative potential does not align with the actual impact of environments on restoration.

While individuals perceive differences in restorative potential across diverse environments, their ability to accurately predict true restorative capacity based on the PRS may be limited. This could be attributed to the PRS's inability to account for the complex interplay of factors that contribute to an environment's restorative potential.

Beyond the restorative measures, a strong, significant correlation was found between Preference and the PRS, demonstrating that perceived restorative potential is closely linked to participants' preferences. While preference is not a restorative measure, this correlation sheds light on a factor (aesthetic preference) individuals may consider when evaluating an environment's restorative capacity. This finding emphasizes the role of subjective preferences in shaping perceptions of restorative potential, suggesting that personal preferences may play a crucial role in determining how individuals perceive an environment's ability to foster restoration. Kaplan and Kaplan (1989) and Ulrich (1983) predicted that preferences are tied to individual needs (i.e., restoration), providing a reasonable explanation for the strong correlation observed between Preference and the PRS. Interestingly, while the PRS did not correlate with restorative outcomes, Preference was, as there was a small but significant correlation between NA and Preference $r(124) = -.190$, $p < .05$. While this correlation is very small this suggests that Preference might be a better indicator of restorative potential than the PRS. This is further supported by the alignment of Preference and observed restorative outcomes, as participants experienced lower NA in environments they preferred, demonstrating a direct connection between Preference and actual restorative outcomes. This finding suggests that participants' subjective preferences may greatly influence their perception of an environment's capacity to promote restoration. Consequently, understanding these preferences could provide valuable insight into the relationship between individuals and their surroundings, potentially informing the design of spaces that are more conducive to restorative experiences.

The absence of correlations between the PRS and other restorative measures is likely due to the lack of significant findings overall. Thus, further research is needed with greater significant restorative outcomes to understand the link between the PRS scale and its use in

finding truly restorative environments in terms of stress, attention, and affect based on restorative potential. Additionally, more research is needed to understand how Preference was highly negatively correlated with NA indicating participants preferences were tied to their need to reduce NA for a restorative experience. These findings complicate the assessment of the hypothesis, as participants could predict restorative outcomes based on preferences, but not based on the PRS scale. In light of these findings, further research is necessary to determine whether individuals can accurately identify restorative potential in various environments, although the current results appear to support this possibility.

Exploring Contributing Factors for Insignificant Results

An intriguing finding across the studies in this dissertation was the noticeable absence of significant differences among various conditions. Contrary to Menardo et al. (2021) who claim that nature's restorative potential is a "given", this dissertation's findings challenge this assumption. The lack of significant differences in restorative outcomes between urban and natural environments indicates inconsistent evidence supporting nature's restorative value.

The absence of significant differences might be attributed to the positioning of these environments along a restorative potential continuum. The results may suggest that the selected natural environments were not substantially different regarding their impact on participants compared to the urban conditions, implying that not all natural settings are inherently more restorative than urban ones. This may have complicated the detection of variations in restorativeness. I argue that the current methodology in the restorative literature may have artificially inflated the perceived restorative value of natural environments by frequently contrasting them with stress-inducing urban spaces, while the urban conditions chosen in this dissertation were not as drastically different and detrimental to the restorative measures reducing

the likelihood of finding significant effects. Bornioli and Subiza-Pérez (2023) have pointed out that restorative environment research often idealizes natural environments, focusing mainly on tranquil, serene green spaces that promote relaxation and stress recovery. While contrasting these natural environments with unappealing urban settings, such as commercial areas or peripheral regions with motor traffic (Bornioli & Subiza-Pérez 2023). Thus, the emphasis on the benefits of natural environments has largely overlooked the potential psychological advantages of dynamic urban settings that inherently involve people and various activities. This practice might have negatively influenced the evidence on the restorative potential of urban settings and perpetuated a negative perspective on city environments. It is possible that the lack of restorative effects discovered in this thesis can be attributed to an overstated restorative effect of nature in previous research. As based on my results, the restorative effect of nature is not as strong as once thought when studying multiple examples of natural and urban environments.

The Value of Restorative Potential as a Variable to differentiate Environment Types (Urban and Natural)

It was not until I introduced the Restorative Potential variable in Study 2 that had conditions with not only dichotomous characteristics, but also variations in types of urban and natural environments that I found diverse restorative effects, including that some urban environments can be restorative (i.e., the LRP conditions in Study 2 reduced NA and the LRP conditions in Study 3 increased PA and Vitality). However, if I only compared a LRP nature condition with a LRP urban condition or a HRP nature condition with a HRP urban condition I would have found no significant differences in restorative potential, leading to the "File Drawer Problem". It seems likely that there have been other studies (comparing two environments) that were never published due to a lack of significant results, leading to a large gap in the literature

that might have evidence related to restorative urban environments, or less restorative natural environments. Often dismissed as irrelevant, insignificant findings involving nonrestorative environments may actually hold value for the scientific community. Recognizing the significance of nonsignificant results is vital for acquiring a more holistic understanding of the intricate factors influencing restorative experiences. These findings underscore a significant challenge within the restorative literature – potentially valuable nonsignificant results, such as those indicating no difference between natural and urban environments, are often disregarded despite their potential contributions to understanding restorative experiences across various environments.

This dissertation discovered significant differences between environments by incorporating two diverse environment types based on perceived restorative potential. Incorporating a diverse array of environment types in future studies could contribute to a greater understanding of what makes an environment restorative be it urban or natural. This would offer valuable insights into distinguishing between environments that are genuinely detrimental and those that hold potential for supporting restoration. This is also important because cities have limited resources, and it is imperative that those resources go toward the environments that negatively impact human health the most.

Urban Restorative Potential: Insights and Discoveries

One of the features used to manipulate restorative potential in the urban conditions was building height. Previous studies have shown that tall buildings induce stress (Asgarzadeh et al., 2012), thus this feature was manipulated between the LRP and HRP urban conditions. Additionally, traffic was kept at a distance, or conditions were found without traffic (another known stressor; Ndrepena & Twardella, 2011), to focus on one stressful stimulus at a time

(Study 1, 2, and 3). Thus, in the HRP-urban conditions, low building height was incorporated, while the LRP-urban conditions all had tall buildings. I also manipulated the presence of cultural areas (Weber & Trojan, 2018), commercial streets (Barros et al., 2021), architectural variation, and multisensory stimulation as these have been proposed to impact the restorativeness of urban environments (Bornioli & Subiza-Pérez, 2023; Kaplan, 1995).

In Study 2 the LRP conditions reduced NA, while in Study 3 the LRP conditions increased PA. This suggests that the amount of stress imposed on people from tall buildings may vary depending on other factors. For example, the distance between participants and the surrounding buildings might have played a role in mitigating the stress-inducing effects of the tall buildings. In Asgarzadeh et al. (2012) study, oppressiveness significantly increased when the solid angle of the building was enlarged, suggesting participants need to be facing the tall buildings to invoke the oppressive stress. In Study 2 participants could walk down the middle of a quiet street as opposed to walking on the sidewalk right next to the buildings, while in Study 3, to replicate an everyday experience, I had participants face the courtyard rather than the buildings, providing a more typical urban setting experience. This difference in participant perspective of the buildings may have mitigated the stress from this type of urban stressor. Additionally, Asgarzadeh et al. (2014) also discovered that trees obscuring the height of buildings could reduce perceived oppressiveness and enhance the perception of spaciousness. While Study 2 did not have trees, small trees were present in the courtyard in Study 3 potentially contributed to a less oppressive ambiance. This could have played a role in mitigating the stress that participants might have otherwise experienced due to the surrounding buildings. These findings indicate a more complex relationship between restoration and building height than previously thought. This is important

because tall buildings are a constant presence in urban environments. Clearly more research is needed on how everyday urban environment experiences impact restoration and stress.

Another notable difference between the LRP and HRP urban conditions in Study 3 was the presence of traffic. While the LRP-urban condition situated participants in a courtyard surrounded by tall buildings that blocked traffic views, the HRP-urban condition featured low buildings and an open shopping area with interesting architecture adjacent to a parking lot with a view of a major road. These results imply that traffic or other factors might have played a more significant role in shaping participants' restorative experiences as building height, commercial streets (Barros et al., 2021), and architectural variation (Bornioli & Subiza-Pérez, 2023) have all been suggested to increase restorative potential. Additionally, the HRP-urban condition in Study 2 had architectural variation, however, it was the LRP conditions that reduced NA, further suggesting that architectural variation alone is not a strong predictor of restorative potential.

Study 2 and Study 3's findings provide insight into the potential hierarchy of restorative elements and detrimental elements within restorative urban environments. In Study 2 low building height and architectural variation did not lead to a restorative experience, while the presence of traffic in the HRP-urban condition from Study 3 may have diminished the restorative impact of shopfronts, interesting architecture, and low building height. While in Study 2 and 3 the LRP-urban conditions featured tall, imposing buildings with few architectural features of interest, but supported restorative effects. These results emphasize the importance of considering the combined influence of various elements when designing and evaluating urban spaces for their restorative potential.

In Study 4, the HRP-urban environment showcased the potential for urban settings with restorative elements, such as historical places (Fornara, 2011; Masullo et al., 2021), and minimal

traffic to yield restorative outcomes. The HRP conditions reduced NA suggesting a restorative experience, additionally, the LRP conditions increased DBP, meaning there was no negative effect of this HRP-urban condition contrary to the other studies of HRP features. These findings imply that this specific type of urban environment can offer some restorative benefits and does not evoke the negative effects commonly associated with other urban settings suggesting some urban environments can be restorative.

Further investigation into these factors is warranted to better understand the impact of urban environments on stress. It appears that the existing restorative literature has primarily focused on the effects of stressful urban environments on individuals, rather than examining the potential restorative qualities of various environments. The findings reveal that numerous urban environments impact restorative measures similarly to natural environments, a phenomenon that has not been extensively discussed in the literature.

Nature's Restorative Potential: Insights and Discoveries

Across all of the studies, there were no statistically significant differences found between the LRP and HRP natural conditions. This was unexpected as I had included significantly more and larger trees in both HRP-nature conditions, in Study 2 and 3. Trees are suggested to provide restorative potential with a positive dose response correlation (e.g., Lindal & Hartig, 2015; Jiang et al., 2014; Lohr & Pearson-Mims, 2006; Simkin et al., 2020; Wang et al., 2019). However, there was no difference found between the restorative measures and the variations in trees.

I had also anticipated that the elements of overgrowth and deadwood included in Study 3's LRP-nature condition would induce stress, as previous research indicates that these features are often perceived negatively. This is because overgrowth and deadwood are frequently associated with neglect, mismanagement, and wastefulness (Merganiov et al., 2012; Janeczko et al., 2021).

Unkempt bushes and deadwood can also create hiding places, contributing to stress and fear in urban parks (Jorgensen & Anthopoulou, 2007; Kaplan & Kaplan, 1989; Martens et al., 2011). Moreover, deadwood is generally disliked because it detracts from scenic beauty and recreational potential (Janeczko et al., 2021). However, the results suggest that these negative elements did not hinder restoration recovery.

Another aspect of natural environments that I manipulated was biodiversity and survival advantages in Study 4. The HRP-nature condition offered high biodiversity and potential food and shelter options in a rainforest setting, while the LRP-nature condition featured low plant diversity and fewer survival advantages, with participants situated in a winter forest setting amid bare trees. However, again I found no significant differences between the two nature conditions. Interestingly, these results appear to challenge the predictions of the SRT, suggesting that the restorative potential of an environment may not be solely dependent on the presence of biodiversity, living organisms and survival advantages, as posited by Ulrich (1993). Additional research is needed to further dissect these findings, but the current studies indicates that a restorative experience may involve a more complex interplay of factors beyond simply being surrounded by living elements and the availability of survival advantages.

These results highlight the complexity of restorative environments and the need to consider a broader range of factors beyond what has traditionally been studied. By further exploring the intricate interplay of various features in both natural and urban settings, I hope to deepen our understanding of the factors that contribute to restorative experiences and ultimately enhance the design of environments that promote restoration.

Rethinking Restorative Potential: Findings from Urban and Natural Environments

This dissertation initially employed both the SRT and the ART to explore variations in restorative potential across environments. Contrary to prevailing views that nature always provides more restorative environments compared to urban settings (Kaplan & Kaplan 1989; Berto, 2014), the studies in this dissertation found few differences between the natural and urban conditions.

The incorporation of objective measures of stress and attention, alongside subjective measures, was used to help mitigate bias and bolster the evidence for restorative environment theories. In the studies, few significant differences emerged between environment conditions and psychophysiological or attention measures. However, affective measures varied across restorative potential, nature, and urban conditions, underscoring the impact of these settings on emotional states. Bowler et al. (2010) conducted a systematic review of short-term exposure to nature and the most often reported result was a change in subjective emotions consistent with the findings of this dissertation. They concluded their review by suggesting that natural environments have a positive impact on well-being, but more research is needed to further understand the relation between nature and other restorative outcomes. Additionally, reviews of the Shinrin-yoku literature by Antonelli et al. (2019) and Tsunetsugu et al. (2010) uncovered discrepancies in existing psychophysiological data, leading them to also recommend further research on the physiological outcomes of Shinrin-yoku. Finally, Corazon et al. (2019) found that outdoor nature interventions have a positive effect on emotional parameters related to stress relief. However, studies using physiological (objective) measures of stress showed more ambiguous results (Corazon et al., 2019).

The lack of significant physiological outcomes was unexpected as many studies have indicated that simple visual access to natural environments can reduce physiological symptoms of stress. However, my findings did not align with this research, but does align with existing systematic reviews and meta-analyses which found heterogeneous results for psychophysiological stress and attention measures (e.g., Corazon et al., 2019; Antonelli et al., 2019; Ohly et al., 2016). This suggests that the psychology-to-physiology trigger theory which has been assumed (Mauss et al., 2005) may not be as strong as once thought. There is limited research directly exploring the relationship between physiological and emotional stress responses (Campbell & Ehlert, 2012). The findings of this dissertation align with Dickerson and Kemeny's (2004) meta-analysis, which revealed no consistent connection between stress responses and subjective distress, further highlighting the need to better understand the relationship between physiological and emotional aspects of stress and restorative experiences. However, emotion-based restoration measures remained consistent with the literature, pointing to the need to investigate the complexities of restorative environments and their attainable restorative outcomes. Specifically, focusing on the SRT and ART is crucial, as my findings did not yield objective evidence of stress reduction and attention restoration in the studied environments.

Visual Methods of Displaying Environments

Throughout this dissertation, multiple studies were conducted to explore the restorative potential of various environments. To gain a comprehensive understanding, I employed different mediums, including computer-generated VR environments, 360 VR videos, and field studies. The rationale behind using multiple methods was to balance ecological validity, experimental control, and accessibility. Additionally, natural environments may be inaccessible for certain individuals. While field studies provide more ecologically valid results, VR and video methods

offer a more resource-efficient and controlled alternative (García et al., 2006). Moreover, Alyan et al. (2021) suggest realistic virtual environments can reduce sympathetic nervous system activity, which may result in quicker recovery from stress, suggesting VR is a viable tool to use for studying reductions in stress.

In Study 1 the VR urban condition significantly reduced Subjective Attention, suggesting this condition was more attentionally demanding, however, no restorative effects were observed for the Nature conditions. In Study 2 there was a restorative effect due to a decrease in NA from exposure to the LRP conditions, however, no other measure was significant, suggesting the computer-generated VR environments were not ideal for studying the restorative effect as the environments were less effective in inducing significant restoration. Additionally, Subjective Attention decreased following the VR interventions.

The use of 360 VR videos in Study 4 aimed to incorporate more realistic environments while increasing ecological validity and maintaining experimental control. However, the Subjective Attention measures of Alertness and Attentiveness both decreased following the VR 360 videos, while in Study 3 post intervention Subjective Attention increased. Mayer et al. (2009) specifically investigated whether simulated nature could provide the same benefits as real nature exposure. They discovered that positive affect and the ability to reflect were equally experienced in both the simulated nature (video) and real nature conditions. However, no significant differences were observed for attention measures in either condition. Additionally, prolonged focus on the VR headset's two small LCD screens could lead to eye strain (Canadian Association of Optometrists, 2016), and the awkward visual posture might impede focusing, tracking, and depth perception, impacting restoration (Kjellgren & Buhrkall, 2010). It is possible that participants needed increased directed attention to process the novel stimuli in the VR

environment, contrasting with the effortless fascination of natural elements in real-world settings. Another issue with the VR environments in Study 1 and 2 is that the video game software used to create the environments, may have diminished the restorative quality of nature due to pixelation and reduced realism compared to other forms of stimuli. Caution should thus be exercised when employing the use of VR environments in studying restorative effects, especially in terms of attention.

That being said, the 360 videos demonstrated a small restorative effect, with Nature significantly reducing NA, and the HRP conditions also reducing NA aligning with the results from Study 2. Interestingly, the urban conditions increased DBP, in Study 4, however, that could have been due to the more sensitive blood pressure measurement device.

Study 3, which used real-world environments, had the most consistent results with the literature. PA increased for those exposed to the LRP conditions, Vitality significantly increased following exposure to the Nature conditions, Subjective Attention significantly increased following the intervention, and Subjective Stress significantly decreased after the Nature condition. DBP and SBP both decreased following the intervention, however, this may have been due to blood pressure increasing after the walk at Time 2. Overall, the real-world environments yielded more significant and consistent restorative results, in line with the literature, supporting previous research suggesting field studies have a greater impact on participants compared to simulated environments (Kjellgren & Buhrkall, 2010).

Limitations

A key limitation in this dissertation was the constraint on time and resources. Each experiment was time-consuming due to the use of physiological measures, which required proper explanation and fitting for participants, and the field studies necessitated additional time to

transport participants to the study locations. Moreover, the studies were conducted in Ontario, Canada, where weather conditions and vegetation undergo significant changes throughout the year, further limiting the optimal time frame for data collection. Since participants were students, their availability was highest during the fall semester when weather and vegetation conditions are only consistent until October. The winter semester was unsuitable for data collection due to extreme cold affecting sensor functionality and the absence of relevant vegetation until mid-June. Consequently, there was a restricted window for data collection with longer study durations, resulting in a smaller participant sample size.

I had anticipated that the restorative effects of nature would be strong enough to see significant differences, even with the small samples used here, based on previous studies. However, this was not the case. Thus, while the present sample sizes might be considered too small, they are consistent with what the literature has used. This highlights the need for further research with larger samples to better understand the restorative effects of nature and urban environments.

Conclusion

This dissertation examined the restorative potential of various natural and urban environments. Overall, the findings indicate that the restorative effect of nature may not be as strong as previously thought. In addition, there may be some restorative potential in urban environments, but clearly more research is needed. Future research exploring the impact of a diverse set of environments on stress reduction and attention restoration, using objective measures and larger sample sizes for increased statistical power would be valuable.

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