universität wien

MASTERARBEIT | MASTER'S THESIS

Titel | Title

Understanding Green Environments: A Theoretical Analysis of Plants, Nature, the Colour Green, Well-Being and Psychological Effects

verfasst von | submitted by

Vanessa Jakoubek BSc

angestrebter akademischer Grad | in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien | Vienna, 2026

Studienkennzahl lt. Studienblatt | Degree programme code as it appears on the student record sheet:	UA 066 840
Studienrichtung lt. Studienblatt | Degree programme as it appears on the student record sheet:	Masterstudium Psychologie
Betreut von | Supervisor:	Univ.-Prof. Dipl.-Psych. Dr. Helmut Leder

Table of Contents

Abstract

This theoretical thesis addresses a central issue in environmental psychology, namely that exposure to natural environments is consistently associated with positive psychological outcomes such as reduced stress, improved mood, and enhanced cognitive functioning, but the mechanisms underlying these effects remain insufficiently understood. In particular, it remains unclear whether restorative responses are primarily driven by plant structure and natural content, by the colour green, or by an interaction of both, and this ambiguity constitutes the central research question of the thesis.

Drawing on a critical review of literature from environmental psychology, colour psychology, and restoration theories, the thesis identifies a recurring methodological limitation, namely that visual stimuli often combine colour, form, and semantic associations with nature. This makes it difficult to isolate the specific factors responsible for observed effects and limits precise causal conclusions.

Instead of presenting an empirical study, the thesis develops a structured experimental framework with four controlled conditions, green colour alone, green plant imagery, non-green plant imagery, and a neutral grey baseline. This framework is designed to separate colour-based and nature-based influences and to improve the clarity of future research on visual restoration.

In conclusion, the thesis argues that distinguishing more clearly between colour and nature components is essential for advancing theoretical models of psychological restoration. It also highlights the practical relevance of this distinction for the design of indoor environments such as workplaces, educational settings, and healthcare facilities, where visual elements may be used in more targeted and evidence-based ways to support well-being and cognitive performance.

1. Introduction

Environmental psychology examines how physical surroundings influence human experience, behaviour, and well-being (Berman et al., 2008; Beukeboom et al., 2012; Gaekwad et al., 2022; Rhee et al., 2023). Within this field, growing attention has been given to the role of natural elements and visual exposure to greenery as potential sources of psychological restoration (Michels et al., 2022; Norwood et al., 2019; Yeom et al., 2022; Yin et al., 2020; Zhang et al., 2024). In order to understand these effects more precisely, it is necessary to first consider the broader context in which modern environments shape cognitive and emotional functioning before focusing on specific mechanisms and research questions.

1.1 Background

Modern life is increasingly characterized by prolonged exposure to indoor and highly urbanized environments. In contemporary societies, individuals spend the vast majority of their daily lives inside buildings such as offices, universities, schools, hospitals, and residential spaces rather than in natural outdoor environments (Lei et al., 2021; Zhang et al., 2025). Research suggests that people spend most of their time indoors, particularly in industrialized and urban societies (Danielski et al., 2022; Yang et al., 2025; Yeo, 2021). As a result, everyday psychological experiences are strongly shaped by built environments and the visual conditions they create (Sanchez et al., 2018).

Although indoor environments are designed to support productivity, efficiency, and functionality, they are often visually artificial, cognitively demanding, and lacking in natural elements (Ma et al., 2024; Sanchez et al., 2018). Many contemporary work and study settings are dominated by neutral colours, artificial lighting, digital screens, repetitive architectural structures, and prolonged attentional demands. In addition, dense urban environments frequently reduce opportunities for direct contact with natural settings and restorative outdoor experiences (Budaniya et al., 2025; Zhang et al., 2024; Zhou, 2013). These conditions are particularly relevant in workplaces and educational environments, where sustained concentration and continuous cognitive performance are expected over long periods of time (Amicone et al., 2018; Wallner et al., 2018).

Environmental psychology research increasingly suggests that such environments may contribute to psychological strain and cognitive fatigue (Berto, 2005; Nieuwenhuis et al., 2014). Continuous attentional demands, limited opportunities for mental recovery, and overstimulation through artificial surroundings can negatively influence stress levels, emotional well-being, and cognitive functioning (Mason et al., 2022). In particular, prolonged directed attention has been associated with attentional fatigue, reduced concentration, irritability, and decreased mental restoration (Amicone et al., 2018; Bringslimark et al., 2009; Zhang et al., 2025). Similarly, stressful indoor environments may contribute to elevated psychological stress and reduced comfort, especially when they lack restorative or aesthetically supportive elements (Deng & Deng, 2018; Dijkstra et al., 2008; Sanchez et al., 2018; Zhou, 2013).

At the same time, growing evidence suggests that psychological well-being is not solely determined by internal psychological processes, but is also strongly influenced by the surrounding physical environment (Yang et al., 2025). Environmental characteristics such as colour, lighting, spatial design, natural elements, and visual complexity can affect mood, stress perception, attentional functioning, and overall emotional experience (Chana et al., 2026; Jalil et al., 2012; Michaelis, 2013; Yang et al., 2025). This perspective has contributed to increasing interest in how environmental design can support mental restoration and psychological well-being in everyday life.

Within this context, environmental psychology has increasingly focused on the relationship between humans and their physical surroundings, particularly regarding the restorative potential of natural environments and nature-related visual stimuli. Researchers have become especially interested in understanding how exposure to nature, greenery, and plant-related elements may help counteract stress, attentional fatigue, and cognitive overload in modern indoor settings (Yang et al., 2025; Zhang et al., 2024).

1.2 Nature Exposure and Psychological Benefits

A substantial body of research suggests that exposure to nature is associated with a range of positive psychological and cognitive outcomes. Natural environments are commonly described as restorative because they appear to support emotional recovery, reduce stress, and replenish attentional resources (Grinde & Patil, 2009; Mason et al., 2022; Yin et al., 2020; Zhang et al., 2024). Across environmental psychology literature, nature exposure has repeatedly been linked to improved mood, increased calmness, enhanced perceived restoration, and reduced mental fatigue (Grinde & Patil, 2009; Jabbar et al., 2024; Ma et al., 2024; Norwood et al., 2019; Zhang et al., 2020).

These restorative effects have been observed in a variety of settings and forms of exposure. Direct exposure to natural environments such as parks, forests, gardens, or green outdoor spaces is often associated with lower stress levels, improved emotional well-being, and better attentional functioning (Amicone et al., 2018; Brooks et al., 2017; Brown et al., 2013; Lindemann-Matthies & Matthies, 2018). Nature-based environments are also frequently linked to feelings of relaxation, comfort, and psychological recovery following cognitively demanding tasks or stressful experiences (Bielinis et al., 2021; Wang et al., 2026).

Importantly, restorative responses are not limited to direct outdoor contact with nature. Research suggests that indirect forms of exposure may also produce beneficial effects (Rhee et al., 2023). Studies involving indoor plants, green walls, nature views, plant imagery, or virtual representations of nature often report reduced stress, greater perceived restorativeness, and improvements in mood or attentional functioning (Chen & Yokoyama, 2021; van den Berg et al., 2016; Yin et al., 2020). Even relatively brief exposure to nature-related visual stimuli has been associated with psychological benefits in laboratory and real-world contexts (Brown et al., 2013; Michaelis, 2013).

Within indoor environments, plants are frequently discussed as restorative design elements that may improve perceived comfort, environmental attractiveness, and emotional well-being (Beukeboom et al., 2012; Deng & Deng, 2018; Dijkstra et al., 2008; Yeom et al., 2022). Similarly, visual exposure to natural scenes or vegetation imagery has been associated with relaxation and attentional recovery, suggesting that even symbolic or indirect representations of nature may influence psychological functioning (Brooks et al., 2017; Brown et al., 2013; Li et al., 2025; Michels et al., 2022; Wang et al., 2026).

The restorative potential of nature is commonly explained through frameworks such as Attention Restoration Theory and Stress Reduction Theory, both of which propose that natural environments support recovery from cognitive fatigue and psychological stress (Bratman et al., 2012; Frumkin et al., 2017; Mason et al., 2022; Shibata & Suzuki, 2004; Zhang et al., 2024). Although these theoretical approaches differ in emphasis, they share the assumption that natural environments possess qualities that are psychologically beneficial and restorative for humans.

Overall, the literature consistently suggests that exposure to nature and greenery is associated with positive emotional, cognitive, and stress-related outcomes. As a result, nature is widely considered a restorative environmental resource within environmental psychology research (Michels et al., 2022; Zhang et al., 2024) .

1.3 Problem Statement

Despite the growing evidence supporting the restorative effects of nature exposure, an important conceptual and methodological problem remains unresolved within the literature. Most existing studies treat nature or green environments as broad and unified categories, even though these environments consist of multiple distinct visual and perceptual components (Berman et al., 2008; Bratman et al., 2012; Grinde & Patil, 2009; Yeom et al., 2022; Yin et al., 2020).

Visually, natural environments contain several overlapping elements, including colour, plant structure, texture, spatial complexity, and symbolic associations related to nature and well-being (Beukeboom et al., 2012; Wang et al., 2026; Zhang et al., 2024). In particular, the colour green is strongly associated with natural environments and is often embedded within studies investigating plants, forests, or vegetation (Yang et al., 2025; Zheng et al., 2024). As a result, green colour, plant content, and nature-related meaning are frequently presented simultaneously within the same stimulus condition (Dijkstra et al., 2008; Rhee et al., 2023; Yeo, 2021; Yeom et al., 2022; Yin et al., 2020).

This creates a central problem for interpretation. Although restorative effects are repeatedly observed in studies involving greenery and plants, it remains unclear which specific component is responsible for these outcomes. In many cases, studies compare natural versus urban environments, plants versus no plants, or green spaces versus neutral settings, without isolating the underlying visual mechanisms (Bratman et al., 2015; Brown et al., 2013; Grinde & Patil, 2009). Consequently, it is difficult to determine whether restorative responses are caused primarily by the perceptual properties of green colour, by the presence of plant-based natural structures, or by broader semantic and biophilic associations linked to nature.

Research in colour psychology further complicates this issue. Green has independently been associated with calmness, relaxation, creativity, and attentional functioning in some experimental contexts (Jalil et al., 2012; Michaelis, 2013; Norwood et al., 2019; Zheng et al., 2024; Zhou, 2013). At the same time, studies involving real plants and natural environments often report similar restorative outcomes (Berman et al., 2008; van den Berg et al., 2015). Because these variables are rarely separated experimentally, the current literature does not provide a clear explanation of the underlying mechanism (Dijkstra et al., 2008; Rhee et al., 2023; Zheng et al., 2024).

As discussed throughout the previous chapters, existing research frequently bundles green colour, plant form, visual attractiveness, and nature-related meaning together within the same experimental conditions (Bakker & van der Voordt, 2010; Beukeboom et al., 2012; Yeo, 2021; Yeom et al., 2022; Yin et al., 2020). Consequently, current research does not clearly separate these components, making it difficult to identify whether restorative effects are driven by colour, plant content, or their interaction. Accordingly, the central question of this thesis is whether restorative effects of visual nature exposure are primarily driven by green colour, plant-based structures, or the interaction of both components.

1.4 Research Aim

The present thesis aims to critically examine the relationship between green colour, plant-related stimuli, and restorative psychological effects within the context of environmental psychology. More specifically, the thesis reviews and synthesizes literature on green colour exposure, indoor plants, nature imagery, and combined greenery-related stimuli in order to identify similarities, differences, and unresolved methodological issues across these areas of research.

A central objective of the thesis is to clarify how previous studies conceptualise and investigate restorative environmental effects. Particular attention is given to the extent to which existing research isolates visual variables such as colour and plant structure, as well as to the methodological limitations that arise when these variables are confounded within broader nature-based stimuli.

Building on this critical review, the thesis proposes a controlled experimental framework designed to separate green colour from plant content more systematically. The proposed design includes distinct conditions involving green colour alone, green plant imagery, non-green plant imagery, and a neutral grey control condition. Through this structure, the framework aims to address the central research gap identified throughout the literature review: the lack of experimental separation between colour-based and nature-based effects.

The relevance of this topic extends beyond theoretical questions within environmental psychology. If relatively simple visual elements such as colour or plant imagery are capable of influencing stress, mood, or cognitive functioning, this may have important implications for the design of modern indoor environments. Such findings could contribute to evidence-based approaches in architecture, workplace design, educational settings, and healthcare environments, where opportunities for direct nature exposure are often limited.

Accordingly, the thesis seeks not only to evaluate existing findings, but also to contribute to a more precise understanding of how visual environmental factors influence psychological well-being and cognitive restoration in contemporary indoor settings.

1.5 Structure of the Thesis

This thesis begins by introducing the research topic, outlining the central problem, and defining the overall aim of investigating how green colour and nature-related visual stimuli influence psychological and cognitive processes. It then develops a theoretical foundation by reviewing research on nature exposure and its effects on well-being, alongside key theories, colour psychology, indoor plant research, and the methodological challenges of separating colour from nature-related content. Building on this, the third chapter critically examines existing empirical studies, comparing their designs, stimuli, and measures, while identifying key methodological limitations and highlighting the unresolved gap in distinguishing between green colour and natural content effects. The fourth chapter then presents a proposed experimental approach designed to address this gap, explaining the rationale, outlining the four experimental conditions, and discussing the control structure as well as the theoretical, methodological, and practical implications of the design. Finally, the thesis concludes by reflecting on the broader significance of the findings and providing an outlook on future research directions in the field.

2. Theoretical Background

Over the past decades, increasing attention has been given to the relationship between natural environments and human well-being (Michels et al., 2022). A growing body of research suggests that exposure to nature can positively influence both psychological and physical functioning in a variety of ways, including reducing stress, improving mood, supporting attention and cognitive restoration, and contributing to physiological recovery and overall health (Budaniya et al., 2025; Yang et al., 2025; Zhang et al., 2024). As modern environments are often associated with high levels of stress, cognitive fatigue, and limited contact with natural settings (Danielski et al., 2022; Ma et al., 2024), researchers in environmental psychology have become increasingly interested in understanding how and why nature may contribute to improved well-being and functioning (Bringslimark et al., 2009; Ulrich, 1984).

Previous research consistently links exposure to nature with psychological restoration and improved cognitive functioning, although the strength and form of these effects vary across studies. Studies on parks, forests, school gardens, and other green spaces have reported improvements in well-being, more positive mood outcomes, reduced tension and anxiety, lower negative affect, and enhanced attention and concentration following nature exposure (Bratman et al., 2015; Choi et al., 2016; Han, 2017; Kuo et al., 2018; Nieuwenhuis et al., 2014; Wallner et al., 2018). Nature is therefore not only understood as an aesthetically pleasant stimulus, but also as a restorative resource that may support psychological and physiological recovery. Prior literature further suggests that contact with nature can reduce stress, improve mood, support mental restoration, and in some cases even contribute to recovery from stress-related symptoms or medical conditions (Brown et al., 2013; Grinde & Patil, 2009; Lindemann-Matthies & Matthies, 2018).

Among these effects, stress reduction, attentional restoration, and cognitive recovery are the most consistently supported findings, whereas mood-related outcomes appear more variable across studies (Grinde & Patil, 2009; Rhee et al., 2023). These restorative effects are commonly explained through theoretical frameworks such as the Biophilia Hypothesis, Attention Restoration Theory (ART), and Stress Reduction Theory (SRT), which propose that nature supports restoration through mechanisms such as soft fascination - which describes a state of effortless, gentle attention that allows the brain to rest and recover from cognitive fatigue - recovery of directed attention, and psychophysiological stress recovery (Grinde & Patil, 2009; Yin et al., 2020). In addition, research indicates that different forms of nature exposure can be effective, including direct outdoor nature, window views, images and videos, as well as indoor plants.

However, the effectiveness may depend on the intensity and quality of exposure, as very minimal greenery may have limited effects, while overly intense stimuli may become overwhelming (Grinde & Patil, 2009; Lei et al., 2021; Rhee et al., 2023). Overall, the literature suggests that nature is an important psychological resource that can support restoration, reduce stress, improve attention, and enhance well-being, although the consistency of mood-related effects remains less stable across studies (Grinde & Patil, 2009).

2.1 Nature and Well-Being

Nature exposure has been studied as a factor that may relate to several aspects of well-being, including psychological, cognitive, and physiological outcomes. In this section, the focus is on the psychological effects that are most frequently discussed in the literature.

2.1.1 Psychological Effects

On the psychological side, the most consistently reported effects of nature exposure include improved mood, reduced negative affect, lower levels of tension and anxiety, greater relaxation and a stronger subjective sense of restoration or recovery after stress (Bratman et al., 2015; Brooks et al., 2017; Choi et al., 2016; Ding et al., 2026; Wallner et al., 2018; Zhang et al., 2024).

Overall, the literature suggests that nature tends to have a generally positive psychological influence; however, mood-related findings are not entirely consistent across studies. While many studies report more pleasant, calm, or positive emotional states following nature exposure, as well as reduced stress and improved restoration, other findings show either no clear differences in mood or effects limited to specific emotional dimensions rather than overall mood changes (Grinde & Patil, 2009; Lindemann-Matthies & Matthies, 2018).

In some experiments,, self-esteem emerges as one of the more stable psychological outcomes, with evidence suggesting that it can improve after nature exposure and remain robust even following mild stress induction, whereas general mood measures such as PANAS (Positive and Negative Affect Schedule) do not always show condition-specific effects, and reductions in negative affect may occur across both nature and control conditions rather than exclusively in response to nature exposure (Brown et al., 2013).

Where clearer mood effects are observed, they are typically described as increases in positive affect and decreases in negative affect; for example, exposure to green walls has been associated with higher positive affect, lower negative affect, and reduced perceived task load, even though objective task performance does not necessarily change (Yeom et al., 2022).

The literature further explains these psychological effects within a broader restorative framework, suggesting that mechanisms proposed by Biophilia, Stress Recovery Theory and Attention Restoration Theory jointly help explain why exposure to nature can improve affect, reduce negative emotional states, and support recovery from stress, particularly when the sensory connection to nature is more direct or salient (Gaekwad et al., 2022; Yin et al., 2020).

A key limitation highlighted in the literature is that mood effects are rarely attributable to a single isolated factor, since many studies combine elements such as natural scenery, greenness, plant presence, and built-environment contrast, making it difficult to clearly disentangle the specific mechanisms responsible for observed psychological changes (Brown et al., 2013).

2.1.2 Stress Reduction Effects

Stress reduction is one of the most consistently reported psychological benefits of exposure to natural environments, and it has been demonstrated across a wide range of experimental and real-world contexts. One of the most influential early findings comes from a study showing that after exposure to a stressful accident film, participants recovered faster when viewing natural scenes compared to urban scenes, with quicker reductions in physiological stress indicators such as heart period, pulse transit time, skin conductance, and muscle tension, as well as more positive affect (Ulrich et al., 1991). This study is often used to argue that nature may reduce stress more effectively than urban environments because natural stimuli are evolutionarily linked to safety and survival, while also showing that stress recovery cannot be explained by attention capture alone, since the initial stressor already strongly engaged attention (Ulrich et al., 1991). Supporting this, laboratory evidence suggests that even brief exposure to green scenes can facilitate stress recovery, primarily through parasympathetic activation, as indicated by increased RSA (Respiratory Sinus Arrhythmia), although sympathetic recovery was less consistently observed (van den Berg et al., 2015). Importantly, this study suggests that even short visual exposure to natural stimuli, such as images rather than real environments, can already produce measurable restorative effects (van den Berg et al., 2015).

Further evidence from real-world and semi-natural environments strengthens this pattern. Exposure to pocket parks - which are small neighborhood parks or pocket-sized green spaces inside the city - has been shown to support stress recovery, with features such as species richness and landscape type influencing outcomes, and perceived aesthetic quality partially mediating these effects (Wang et al., 2026). At the same time, this research highlights that the mechanism is not simply driven by nature or colour alone, but rather by a combination of natural content and visual environmental composition (Wang et al., 2026). Similarly, experimental work comparing plants and green colour indicates that while both can contribute to positive affect recovery, the strongest effects are typically observed when plant imagery is present, suggesting that vegetation content may play a more central role than colour alone (Michels et al., 2022). In line with this, studies in real environments, such as hospital waiting rooms, show that both real plants and plant posters reduce perceived stress compared to non-nature controls, with effects partially explained by increased aesthetic appeal (Beukeboom et al., 2012; Dijkstra et al., 2008).

Evidence from indoor environments further supports these findings. Exposure to green walls - which are indoor walls of living plants - in classroom settings has been associated with reduced stress-related responses, including lower blood pressure and heart rate, alongside increased relaxation and positive affect (Ma et al., 2024). These findings are often explained through both Attention Restoration Theory and Stress Recovery Theory, with physiological changes interpreted as indicators of stress reduction (Ma et al., 2024). Similarly, studies in vegetated office environments show that even relatively short exposure, such as one hour in a green room, can reduce perceived stress and fatigue, with additional but less consistent physiological changes such as reductions in blood pressure and heart rate (Zhang et al., 2025). Real planted indoor environments, such as green office rooms with potted plants, further suggest that stress reduction effects are linked to actual environmental exposure rather than screen-based stimuli alone (Zhang et al., 2025). Comparable findings are reported in laboratory studies using real plants, such as hydrangeas, although limited exposure duration and ecological realism are noted as constraints for generalizability (Li et al., 2026).

Beyond indoor contexts, exposure to natural outdoor environments such as pocket parks after stress induction has been shown to support recovery through calming and non-threatening stimuli (Wang et al., 2026). Broader reviews of forest bathing further support significant reductions in depression and anxiety, although physiological outcomes such as blood pressure and heart rate are less consistently affected (Siah et al., 2023). These effects are explained through a combination of evolutionary, emotional, physiological, and mindfulness-related mechanisms rather than a single factor (Siah et al., 2023). Similarly, nature exposure in or near workplaces has been associated with reduced anxiety, improved well-being, and lower physiological stress indicators, with effects generally stronger for outdoor natural environments compared to indoor ones (Choi et al., 2016; Perrins et al., 2021).

Additional evidence shows that even brief or repeated exposure can be beneficial, with studies reporting positive effects after short durations such as five minutes of green exposure or around 120 minutes per week, although the optimal dose remains unclear (Zhang et al., 2024). School-based research further suggests that greener environments support reduced stress and improved attention in children, while real-world studies confirm that natural surroundings help restore cognitive capacity and improve mood more quickly than urban environments (Kuo et al., 2018; Mason et al., 2022; Taylor et al., 2018). Overall, brief exposure to natural environments reliably improves affect, although cognitive recovery may require longer exposure times (Hartig et al., 1996).

Across the literature, stress reduction is commonly explained through Stress Reduction Theory and Attention Restoration Theory, which propose that natural environments support parasympathetic activation, reduce physiological arousal, and promote relaxation and recovery from stress (Gaekwad et al., 2022; Yin et al., 2020). Empirical findings support this, showing faster physiological recovery following nature exposure compared to urban conditions, as well as improved autonomic responses during recovery phases (Brown et al., 2013). However, the literature also highlights important limitations, particularly that stress reduction is often inferred rather than directly isolated. Many studies rely on self-report measures, lack consistent physiological markers, and combine multiple environmental features such as colour, plants, aesthetics, daylight, and urban context, making it difficult to identify the precise underlying mechanism (Budaniya et al., 2025; Bratman et al., 2015; Mason et al., 2022; Yeo, 2021). This limitation is also explicitly acknowledged in studies on pocket parks and plant landscapes, which emphasize that while nature exposure is beneficial, it remains unclear whether effects are driven by colour, plant structure, biodiversity, or broader environmental context (Wang et al., 2026). Overall, stress reduction appears to be the most robust and consistent outcome of nature exposure, but the exact mechanisms remain partially unresolved and likely reflect a combination of physiological, cognitive, and aesthetic processes (Bratman et al., 2012; Bringslimark et al., 2009; Mason et al., 2022).

2.1.3 Cognitive Effects

Cognitive effects of nature exposure are reported across a range of studies, although the findings are not fully consistent. Some research shows specific cognitive improvements such as enhanced working memory, sustained attention, operation-span performance, and faster reaction times, while other studies place greater emphasis on emotional recovery and perceived restorativeness rather than measurable improvements in task performance (Bratman et al., 2015; Li et al., 2026; Pasanen et al., 2018; Sanchez et al., 2018; Zhang et al., 2025). Overall, the literature commonly frames nature as a resource that supports cognitive functioning by helping to restore attention and reduce mental fatigue, particularly in contexts where individuals are exposed to cognitively demanding or overstimulating modern environments (Brown et al., 2013; Grinde & Patil, 2009; Lei et al., 2021).

More specifically, nature exposure is associated with improved attention, memory, and general task performance, with studies using a variety of cognitive measures such as reaction-time tasks, backward digit span, working-memory tasks, and sustained attention paradigms (Lei et al., 2021; Rhee et al., 2023). These effects are most commonly explained through Attention Restoration Theory, which proposes that natural environments facilitate soft fascination, allowing directed attention to rest and recover from fatigue, thereby improving subsequent cognitive performance (Grinde & Patil, 2009; Lei et al., 2021; Yin et al., 2020). However, the evidence is not uniformly strong. While some studies report improvements in attention or cognitive performance, others find no significant differences between natural and built environments, or only weak effects limited to specific tasks such as backward digit span (Brown et al., 2013; Grinde & Patil, 2009; Michaelis, 2013). This suggests that cognitive benefits may depend on task type, exposure conditions, and methodological differences across studies.

The literature also indicates that the type and intensity of nature exposure play an important role in determining outcomes. Moderate levels of greenery and restorative natural scenes tend to produce positive cognitive effects, whereas very weak exposure may have little impact and overly intense natural stimuli may even become overwhelming (Lei et al., 2021; Rhee et al., 2023). In line with this, several studies highlight that real outdoor nature, such as parks, forests, gardens, and nature walks, is generally considered the most ecologically valid and effective form of cognitive restoration, although indirect forms of exposure—such as window views, photographs, VR (Virtual Reality) environments, and indoor plants—can still produce measurable benefits (Berto, 2005; Brooks et al., 2017; Feng et al., 2026; Ma et al., 2024; Michels et al., 2022; Zhang et al., 2024). Short-term exposure studies further support this pattern, showing cognitive and restorative effects after brief interventions such as 10-minute park visits, one-hour nature walks, or short visual exposure following a stressor, suggesting that even limited contact with nature can support cognitive recovery(Bratman et al., 2015; Michels et al., 2022; van den Berg et al., 2015; Wang et al., 2026).

At the same time, the literature also highlights an important limitation: many studies combine multiple environmental features such as colour, plant structure, room aesthetics, daylight, and broader contextual factors, making it difficult to isolate which specific elements drive cognitive effects (Chen & Yokoyama, 2021; Dijkstra et al., 2008; Ma et al., 2024; Yeo, 2021). Overall, nature exposure is generally presented as a supportive factor for cognitive functioning, particularly through attention restoration and mental fatigue recovery, but the empirical findings remain mixed and suggest that cognitive effects are not uniformly strong across all conditions and study designs (Brown et al., 2013; Grinde & Patil, 2009; Lei et al., 2021).

2.1.4 Physiological Effects

Physiological evidence in the literature is most consistently interpreted as supporting a stress-recovery mechanism linked to nature exposure. Across studies, exposure to natural environments is associated with lower heart rate, reduced blood pressure, decreased cortisol levels, lower skin conductance, and overall reduced autonomic arousal, which aligns strongly with Stress Reduction Theory (Bratman et al., 2012; Mason et al., 2022; Nieuwenhuis et al., 2014; Zhang et al., 2024). In addition to these general stress-related indicators, several studies report more specific autonomic effects, such as improved autonomic balance, stronger parasympathetic activation, higher respiratory sinus arrhythmia (RSA), and reduced sympathetic activation, suggesting that nature exposure may facilitate a faster physiological return to baseline after stress (Ulrich et al., 1991; van den Berg et al., 2015; Vella-Brodrick &

Gilowska, 2022; Zhang et al., 2024; Zhang et al., 2025). Broader physiological outcomes such as improved sleep quality and enhanced immune functioning are also reported, indicating that the effects may extend beyond immediate stress recovery (Zhang et al., 2024).

More specifically, the literature repeatedly reports lower heart rate (Ma et al., 2024; Nieuwenhuis et al., 2014; Zhang et al., 2025), lower blood pressure ((Nieuwenhuis et al., 2014; Ma et al., 2024; Zhang et al., 2024; Zhang et al., 2025), reduced cortisol and stress hormones (Bratman et al., 2012; Mason et al., 2022; Zhang et al., 2025), and reduced skin conductance or faster recovery of electrodermal activity (Nieuwenhuis et al., 2014; Ulrich et al., 1991). Additional findings include reduced autonomic nervous system activation (Bratman et al., 2016; Choi et al., 2016), increased parasympathetic activity such as higher RSA (Ulrich et al., 1991; van den Berg et al., 2015), reduced sympathetic activation (Bratman et al., 2012; Ma et al., 2024; Zhang et al., 2024), lower pulse transit time and muscle tension (Ulrich et al., 1991), as well as EEG indicators of relaxation such as increased alpha activity (Ding et al., 2026). Even when some studies report mixed or null effects for individual physiological measures, the overall pattern still points toward reduced physiological stress responses following nature exposure (Siah et al., 2023; Vella-Brodrick & Gilowska, 2022).

A central explanation for these findings is that nature exposure facilitates autonomic recovery after stress, particularly by enhancing parasympathetic reactivation and reducing physiological arousal more quickly following a stressor (Brown et al., 2013; Yin et al., 2020). Experimental evidence supports this pattern: in one study, both natural and urban scenes initially increased stress responses, but recovery was significantly faster in the nature condition, with higher HRV (heart rate variability) during the recovery phase (Brown et al., 2013). Similarly, biophilic VR environments have been shown to produce stronger physiological recovery than non-biophilic settings, including faster reductions in blood pressure and heart rate and improved HRV recovery, particularly in indoor-green conditions (Yin et al., 2020).

At the same time, the literature highlights important limitations. Some studies do not find significant differences in HRV, skin conductance, or other physiological markers, which may be due to weak stress induction, short exposure durations, or the fact that many experimental designs combine multiple environmental features such as greenery, colour, visual complexity, and contextual cues (Brown et al., 2013; Lei et al., 2021). This makes it difficult to isolate the exact driver of physiological change. Overall, the evidence suggests that nature exposure can reliably support autonomic recovery and reduce physiological stress load, but the precise mechanisms remain only partially disentangled from broader biophilic and environmental factors (Brown et al., 2013; Lei et al., 2021).

2.2 Exposure Conditions

This section introduces the conditions under which exposure is experienced. It provides a brief framework for understanding the main variables that can shape how a stimulus is perceived and evaluated.

2.2.1. Exposure Duration

Exposure time is an important factor in the literature, but the findings suggest that even relatively short contact with nature can already produce measurable psychological and physiological effects. Several studies show that brief exposures, such as a 10-minute visit to a park after a stress induction, a one-hour nature walk, or short exposure in classroom and office settings, are sufficient to support recovery from stress and mental fatigue (Berto, 2005; Bratman et al., 2015; van den Berg et al., 2016; Wang et al., 2026; Zhang et al., 2025). This indicates that nature does not necessarily need to be experienced for long periods to have restorative effects, but can already be beneficial within short time frames.

At the same time, the evidence suggests that these benefits do not increase linearly with longer exposure. One experimental finding shows that viewing nature scenes for only the first five minutes leads to stronger physiological recovery compared to built environments, while an additional five minutes does not significantly add to this effect, suggesting an early saturation of benefits rather than continuous improvement over time (Brown et al., 2013). Similarly, controlled short-term exposure paradigms, such as viewing 20 nature images for 30 seconds each over a total of 10 minutes followed by a stressor and recovery phase, are mainly used to capture immediate restorative responses rather than long-term effects (Brown et al., 2013).

Across the broader literature, exposure duration varies considerably, and many studies are explicitly short-term in design. As a result, the evidence base is stronger for immediate or brief restorative effects than for conclusions about sustained long-term benefits (Berry et al., 2014; Grinde & Patil, 2009). Overall, the pattern suggests that brief exposure to natural environments is sufficient to trigger recovery, improve attention, or enhance perceived restorativeness, but there is no clear evidence for a simple dose–response relationship in which longer exposure always leads to stronger effects. Instead, some findings point to an early benefit that may plateau over time, highlighting the need for further research on longer-term and real-world exposure conditions (Brown et al., 2013).

2.2.2 Exposure Type

Across the literature, a clear pattern emerges: nature-related effects are not limited to direct outdoor exposure, but extend across a spectrum of visual and environmental representations, including real nature, window views, indoor plants, photographs, and VR-based simulations (Brooks et al., 2017; Feng et al., 2026; Zhang et al., 2024). However, a consistent finding is that the strength of the effect depends on how complete the exposure is. Real environments and window views are repeatedly described as producing the most robust and ecologically valid outcomes, particularly for stress reduction and attentional restoration, because they include multisensory and contextual information beyond pure visual input (Yeom et al., 2022; Yin et al., 2020).

In contrast, image-based or laboratory-controlled exposures such as photographs or slideshows tend to produce more limited but still positive effects, mainly related to immediate visual restoration rather than full environmental recovery (Berto, 2005; Brown et al., 2013). Similarly, indoor plants and green design elements generally show beneficial but more variable effects, with improvements often appearing in perceived restorativeness or stress, while cognitive and performance outcomes are less consistent (Lei et al., 2021; Rhee et al., 2023; Yeom et al., 2022). VR-based environments fall in between these categories, as they can still trigger stress and anxiety reduction, but do not fully replicate real-world nature due to missing sensory input (Yin et al., 2020).

A second recurring theme is that effects are consistently explained in bundled terms rather than isolated mechanisms. Across studies, it remains unclear whether observed benefits are driven by greenness as a colour, plant structure, visual complexity, or broader environmental context, since most research combines several of these elements simultaneously (Lei et al., 2021; Yeom et al., 2022; Yin et al., 2020). As a result, the literature supports a general nature effect, but does not clearly isolate which specific component is responsible, making it more appropriate to interpret findings in terms of broader biophilic or nature-based restoration rather than single-factor explanations.

2.3 Theoretical Explanations and Mechanisms

The main theoretical frameworks across literature can be summarized through three central approaches: Biophilia, Attention Restoration Theory (ART), and Stress Reduction Theory (SRT). Biophilia proposes that humans have an innate tendency to respond positively to nature and living systems, suggesting that natural environments are not only aesthetically pleasing but also psychologically meaningful for well-being (Akers et al., 2012; Bringslimark et al., 2009; Budaniya et al., 2025; Zhang et al., 2024). In this view, humans are evolutionarily predisposed to benefit from contact with nature, although this response is also shaped by experience and cultural context.

ART and SRT provide more process-based explanations for how these benefits emerge. ART focuses on cognition, arguing that natural environments restore directed attention through soft fascination, thereby improving attention, concentration, and working memory after mental fatigue (Sanchez et al., 2018; Vella-Brodrick & Gilowska, 2022; Zhang et al., 2024). In contrast, SRT explains the emotional and physiological side of nature exposure, proposing that natural environments reduce stress, lower arousal, and support relaxation and mood recovery (Bratman et al., 2012; Frumkin et al., 2017; Mason et al., 2022; Zhang et al., 2024). Across the document, ART is mainly linked to cognitive restoration, while SRT is more strongly associated with stress and affective recovery (Brooks et al., 2017; Vella-Brodrick & Gilowska, 2022; Zhang et al., 2024).

A central limitation highlighted throughout the literature is that most studies do not isolate a single causal factor. Natural stimuli typically combine multiple elements such as colour, plant structure, visual complexity, daylight, spatial context, and symbolic meaning, making it difficult to attribute effects to any one component (Choi et al., 2016; Du et al., 2025; Frumkin et al., 2017; Ma et al., 2024; Zhang et al., 2024). Even more controlled designs often compare bundled conditions (e.g., plants with daylight or decorative environments), meaning that observed benefits likely reflect combined rather than isolated effects (Jang et al., 2014; Michels et al., 2022; Sanchez et al., 2018; Yang et al., 2025).

Some authors therefore argue for a mixed-explanation model, where perceived attractiveness, familiarity, biophilic responses, and attentional processes jointly contribute to the effects rather than a single visual cue such as colour alone (Bringslimark et al., 2009; Dijkstra et al., 2008; Michels et al., 2022; Vella-Brodrick & Gilowska, 2022). Overall, the literature supports the conclusion that nature-related exposure is beneficial, but the precise causal mechanism remains unresolved due to overlapping environmental features and methodological constraints (Chen & Yokoyama, 2021; Jang et al., 2014; Vella-Brodrick & Gilowska, 2022).

2.3.1 Biophilia Hypothesis

Biophilia is presented in the literature as a broad, foundational framework suggesting that humans have an inherent tendency to respond positively to nature and living systems. It is often described as an evolutionary predisposition, meaning that contact with natural elements is not only aesthetically pleasing but also psychologically meaningful and potentially beneficial for well-being (Akers et al., 2012; Bringslimark et al., 2009; Zhang et al., 2024). In this sense, biophilia functions as a general background assumption across much of the literature: humans are expected to feel more comfortable, relaxed, or positively engaged in environments that contain natural features compared to highly artificial or urban settings.

At the same time, the document emphasizes that biophilia is not a precise mechanism on its own, but rather a broad explanatory concept that is often shaped by experience, learning, and cultural influences (Grabowska-Chenczke et al., 2022). While the theory assumes an innate affinity for nature, it does not fully determine how this affinity is expressed or under which conditions it becomes stronger or weaker. For this reason, biophilia is frequently treated as a starting point rather than a complete explanation of observed psychological or physiological effects.

Importantly, the literature consistently situates biophilia within a broader theoretical cluster together with Attention Restoration Theory (ART) and Stress Reduction Theory (SRT). In this combined framework, biophilia is interpreted as the evolutionary “why” behind human-nature interactions, whereas ART and SRT explain the “how” in terms of cognitive and physiological processes (Frumkin et al., 2017; Vella-Brodrick & Gilowska, 2022; Zhang et al., 2024). This means that biophilia alone does not account for specific outcomes such as reduced stress or improved attention, but rather supports the idea that such outcomes are plausible because humans are biologically and historically adapted to respond to natural environments.

The literature also connects biophilia to biophilic design, which refers to the intentional integration of natural elements into built environments such as workplaces, schools, or healthcare settings. This includes features like indoor plants, natural materials, green walls, or daylight exposure, which are assumed to partially recreate nature-like conditions indoors (Budaniya et al., 2025; Sanchez et al., 2018). However, the literature also makes clear that these interventions do not always replicate full natural environments and may only partially activate biophilic responses.

Overall, biophilia is best understood as a broad theoretical umbrella term that explains why humans might generally prefer or benefit from nature-related stimuli, but it does not specify which environmental features are most important or how exactly these effects are produced. The existing literature repeatedly highlights that outcomes are likely influenced by multiple interacting factors, including perception, aesthetics, symbolic meaning, and context, rather than a single biological response to nature alone (Bringslimark et al., 2009; Vella-Brodrick & Gilowska, 2022; Zhang et al., 2024).

2.3.2 Attention Restoration Theory (ART)

Attention Restoration Theory (ART) is one of the central cognitive frameworks used in existing literature to explain why exposure to nature improves mental functioning. The core assumption of ART is that directed attention is a limited cognitive resource that becomes depleted through sustained mental effort, such as studying, working, or navigating complex urban environments (Bratman et al., 2012; Kaplan, 1995; Mason et al., 2022). Once this attentional capacity is fatigued, performance on tasks requiring focus, inhibition, and cognitive control tends to decline.

ART proposes that natural environments facilitate recovery from this attentional fatigue by engaging involuntary attention in a gentle and effortless way, a process described as soft fascination (Berto, 2005; Kaplan, 1995). Unlike demanding environments that require constant focus, natural scenes contain stimuli that are interesting but not overwhelming, allowing directed attention to rest while still keeping the mind gently engaged. This restorative process is further supported by additional ART components, including being away (psychological distance from routine demands), extent (a coherent and immersive environment), and compatibility (fit between environment and individual needs) (Chen & Yokoyama, 2021; Perrins et al., 2021).

Across studies, ART is primarily used to explain cognitive outcomes of nature exposure, particularly improvements in attention, working memory, concentration, and cognitive performance. Several studies report enhanced performance on tasks such as reaction-time paradigms, backward digit span tests, and sustained attention measures following exposure to natural environments (Bratman et al., 2015; Vella-Brodrick & Gilowska, 2022; Wallner et al., 2018). These findings are interpreted as evidence that nature helps restore depleted attentional resources, especially after mental fatigue or cognitive overload.

However, the literature also makes clear that ART effects are not fully consistent across all studies. While some research shows clear improvements in cognitive performance after nature exposure, other studies find weaker or non-significant effects, or effects limited to specific tasks rather than general cognitive enhancement (Hartig et al., 1996; Mason et al., 2022; Yeo, 2021). This variability suggests that ART effects may depend on factors such as exposure duration, type of nature stimulus, and the level of prior cognitive fatigue.

Another important point is that ART is not limited to real outdoor environments. Previous studies show that similar restorative effects can occur with images of nature, VR simulations, window views, and indoor greenery, although real environments are generally considered more ecologically valid and potentially more effective (Brooks et al., 2017; Ma et al., 2024; van den Berg et al., 2016). This supports the idea that it is not physical immersion alone that drives restoration, but rather the presence of certain perceptual and attentional qualities in the environment.

Overall, ART is presented as a strong but not exclusive explanation for cognitive restoration. It provides a clear framework for understanding how nature can improve attention and mental performance, but the literature also highlights that ART effects often overlap with emotional and physiological processes described in SRT, making it difficult to fully separate cognitive restoration from stress recovery (Bratman et al., 2012; Mason et al., 2022; Yeo, 2021).

2.3.3 Stress Reduction Theory (SRT)

Stress Reduction Theory (SRT) is the main framework used across studies to explain the emotional and physiological benefits of nature exposure. The central idea is that natural environments reduce stress by triggering an automatic psychophysiological relaxation response, which lowers arousal and helps the body return to a balanced state after stress (Bratman et al., 2012; Mason et al., 2022; Zhang et al., 2024). This process is often described as rapid and partly evolutionary, suggesting that humans may be biologically predisposed to perceive natural environments as safe or non-threatening (Ulrich et al., 1991).

Within this framework, SRT is closely linked to measurable physiological changes. The literature repeatedly reports reductions in heart rate, blood pressure, cortisol levels, skin conductance, and muscle tension following exposure to natural environments (Bratman et al., 2012; Ulrich et al., 1991; van den Berg et al., 2015; Zhang et al., 2024). In addition, several studies highlight increased parasympathetic activity and improved autonomic balance, indicating a shift from stress-related sympathetic activation toward a calmer physiological state (Choi et al., 2016; Vella-Brodrick & Gilowska, 2022). These changes are interpreted as evidence that nature exposure supports genuine stress recovery at a bodily level, not only at a subjective or emotional level.

SRT is also strongly associated with emotional outcomes such as reduced negative affect, lower perceived stress, increased relaxation, and improved mood recovery after stress exposure (Mason et al., 2022; Perrins et al., 2021; Zhang et al., 2024). Prior studies frequently emphasize that these emotional effects often occur quickly, sometimes within minutes of exposure, suggesting that even brief contact with nature can initiate stress recovery processes (Brown et al., 2013; Wang et al., 2026). This is consistent with findings from studies using short exposures such as park visits, nature images, or VR environments.

At the same time, SRT is not presented as a simple or uniform mechanism. While many studies show clear reductions in perceived stress, physiological findings are sometimes weaker or inconsistent, with some studies reporting no significant changes in certain biomarkers despite positive subjective outcomes (Lei et al., 2021; Siah et al., 2023; van den Berg et al., 2015). This suggests that stress recovery may not always be fully captured by physiological measures alone, or that different components of stress respond differently to nature exposure.

Another important aspect of SRT in studies is that it applies across many types of exposure, including real outdoor environments, indoor plants, green walls, photographs, and VR simulations. While real nature is often considered the most effective, simulated or indirect forms of nature can still produce measurable reductions in stress and improvements in affect (Beukeboom et al., 2012; Brooks et al., 2017; Ma et al., 2024). This reinforces the idea that the psychological appraisal of the environment, rather than physical immersion alone, plays an important role in stress reduction.

Finally, the existing literature emphasizes that SRT overlaps strongly with ART, and that the two theories are difficult to fully separate in practice. Stress reduction may support cognitive restoration, and attentional recovery may in turn reduce stress, suggesting that both processes are interconnected rather than independent (Bratman et al., 2012; Mason et al., 2022). Overall, SRT is presented as a robust explanation for the calming and restorative effects of nature, but one that still requires further clarification regarding its precise physiological and psychological mechanisms.

2.4 Colour and Well-being

Colour is widely discussed in environmental psychology as a factor that can influence emotion, cognition, and behaviour beyond aesthetic preference (Elliot & Maier, 2014; Jalil et al., 2012). However, its effects are highly context-dependent and vary by hue, brightness, and environmental setting. In this context, green is particularly complex, as it is studied both as an isolated colour and as a cue for natural environments (Elliot & Maier, 2014; Jalil et al., 2012; Kaya & Epps, 2004; Michaelis, 2013; Tham et al., 2020; Valdez & Mehrabian, 1994).

2.4.1 Colour Psychology and Emotional-Cognitive Effects

The literature conceptualises colour psychology as the study of how colour perception influences emotion, cognition, and behaviour beyond aesthetic preference. A central framework in this field is the Pleasure–Arousal–Dominance (PAD) model, which explains emotional responses to colour along these three dimensions. Within this model, brightness and saturation are considered stronger predictors of emotional response than hue itself. Brighter and more saturated colours are generally associated with higher pleasantness and arousal, while darker colours are linked to greater feelings of dominance. Empirical findings further suggest that hues such as blue, blue-green, green, red-purple, and purple are typically rated as more pleasant, whereas green-yellow and yellow tend to be evaluated less positively. (Valdez & Mehrabian, 1994)

Beyond affective responses, colour is also described as influencing cognition and behaviour through motivational mechanisms. Red is often associated with avoidance motivation and enhanced performance in detail-oriented or vigilant tasks, while blue is linked to approach motivation and more creative or flexible thinking. Green is occasionally discussed in similar terms, particularly as having calming or stabilising effects in specific contexts. However, the document emphasises that these effects are not purely symbolic; they may also emerge from perceptual processing and learned associations with the environment. Physiological findings such as changes in EEG activity and heart rate further suggest that colour exposure can influence arousal and cognitive state, particularly in more saturated visual environments (Elliot & Maier, 2014; Küller et al., 2009; Mehta & Zhu, 2009; Valdez & Mehrabian, 1994).

A key limitation highlighted in the literature is the difficulty of isolating colour as an independent variable. While some studies treat colour as a controlled visual stimulus, many nature-related studies embed colour within broader environmental contexts such as vegetation, architecture, or spatial composition. As a result, the document emphasises that colour effects are often confounded with meaning and context, meaning that observed outcomes cannot always be attributed to hue alone (Qin et al., 2013; Valdez & Mehrabian, 1994).

Overall, colour psychology is typically categorised into three domains: mood and emotion, stress-related responses, and cognitive performance. Across these domains, findings are generally context-dependent and inconsistent. Colours may enhance attention, arousal, or performance in some situations, but they may also produce neutral or negative outcomes such as distraction, fatigue, or reduced attentional control depending on task demands and environmental conditions (Jalil et al., 2012).

Within this framework, green is generally positioned as one of the more positively evaluated hues, frequently associated with calmness, relaxation, and reduced anxiety, especially in contrast to more arousing colours such as red. However, the literature also makes clear that these effects are not stable across all contexts or studies (Elsadek et al., 2017; Michaelis, 2013).

Importantly, the strongest effects in colour psychology research often emerge when colour is combined with contextual elements rather than studied in isolation. Many findings include plants, architectural environments, or natural scenes, making it difficult to distinguish pure colour effects from broader environmental associations, personal preferences, or cultural meanings (Jalil et al., 2012). In sum, colour psychology does not present a fixed hierarchy of colours but instead shows that effects vary across hue, context, and task. While red is often linked to arousal and vigilance, blue to creativity and approach orientation, and green to more neutral or calming associations, these patterns are not universal (Jalil et al., 2012).

2.4.2 Green and Psychological Associations

Across the literature, green is most consistently associated with calmness, relaxation, recovery, and restoration. It is repeatedly linked to feelings of peace, comfort, stress relief, and freshness, and in some contexts also to perceived health and vitality rather than symbolic meaning alone (Kaya & Epps, 2004; Tham et al., 2020; Wang & Liu, 2026; Yang et al., 2026). On the cognitive level, green is frequently described as having restorative properties, particularly in relation to attention recovery, reduced mental fatigue, and improved concentration. At the same time, the literature notes that excessive exposure to green in certain environments, such as educational settings, may potentially reduce cognitive stimulation, suggesting that its effects depend on balance and context rather than being uniformly beneficial (Li et al., 2025; Norwood et al., 2019; Wang et al., 2026; Zhou, 2013).

The dominant explanatory account is that green functions as a cue for nature and vegetation. Exposure to green is thought to trigger recognition of natural environments, which in turn evokes relaxation, calmness, and positive affect. In this sense, green is often interpreted less as an independent psychological stimulus and more as a visual marker of plants, foliage, and life (Elliot & Maier, 2014; Kaya & Epps, 2004; Tham et al., 2020).

Additional explanations also include perceptual and physiological pathways. Green-rich environments are associated with reduced arousal, attention restoration, and parasympathetic activation, although the literature consistently notes that many studies cannot separate the effect of green as a colour from the effect of actual vegetation or full natural scenes (Valdez & Mehrabian, 1994; van den Berg et al., 2015; Zhang et al., 2024).

Overall, green is best understood as a colour strongly linked to nature-based associations and restorative experiences, with its psychological effects emerging from a combination of learned associations, perceptual processing, and broader environmental context (Hartig et al., 1996; Kaya & Epps, 2004).

2.4.3 Empirical Studies on Green as a Colour Stimulus

Only a limited number of studies in the literature examine green as a truly isolated colour stimulus. Most green findings are embedded in plant-based or environmental contexts and therefore do not represent pure colour manipulations (Amini Vishteh et al., 2019; Lichtenfeld et al., 2012).

One of the clearest colour-only experiments involved brief exposure to a green stimulus (e.g., a green rectangle) prior to creativity tasks. This study found that green improved creative performance but had no significant effect on mood or positive activation, and stress was not assessed (Lichtenfeld et al., 2012).

Another study examined reaction times under different coloured light conditions. Green produced intermediate effects, with no specific calming advantage compared to other colours. The study focused on perceptual speed and did not assess mood or stress (Amini Vishteh et al., 2019). A related study on a blue-green office environment found improvements in mood-related outcomes such as reduced negative affect and increased vigor, but cognitive effects varied across individuals and physiological stress was not measured. However, this design does not isolate green as a pure variable (Kwallek et al., 1997).

Taken together, the strongest conclusion from isolated colour studies is that green may enhance creativity in brief experimental settings and has limited effects on basic cognitive processing. However, there is no strong evidence that green as a standalone colour reliably improves mood or reduces stress (Lichtenfeld et al., 2012).

More advanced controlled work using VR-based manipulations suggests that green colour attributes can influence cognitive and attentional processes such as arousal, impulsiveness, and detail-oriented thinking. However, these effects again focus on cognition rather than emotional or physiological outcomes (Xia et al., 2023).

Overall, green appears more consistently linked to cognitive modulation than to stable affective or stress-related outcomes when studied in isolation (Jalil et al., 2012; Xia et al., 2023).

2.4.4 Critical Discussion of Colour Effects

The literature's central critical argument is that colour effects are not universal properties of hue alone. Instead, they are context-dependent, culturally shaped, and often embedded within broader environmental or symbolic systems. Many studies therefore do not isolate pure colour effects but instead measure combined colour–meaning–context influences (Elliot & Maier, 2014; Kaya & Epps, 2004).

A key issue is the presence of boundary conditions. Colour effects vary depending on task demands and situational context: red may support vigilance or detail-focused tasks, blue may support creativity and approach-oriented thinking, and green is often interpreted as a cue for nature, growth, or health rather than a universal calming stimulus (Lichtenfeld et al., 2012; Mehta & Zhu, 2009). Cultural variation further complicates interpretation. Some colour associations appear relatively universal, while others are learned and culturally specific. Green, for example, is often associated with nature and health, but this association is still shaped by experience and context rather than being inherently fixed (Tham et al., 2020).

A major methodological limitation is confounding: many studies combine colour with plants, natural scenes, architecture, or environmental design. As a result, observed effects may reflect combined environmental features rather than colour alone (Grinde & Patil, 2009; Michaelis, 2013; Shibata & Suzuki, 2004).

Finally, the literature highlights the importance of meaning and association. Some effects attributed to nature may in fact arise from learned associations between colours (especially green and blue) and concepts such as calmness and restoration, making it difficult to separate colour psychology from nature psychology (Jalil et al., 2012; Michaelis, 2013).

In summary, the critical consensus is that colour effects exist but are highly context-sensitive and embedded within broader cognitive, cultural, and environmental systems. This implies that green, plant imagery, and natural environments should be treated as distinct variables rather than interchangeable constructs in empirical research (Jalil et al., 2012).

2.5 Effects of Plants and Plant Imagery

Indoor plants and plant-related imagery are widely discussed in the literature in relation to their effects on psychological and cognitive outcomes. Research in this area generally focuses on how exposure to real vegetation or visual representations of plants can influence stress, mood, attention, and perceived environmental quality (Beukeboom et al., 2012; Budaniya et al., 2025; Dijkstra et al., 2008). However, these findings are often intertwined, as real plants and plant images are frequently studied under similar frameworks despite differing in sensory richness and contextual realism (Brown et al., 2013; Du et al., 2025; Lei et al., 2021; Li et al., 2026; Rhee et al., 2023.

2.5.1 Psychological and Cognitive Effects of Indoor Plants

The literature generally indicates that indoor plants are associated with beneficial psychological outcomes, particularly in relation to stress reduction, improved mood, and, in some cases, enhanced cognitive performance. However, these effects are not fully consistent across studies, and results vary depending on methodological design, environmental context, and participant characteristics (Deng & Deng, 2018; Grinde & Patil, 2009).

One of the most consistently reported effects is a reduction in perceived stress. Exposure to indoor plants is repeatedly linked to lower self-reported stress, fatigue, anger, and negative affect, alongside increased comfort, satisfaction, and perceived attractiveness of indoor environments (Bringslimark et al., 2009; Budaniya et al., 2025; Yeo, 2021). However, physiological indicators such as heart rate or blood pressure often show weaker or inconsistent changes, suggesting that the primary effects may be psychological rather than strictly physiological (Dijkstra et al., 2008; Lohr & Pearson-Mims, 2000; Zhang et al., 2025).

In terms of mood, indoor plants are frequently associated with increased positive affect, calmness, and perceived pleasantness of environments. Plant-rich settings are generally rated as more soothing compared to control conditions (Bringslimark et al., 2009; Lohr & Pearson-Mims, 2000). At the same time, some studies report weak or null effects, indicating that mood improvements are not universal and depend strongly on context and study design (Bringslimark et al., 2009).

Findings regarding cognitive performance are mixed but tend to show potential benefits under certain conditions. Indoor plants have been linked to improved attention, reaction time, concentration, and occasionally creativity. Some studies report faster responses, improved memory performance, and EEG patterns associated with relaxation and positive affect in plant-rich environments (Budaniya et al., 2025; Ma et al., 2024; Mason et al., 2022; Yeo, 2021). However, other studies find no significant effects on task performance or working memory, suggesting that cognitive benefits are not stable across contexts.

Overall, the literature suggests that indoor plants can have beneficial effects on stress, mood, and cognition, but these effects are variable and strongly dependent on methodological and contextual factors. Importantly, plant-related effects are often intertwined with broader environmental qualities rather than functioning as isolated stimuli (Bringslimark et al., 2009; Dijkstra et al., 2008).

Additional empirical evidence further supports this variability. Experimental studies show that indoor plants can reduce stress, improve mood, increase comfort, and occasionally enhance task performance, but the strength of these effects depends on design and environmental conditions (Deng & Deng, 2018; Grinde & Patil, 2009). For example, in classical room-condition comparisons, participants exposed to rooms with plants reported improved mood and, in some cases, better cognitive performance compared to control environments. However, these findings also highlight the difficulty of isolating plant effects from visual attractiveness and contextual factors (Shibata & Suzuki, 2004).

Vegetation density also appears to play a role, with moderate levels of greenery associated with higher perceived restorativeness and improved attention, while too little greenery produces weak effects and excessive greenery may become overstimulating (Lei et al., 2021; Rhee et al., 2023).

Indoor plants are also consistently found to improve subjective environmental quality. Spaces containing plants are typically rated as more attractive, comfortable, and calming, which may indirectly contribute to stress reduction and improved emotional states (Deng & Deng, 2018).

Findings on cognitive performance remain inconsistent overall. Some studies report improvements in creativity, attention, and productivity, while others find no significant differences or even potential distractions when plants draw attention away from tasks (Deng & Deng, 2018; Grinde & Patil, 2009; Shibata & Suzuki, 2004).

In addition, some explanations extend beyond psychological mechanisms. Indoor plants may contribute to improved air quality, humidity regulation, and oxygen production, although these physical effects are generally modest and interact with psychological pathways rather than operating independently (Deng & Deng, 2018).

2.5.2 Mechanisms Underlying Plant Effects

The effects of indoor plants are generally explained through multiple interacting mechanisms rather than a single causal pathway. Across the literature, the most frequently discussed explanations include biophilic tendencies, attention restoration, stress reduction, aesthetic experience, positive distraction, and broader nature-based associations (Bringslimark et al., 2009; Budaniya et al., 2025).

A central framework is biophilia, which describes a general human tendency to respond positively to natural elements such as vegetation. However, this tendency is not purely biological, as cultural background and individual experience also influence responses to plants (Bringslimark et al., 2009; Budaniya et al., 2025).

Closely related are Attention Restoration Theory and Stress Reduction Theory, which suggest that vegetation supports recovery from directed-attention fatigue and reduces physiological and psychological stress, leading to more relaxed and restored states (Bringslimark et al., 2009; Zhang et al., 2024; Zhang et al., 2024).

Another important mechanism is visual aesthetics. Indoor plants are consistently described as increasing the attractiveness, comfort, and visual richness of environments through their natural forms, textures, and structures (Bringslimark et al., 2009; Budaniya et al., 2025; Dijkstra et al., 2008; Ma et al., 2024). However, this also introduces a methodological challenge, since aesthetic improvement itself may act as a confounding factor.

Symbolic meaning and learned associations are also relevant. Plants may evoke cultural ideas related to nature, life, and well-being, meaning that responses can depend not only on perception but also on meaning attribution (Bringslimark et al., 2009).

Finally, indirect environmental mechanisms are sometimes proposed. Plants may influence indoor conditions such as air quality, humidity, temperature, and light, which may in turn affect comfort and psychological outcomes (Bakker & van der Voordt, 2010).

Overall, these mechanisms are not independent but typically operate together, and most studies do not isolate them clearly (Bringslimark et al., 2009; Budaniya et al., 2025; Ma et al., 2024).

2.5.3 Indoor Environments and Applications

Modern life is predominantly indoor-based, with people spending most of their time indoors. Indoor environments can also be psychologically demanding due to factors such as poor ventilation, crowding, and environmental discomfort often described in relation to sick building conditions. In this context, indoor plants are positioned as restorative elements that can improve well-being, comfort, and sometimes performance (Budaniya et al., 2025; Danielski et al., 2022; Yeo, 2021; Yang et al., 2025).

The application of indoor plants spans a wide range of environments, including offices, schools, hospitals, laboratories, residential spaces, and public buildings (Bringslimark et al., 2009; Danielski et al., 2022; Yeo, 2021; Zhou, 2013).

In workplaces, plants are associated with reduced stress, improved comfort, and enhanced attention or productivity, particularly in dense urban office environments (Budaniya et al., 2025; Ma et al., 2024; Zhang et al., 2025). In educational settings, indoor plants are linked to improved concentration, perceived restorativeness, and better indoor air quality, supporting more comfortable learning environments (Danielski et al., 2022).In healthcare environments, plants are used to reduce stress and improve perceived comfort and attractiveness in hospitals and waiting areas, which may contribute to healing-oriented design (Beukeboom et al., 2012; Dijkstra et al., 2008). In residential contexts, indoor plants are integrated into everyday spaces such as living rooms, bedrooms, and kitchens, where they are associated with improved mood, reduced fatigue, and increased relaxation (Zhou, 2013).

Overall, indoor plants are most commonly used in environments where people spend extended periods and where comfort, recovery, and stress reduction are particularly relevant (Michels et al., 2022; Yang et al., 2025).

2.5.4 Critical Perspective on Plant Research

A central methodological limitation in the literature is the difficulty of isolating green colour as an independent variable, since plant form, vegetation content, and environmental context are typically combined within the same stimulus. As a result, observed effects often reflect a mixed greenery or biophilic condition rather than a pure plant or colour effect (Bakker & van der Voordt, 2010; Jang et al., 2014; Ma et al., 2024).

This confounding is especially evident when different plant types (e.g., foliage versus flowering plants) are compared, as multiple variables such as colour, species, texture, and visual complexity change simultaneously (Jang et al., 2014; Li et al., 2026; Yang et al., 2025). The literature emphasises that this limits causal interpretation, since appropriate controls (e.g., green objects without plants or plants with non-green appearance) are rarely included (Choi et al., 2016; Dijkstra et al., 2008; Yang et al., 2025).

More broadly, many studies treat green colour, plant presence, and natural meaning as a single experimental package, making it difficult to separate perceptual, structural, and symbolic effects (Rhee et al., 2023; Yeom et al., 2022; Yin et al., 2020). Examples such as green wall studies or simple plant-versus-empty-room comparisons further illustrate this issue, as multiple environmental variables change simultaneously (Yeom et al., 2022; Yin et al., 2020; Shibata & Suzuki, 2004).

Consequently, the literature generally concludes that many observed plant effects reflect combined biophilic and environmental influences rather than isolated effects of colour or plant structure alone (Lei et al., 2021; Shibata & Suzuki, 2004; Yin et al., 2020).

2.5.5 Plant Images as Visual Nature Stimuli

Plant image studies are widely used as a simplified way to examine responses to nature-related stimuli. These studies typically use photographs, posters, or VR representations of vegetation, which can elicit psychological responses similar to real plants. However, they rarely isolate key variables such as colour, plant structure, or spatial context (Beukeboom et al., 2012; Du et al., 2025; Li et al., 2026).

Overall, plant images are associated with reduced stress, increased positive affect, and greater perceived restorativeness (Michels et al., 2022). In healthcare settings, both real plants and plant images can reduce perceived stress, with images sometimes approaching the effectiveness of real vegetation due to increased environmental attractiveness (Beukeboom et al., 2012; Dijkstra et al., 2008). Some studies also report limited physiological or cognitive effects, such as changes in attention or arousal, although findings are inconsistent (Chen & Yokoyama, 2021; Ding et al., 2026; Michels et al., 2022).

However, a key limitation is that plant images often combine multiple variables, including plant identity, colour, and natural form, making it difficult to isolate specific mechanisms

(Beukeboom et al., 2012). In addition, some studies extend beyond images into VR or real environments, further blurring methodological boundaries (Berman et al., 2008; Mason et al., 2022; Ulrich, 1984).

Overall, plant images are best understood as a proxy for visual nature exposure, producing generally positive but variable effects, while the exact mechanism remains confounded (Bratman et al., 2012; Beukeboom et al., 2012; Kuo, 2015).

More broadly, findings suggest that plant images support perceived restoration and stress reduction, but effects on mood and cognition are less consistent (Grinde & Patil, 2009; Rhee et al., 2023). Because these studies typically rely on static visual representations rather than real environments, results reflect responses to visual nature cues rather than full ecological experience (Brown et al., 2013; Rhee et al., 2023).

Consequently, plant image research is best interpreted as evidence for a general nature or greenery effect, rather than isolated effects of colour or plant structure (Brown et al., 2013; Rhee et al., 2023).

2.6 Methodological Challenges in Separating Green Colour and Nature Effects

The literature overall converges on the finding that both nature exposure and indoor plants are consistently associated with positive psychological outcomes, particularly reduced stress, improved mood, increased comfort, and in some cases enhanced attention and task performance. Real plants, green walls, and natural environments are repeatedly linked to lower perceived stress, greater emotional restoration, and improved environmental evaluations, with occasional benefits for cognitive performance such as attention or reaction time (Dijkstra et al., 2008; Ma et al., 2024; Yeo, 2021). In parallel, colour-only studies show that colour can influence cognition and emotion, but these effects are more limited and context-specific, often emerging in controlled laboratory tasks rather than in broader environmental settings. For example, brief exposure to a green stimulus improved creativity without affecting mood, while studies of coloured light mainly found reaction-time differences rather than stable affective changes (Amini Vishteh et al., 2019; Lichtenfeld et al., 2012). Plant-related studies, in turn, tend to show robust but variable benefits, particularly for stress reduction and perceived restorativeness, although results depend strongly on study design and context (Deng & Deng, 2018; Grinde & Patil, 2009).

When comparing these strands of research more directly, it becomes clear that the green or nature conditions being studied are rarely equivalent across studies. Most comparisons involve natural versus non-natural environments, such as green nature versus urban or grey settings, rooms with plants versus rooms without plants, or plant images and green walls versus neutral control scenes (Beukeboom et al., 2012; Chen & Yokoyama, 2021; Dijkstra et al., 2008; Du et al., 2025). Similarly, indoor plant studies often compare vegetated rooms to empty spaces or minimally furnished control environments, while colour studies typically manipulate hue or lighting in isolation under simplified conditions (Kwallek et al., 1997; van den Bogerd et al., 2021). What is rarely examined, however, are more fine-grained contrasts such as green versus non-green plants, colour versus plant structure, or plant-free green stimuli matched for visual complexity and attractiveness.

This leads to a central methodological issue: the lack of proper control conditions and the resulting inability to isolate variables. Across the literature, green colour, plant presence, vegetation density, visual complexity, and symbolic associations with nature are frequently manipulated together, meaning that observed effects cannot be confidently attributed to any single factor (Beukeboom et al., 2012; Bringslimark et al., 2009; Dijkstra et al., 2008; Ma et al., 2024; Yang et al., 2025). In many cases, plants are inherently green and visually complex, so the experimental condition effectively represents a bundled nature experience rather than a separable colour or structural manipulation. As a result, the literature often captures combined greenery or biophilic effects rather than isolating whether outcomes are driven by hue, plant form, or broader environmental meaning (Brown et al., 2013; Grinde & Patil, 2009; Yin et al., 2020).

Taken together, the current research therefore provides strong evidence that natural and plant-rich environments are beneficial for psychological well-being, but it does not allow a clear conclusion about why these effects occur. While both colour and plant-related studies suggest positive influences, the underlying mechanisms remain empirically entangled due to insufficient experimental control and frequent confounding between colour, structure, and environmental context (Bringslimark et al., 2009; Bakker & van der Voordt, 2010; Dijkstra et al., 2008).

Against this background, the present thesis is important because it directly addresses this gap in the literature by attempting to disentangle green colour from plant structure and broader nature associations. By improving experimental control and separating these variables more systematically, the study aims to clarify whether observed effects are driven by colour itself, by vegetation and plant form, or by their combined perceptual and contextual meaning. This contributes to a more precise understanding of green as a psychological stimulus and helps resolve a key limitation in current research on colour, plants, and restorative environments.

3. Critical Review of Existing Research

The following chapter reviews the existing literature and brings together the most relevant findings for the present topic. It provides a general basis for identifying key patterns, limitations, and gaps before moving into the more specific discussion in the next subsection.

3.1 Comparison of Studies

Across the literature, studies on plants, plant imagery, and colour differ substantially in their experimental designs, types of stimuli, and outcome measures, but they consistently aim to test effects on mood, stress, cognition, and physiological responses. Table 1 provides an overview of the studies included in this comparison and highlights their main methodological and conceptual differences.

Table 1
Overview and Comparison of Studies on Colour- and Nature-Related Restorative Effects

Study	Stimuli	Design	Plants	Colour Green	Measures	Findings	Limitations
Michels et al. (2022)	2x2 slideshow, plants vs objects, colour x grayscale	Randomized lab, n=92, TSST	✓	✓	Restorativeness, affect, HRV, hunger, craving	More restorativeness, positive affect, less craving	Plant vs colour contrast not clean
Jang et al. (2014)	Green foliage plants vs coloured flowers	Lab, n=30	✓	✓	EEG, emotion scale	Green plants, more positive emotion, better attention cues	Colour and form bundled
Li et al. (2026)	15 hydrangeas, colour x structure	Lab viewing, n=28	✓	✓	Mood, restoration, BP, HRV, GSR, tasks	Different colours/forms, often better with green or plant-like types	Colour, plant, form mixed
Du et al. (2025)	Blank, green wall, 3 floral walls	VR stress recovery, n=96	✓	✓	STAI, restoration, HRV, BP, tasks	All walls helped, colour-specific effects	Mixed colour and vegetation
Ding et al. (2026)	Plant photos, distance x colour	Photo study, n=44	✓	✓	Restoration scale, EEG	Varied by community type and distance	Shape and colour mixed
Dijkstra et al. (2008)	Hospital room, plants vs urban painting	Lab, imagined hospitalization, n=77	✓	✗	Stress, attractiveness	Plants lowered stress, raised attractiveness	Not colour-specific

Beukeboom et al. (2012)	Real plants, plant posters, no nature	Field, n=457	✓	✗	POMS, STAI-6, attractiveness	Plants and posters lowered stress	Bundles plant, image, colour
Lohr & Pearson-Mims (2000)	Plain room, decor, live plants	Lab, n=198	✓	✗	Appraisal, emotion, BP, temp, pain tolerance	Plant rooms felt better, more comfort	Plant form and colour mixed
van den Berg et al. (2016)	Green walls vs no green walls	School, prospective, n=170	✓	✓	Attention, mood, wellbeing	Better attention, better classroom ratings	Mechanism not isolated
Ma et al. (2024)	No wall, small wall, large wall	Indoor lab, n=144	✓	✓	Thermal, cognition, BP, HR, EEG	More greenery, better comfort and performance	Plants and form bundled
Zhang et al. (2025)	Vegetated office vs plant-free room	Real-life crossover, n=40	✓	✗	Stress, fatigue, BP, HR, cortisol, Stroop	Less stress and fatigue	Not colour-specific
Budaniya et al. (2025)	Office with plants vs without	Between-subj, n=120	✓	✗	Affect, comfort, air quality, symptoms, performance	Greener office, better comfort and productivity	Mixed outcomes, no colour test
Nieuwenhuis et al. (2014)	Green office vs lean office	Field experiments	✓	✗	Air quality, concentration, satisfaction, productivity	Green office helped satisfaction and concentration	Plants vs no plants, not colour
Danielski et al. (2022)	Classroom plants vs no plants	Pilot school case study	✓	✗	Climate, questionnaires, interviews	Better indoor environment, positive perceptions	Mostly descriptive
Mason et al. (2022)	Green school garden vs usual classroom	Within-subj, n=65	✓	✗	Attention, math, mood, restorativeness	Better attention, math, restorativeness	Green context, not colour isolate
Amicone et al. (2018)	Green breaks vs built area	Field experiments, primary school	✓	✗	Attention, WM, impulse control, restorativeness	Better attention and restorativeness	Nature-based, not colour-only
Akers et al. (2012)	Same cycling video, green vs grayscale vs red	Lab cycling, n=14 men	✗	✓	Mood disturbance, exertion, HR, VO2	Green lowered mood disturbance and exertion	Nature scene still present
Mehta & Zhu (2009)	Red vs blue backgrounds	Multiple lab studies	✗	✗	Tasks, mood, activation	Red detail focus, blue creativity	Not nature

Valdez & Mehrabian (1994)	Controlled colours by hue, sat, brightness	3 controlled studies	✗	✗	PAD, pleasure, arousal, dominance	Brightness, sat mattered most	Colour background only
van den Bogerd et al. (2021)	Study room with plants vs without	Quasi-experi ment, study room	✓	✗	Mood, cognition, quality, stay time	Room felt nicer, little mood/cognition change	Weak effects
Brown et al. (2013)	Nature scenes vs urban scenes	Randomized crossover	✗	✗	PANAS, self-esteem, HR, BP, RMSSD	Better autonomic recovery after nature	Greenness bundled with nature
Michaelis (2013)	Urban, foliage, aquatic scenes in BW, natural, blue, green	Lab pre-post, n=119	✓	✓	Anxiety, digit span, attention, preference	Mostly null, small cognitive gains	Colour and environment confounded
Rhee et al. (2023)	0% to 100% vegetation density	Image lab, EEG	✓	✗	PRS-11, EEG, attention	More vegetation, better restorativeness and attention	Color not isolated
Lei et al. (2021)	0% to 20% green coverage, plus VR	Repeated measures workplace study	✓	✓	Eye tracking, health, productivity	About 12% greenery looked best	Colour, plants, space bundled
Yeom et al. (2022)	No wall vs 1, 2, full green walls	VR, n=27	✓	✓	PANAS, cognitive tests, NASA-TLX, IPQ	Green walls improved affect, lowered load	Task performance little change
Sedghikhan shir et al. (2024)	Virtual green wall, different sizes	IVR, n=60	✓	✓	HR, HRV, EDA, ratings, eye tracking	Mixed effects, some recovery benefit	No colour only test
Elsadek et al. (2017)	Hedera helix varieties, different foliage colours	Within-subj, n=30 men	✓	✓	Eye movement, NIRS, emotion ratings	Bright green most positive	Real plants only
Xia et al. (2023)	Green colour in VR, chroma, brightness	Immersive VR colour study	✗	✓	Tasks, arousal, impulsivenes s	Lower chroma reduced impulsiveness	Colour only

Note. Own synthesis based on reviewed literature. The table compares key methodological features and stimulus types across studies on colour and nature-related restorative effects.

A large group of studies uses real indoor plants or real vegetation environments as stimuli. For example, Zhang et al. (2025) used a real vegetated office compared to a plant-free room in a crossover design with working adults, measuring perceived stress, fatigue, heart rate, blood pressure, cortisol, and Stroop performance. Similarly, Ma et al. (2024) manipulated green wall size in a laboratory office setting (no wall, small wall, large wall) and measured thermal comfort, cognitive performance (reaction time and memory span), heart rate, blood pressure, and EEG-based emotional indicators. Budaniya et al. (2025) compared an open-plan office with and without plants, assessing affect, perceived air quality, sick-building symptoms, subjective productivity, and working memory performance. Nieuwenhuis et al. (2014) also used real offices, comparing lean office spaces with enriched green office environments, focusing on concentration, satisfaction, perceived air quality, and productivity outcomes. Across these workplace studies, the general pattern is that plants are treated as a full environmental intervention rather than a single variable.

In school and classroom contexts, similar real-environment designs are used. van den Berg et al. (2016) introduced green walls into classrooms and measured selective attention, processing speed, mood, and classroom evaluations over several months. Mason et al. (2022) compared lessons in a green school garden versus a standard classroom, assessing attention, math performance, mood, and perceived restorativeness in children. Danielski et al. (2022) examined real classrooms with and without indoor plants, using indoor climate measurements alongside questionnaires and teacher interviews. Amicone et al. (2018) compared nature-based recess areas with built school environments and measured attention, working memory, impulse control, and perceived restorativeness. These studies consistently combine behavioural, cognitive, and self-report measures.

A second group of studies uses controlled laboratory or VR-based green wall or vegetation manipulations. Du et al. (2025) used a VR underground room with multiple wall conditions (blank, green wall, white-floral, yellow-floral, red-floral) and measured anxiety, perceived restoration, heart rate variability, blood pressure, and cognitive tasks such as arithmetic, reaction time, and digit span. Yeom et al. (2022) similarly used VR office environments with no wall, single green wall, and multiple green walls, measuring PANAS affect scales, auditory cognitive tasks, workload, and presence. Sedghikhanshir et al. (2024) used immersive VR green wall environments with different wall sizes and recorded heart rate, HRV, electrodermal activity, restoration ratings, and eye-tracking fixation time.

Other studies focus on real plants or controlled room comparisons in laboratory or semi-field settings. Dijkstra et al. (2008) compared a hospital room with plants versus an urban painting condition and measured perceived stress and attractiveness. Lohr and Pearson-Mims (2000) tested three room conditions (empty room, decorative objects, and live plants), measuring emotional ratings, blood pressure, skin temperature, and pain tolerance. Shibata and Suzuki (2004) compared a plant room, magazine rack room, and empty room, assessing mood and association task performance. van den Bogerd et al. (2021) used a real university library study room with and without plants and measured mood, cognitive performance, perceived environmental quality, and time spent in the space.

A further group examines vegetation structure, density, and species composition. Rhee et al. (2023) used image-based indoor vegetation conditions with different vegetation density levels (0% to 100%) and measured perceived restorativeness, EEG activity, and selective visual attention. Lei et al. (2021) manipulated green coverage levels (0% to 20%) in office environments and measured eye tracking alongside health and productivity outcomes. Lindemann-Matthies and Matthies (2018) varied plant species richness in meadow-like displays (1 to 64 species) and measured blood pressure recovery after stress. Ding et al. (2026) used plant community photographs at different distances and quantified visual structure and colour composition while measuring restoration ratings and EEG alpha/beta indices.

A number of studies focus on plant imagery and visual representations of nature. Beukeboom et al. (2012) used a hospital waiting room design with real plants, plant posters, and no nature condition, measuring stress and perceived attractiveness. Michels et al. (2022) used a 2×2 image design (green plants, green objects, greyscale plants, greyscale objects) after stress induction, measuring perceived restorativeness, affect, heart-rate recovery, craving, and food choice. Ding et al. (2026) and Chen & Yokoyama (2021) used VR or image-based nature exposure and measured restoration, arousal recovery, EEG, and task performance effects.

Finally, colour-only studies isolate hue and brightness without plants or natural scenes. Mehta and Zhu (2009) manipulated red versus blue backgrounds and tested cognition through tasks such as the Remote Associates Test, memory recall, proofreading, and creative generation. Akers et al. (2012) used identical rural cycling videos filtered in green, red, and greyscale and measured mood, perceived exertion, heart rate, and oxygen uptake. Valdez and Mehrabian (1994) systematically tested colour samples varying in hue, saturation, and brightness, measuring emotional responses. Xia et al. (2023) used VR colour environments (including green variations) and assessed cognitive performance, arousal, and impulsivity.

Overall, across all study types, the most common outcome measures include perceived stress, mood (often PANAS-based), perceived restorativeness, cognitive performance (attention, memory, reaction time), and physiological indicators such as heart rate, HRV, blood pressure, EEG, and skin conductance. The literature therefore spans a wide methodological range, from controlled colour experiments to immersive VR environments and real-world field studies, but consistently targets psychological, cognitive, and physiological responses to visual and environmental conditions.

3.2 Methodological Limitations and Confounds

A central methodological issue in the literature is that key variables such as green colour, plant presence, and nature content are rarely isolated. Instead, they are typically embedded within the same experimental stimulus, meaning that observed effects cannot be attributed to a single factor with confidence. Green is often operationalised as real vegetation, green walls, plant scenes, or nature environments, which makes it difficult to distinguish whether outcomes are driven by colour, plant structure, or broader natural associations (Grinde & Patil, 2009; Lei et al., 2021; Yin et al., 2020; Yeom et al., 2022).

One major problem is the confounding of colour and plant content. In many studies, green is not a pure visual attribute but part of a living plant or natural scene, meaning that hue is always intertwined with plant morphology, species differences, texture, and environmental context. As a result, it is not possible to determine whether effects are caused by green colour itself or by the presence of vegetation and its associated features (Elsadek et al., 2017; Shibata & Suzuki, 2004; Yin et al., 2020).

Closely related to this is the frequent bundling of nature and colour effects. Many studies compare nature versus urban scenes, plants versus no plants, or vegetation-rich environments versus built environments, rather than systematically contrasting green versus non-green plants or isolating colour from form. This means that positive outcomes may reflect nature exposure more broadly rather than colour-specific effects (Grinde & Patil, 2009; Lindemann-Matthies & Matthies, 2018; Michaelis, 2013).

A further limitation is the frequent use of weak or mismatched control conditions. Common comparisons include empty rooms, magazine racks, bare landscapes, or urban scenes, which differ from the plant condition in multiple ways simultaneously. These designs do not hold visual complexity, attractiveness, or structural features constant, making causal interpretation difficult (Lindemann-Matthies & Matthies, 2018; Shibata & Suzuki, 2004).

In addition, there is substantial heterogeneity in study design and stimuli. Research ranges from real indoor environments (e.g., offices, classrooms, hospitals) to laboratory images, VR simulations, and outdoor natural scenes. While real-world studies offer ecological validity, they often lack control, whereas laboratory-based studies improve control but may not capture real environmental interaction (Lei et al., 2021; Rhee et al., 2023; Yin et al., 2020).

Outcome measures are also highly inconsistent across studies. Some research focuses on mood and stress, others on physiological markers, cognitive performance, perceived restorativeness, or simple environmental appraisal. Even within similar domains, different measurement tools are used, which limits comparability across findings (Brown et al., 2013; Deng & Deng, 2018; Rhee et al., 2023).

Another issue is the reliance on short-term exposure paradigms. Many studies examine immediate or very brief responses, such as viewing images for a few minutes or single-session exposure to a room, which does not provide insight into long-term or cumulative effects of indoor greenery (Akers et al., 2012; Li et al., 2026; Michels et al., 2022). Sample limitations also appear frequently. Several studies rely on student samples, narrow age groups, or relatively small participant numbers, which restricts generalisability to broader populations (Akers et al., 2012; Ma et al., 2024; van den Berg et al., 2016).

Finally, many studies rely on indirect or incomplete measures of psychological and physiological outcomes. Stress, for example, is often assessed through self-report or indirect physiological indicators, while cognitive performance is frequently tested using a single task type, limiting broader interpretation (Budaniya et al., 2025; Kwallek et al., 1997; Lohr & Pearson-Mims, 2000).

Mechanistically, explanations such as biophilia, stress reduction, or attention restoration are often invoked post hoc rather than directly tested, meaning that the causal pathway remains largely inferred rather than empirically verified (Dijkstra et al., 2008; Li et al., 2026; van den Berg et al., 2016).

Overall, the literature consistently supports beneficial effects of plants and green environments, but it does not allow clear conclusions about the underlying mechanism. Because colour, plant structure, nature content, and environmental aesthetics are typically intertwined, current research rarely isolates whether effects are driven by green colour itself, vegetation presence, or their combination (Bakker & van der Voordt, 2010; Bringslimark et al., 2009; Budaniya et al., 2025). This methodological gap directly motivates more controlled experimental approaches that systematically separate green colour, plant presence, and neutral conditions, which is precisely what current research designs often fail to achieve (Yeom et al., 2022).

3.3 Remaining Gap: Separation of Colour and Nature Effects

A central research gap identified in the literature is the inability to clearly separate green colour from nature-related content in most experimental designs. Across studies, green is typically embedded within live plants, vegetation scenes, or biophilic environments, meaning that colour, plant structure, visual complexity, image format, and perceived attractiveness are all manipulated simultaneously. As a result, it is not possible to determine with confidence whether observed effects are driven by green colour itself, by nature or plant exposure, or by a combination of both (Bringslimark et al., 2009; Dijkstra et al., 2008; Yang et al., 2025).

This issue is consistently emphasised throughout the literature, which shows that green colour, plant presence, vegetation density, and broader nature associations are repeatedly bundled into single experimental conditions. Consequently, while the evidence supports a general restorative effect of greenery and natural environments, it does not allow for a clear distinction between colour-based and nature-based mechanisms (Grinde & Patil, 2009; Yeom et al., 2022; Yin et al., 2020).

Therefore, the underlying mechanism remains unresolved. Current findings cannot definitively explain whether the beneficial effects stem from green as a visual colour stimulus, from the presence of plants and natural structures, or from their interaction (Grinde & Patil, 2009; Lei et al., 2021; Yin et al., 2020). This persistent ambiguity represents the key gap in the field and directly motivates the need for more controlled experimental designs that systematically separate green colour, plant-based stimuli, and neutral conditions, as highlighted in the literature (Grinde & Patil, 2009; Yeom et al., 2022).

4. Proposed Experimental Approach

The restorative and positive impacts of greenery and natural environments on psychological well-being have been widely documented. Research consistently shows that exposure to natural environments is associated with reduced stress, improved mood, enhanced cognitive functioning, and broader benefits such as increased perceived restoration and physiological relaxation (Beukeboom et al., 2012; Bringslimark et al., 2009; Dijkstra et al., 2008; Han, 2017; Pasanen et al., 2018; Zheng et al., 2024). However, despite this robust body of evidence, the underlying mechanisms remain insufficiently understood. In particular, it is still unclear whether these effects are primarily driven by the perceptual properties of the colour green, by the cognitive and semantic associations with natural environments, or by an interaction of both factors (Elliot & Maier, 2014; Jalil et al., 2012; Kuo, 2015; Yeom et al., 2022; Yin et al., 2020).

Building on these theoretical considerations, a controlled experimental design can help disentangle these mechanisms more precisely. Such a design allows for systematic manipulation of visual components and enables clearer attribution of observed psychological and cognitive outcomes. This is particularly relevant in environmental psychology, where natural stimuli are often treated as a unified category, even though they consist of separable visual and conceptual elements that may independently influence human perception and performance (Bakker & van der Voordt, 2010; Bringslimark et al., 2009; Grinde & Patil, 2009; Lei et al., 2021; Li et al., 2026).

Originally, this master thesis was planned to include the empirical execution of such an experimental study. The study design was developed in detail and intended to be implemented in a laboratory setting. However, due to practical and organisational limitations during the research process, it was not possible to conduct the experimental phase as originally intended. Therefore, the present thesis includes the previously developed design in a theoretical framework. This allows for a structured methodological contribution while still addressing the central research question.

4.1 Rationale

The rationale for this experimental design is based on a central limitation in the current literature: most studies on nature exposure either rely on correlational evidence or compare complex natural environments with neutral or urban controls, without isolating the specific visual components responsible for the observed effects (Berman et al., 2008; Bratman et al., 2015; Grinde & Patil, 2009; Li et al., 2025; van den Berg et al., 2015; Yeom et al., 2022). As a result, it remains unclear whether restorative outcomes are primarily driven by the perceptual effects of green colour, by exposure to natural or plant-based content, or by an interaction between both (Li et al., 2025; Yin et al., 2020; Zheng et al., 2024).

Previous research suggests that green colour alone can induce relaxation and reduce stress responses while exposure to plants and natural environments has been associated with attention restoration, improved mood, and enhanced cognitive performance (Berman et al., 2008; Brooks et al., 2017; Dijkstra et al., 2008; Michaelis, 2013; Rhee et al., 2023; van den Berg et al., 2015). However, because these elements typically co-occur in real-world settings, their individual contributions cannot be clearly separated (Grinde & Patil, 2009; Li et al., 2025; Yin et al., 2020).

The proposed experimental approach directly addresses this issue by systematically isolating colour and content variables. This makes it possible to examine whether restorative effects are primarily caused by chromatic properties, by nature-related content, or by their interaction. In addition, the design aligns with recommendations in environmental psychology for more tightly controlled laboratory studies that allow clearer separation of overlapping visual and perceptual factors (Amend et al., 2024; Chen & Yokoyama, 2021; Grinde & Patil, 2009; Yeo, 2021).

4.2 Design

The proposed experimental design follows a between-subjects framework in which participants are randomly assigned to one of four conditions. Each condition represents a distinct combination of visual properties that allows for systematic separation of colour-based effects and nature-based content effects. The overall aim is to clarify whether restorative outcomes are driven by green colour alone, plant-based content, or their interaction.

In the green colour condition, participants are exposed to a solid green visual stimulus without any object or nature-related content. This condition isolates the perceptual effects of green hue alone.

In the green plant condition, participants view images of real plants containing natural green colouration. This represents a typical nature exposure condition combining both colour and plant structure, as commonly used in previous research.

To separate colour from plant structure, a non-green plant condition is included. Here, the same plant images are used but digitally altered to a non-green hue (orange-brown). This preserves plant form, texture, and semantic content while removing the specific influence of green colouration.

Finally, a grey control condition serves as a neutral baseline. This condition consists of a uniform grey stimulus without plant or nature-related content and is expected to evoke minimal restorative response, providing a comparison point for all experimental conditions.

All participants are exposed to their assigned stimulus for a fixed duration of three minutes. In the plant-image conditions, stimuli are presented as a slideshow of 12 sequential images, whereas the green and grey conditions consist of a single static stimulus presented for the same duration. This ensures consistency in exposure time while maintaining ecological differences between static and image-based conditions.

The design enables multiple theoretically meaningful comparisons. A direct comparison between the green and grey conditions tests pure colour effects. Comparisons between plant conditions and the grey baseline allow examination of plant- or nature-related effects. Most importantly, comparisons between the green plant condition, the green-only condition, and the non-green plant condition enable assessment of interaction effects and help determine whether combined exposure produces additive or distinct effects.

Psychological and cognitive outcomes are assessed using a pre–post measurement design. Mood is measured using the Positive and Negative Affect Schedule (PANAS), capturing changes in both positive and negative affect. Stress is assessed using the Perceived Stress Scale (PSS), measuring subjective stress responses to the visual stimuli. Cognitive performance is measured using a Mental Arithmetic Task (MAT), which evaluates working memory, attention, and processing speed (Ashcraft, 1992; Cohen, Kamarck, & Mermelstein, 1983; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Watson, Clark, & Tellegen, 1988).

Together, these measures provide a multidimensional assessment of restoration effects, covering emotional, stress-related, and cognitive outcomes. This aligns with established approaches in environmental psychology, where restoration is conceptualised as a combination of affective and cognitive changes.

4.3 Control Conditions

A central strength of the proposed design lies in its systematic use of control conditions to disentangle variables that are typically conflated in existing research (Grinde & Patil, 2009; van den Berg et al., 2015; Yeom et al., 2022; Zheng et al., 2024). Many studies treat green environments as a single stimulus category, despite the fact that colour, plant structure, and semantic associations are often simultaneously present (Beukeboom et al., 2012; Yin et al., 2020; Zhang et al., 2025). The present design explicitly separates these components, allowing for a more precise interpretation of restorative effects.

The inclusion of a grey baseline condition provides a neutral reference point without chromatic or nature-related associations. This enables all effects to be interpreted relative to a true baseline, strengthening internal validity and allowing clearer causal inference.

The green-only condition isolates the effect of colour independently from plant structure or nature content. This makes it possible to test whether green hue alone is sufficient to produce restorative responses.

The non-green plant condition isolates plant structure and semantic meaning while removing green colouration. This allows examination of whether plant-based effects persist independently of colour.

Finally, the green plant condition represents the combined stimulus most commonly used in previous studies. Comparing this condition with the isolated components allows assessment of whether combined exposure produces additive, interactive, or redundant effects.

Together, these conditions directly address a key limitation in the existing literature, namely the lack of clean separation between colour, plant content, and nature associations (Grinde & Patil, 2009; Yin et al., 2020). By enabling systematic comparison across these factors, the design allows for clearer interpretation of whether restorative effects are driven by chromatic properties, natural content, or their interaction (Lei et al., 2021; Yeom et al., 2022).

4.4 Potential Contributions and Implications

The proposed experimental framework is intended to contribute to several areas of research within environmental psychology, particularly to the ongoing discussion surrounding the restorative effects of visual exposure to nature (Brooks et al., 2017; Grinde & Patil, 2009; Ma et al., 2024; Nieuwenhuis et al., 2014; Zhang et al., 2024). Existing literature consistently suggests that greenery, plants, and natural environments are associated with reduced stress, improved mood, and enhanced cognitive functioning (Bratman et al., 2012; Danielski et al., 2022; Rhee et al., 2023; Zhang et al., 2020). However, as discussed in the previous chapters, many studies do not sufficiently isolate the visual variables involved, making it difficult to determine whether these effects are primarily caused by the colour green, by plant-related natural content, or by an interaction between both factors (Akers et al., 2012; Berto, 2005; Lei et al., 2021; Neilson et al., 2021; Yeom et al., 2022; Yin et al., 2020). The value of the proposed framework therefore lies less in predicting specific outcomes and more in its potential to clarify unresolved theoretical and methodological questions within the current research landscape.

4.4.1 Theoretical Contributions

One of the central contributions of the proposed framework lies in its potential to clarify competing theoretical explanations for restorative effects associated with greenery and natural stimuli. In environmental psychology, restorative responses are commonly explained through theories such as the Biophilia Hypothesis, Attention Restoration Theory, and Stress Reduction Theory (Bratman et al., 2012; Frumkin et al., 2017; Gaekwad et al., 2022; Yin et al., 2020; Zhang et al., 2024). These perspectives generally assume that humans respond positively to natural environments because of evolutionary, cognitive, or affective mechanisms connected to nature exposure (Gaekwad et al., 2022; Liu & Green, 2025). However, many existing studies treat nature as a broad and unified category without distinguishing between the specific visual characteristics that may contribute to restorative outcomes (Akers et al., 2012; Berto, 2005; Lei et al., 2021; Neilson et al., 2021; Yeom et al., 2022).

At the same time, research in colour psychology suggests that colours themselves may independently influence emotional and cognitive states (Jalil et al., 2012; Wang & Liu, 2026; Zheng et al., 2024). In particular, green has repeatedly been associated with calmness, relaxation, positive affect, and attentional restoration (Jalil et al., 2012; Michaelis, 2013; Norwood et al., 2019; Yang et al., 2025; Zhang et al., 2024; Zhou, 2013). This creates an important theoretical question: are restorative effects primarily driven by nature-related meaning and plant content, or can they already emerge through exposure to the perceptual properties of the colour green alone?

The proposed design contributes to this debate by systematically separating green colour, plant structure, and their combination into distinct experimental conditions. This allows restorative responses to be examined more precisely than in many previous studies, where green colour and natural content are strongly confounded (Choi et al., 2016; Ding et al., 2026; Lei et al., 2021; Yeom et al., 2022). By distinguishing between a pure colour condition, a plant-content condition, and a combined green-plant condition, the framework enables a more differentiated interpretation of restorative mechanisms.

In this way, the proposed approach contributes to a more nuanced conceptual understanding of visual restoration. Rather than assuming that all forms of nature exposure operate through the same mechanism, the framework acknowledges that restorative responses may arise from multiple overlapping visual and psychological processes. Consequently, the study has the potential to refine existing theoretical models by identifying whether colour-based processes, biophilic responses, or combined interactions are most relevant for explaining restorative outcomes (Akers et al., 2012; Gaekwad et al., 2022; Lei et al., 2021; Liu & Green, 2025; Zhang et al., 2024).

The framework may also contribute to broader discussions regarding visual perception and environmental processing. If restorative effects differ systematically between the experimental conditions, this would suggest that relatively basic visual properties such as hue and colour composition may play a more important role in environmental experience than previously assumed. Conversely, if plant imagery produces stronger effects independently of colour, this would support the idea that semantic meaning and associations with nature are central components of restoration (Berman et al., 2008; Beukeboom et al., 2012; Brown et al., 2013; Yin et al., 2020).

4.4.2 Methodological Contributions

In addition to its theoretical relevance, the proposed framework also contributes to methodological discussions within environmental psychology. As identified in the critical review, one of the most persistent limitations of previous research is the lack of sufficiently controlled experimental conditions (Bakker & van der Voordt, 2010; Beukeboom et al., 2012; Jalil et al., 2012; Yeo, 2021). Many studies compare natural and urban environments, plants and non-plants, or green and non-green settings without isolating the specific visual variables involved (Brooks et al., 2017; Grinde & Patil, 2009; Neilson et al., 2021; Zheng et al., 2024). As a result, colour, plant structure, visual complexity, familiarity, attractiveness, and semantic meaning are frequently bundled together within the same stimulus (Bratman et al., 2012; Yeo, 2021; Yin et al., 2020).

Although such approaches often possess high ecological validity, they make it difficult to determine which exact component is responsible for the observed psychological effects. Consequently, many findings remain correlational or conceptually ambiguous, limiting the possibility of drawing precise causal conclusions about restorative mechanisms (Akers et al., 2012; Bratman et al., 2015; Lei et al., 2021).

The proposed design addresses this methodological problem through the inclusion of carefully differentiated control conditions. By separating green colour from plant structure and comparing both to a neutral grey baseline, the framework introduces a level of experimental control that is often missing in previous studies. This allows the individual and combined effects of colour and nature-related content to be examined more systematically (Lohr et al., 2000; van den Berg et al., 2015; Yeom et al., 2022).

A particular methodological strength lies in the inclusion of the non-green plant condition. While many previous studies compare plants with non-plant environments, they rarely examine plant imagery independently of green colouration (Beukeboom et al., 2012; Yin et al., 2020). The present framework therefore adds an important comparison that allows plant structure and semantic nature associations to be investigated separately from colour-based effects. This directly responds to the central methodological criticism identified throughout the literature review (Grinde & Patil, 2009; Yeo, 2021; Zhang et al., 2025).

The use of random assignment and a pre–post measurement structure further strengthens the internal validity of the design. Measuring mood, stress, and cognitive performance before and after exposure increases sensitivity to short-term changes while simultaneously controlling for individual baseline differences. Compared to studies relying solely on post-exposure comparisons, this approach allows a more reliable assessment of restoration-related changes (Pasanen et al., 2018; Wang et al., 2026).

At the same time, the framework demonstrates how controlled laboratory approaches can complement more ecologically valid field studies. While naturalistic environments are important for understanding real-world experiences, laboratory designs remain essential for isolating mechanisms under controlled conditions. The proposed approach therefore contributes to a broader methodological balance within environmental psychology by combining theoretical precision with practical applicability (Amend et al., 2024; Danielski et al., 2022; Grinde & Patil, 2009).

Overall, the framework illustrates how future studies may move beyond broad comparisons between nature and non-nature environments toward more refined analyses of the visual components underlying restorative experiences (Akers et al., 2012; Yeom et al., 2022).

4.4.3 Practical Implications

Beyond its theoretical and methodological relevance, the proposed framework also has several potential practical implications. In contemporary societies, individuals spend a substantial amount of time in indoor environments such as offices, classrooms, hospitals, and other built settings where direct access to natural environments is often limited (Lei et al., 2021; Ma et al., 2024; Wallner et al., 2018; Yin et al., 2020). Understanding how specific visual properties influence psychological well-being may therefore have important implications for environmental and interior design (Deng & Deng, 2018; Zhang et al., 2024).

One potential area of application concerns architecture and workplace design. If future research demonstrates that green colour alone contributes to restoration, relatively simple visual interventions such as colour schemes, lighting concepts, or digital displays could potentially be used to support stress reduction and attentional recovery in cognitively demanding environments (Chen & Yokoyama, 2021; Wang & Liu, 2026). On the other hand, if plant structure or nature-related content proves more influential, this would support the integration of real or simulated natural elements into indoor spaces (Yin et al., 2020; Zhang et al., 2025).

Such findings may be particularly relevant in office environments, where prolonged cognitive demands and sustained attentional load often contribute to stress and mental fatigue (Lei et al., 2021; Nieuwenhuis et al., 2014; Yeom et al., 2022). Integrating restorative visual elements into workplaces could represent a comparatively low-cost and scalable strategy for improving employee well-being and concentration (Deng & Deng, 2018). Depending on the underlying mechanism, interventions could range from indoor plants and green walls to visual simulations or carefully designed colour environments (Chen & Yokoyama, 2021; Yin et al., 2020).

Educational settings may also benefit from these insights. Students frequently work under conditions of sustained mental effort that require attention, memory, and concentration (Amicone et al., 2018; Wallner et al., 2018). If restorative visual stimuli are shown to support cognitive recovery or reduce mental fatigue, schools and universities could integrate such elements into classrooms, study spaces, or digital learning environments (Mason et al., 2022; van den Bogerd et al., 2021). Importantly, many of these interventions could potentially be implemented without extensive architectural changes (Chen & Yokoyama, 2021; Rhee et al., 2023).

The proposed framework may additionally have implications for therapeutic and healthcare environments. Hospitals, waiting areas, and therapy rooms are often associated with elevated stress, anxiety, and emotional discomfort (Deng & Deng, 2018; Dijkstra et al., 2008; Grinde & Patil, 2009). Previous studies already suggest that nature-related stimuli can contribute to relaxation and emotional recovery in such settings (Beukeboom et al., 2012; Yin et al., 2020). A clearer understanding of whether these effects are driven primarily by colour, plant content, or their interaction may help optimize environmental design strategies in healthcare contexts and improve supportive conditions for patients and visitors.

More broadly, the framework contributes to discussions regarding evidence-based environmental design. Rather than relying solely on general assumptions about green environments, the proposed approach encourages more precise consideration of which visual properties are actually beneficial and under which conditions they operate most effectively.

4.4.4 Summary of Contributions

In summary, the proposed experimental framework contributes to environmental psychology by addressing a central unresolved issue within the current literature: the difficulty of distinguishing between the restorative effects of green colour and those of nature-related content (Berman et al., 2008; Yeom et al., 2022; Zheng et al., 2024). By systematically separating colour, plant structure, and their combination into controlled experimental conditions, the framework enables a more differentiated investigation of restorative mechanisms than is common in many previous studies (Chen & Yokoyama, 2021; Choi et al., 2016; Grinde & Patil, 2009).

The proposed design contributes theoretically by clarifying competing explanations related to biophilia, colour psychology, and restorative environmental theories. Methodologically, it responds directly to major limitations in existing research by introducing more rigorous control conditions and clearer variable isolation. Practically, the framework may help inform evidence-based approaches to architecture, workplace design, educational environments, and therapeutic spaces.

Although the framework does not provide definitive empirical conclusions in its current theoretical form, its value lies in offering a structured and methodologically informed basis for future experimental research. In this way, it contributes to a more precise understanding of how visual environments influence psychological well-being, stress, and cognitive functioning.

5. Discussion

The present thesis is best understood as a conceptual and methodological contribution rather than an empirical one. Because the experimental phase could not be carried out as originally intended, the work does not provide definitive outcome data, but instead offers a theoretically structured framework for clarifying a central unresolved issue in the literature, namely whether restorative effects are primarily driven by green colour, plant-related content, or the interaction between both. Although many studies report beneficial effects of greenery and nature exposure, the mechanisms underlying these effects remain insufficiently differentiated (Brown et al., 2013; Ding et al., 2026; Grinde & Patil, 2009; Ma et al., 2024; Zhang et al., 2020; Zhang et al., 2024). The thesis therefore contributes by critically analysing existing research, identifying recurring methodological limitations, and proposing a more controlled experimental framework that addresses these issues directly.

At a broader level, this discussion reflects an important development within environmental psychology itself. The literature reviewed throughout the thesis consistently suggests that greenery, plants, and natural environments are associated with reduced stress, improved mood, enhanced attention, and greater perceived restoration (Grinde & Patil, 2009; Ma et al., 2024; Zhang et al., 2024). However, despite the consistency of these general findings, many studies fail to isolate the specific visual variables involved with sufficient precision (Bakker & van der Voordt, 2010; Berman et al., 2008; Brown et al., 2013; Lindemann-Matthies & Matthies, 2018; Yeo, 2021). As a result, the field currently has relatively strong evidence for a broad restorative association, but considerably weaker evidence regarding the exact mechanisms responsible for these effects (Akers et al., 2012; Grinde & Patil, 2009; Zhang et al., 2024).

5.1 Theoretical Interpretation

One of the central theoretical contributions of this thesis lies in its attempt to separate explanations that are often treated as interchangeable within the literature. Environmental psychology commonly explains restorative responses through frameworks such as Biophilia Theory, Attention Restoration Theory, and Stress Reduction Theory, all of which emphasise the beneficial influence of natural environments on psychological functioning (Bratman et al., 2012; Frumkin et al., 2017; Grinde & Patil, 2009; Yin et al., 2020; Zhang et al., 2024). At the same time, colour psychology proposes that visual properties such as hue, brightness, and saturation may independently influence affective and cognitive states (Jalil et al., 2012; Valdez & Mehrabian, 1994; Wang & Liu, 2026). The present thesis therefore raises a more specific question that is often overlooked in previous research: whether restorative effects are caused primarily by semantic associations with nature, by perceptual properties of green colour, or by an interaction between both mechanisms (Brown et al., 2013; Gaekwad et al., 2022; Zhang et al., 2024; Zhou, 2013).

This distinction is theoretically important because much of the existing literature relies on the broad category of nature exposure without specifying which components of nature are psychologically relevant (Berman et al., 2008; Grinde & Patil, 2009; Neilson et al., 2021). Green walls, indoor plants, or natural scenes usually combine multiple visual features simultaneously, including colour, organic structure, texture, complexity, and symbolic associations with nature (Beukeboom et al., 2012; Choi et al., 2016; Yeom et al., 2022; Yin et al., 2020). Consequently, positive effects are often interpreted as evidence for nature restoration in general, even though the active mechanism remains unclear (Choi et al., 2016; Dijkstra et al., 2008; Grinde & Patil, 2009). By separating green colour, plant structure, and combined green-plant stimuli conceptually, the thesis shifts the discussion away from a general yes-or-no question about nature and toward a more differentiated analysis of which visual features matter, under which conditions, and through which psychological pathways.

The thesis also highlights that restorative theories are often applied retrospectively rather than tested directly (Gaekwad et al., 2022; Mason et al., 2022; Vella-Brodrick & Gilowska, 2022). Many studies interpret improvements in mood, stress, or attention through frameworks such as Attention Restoration Theory or Stress Reduction Theory without operationalising the proposed mechanisms themselves (Bratman et al., 2015; Lei et al., 2021). As a result, restoration is frequently inferred from general positive outcomes rather than directly linked to specific cognitive or affective processes (Berto, 2005; Brown et al., 2013; Gaekwad et al., 2022). This creates a risk of theoretical overextension, where broad restorative explanations are used to account for effects that may partly arise from simpler perceptual or aesthetic factors.

If the proposed experimental conditions were to produce different outcomes, the interpretation would be theoretically informative in several ways. Stronger effects for green colour alone would support the assumption that relatively basic perceptual properties contribute substantially to restoration (Michaelis, 2013; Wang & Liu, 2026; Zheng et al., 2024). In contrast, stronger effects for plant imagery would suggest that semantic meaning and associations with living nature are more important than colour itself (Choi et al., 2016; Dijkstra et al., 2008; Shibata & Suzuki, 2004). Alternatively, if the combined green-plant condition produced the strongest outcomes, this would indicate that restorative effects emerge through the interaction of perceptual and semantic components rather than through one isolated factor alone (Lei et al., 2021; Zheng et al., 2024). In this sense, the framework contributes not by confirming a single theory, but by refining the conceptual boundaries between competing explanations.

5.2 Critical Reflection on the Existing Literature

A broader critical reflection on the reviewed literature reveals that environmental psychology is characterised by a certain conceptual vagueness regarding what is actually meant by nature exposure (Berman et al., 2008; Grinde & Patil, 2009; Yeom et al., 2022; Yeo, 2021; Zhang et al., 2024). Although many studies report positive effects of greenery and natural environments, the stimuli used are often highly heterogeneous and difficult to compare directly (Amend et al., 2024; Brown et al., 2013; Pasanen et al., 2018; van den Berg et al., 2015; Yin et al., 2020). Some studies rely on immersive outdoor environments, others on photographs, VR simulations, indoor plants, green walls, or abstract colour manipulations, while outcome measures range from subjective restorativeness and mood ratings to physiological stress indicators and cognitive tasks (Beukeboom et al., 2012; Chen & Yokoyama, 2021; Grinde & Patil, 2009; Yang et al., 2025). Consequently, the literature frequently creates the broad impression that green or nature is beneficial without clearly identifying which exact visual properties are responsible for these effects (Bratman et al., 2012; Brown et al., 2013).

This issue becomes particularly problematic because many studies implicitly treat green colour, plant structure, and nature meaning as interchangeable concepts, even though they may operate through different psychological mechanisms (Yeom et al., 2022; Zheng et al., 2024). For example, a green wall simultaneously contains colour information, organic structure, visual complexity, texture, and semantic associations with health or naturalness (Beukeboom et al., 2012; Choi et al., 2016; Grinde & Patil, 2009; Lindemann-Matthies & Matthies, 2018). Similarly, comparisons between natural and urban scenes often differ in multiple dimensions at once, including brightness, openness, familiarity, and emotional valence (Berman et al., 2008; Brown et al., 2013; Dijkstra et al., 2008). As a result, many findings support the restorative value of nature in a broad sense, but provide only limited evidence regarding the causal pathways underlying these effects (Akers et al., 2012; Bratman et al., 2015; Brown et al., 2013; Grinde & Patil, 2009).

Another critical issue concerns the balance between ecological validity and experimental control. Studies conducted in real offices, classrooms, or healthcare environments often have high practical relevance because they reflect authentic experiences, but they also introduce numerous uncontrolled variables that complicate interpretation (Danielski et al., 2022; Gaekwad et al., 2022; Sanchez et al., 2018). In contrast, laboratory studies using photographs, slideshows, or VR environments improve internal validity by controlling stimuli more precisely, yet they may oversimplify how natural environments are experienced in everyday life (Brown et al., 2013; Chen & Yokoyama, 2021; Qin et al., 2013; Rhee et al., 2023). The literature therefore reflects an ongoing methodological tension between realism and control. The present thesis positions controlled experimentation not as a replacement for ecological approaches, but as a necessary complement that allows specific mechanisms to be isolated more clearly.

The literature additionally reveals substantial inconsistency in research designs and outcome measures. Some studies focus on subjective mood and stress, others on physiological indicators such as heart rate variability or blood pressure, while others prioritise attention, productivity, or perceived restorativeness (Lei et al., 2021; Pasanen et al., 2018; Wang et al., 2026; Yang et al., 2025; Yin et al., 2020). Exposure durations also vary considerably, ranging from brief image viewing to long-term workplace interventions (Grinde & Patil, 2009; van den Berg et al., 2015; Zhang et al., 2025). Because these methodological approaches differ so strongly, direct comparison between studies remains difficult, even when they appear to investigate similar restorative phenomena (Bakker & van der Voordt, 2010; Jalil et al., 2012).

Taken together, the reviewed research demonstrates that environmental psychology has produced convincing evidence that green and nature-related environments are often beneficial, but substantially less clarity regarding why these effects occur (Grinde & Patil, 2009; Rhee et al., 2023; Shibata & Suzuki, 2004; Zhang et al., 2024). The present thesis therefore contributes primarily by refining the research question itself. Instead of asking whether nature is restorative in general, it asks which visual elements of nature may be restorative, under which conditions, and through which mechanisms. This shift from broad environmental categories toward more differentiated visual analysis may represent an important next step for future research in this field (Brown et al., 2013; Choi et al., 2016; Zheng et al., 2024).

5.3 Experimental Control and Design Strengths

Methodologically, the thesis addresses one of the most persistent weaknesses in the existing literature, namely insufficient control over confounding variables. Many previous studies compare natural and urban environments, or plant and non-plant conditions, without isolating colour, structure, familiarity, attractiveness, or semantic meaning (Berman et al., 2008; Brown et al., 2013; Lindemann-Matthies & Matthies, 2018; Shibata & Suzuki, 2004; Yeo, 2021). As a result, causal interpretation remains limited because multiple variables change simultaneously (Beukeboom et al., 2012; Brown et al., 2013).

The proposed design responds directly to this issue through differentiated control conditions consisting of green colour alone, green plant imagery, non-green plant imagery, and a neutral grey baseline. The inclusion of a non-green plant condition is especially important because it allows plant structure and semantic nature associations to be examined independently from green colour. This creates a level of experimental separation that is largely missing in existing studies (Brown et al., 2013; Chen & Yokoyama, 2021; Grinde & Patil, 2009; van den Berg et al., 2015). Combined with random assignment and a pre-post measurement structure, the framework strengthens internal validity and improves sensitivity to short-term changes in mood, stress, and cognition.

At the same time, the thesis does not treat experimental control as inherently superior to ecological realism. Rather, it argues that both approaches are necessary and complementary. Field studies provide insight into how restorative environments function under realistic conditions, whereas controlled laboratory designs are necessary for identifying underlying mechanisms with greater precision (Amend et al., 2024; Danielski et al., 2022; Gaekwad et al., 2022; Yin et al., 2020). The present framework therefore contributes to methodological discussions within environmental psychology by demonstrating how stronger control logic can help clarify findings that have previously remained conceptually broad or ambiguous.

5.4 Practical Relevance

The thesis also has practical implications beyond the theoretical debate. If future empirical research confirms that green colour alone contributes to restoration, relatively simple interventions such as colour design, lighting concepts, or digital visual displays could potentially support psychological well-being in indoor environments (Chen & Pei, 2026; Xia et al., 2023; Zheng et al., 2014). In contrast, if plant structure or semantic associations with nature prove more important, then real or simulated natural elements would represent the more effective strategy (Nieuwenhuis et al., 2014; Yeom et al., 2022; Yin et al., 2020).

This question is especially relevant because modern life is increasingly characterised by indoor environments with limited direct contact with nature (Danielski et al., 2022; Lei et al., 2021; Ma et al., 2024). Offices, schools, universities, and healthcare settings are often visually artificial and cognitively demanding, while opportunities for recovery are reduced (Sanchez et al., 2018; Zhang et al., 2025; Yeom et al., 2022; Yin et al., 2020). Understanding which visual elements are actually restorative could therefore contribute to more targeted and evidence-based environmental design (Berman et al., 2008; Chen & Yokoyama, 2021; Grinde & Patil, 2009; Lei et al., 2021).

In workplaces, such findings may help reduce cognitive fatigue and support concentration in high-demand environments (Ma et al., 2024; Nieuwenhuis et al., 2014; Yeom et al., 2022). In educational settings, restorative visual elements could potentially improve attention and reduce mental exhaustion during learning tasks (Amicone et al., 2018; Jalil et al., 2012; Mason et al., 2022). In healthcare environments, more precise knowledge regarding colour and plant effects could contribute to therapeutic spaces that better support emotional comfort and stress reduction (Beukeboom et al., 2012; Dijkstra et al., 2008; Yin et al., 2020). Importantly, many of these interventions could be implemented relatively easily and cost-effectively through visual modifications rather than large structural redesigns (Chen & Yokoyama, 2021; Grinde & Patil, 2009; Lei et al., 2021).

5.5 Limitations

The central limitation of the thesis is that it remains theoretical and does not provide empirical findings. Although the framework identifies a promising research gap and proposes a structured experimental approach, it cannot yet determine which visual factor actually produces the strongest restorative effect in practice. The conclusions therefore remain conceptual and hypothesis-generating rather than confirmatory.

A second limitation concerns the simplified nature of laboratory-oriented experimental designs. Natural environments are dynamic, multisensory, and context-dependent, whereas the proposed framework deliberately reduces this complexity in order to isolate visual mechanisms more clearly (Brown et al., 2013; Chen & Yokoyama, 2021; Danielski et al., 2022; Gaekwad et al., 2022). Although this trade-off is methodologically justified, it also means that future findings would need to be interpreted carefully before being generalised to real-world environments (Qin et al., 2013; Yin et al., 2020).

A third limitation relates to the broader literature itself. Many existing studies rely on relatively small or narrow samples, short exposure durations, indirect stress measures, or heterogeneous methodologies, all of which restrict comparability and generalisability (Grinde & Patil, 2009; Jalil et al., 2012; Pasanen et al., 2018; Sanchez et al., 2018; van den Berg et al., 2015; Wang et al., 2026). The present thesis addresses these weaknesses conceptually, but cannot fully resolve them without empirical implementation.

5.6 Future Research

Future research should empirically test the proposed framework by directly comparing the four stimulus conditions under controlled laboratory conditions. A pre-post design with random assignment and multidimensional outcome measures including mood, stress, attention, and cognitive performance would represent an important next step in clarifying the mechanisms underlying restorative effects (Lei et al., 2021; Pasanen et al., 2018; van den Berg et al., 2015; Yang et al., 2025; Yeom et al., 2022).

Beyond laboratory implementation, future studies should combine experimental precision with ecologically valid field research. This would allow researchers to examine whether effects observed under controlled conditions also emerge in real offices, classrooms, hospitals, or other everyday settings where visual environments are experienced more dynamically and continuously (Danielski et al., 2022; Lei et al., 2021; Pasanen et al., 2018; van den Berg et al., 2015; Yang et al., 2025; Yeom et al., 2022; Yin et al., 2020; Zhang et al., 2025).

Further research should additionally investigate potential moderating factors such as age, cultural background, task demands, personality variables, and baseline stress levels. Because colour associations are not entirely universal and may depend partly on cultural or contextual meaning, these factors are likely to influence whether green colour, plant imagery, or combined exposure produces the strongest restorative effects (Elliot & Maier, 2014; Jalil et al., 2012; Kaya & Epps, 2004; Wang & Liu, 2026; Xiu et al., 2023).

Overall, the thesis contributes less by claiming a definitive answer than by refining the research question itself. Its primary achievement lies in moving the discussion beyond broad assumptions about nature exposure toward a more differentiated analysis of the visual components that may underlie restoration. In doing so, it provides a structured conceptual basis for future empirical work aimed at clarifying how visual environments influence psychological well-being and cognitive functioning.

6. Conclusion

The present thesis addressed a central unresolved issue within environmental psychology: although a large body of research demonstrates that nature, greenery, and indoor plants are associated with positive psychological and cognitive outcomes, the mechanisms underlying these effects remain insufficiently understood (Ding et al., 2026; Grinde & Patil, 2009; Ma et al., 2024; Rhee et al., 2023; Zhang et al., 2024). Across much of the existing literature, green colour, plant structure, visual complexity, and broader nature associations are combined within the same stimuli, making it difficult to determine which specific components are actually responsible for restorative effects (Berman et al., 2008; Brown et al., 2013; Yeom et al., 2022).

The theoretical analysis and critical review conducted in this thesis showed that exposure to natural environments and indoor greenery is consistently linked to reduced stress, improved mood, enhanced attention, and greater perceived restoration (Grinde & Patil, 2009; Norwood et al., 2019; Zhang et al., 2020). These effects have been supported across a wide range of contexts, including workplaces, classrooms, healthcare environments, virtual settings, and laboratory studies (Beukeboom et al., 2012; Chen & Yokoyama, 2021; Danielski et al., 2022; Dijkstra et al., 2008; Rhee et al., 2023; Yeom et al., 2022; Yin et al., 2020). At the same time, research on colour psychology suggests that green itself may independently influence emotional and cognitive processes, particularly in relation to calmness, relaxation, and attentional functioning (Jalil et al., 2012; Michaelis, 2013; Wang & Liu, 2026; Zheng et al., 2024; Zhou, 2013).

However, the thesis also demonstrated that current findings remain methodologically limited because many studies do not isolate colour from nature-related content (Bakker & van der Voordt, 2010; Brown et al., 2013). Most experimental designs compare natural and urban environments, plants and non-plants, or green and non-green scenes, while simultaneously varying multiple visual characteristics such as structure, texture, brightness, familiarity, and semantic meaning (Berman et al., 2008; Dijkstra et al., 2008; Lindemann-Matthies & Matthies, 2018; Shibata & Suzuki, 2004; van den Berg et al., 2025). Consequently, the literature provides strong evidence that greener and more natural environments are often beneficial, but substantially weaker evidence regarding why these effects occur and which visual mechanisms are responsible for them (Akers et al., 2012; Brown et al., 2013; Grinde & Patil, 2009; Zhang et al., 2024).

For this reason, the thesis argues that separating colour and nature is essential for the future development of environmental psychology research. Without clearer experimental differentiation between green colour, plant structure, and combined nature stimuli, restorative effects risk remaining conceptually broad and theoretically ambiguous. More controlled approaches are therefore necessary in order to determine whether restoration is primarily driven by perceptual colour properties, semantic associations with nature, structural characteristics of plants, or the interaction between these components (Chen & Yokoyama, 2021; Lei et al., 2021; Lohr & Pearson-Mims, 2000; Shibata & Suzuki, 2004; Zheng et al., 2024).

To address this issue, the thesis proposed a theoretical experimental framework consisting of four differentiated stimulus conditions: green colour alone, green plant imagery, non-green plant imagery, and a neutral grey baseline. Although the empirical implementation could not be completed within the scope of the present work, the framework itself represents an important conceptual contribution because it directly responds to one of the most persistent methodological weaknesses in the existing literature, namely insufficient control over confounding variables. By systematically separating colour and content, the proposed design offers a clearer basis for investigating restorative mechanisms under controlled conditions.

Beyond its theoretical and methodological relevance, the topic also has important practical implications. Modern life increasingly takes place in indoor environments such as offices, universities, schools, and healthcare facilities, where people are exposed to cognitively demanding tasks, prolonged screen use, and visually artificial surroundings with limited opportunities for psychological recovery (Ma et al., 2024; Sanchez et al., 2018; Yeom et al., 2022; Yin et al., 2020). Understanding which visual elements contribute to restoration therefore has direct relevance for architecture, workplace design, educational environments, and therapeutic settings (Grinde & Patil, 2009; Lei et al., 2021; van den Berg et al., 2016; Zhang et al., 2025).

If future research confirms that green colour alone has restorative potential, relatively simple interventions such as colour design, lighting concepts, or digital visual displays may already provide psychological benefits in demanding indoor environments (Elliot & Maier, 2014; Jalil et al., 2012; Xie et al., 2023). If, however, plant structure and semantic associations with nature prove more important, then real or simulated natural elements would represent the more effective intervention strategy (Nieuwenhuis et al., 2014; Yin et al., 2020). In either case, clearer knowledge regarding the mechanisms of restoration would support more targeted and evidence-based environmental design approaches.

At the same time, the thesis also has clear limitations. Because the work remains conceptual and does not include empirical findings, the conclusions remain hypothesis-generating rather than confirmatory. Furthermore, the proposed framework necessarily simplifies complex real-world environments in order to isolate visual mechanisms more clearly. Natural environments are dynamic, multisensory, and context-dependent, meaning that future experimental findings would need to be interpreted carefully before being generalized to everyday settings (Amend et al., 2024; Brown et al., 2013; Qin et al., 2013). Nevertheless, these limitations do not reduce the importance of the underlying research question. Rather, they highlight the need for future empirical studies that combine strong experimental control with ecological validity.

Overall, the thesis demonstrates that the central challenge in this field is no longer whether nature-related environments influence psychological well-being, but how these effects should be understood (Berman et al., 2008; Brown et al., 2013; Grinde & Patil, 2009; Zhang et al., 2024). By critically examining the relationship between green colour, plant imagery, and restorative outcomes, the thesis contributes to a more differentiated understanding of visual environmental effects and provides a structured basis for future research. Separating colour from nature is therefore not only a methodological necessity, but also a prerequisite for developing more precise theories and more effective practical applications within environmental psychology.

References

Akers, A., Barton, J., Cossey, R., Gainsford, P., Griffin, M., & Micklewright, D. (2012). Visual Color Perception in Green Exercise: Positive Effects on Mood and Perceived Exertion. *Environmental Science & Technology*, *46*(16), 8661–8666. https://doi.org/10.1021/es301685g

Amend, L., Mikuni, J., Dehove, M., Dörrzapf, L., Moser, M. K., Resch, B., Böhm, P., Prager, K., Leder, H., & Oberzaucher, E. (2024). The impact of urban street green transformation on subjective well-being and evaluation of the location: A case study in Vienna, Austria. *Environment and Social Psychology*, 9(9), 2861. https://doi.org/10.59429/esp.v9i9.2861

Amicone, G., Petruccelli, I., De Dominicis, S., Gherardini, A., Costantino, V., Perucchini, P., & Bonaiuto, M. (2018). Green Breaks: The Restorative Effect of the School Environment's Green Areas on Children's Cognitive Performance. *Frontiers in Psychology*, *9*, 1579. https://doi.org/10.3389/fpsyg.2018.01579

Amini Vishteh, R., Mirzajani, A., Jafarzadehpour, E., & Darvishpour, S. (2019). Evaluation of Simple Visual Reaction Time of Different Colored Light Stimuli in Visually Normal Students. *Clinical Optometry (Auckland)*, *11*, 167–171. https://doi.org/10.2147/OPTO.S236328

Ashcraft, M. H. (1992). Cognitive arithmetic: A review of data and theory. *Cognition*, 44(1), 75–106. https://doi.org/10.1016/0010-0277(92)90051-I

Bakker, I., & van der Voordt, T. (2010). The influence of plants on productivity: A critical assessment of research findings and test methods. *Facilities (Bradford, West Yorkshire, England)*, *28*(9/10), 416–439. https://doi.org/10.1108/02632771011057170

Barton, J., & Pretty, J. (2010). What is the Best Dose of Nature and Green Exercise for Improving Mental Health? A Multi-Study Analysis. *Environmental Science & Technology*, *44*(10), 3947–3955. https://doi.org/10.1021/es903183r

Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. Psychological Science, 19(12), 1207-1212.

Berry, M. S., Sweeney, M. M., Morath, J., Odum, A. L., & Jordan, K. E. (2014). The Nature of Impulsivity: Visual Exposure to Natural Environments Decreases Impulsive

Decision-Making in a Delay Discounting Task. *PloS One*, *9*(5), e97915. https://doi.org/10.1371/journal.pone.0097915

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

Beukeboom, C. J., Langeveld, D., & Tanja-Dijkstra, K. (2012). Stress reducing effects of real and artificial nature in a hospital waiting room. *Journal of Alternative and Complementary Medicine*, 18(4), 329-333. https://doi.org/10.1089/acm.2011.0488

Bielinis, E., Janeczko, E., Takayama, N., Zawadzka, A., Słupska, A., Piętka, S., Lipponen, M., & Bielinis, L. (2021). The effects of viewing a winter forest landscape with the ground and trees covered in snow on the psychological relaxation of young Finnish adults: A pilot study. *PloS One*, *16*(1), e0244799. https://doi.org/10.1371/journal.pone.0244799

Bratman, G. N., Hamilton, J. P., & Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Annals of the New York Academy of Sciences*, *1249*(1), 118–136. https://doi.org/10.1111/j.1749-6632.2011.06400.x

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, *138*, 41–50. https://doi.org/10.1016/j.landurbplan.2015.02.005

Bringslimark, T., Hartig, T., & Patil, G. G. (2009). The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of Environmental Psychology*, 29, 422-433. https://doi.org/10.1016/j.jenvp.2009.05.001

Brooks, A. M., Ottley, K. M., Arbuthnott, K. D., & Sevigny, P. (2017). Nature-related mood effects: Season and type of nature contact. *Journal of Environmental Psychology*, 54, 91-102. https://doi.org/10.1016/j.jenvp.2017.10.004

Brown, D. K., Barton, J. L., & Gladwell, V. F. (2013). Viewing Nature Scenes Positively Affects Recovery of Autonomic Function Following Acute-Mental Stress. *Environmental Science & Technology*, *47*(11), 5562–5569. https://doi.org/10.1021/es305019p

Budaniya, M., Mishra, A. K., Rai, A. C., & Dasgupta, M. S. (2025). Indoor plants' effect on occupants' performance, perceived comfort, and affect in an open-plan space in composite climatic regions, India. *Building and Environment*, *274*, 112785. https://doi.org/10.1016/j.buildenv.2025.112785

Chana, K., Dehove, M., Mikuni, J., Specker, E., Knoll, A. L., Barrière, T., Trupp, M. D., Pelowski, M., Oberzaucher, E., & Leder, H. (2026). Aesthetic components of urban environments and their relation to wellbeing: a scoping review. *Cities & Health*, *10*(2), 491–512. https://doi.org/10.1080/23748834.2025.2569732

Choi, J.-Y., Park, S.-A., Jung, S.-J., Lee, J.-Y., Son, K.-C., An, Y.-J., & Lee, S.-W. (2016). Physiological and psychological responses of humans to the index of greenness of an interior space. *Complementary Therapies in Medicine*, *28*(NA), 37–43. https://doi.org/10.1016/j.ctim.2016.08.002

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 24(4), 385-396. https://doi.org/10.2307/2136404

Danielski, I., Svensson, Å., Weimer, K., Lorentzen, L., & Warne, M. (2022). Effects of Green Plants on the Indoor Environment and Wellbeing in Classrooms—A Case Study in a Swedish School. *Sustainability*, *14*(7), 3777. https://doi.org/10.3390/su14073777

Deng, L., & Deng, Q. (2018). The basic roles of indoor plants in human health and comfort. *Environmental Science and Pollution Research International*, *25*(36), 36087–36101. https://doi.org/10.1007/s11356-018-3554-1

Dijkstra K, Pieterse ME, Pruyn A. Stress-reducing effects of indoor plants in the built healthcare environment: the mediating role of perceived attractiveness. *Prev Med.* 2008 Sep;47(3):279-83. doi: 10.1016/j.ypmed.2008.01.013. Epub 2008 Jan 26. PMID: 18329704.

Ding, Y., Qu, H., & Qu, H. (2026). A dose–response curve of restorative benefits of plant communities: based on visual distances and yellow to green hue range. *Journal of Forestry Research*, *37*(1), 2–2. https://doi.org/10.1007/s11676-025-01944-6

Du, M., Zhang, Y., Zhang, X., Tang, Z., Zhai, M., & Hong, B. (2025). Floral walls versus green wall for stress recovery and cognitive restoration in underground environments: A

VR-based experimental study. *Developments in the Built Environment*, *24*, 100819. https://doi.org/10.1016/j.dibe.2025.100819

Elliot, A. J., Maier, M. A., & Fiske, S. (2014). Color Psychology: Effects of Perceiving Color on Psychological Functioning in Humans. *Annual Review of Psychology*, *65*(1), 95–120. https://doi.org/10.1146/annurev-psych-010213-115035

Elsadek, M., Sun, M., & Fujii, E. (2017). Psycho-physiological responses to plant variegation as measured through eye movement, self-reported emotion and cerebral activity. *Indoor + Built Environment*, *26*(6), 758–770. https://doi.org/10.1177/1420326X16638711

Feng, Y., Wei, W., Yin, Y., & Li, X. (2026). The psychological mediations of green window view exposure on campus and freshman adaptation: a cross-sectional study in Nanjing, China. *Frontiers in Forests and Global Change*, *9*, 1741821. https://doi.org/10.3389/ffgc.2026.1741821

Frumkin, H., Bratman, G. N., Breslow, S. J., Cochran, B., Kahn Jr, P. H., Lawler, J. J., Levin, P. S., Tandon, P. S., Varanasi, U., Wolf, K. L., & Wood, S. A. (2017). Nature Contact and Human Health: A Research Agenda. *Environmental Health Perspectives*, *125*(7), 075001. https://doi.org/10.1289/EHP1663

Gaekwad, J. S., Sal Moslehian, A., Roös, P. B., & Walker, A. (2022). A Meta-Analysis of Emotional Evidence for the Biophilia Hypothesis and Implications for Biophilic Design. *Frontiers in Psychology*, *13*, 750245. https://doi.org/10.3389/fpsyg.2022.750245

Goldstein, K. (1942). SOME EXPERIMENTAL OBSERVATIONS CONCERNING THE INFLUENCE OF COLORS ON THE FUNCTION OF THE ORGANISM. *American Journal of Physical Medicine & Rehabilitation, 1*, 147–151.

Grabowska-Chenczke, O., Wajchman-switalska, S., & Wozniak, M. (2022). Psychological Well-Being and Nature Relatedness. *Forests*, *13*(7), 1048. https://doi.org/10.3390/f13071048

Grinde, B., & Patil, G. G. (2009). Biophilia: Does Visual Contact with Nature Impact on Health and Well-Being? *International Journal of Environmental Research and Public Health*, *6*(9), 2332–2343. https://doi.org/10.3390/ijerph6092332

Hartig, T., Book, A., Garvill, J., Olsson, T., & Garling, T. (1996). Environmental influences on psychological restoration. *Scandinavian Journal of Psychology*, 37, 378-393.

Han, K.-T. (2017). The effect of nature and physical activity on emotions and attention while engaging in green exercise. *Urban Forestry & Urban Greening*, *24*, 5–13. https://doi.org/10.1016/j.ufug.2017.03.012

Hemphill, M. (1996). A Note on Adults' Color-Emotion Associations. *The Journal of Genetic Psychology*, *157*(3), 275–280. https://doi.org/10.1080/00221325.1996.9914865

Hung, S.-H., Lee, T.-A., Lee, A.-Y., & Chang, C.-Y. (2025). Enhancing physiological effects, subjective vitality, and emotional well-being through immersive experiences in biologically diverse environments. *Landscape and Ecological Engineering*, *21*(4), 773–791. https://doi.org/10.1007/s11355-025-00673-6

Jabbar, M., Nasar-u-Minallah, M., & Yusoff, M. M. (2024). Measuring and modeling the association between human psychological well-being and urban green spaces of Lahore, Pakistan. *Journal of Environmental Studies and Sciences*, *14*(4), 732–743. https://doi.org/10.1007/s13412-024-00895-4

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, 105(19), 6829-6833. https://doi.org/10.1073/pnas.0801268105

Jalil, N. A., Yunus, R. M., & Said, N. S. (2012). Environmental Colour Impact upon Human Behaviour: A Review. *Procedia, Social and Behavioral Sciences*, *35*, 54–62. https://doi.org/10.1016/j.sbspro.2012.02.062

Jang, H. S., Kim, J., Kim, K. S., & Pak, C. H. (2014). Human brain activity and emotional responses to plant color stimuli. *Color Research and Application*, *39*(3), 307–316. https://doi.org/10.1002/col.21788

Kaplan, S. (1987). Aesthetics, Affect, and Cognition: Environmental Preference from an Evolutionary Perspective. *Environment and Behavior*, *19*(1), 3–32. https://doi.org/10.1177/0013916587191001

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

Kaya, N., & Epps, H. H. (2004). Relationship between Color and Emotion: A Study of College Students. *College Student Journal*, *38*(3), 396.

Knoll, A. L., Barrière, T., Weigand, R., Jacobsen, T., Leder, H., & Specker, E. (2024). Experiencing beauty in everyday life. *Scientific Reports*, *14*(1), 9463–13. https://doi.org/10.1038/s41598-024-60091-w

Kuo, M. (2015). How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Frontiers in Psychology*, *6*, 1093. https://doi.org/10.3389/fpsyg.2015.01093

Kuo, M., Browning, M. H. E. M., Sachdeva, S., Lee, K., & Westphal, L. (2018). Might School Performance Grow on Trees? Examining the Link Between "Greenness" and Academic Achievement in Urban, High-Poverty Schools. *Frontiers in Psychology*, *9*, 1669. https://doi.org/10.3389/fpsyg.2018.01669

Kwallek, N., Woodson, H., Lewis, C. M., & Sales, C. (1997). Impact of three interior color schemes on worker mood and performance relative to individual environmental sensitivity. *Color Research and Application*, *22*(2), 121–132. https://doi.org/10.1002/(SICI)1520-6378(199704)22:2<121::AID-COL7>3.0.CO;2-V

Küller, R., Mikellides, B., & Janssens, J. (2009). Color, arousal, and performance-A comparison of three experiments. *Color Research and Application*, *34*(2), 141–152. https://doi.org/10.1002/col.20476

Lei, Q., Yuan, C., & Lau, S. S. Y. (2021). A quantitative study for indoor workplace biophilic design to improve health and productivity performance. *Journal of Cleaner Production*, *324*, 129168. https://doi.org/10.1016/j.jclepro.2021.129168

Lichtenfeld, S., Elliot, A. J., Maier, M. A., & Pekrun, R. (2012). Fertile Green: Green Facilitates Creative Performance. *Personality & Social Psychology Bulletin*, *38*(6), 784–797. https://doi.org/10.1177/0146167212436611

Li, Y., Yu, Y., Hu, D., Shang, X., Wang, T., Liu, K., Mou, S., & Zhang, X. (2025). The Influence of Campus Landscape Color Environment on Students' Emotions: A Case Study of Shandong Agricultural University. *Buildings (Basel)*, *15*(23), 4290. https://doi.org/10.3390/buildings15234290

Li, Q., Ou, X., Cai, S., Guo, L., Zhou, X., Gong, X., Li, Y., Zhai, Z., Elsadek, M., & Tang, H. (2026). A Study on the Restorative Effects of Hydrangea Flower Color and Structure on Human Psychology and Physiology. *Horticulturae*, *12*(1), 34. https://doi.org/10.3390/horticulturae12010034

Lohr, V. I., & Pearson-Mims, C. H. (2000). Physical Discomfort May Be Reduced in the Presence of Interior Plants. *HortTechnology (Alexandria, Va.)*, *10*(1), 53–58. https://doi.org/10.21273/HORTTECH.10.1.53

Mason, L., Manzione, L., Ronconi, A., & Pazzaglia, F. (2022). Lessons in a Green School Environment and in the Classroom: Effects on Students' Cognitive Functioning and Affect. *International Journal of Environmental Research and Public Health*, *19*(24), 16823. https://doi.org/10.3390/ijerph192416823

Mason, L., Ronconi, A., Scrimin, S., & Pazzaglia, F. (2022). Short-Term Exposure to Nature and Benefits for Students' Cognitive Performance: a Review. *Educational Psychology Review*, *34*(2), 609–647. https://doi.org/10.1007/s10648-021-09631-8

Ma, X., Du, M., Deng, P., Zhou, T., & Hong, B. (2024). Effects of green walls on thermal perception and cognitive performance: An indoor study. *Building and Environment*, *250*, 111180. https://doi.org/10.1016/j.buildenv.2024.111180

Mehta, R., & Zhu, R. (2009). Blue or Red? Exploring the Effect of Color on Cognitive Task Performances. *Science (American Association for the Advancement of Science)*, *323*(5918), 1226–1229. https://doi.org/10.1126/science.1169144

Michaelis, J. R. (2013). The restorative effects of color and environment type on cognitive functioning [Master's thesis, University of Central Florida]. *STARS*. https://stars.library.ucf.edu/etd/2663

Michels, N., Debra, G., Mattheeuws, L., & Hooyberg, A. (2022). Indoor nature integration for stress recovery and healthy eating: A picture experiment with plants versus green color. *Environmental Research*, 212, 113643. https://doi.org/10.1016/j.envres.2022.113643

Neilson, B. N., Craig, C. M., Curiel, R. Y., & Klein, M. I. (2021). Restoring Attentional Resources With Nature: A Replication Study of Berto's (2005) Paradigm Including Commentary From Dr. Rita Berto. *Human Factors*, *63*(6), 1046–1060. https://doi.org/10.1177/0018720820909287

Nieuwenhuis, M., Knight, C., Postmes, T., & Haslam, S. A. (2014). The Relative Benefits of Green Versus Lean Office Space: Three Field Experiments. *Journal of Experimental Psychology. Applied*, *20*(3), 199–214. https://doi.org/10.1037/xap0000024

Norwood, M. F., Lakhani, A., Fullagar, S., Maujean, A., Downes, M., Byrne, J., Stewart, A., Barber, B., & Kendall, E. (2019). A narrative and systematic review of the behavioural, cognitive and emotional effects of passive nature exposure on young people: Evidence for prescribing change. *Landscape and Urban Planning*, *189*, 71–79. https://doi.org/10.1016/j.landurbplan.2019.04.007

Noseworthy, M. W., Wei, N., Grant, S., Zou, J., Puterman, E., Handy, T. C., & Liu‐Ambrose, T. (2024). Supporting Aging through Green Exercise (SAGE): Comparing the cognitive effects of outdoor versus indoor aerobic exercise in older adults with mild cognitive impairment—A 12‐week proof‐of‐concept randomized controlled trial. *Alzheimer's & Dementia*, *20*(S7), n/a-n/a. https://doi.org/10.1002/alz.091114

Pasanen, T., Johnson, K., Lee, K., & Korpela, K. (2018). Can Nature Walks With Psychological Tasks Improve Mood, Self-Reported Restoration, and Sustained Attention? Results From Two Experimental Field Studies. *Frontiers in Psychology*, *9*, 2057. https://doi.org/10.3389/fpsyg.2018.02057

Perrins, S. P., Varanasi, U., Seto, E., & Bratman, G. N. (2021). Nature at work: The effects of day-to-day nature contact on workers' stress and psychological well-being. *Urban Forestry & Urban Greening*, *66*, 127404. https://doi.org/10.1016/j.ufug.2021.127404

Qin, J., Zhou, X., Sun, C., Leng, H., & Lian, Z. (2013). Influence of green spaces on environmental satisfaction and physiological status of urban residents. *Urban Forestry & Urban Greening*, *12*(4), 490–497. https://doi.org/10.1016/j.ufug.2013.05.005

Reese, G., Stahlberg, J., & Menzel, C. (2022). Digital shinrin-yoku: do nature experiences in virtual reality reduce stress and increase well-being as strongly as similar experiences in a physical forest? *Virtual Reality : The Journal of the Virtual Reality Society*, *26*(3), 1245–1255. https://doi.org/10.1007/s10055-022-00631-9

Rhee, J. H., Schermer, B., & Cha, S. H. (2023). Effects of indoor vegetation density on human well-being for a healthy built environment. *Developments in the Built Environment*, *14*, 100172–100172. https://doi.org/10.1016/j.dibe.2023.100172

Shibata, S., & Suzuki, N. (2004). Effects of an indoor plant on creative task performance and mood. *Scandinavian Journal of Psychology*, *45*(5), 373–381. https://doi.org/10.1111/j.1467-9450.2004.00419.x

Ayuso Sanchez, J., Ikaga, T., & Vega Sanchez, S. (2018). Quantitative improvement in workplace performance through biophilic design: A pilot experiment case study. *Energy and Buildings*, *177*, 316–328. https://doi.org/10.1016/j.enbuild.2018.07.065

Sedghikhanshir, A., Zhu, Y., Beck, M. R., & Jafari, A. (2024). Exploring the impact of green wall and its size on restoration effect and stress recovery using immersive virtual environments. *Building and Environment*, *262*, 111844. https://doi.org/10.1016/j.buildenv.2024.111844

Shin, J.-Y., Chun, S.-Y., & Lee, C.-S. (2013). Analysis of the Effect on Attention and Relaxation Level by Correlated Color Temperature and Illuminance of LED Lighting using EEG Signal. *Journal of the Korean Institute of Illuminating and Electrical Installation Engineers*, *27*(5), 9–17. https://doi.org/10.5207/JIEIE.2013.27.5.009

Siah, C. J. R., Goh, Y. S., Lee, J., Poon, S. N., Ow Yong, J. Q. Y., & Tam, W. W. (2023). The effects of forest bathing on psychological well‐being: A systematic review and meta‐analysis. *International Journal of Mental Health Nursing*, *32*(4), 1038–1054. https://doi.org/10.1111/inm.13131

Taylor, L., Hahs, A. K., & Hochuli, D. F. (2018). Wellbeing and urban living: nurtured by nature. *Urban Ecosystems*, *21*(1), 197–208. https://doi.org/10.1007/s11252-017-0702-1

Tham, D. S. Y., Sowden, P. T., Grandison, A., Franklin, A., Lee, A. K. W., Ng, M., Park, J., Pang, W., & Zhao, J. (2020). A Systematic Investigation of Conceptual Color Associations. *Journal of Experimental Psychology. General*, *149*(7), 1311–1332. https://doi.org/10.1037/xge0000703

Ulrich, R. S. (1981). Natural Versus Urban Scenes: Some Psychophysiological Effects. *Environment and Behavior*, *13*(5), 523–556. https://doi.org/10.1177/0013916581135001

Ulrich, R. S. (1984). View through a Window May Influence Recovery from Surgery. *Science (American Association for the Advancement of Science)*, *224*(4647), 420–421. https://doi.org/10.1126/science.6143402

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, 11, 201-230.

Valdez, P., & Mehrabian, A. (1994). Effects of Color on Emotions. *Journal of Experimental Psychology. General*, *123*(4), 394–409. https://doi.org/10.1037/0096-3445.123.4.394

van den Berg, M., Maas, J., Muller, R., Braun, A., Kaandorp, W., Van Lien, R., Van Poppel, M., Van Mechelen, W., & Van den Berg, A. (2015). Autonomic Nervous System Responses to Viewing Green and Built Settings: Differentiating Between Sympathetic and Parasympathetic Activity. *International Journal of Environmental Research and Public Health*, *12*(12), 15860–15874. https://doi.org/10.3390/ijerph121215026

van den Berg, A. E., Wesselius, J. E., Maas, J., & Tanja-Dijkstra, K. (2017). Green Walls for a Restorative Classroom Environment: A Controlled Evaluation Study. *Environment and Behavior*, *49*(7), 791–813. https://doi.org/10.1177/0013916516667976

van den Bogerd, N., Dijkstra, S. C., Koole, S. L., Seidell, J. C., & Maas, J. (2021). Greening the room: A quasi-experimental study on the presence of potted plants in study rooms on mood, cognitive performance, and perceived environmental quality among university students. *Journal of Environmental Psychology*, 73, 101557.

Vella-Brodrick, D. A., & Gilowska, K. (2022). Effects of Nature (Greenspace) on Cognitive Functioning in School Children and Adolescents: a Systematic Review. *Educational Psychology Review*, *34*(3), 1217–1254. https://doi.org/10.1007/s10648-022-09658-5

Wallner, P., Kundi, M., Arnberger, A., Eder, R., Allex, B., Weitensfelder, L., & Hutter, H.-P. (2018). Reloading Pupils' Batteries: Impact of Green Spaces on Cognition and Wellbeing. *International Journal of Environmental Research and Public Health*, *15*(6), 1205. https://doi.org/10.3390/ijerph15061205

Wang, S., & Liu, H. (2026). How colors of the living street interfaces affect positive emotions in winter. *Frontiers in Public Health*, *14*, 1741191. https://doi.org/10.3389/fpubh.2026.1741191

Wang, Y., Ibrahim, F. I., Chang, J., & Zainal Abidin, S. N. (2026). Assessing stress restorative potential of plant species richness and plant landscape types of pocket parks: The mediating role of aesthetic quality. *PloS One*, *21*(2), e0343001. https://doi.org/10.1371/journal.pone.0343001

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, 54(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Wilson, E. O. (1984). *Biophilia*. Harvard University Press.

Xia, G., Henry, P., Chen, Y., Queiroz, F., Westland, S., & Cheng, Q. (2023). The effects of colour attributes on cognitive performance and intellectual abilities in immersive virtual environments. *Computers in Human Behavior*, *148*, 107853. https://doi.org/10.1016/j.chb.2023.107853

Xie, S., Pan, Q., Zheng, H., Xiao, N., & Li, J. (2023). Key Factors Strengthening Residents' Psychological Well-Being and Critical Human-Nature Connections within the Living Spaces—An Example from Beijing. *Diversity (Basel)*, *15*(3), 438. https://doi.org/10.3390/d15030438

Yang, L., Yuan, L., Zhang, G., Shi, J., & Dewancker, B. J. (2025). Impact of the cool and warm colours of flowers on the plant wall on indoor human health. *Indoor + Built Environment*, *34*(9), 1683–1694. https://doi.org/10.1177/1420326X251355618

Yeom, S., Kim, H., Hong, T., Ji, C., & Lee, D. (2022). Emotional impact, task performance and task load of green walls exposure in a virtual environment. *Indoor Air*, *32*(1), e12936-n/a. https://doi.org/10.1111/ina.12936

Yeo, L. B. (2021). Psychological And Physiological Benefits Of Plants In The Indoor Environment: A Mini And In-Depth Review. *International Journal of Built Environment and Sustainability*, *8*(1), 57–67. https://doi.org/10.11113/ijbes.v8.n1.597

Yin, J., Yuan, J., Arfaei, N., Catalano, P. J., Allen, J. G., & Spengler, J. D. (2020). Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environment International*, *136*, 105427. https://doi.org/10.1016/j.envint.2019.105427

Zhang, G., Li, T., Cui, Y., & Ren, T. H. (2025). The restorative effects of working individually in a vegetated office space: A crossover controlled experimental study in real-life workplace setting. *Work (Reading, Mass.)*, *81*(3), 3070–3082. https://doi.org/10.1177/10519815251323994

Zhang, Y., Mavoa, S., Zhao, J., Raphael, D., & Smith, M. (2020). The Association between Green Space and Adolescents' Mental Well-Being: A Systematic Review. *International Journal of Environmental Research and Public Health*, *17*(18), 6640–26. https://doi.org/10.3390/ijerph17186640

Zhang, Z., Jiang, M., & Zhao, J. (2024). The Restorative Effects of Unique Green Space Design: Comparing the Restorative Quality of Classical Chinese Gardens and Modern Urban Parks. *Forests*, *15*(9), 1611. https://doi.org/10.3390/f15091611

Zhang, Z., Ye, B., Yang, W., & Gao, Y. (2024). Effect of Nature Space on Enhancing Humans' Health and Well-Being: An Integrative Narrative Review. *Forests*, *15*(1), 100. https://doi.org/10.3390/f15010100

Zhao, J., Wu, J., & Wang, H. (2020). Characteristics of urban streets in relation to perceived restorativeness. *Journal of Exposure Science & Environmental Epidemiology*, *30*(2), 309–319. https://doi.org/10.1038/s41370-019-0188-4

Zheng, S., Zhou, Y., & Qu, H. (2024). Physiological and psychological responses to tended plant communities with varying color characteristics. *Journal of Forestry Research*, *35*(1), 32–32. https://doi.org/10.1007/s11676-023-01683-6

Zhou, M. (2013). On Interior Greening Decoration of Residence. *Applied Mechanics and Materials*, *275–277*, 2793–2796. https://doi.org/10.4028/www.scientific.net/AMM.275-277.2793

List of Tables

List of Tools and Aids

Tool	Use	Part of Thesis	Notes
Anara and ChatGPT (OpenAI)	Proofreading, stylistic improvement, and structural support	Abstract, Introduction, theoretical sections, Discussion	Used as a language support tool due to English not being the author's first language. All content and academic reasoning were independently developed and checked by the author.

Appendix

Abstract English Version

This theoretical thesis addresses a central issue in environmental psychology, namely that exposure to natural environments is consistently associated with positive psychological outcomes such as reduced stress, improved mood, and enhanced cognitive functioning, but the mechanisms underlying these effects remain insufficiently understood. In particular, it remains unclear whether restorative responses are primarily driven by plant structure and natural content, by the colour green, or by an interaction of both, and this ambiguity constitutes the central research question of the thesis.

Drawing on a critical review of literature from environmental psychology, colour psychology, and restoration theories, the thesis identifies a recurring methodological limitation, namely that visual stimuli often combine colour, form, and semantic associations with nature. This makes it difficult to isolate the specific factors responsible for observed effects and limits precise causal conclusions.

Instead of presenting an empirical study, the thesis develops a structured experimental framework with four controlled conditions, green colour alone, green plant imagery, non-green plant imagery, and a neutral grey baseline. This framework is designed to separate colour-based and nature-based influences and to improve the clarity of future research on visual restoration.

In conclusion, the thesis argues that distinguishing more clearly between colour and nature components is essential for advancing theoretical models of psychological restoration. It also highlights the practical relevance of this distinction for the design of indoor environments such as workplaces, educational settings, and healthcare facilities, where visual elements may be used in more targeted and evidence-based ways to support well-being and cognitive performance.

Abstract German Version

Diese theoretische Masterarbeit behandelt ein zentrales Thema der Umweltpsychologie, nämlich dass die Exposition gegenüber natürlichen Umgebungen konsistent mit positiven psychologischen Effekten wie reduziertem Stress, besserer Stimmung und gesteigerter kognitiver Leistungsfähigkeit assoziiert ist, die zugrunde liegenden Mechanismen dieser Effekte jedoch bislang nicht ausreichend verstanden sind. Insbesondere bleibt unklar, ob diese restaurativen Reaktionen primär durch die Pflanzenstruktur und den Naturgehalt, durch die Farbe Grün oder durch eine Kombination beider Faktoren hervorgerufen werden, und diese Unklarheit bildet die zentrale Forschungsfrage der Arbeit.

Auf Grundlage einer kritischen Literaturübersicht aus der Umweltpsychologie, der Farbpsychologie und den Theorien der Restauration identifiziert die Arbeit eine wiederkehrende methodische Einschränkung, nämlich dass visuelle Stimuli häufig Farbe, Form und semantische Assoziationen mit Natur miteinander verbinden. Dadurch wird es schwierig, die für die beobachteten Effekte verantwortlichen spezifischen Faktoren zu isolieren, wodurch präzise kausale Schlussfolgerungen eingeschränkt werden.

Anstatt eine empirische Studie zu präsentieren, entwickelt die Arbeit ein strukturiertes experimentelles Rahmenmodell mit vier kontrollierten Bedingungen: reine grüne Farbe, grüne Pflanzenbilder, nicht-grüne Pflanzenbilder und eine neutrale graue Ausgangsbedingung. Dieses Rahmenmodell ist darauf ausgelegt, farbbasierte und naturbasierte Einflüsse voneinander zu trennen und die Klarheit künftiger Forschung zur visuellen Wiederherstellung zu verbessern.

Abschließend argumentiert die Arbeit, dass eine klarere Unterscheidung zwischen Farb- und Naturkomponenten wesentlich ist, um theoretische Modelle der psychologischen Wiederherstellung weiterzuentwickeln. Zudem hebt sie die praktische Relevanz dieser Unterscheidung für die Gestaltung von Innenräumen wie Arbeitsplätzen, Bildungsumgebungen und Gesundheitseinrichtungen hervor, in denen visuelle Elemente gezielter und evidenzbasierter eingesetzt werden können, um Wohlbefinden und kognitive Leistungsfähigkeit zu unterstützen.