Destressing University Environments

Evaluating Campuses that Encourage Restoration and Recovery in Students

Cobi Granger

March 28, 2022

Emily Greenwood, Environmental Design: Thesis Advisor

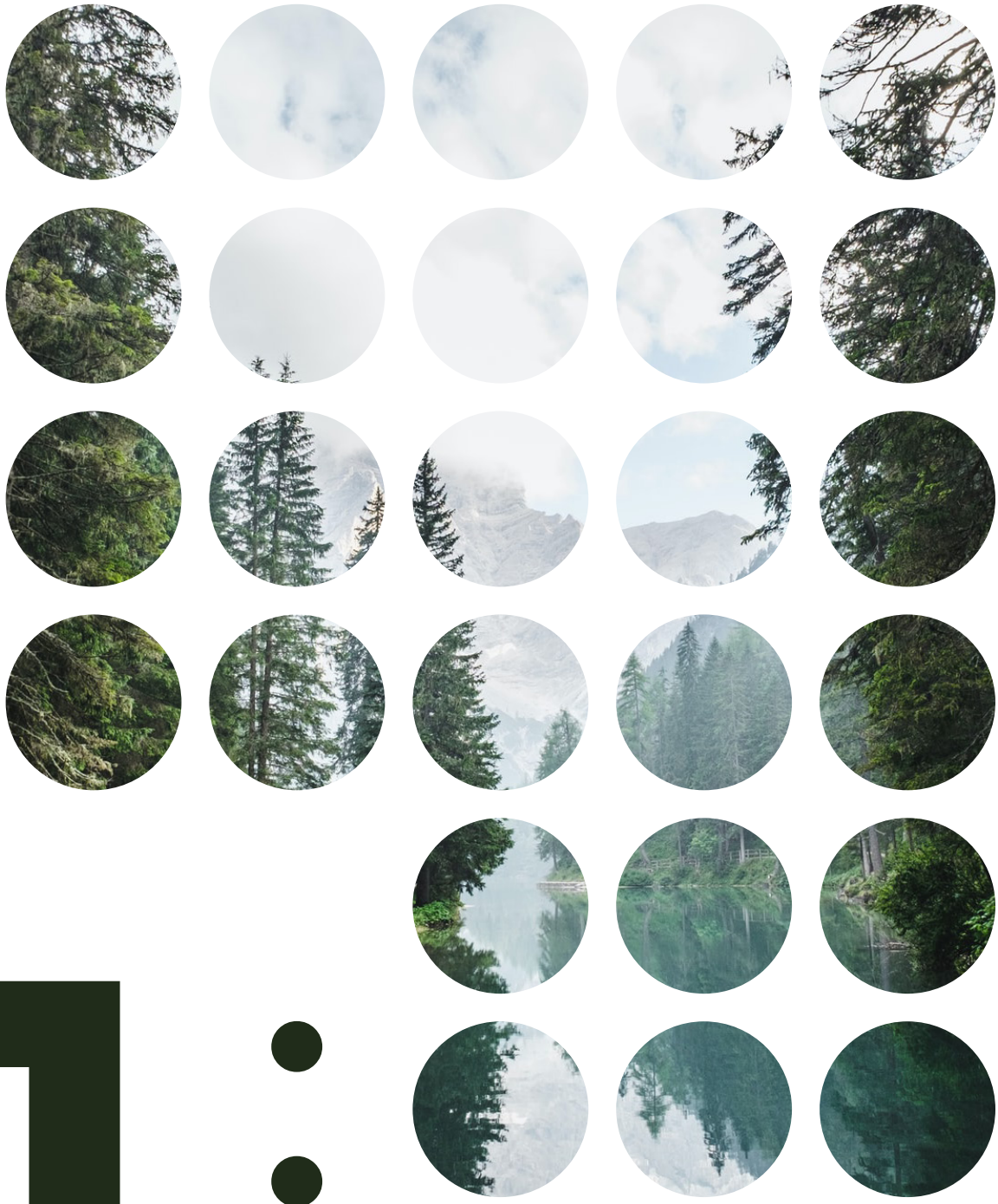
Dr. Paul Chinowsky, Environmental Design: Honors Committee Representative

Dr. Leaf Van Boven, Psychology and Neuroscience: External Committee Member






This thesis is dedicated to Emily Greenwood, my phenomenal advisor and mentor, who has been a constant source of positivity, motivation, and support throughout my entire time at CU. Her commitment to improving the world we live in is inspirational, and her dedication to the ENVD program and all of its students makes me proud to be a part of the community she has helped build.



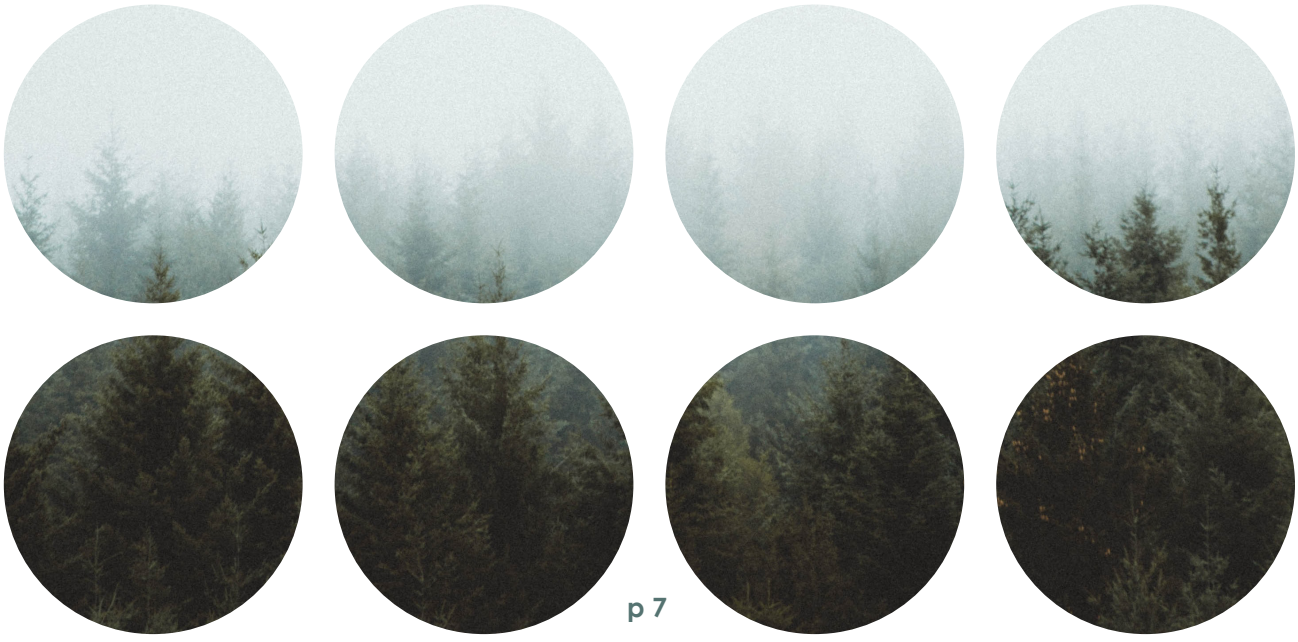
1: ABSTRACT

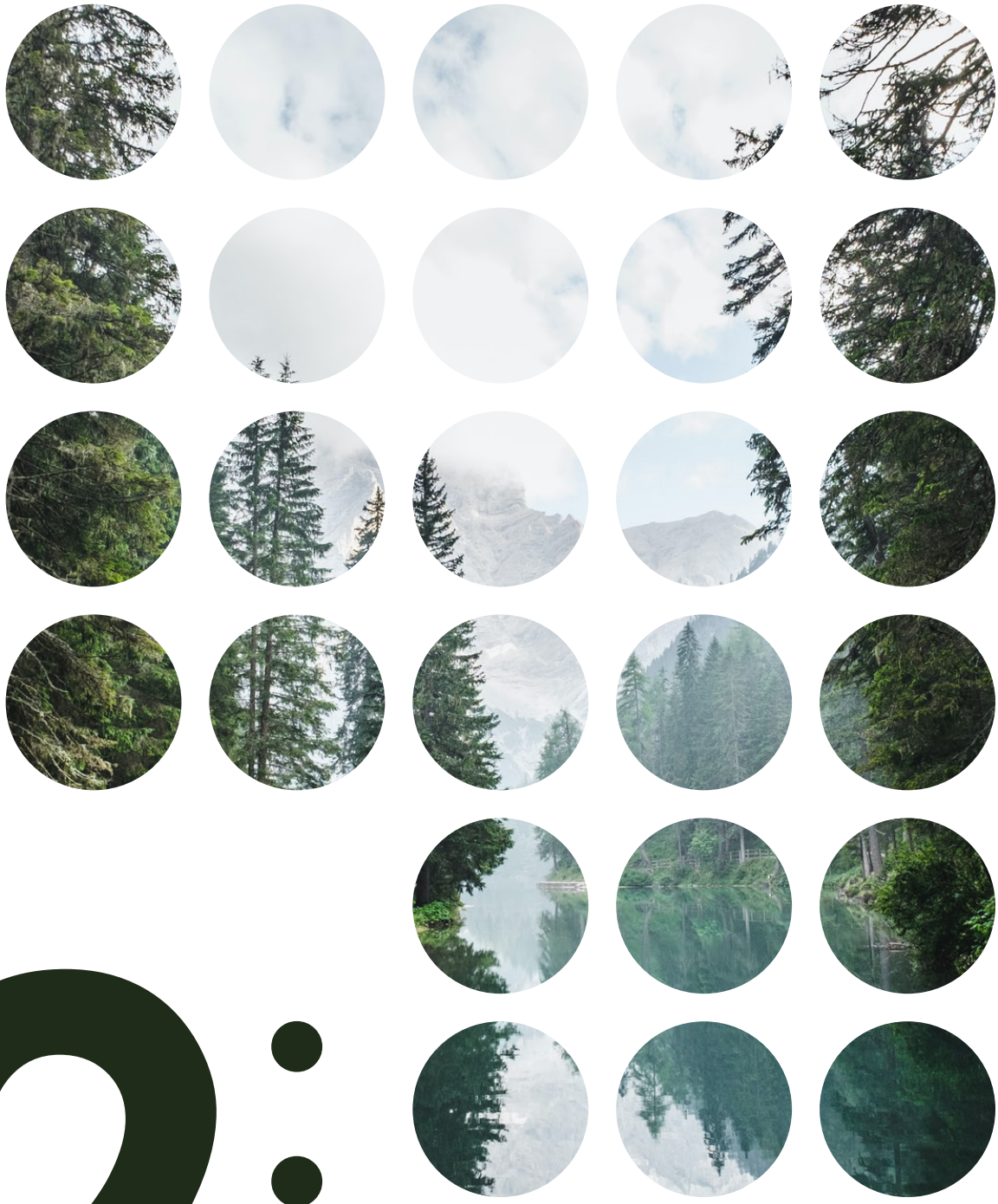
1. Abstract:

The severity, frequency, and impact of mental health problems in college students are becoming a growing concern. Strains on mental health contribute to poor academic performance. Attention restoration psychology argues that physical environments which lack natural stimuli inhibit stress reduction and recovery. Over time this causes illnesses like depression and anxiety. Current practices in university campus design overlook the psychological needs of students, especially on campuses in cold climates. Biophilia, a theory posited by Edward Wilson, offers suggestions for designing spaces that present natural stimuli without reliance on green vegetation year-round. This thesis explores existing frameworks for biophilic design to determine their strengths and flaws. The research presented in this paper establishes a set of Principles of Natural Connectedness for identifying restorative biophilic conditions through proxy research in experimental and evolutionary psychology that fills gaps in pre-existing frameworks. When applied to several sites, the matrix found that college campuses in Colorado lack many conditions that allow for attention restoration and stress recovery. This research begins to bridge a gap between experimental psychology and design and sets a precedent for future studies validating the theories of evolutionary psychology and biophilia.

Table of Contents

List of Figures





2: INTRODUCTION

2. Introduction:

The 2020 Healthy Minds Study found that 39% of college students screen positively for depression, 34% screen for anxiety, and 83% say that their mental health negatively impacts their academic performance ("The Healthy Minds Study" 2020). This is an alarming statistic that should be addressed by all fields that influence universities.

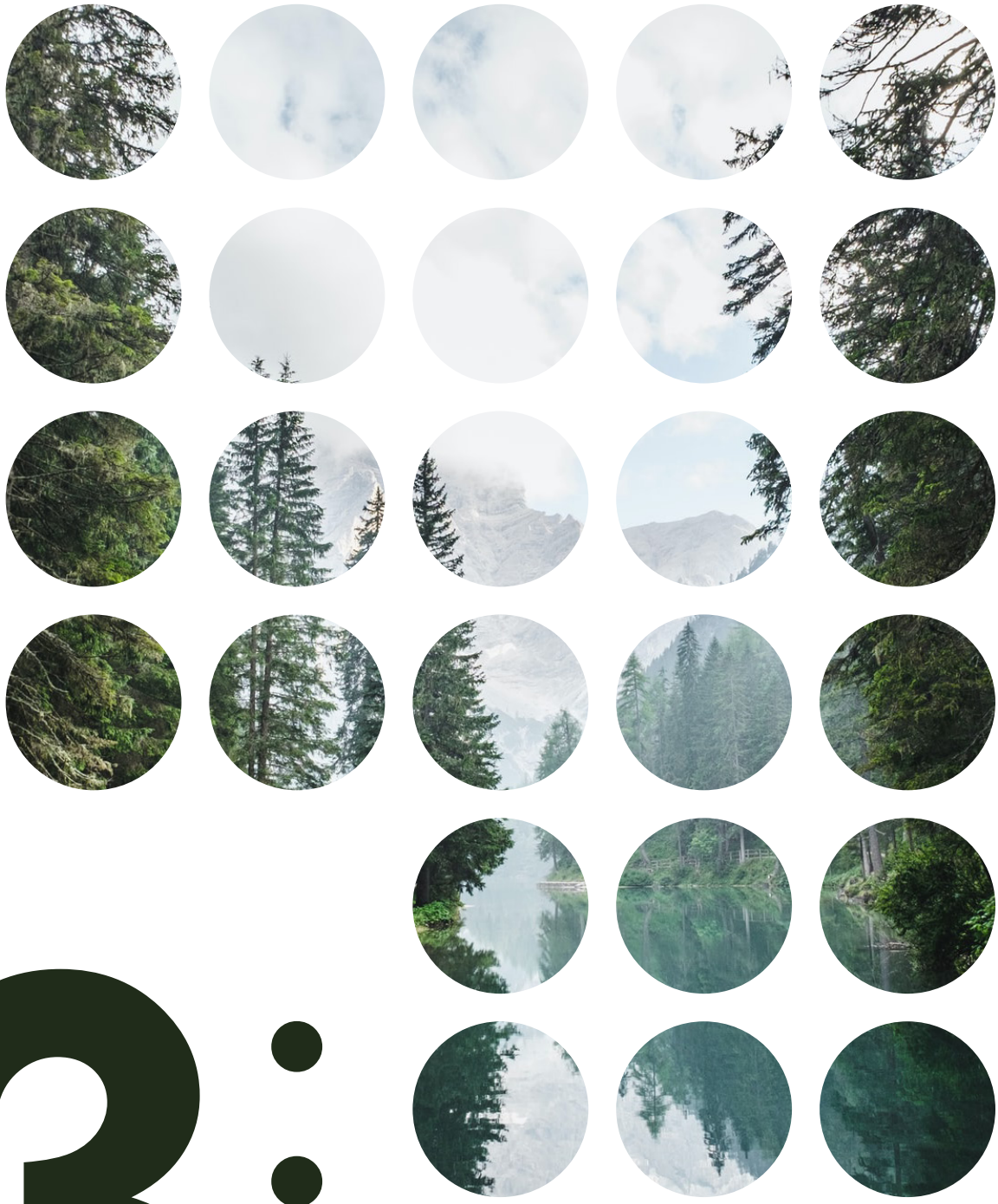
Ming Lu and Jingwan Fu posit that the lack of opportunities for attention restoration on college campuses could increase the number of students struggling with mental health issues. (Lu and Fu, 2019) Researchers have conducted some studies in psychology and physiology to explore the role of greenness and nature in restorative environments, most concluding that increased visual access to natural scenes leads to increased attention restoration and other health benefits (D. Li and Sullivan 2016; Huang et al., 2021; Felsten 2009).

However, university campuses cannot rely on green vegetation for year-round restoration and recovery in climates with harsh winters. These campuses require natural stimuli that can benefit students during cold seasons while most plants are dormant. Edward Wilson's *Biophilia Hypothesis* and following work in social ecology present a possible solution: a framework for connectedness with nature that does not rely exclusively on vegetation. Biophilia will be used to translate ideas in psychology into implementable design features.

This thesis will examine the potential for applying principles of natural connectedness to the design of college campus landscapes to improve attention restoration and stress recovery in students between classes. A review of existing work relating environmental psychology to environmental design will be conducted to develop a set of conditions that should improve opportunities for attention restoration when present in built environments. These conditions are supported by research in evolutionary psychology, physiology, and social ecology. This process has resulted in a framework for observing attention restorative conditions on college campuses.

2.1 Research Question:

Does the degree of natural connectedness on college campuses in cold climates influence student stress recovery and attention restoration?



3: LITERATURE REVIEW

3. Literature Review:

3.1: The Body's Response to Nature:

Research in the effects of natural environments on human psychology and physiology has developed into two complementary theories. The first, Stress Recovery Theory, observes the relationship between physiology and physical settings. This perspective posits that humans are physiologically and psychologically adapted to respond positively to natural environments over urban spaces due to our evolution in natural settings (Ulrich 1983; Berto 2014). The second, Attention Restoration Theory, takes a functionalist approach and argues that humans respond positively to natural environments because of a predisposition to prefer favorable settings for survival during our evolution (Kaplan 1995; Basu, Duvall, and Kaplan 2019; Berto 2014). Stress recovery theory, or SRT, addresses restoration from physiological stress, while Attention restoration theory, or ART, focuses on recovery from mental fatigue. These two theories go hand in hand because stress recovery happens in the absence of mental fatigue. Attentional fatigue can be seen as an aftereffect of stress and a condition that increases vulnerability to stress (Berto 2014).

There are a few different ways to measure the effects of natural environments on the human body. One of the most common methods is to observe cortisol levels in the bloodstream. Cortisol is a hormone produced by the adrenal glands that indicates activation of the hypothalamus, a region at the base of the brain which is responsible for maintaining homeostasis (Johnson 2018). Cortisol is the primary stress hormone that increases glucose in the bloodstream and limits functions that are not essential in fight-or-flight situations like immune responses, growth processes, and the reproductive system. Long-term stress responses overexpose the body to cortisol and increase the risk of depression, anxiety, sleep problems, memory impairment, and difficulty concentrating ("Chronic Stress Puts Your Health at Risk" n.d.). One of the first studies that connected cortisol levels to physical settings was conducted by Ralph Wadeson et al. in 1963, which unintentionally discovered that exposure to different environments directly influenced cortisol levels in blood and urine (WADESON et al. 1963).

Another physiological indicator of stress and stress recovery is autonomic nervous system (ANS) responses. The ANS consists of two opposing components; the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS is activated during stressful situations and controls fight or flight responses, while the PNS conserves energy through relaxation and regulates other bodily functions (Tindle and Tadi 2021). Because the autonomic nervous system controls cardiac functions, heart rate is often observed to determine SNS and PNS activity in studies regarding responses to natural stimuli (Berto 2014). The autonomic nervous system's impact on heart rate is always the balance between the SNS and PNS, so an increased heart rate is indicative of activation in the SNS. In contrast, heart rate recovery is associated with parasympathetic activation (Gordan, Gwathmey, and Xie 2015).

Roger Ulrich measured physiological responses to natural stimuli after stressful activity like heart rate in a study that found that parasympathetic activity increased significantly during and after exposure to nature scenes instead of urban settings (Ulrich 1981). These findings indicate that experiences of nature aid the physiological stress recovery process.
Stress recovery theory and attention restoration theory are the driving factors in the

following discussion. Since college students make up a demographic that is frequently confronted with stressful activity resulting in mental fatigue, their environments must activate physiological responses that assist stress recovery and attention restoration.

3.2 Problems and Trends in the Design of College Campuses:

It can be argued that campus design in the past has generally not considered student mental health to be a priority. CU Boulder, one of the case study campuses for this thesis, has a set of design guidelines that do not mention health, mental health, or even wellbeing (Deno n.d.). This lack of consideration is concerning because the Healthy Minds Study in 2020 found that 39% of university students screen positively for depression, 34% screen for anxiety, and 83% say that their mental health negatively impacts their academic performance ("The Healthy Minds Study" 2020). Overly developed and increasingly non-natural environments might be partially responsible for declining mental health in college students. (Lu and Fu 2019) Stress reduction theory and attention restoration theory suggest that without opportunities to reconnect with natural stimuli between stressful activities, like classes, student mental and physical health is likely to be impacted negatively (Alvarsson, Wiens, and Nilsson 2010; Barton and Pretty 2010; Beckett and Roden 2009; Brown, Barton, and Gladwell 2013; Grahn and Stigsdotter 2010; Stigsdotter and Grahn 2003; Ruso and Atzwanger, n.d.)

Increasing mental health problems among students increase parallel to the architectural departure from traditional university aesthetics. Allan Greenberg argues that sometime between 1940 and 1960, university architecture abandoned historical traditions of design that contributed to the sense of place that students feel. He posits that college buildings have lost their connection to their environments and embraced an aesthetic that fails to acknowledge local contexts in favor of a popular international style (Greenberg 2007). Greenberg contradicts research conducted by Michael Bennett and Stephen Benton that sought to determine how first-year students feel about the architecture of their college campuses. Bennet and Benton surveyed students to learn their opinions about how design impacts their evaluation of individual success, the potency of the environment, and stimulation of the environment. This study found that students generally attributed a greater likelihood of individual success to examples of contemporary architecture than historic architecture (Bennett and Benton 2001). This contradiction implies that contemporary campus environments should approach design with lessons from historical influences in mind and a willingness to innovate and implement novel ideas, like biophilia.

The lack of attention restoration opportunities in educational environments has prompted architects and designers to introduce nature into the built environment. Several studies and articles have already begun to address problems caused by campus architecture by connecting students to natural elements like gardens and greenspaces. One experiment conducted by Jim Determan et al. explored the potential impacts of connectedness with nature in middle school classrooms. They introduced a more substantial visual connection to nature by installing solar responsive blinds and various biomorphic forms in the carpet and ceiling. After comparing students' behaviors and attitudes in the natural classroom to a control classroom, the research concluded that biomimetic design features could enhance the learning process and improve student performance (Determan, n.d.). Another thesis examines the benefits

of converting campus streets to pedestrian malls with an increased natural presence to encourage restoration. J. DeVault proposes a strategy for reclaiming campus streets and making them into "garden streets" to promote physical activity and improve mental wellbeing (DeVault 2015). These approaches generally rely on pleasant weather and active vegetation throughout the year. This gap presents a need for new research that applies to campuses in winter climates.

Research on the topic of biophilia has explored potential impacts on college campuses but has generally lacked evidence and objective support. Terri Peters and Kristen D'Penna conducted a literature review in 2020 that argues biophilic design is an understudied but potentially highly impactful strategy for improving the quality of built environments, specifically college campuses in Canada. Peters and D'Penna consider several theories in their approach: restorative environmental design, place attachment theory, attention restoration theory, stress reduction theory, and prospect refuge theory. Their results conclude that studies of biophilic design related to college landscapes lack design-specific findings. They propose a set of brief guidelines for choosing which biophilic benefits are most relevant in different areas of campus (Peters and D'Penna 2020). A journal article by Mohamed Abdelaal attempts to apply the principles of biophilia to the planning of college campuses. It suggests dividing universities into separate zones, each stressing a different benefit of connection with nature (Abdelaal 2019). Neither of these studies offers science-driven solutions to student mental health issues. Instead, they focus on the environmental and general wellbeing benefits of Browning and Cramer's 14 patterns of biophilic design, which lack specificity and empirical proof of concept.

Classes, tests, quizzes, and lectures demand a high degree of focus and attention. Stephen Kaplan argues that the specific type of attention needed for academic or scholarly activities is different from the attention needed to experience nature (Kaplan 1995). Directed or voluntary attention pertains to tasks that are "against the grain" or attention that requires effort. Academic environments require students to employ directed attention consistently for long periods, leading to attention fatigue. Avik Basu et al. describe things that demand directed attention as hard stimuli and suggest an opposite that provides restorative benefits, soft stimuli (Basu, Duvall, and Kaplan 2019). Soft stimuli require little effort to perceive and understand while providing room for reflection and restoration of mental bandwidth, such as familiar natural elements. The research conducted in this thesis aims to find ways to include soft stimuli in the landscapes and built environments that students occupy between classes, allowing them to restore attention and recover from stress before engaging in more demanding activities.

3.3 Biophilia; History and Trends:

The contemporary understanding of the term biophilia was developed in 1984 by Edward O. Wilson, but the practice of biophilic design has existed implicitly since the beginnings of human civilization (Ramzy 2015). Wilson defines biophilia as "the urge to affiliate with other forms of life," which was not a new idea but a new definition. Steven Kellert and Edward Wilson claim that historic architecture exhibits a deep connection with nature and natural systems. This connection was not engineered for psychological benefits or sustainability but was necessary. The only means for ventilation, lighting, and heating, were natural, so early civilizations learned to capitalize on the pre-existing natural processes in their environments. Additionally, the

gardens of ancient Egyptian nobility, Persian settlements in Mesopotamia, and merchants in medieval China suggest that early civilizations went to great lengths to maintain a constant connection to nature (Kellert and Wilson 1993). The necessary connection to nature diminished over time as human technology advanced. Eleanor Gullone argues that this disconnect culminated during the industrial revolution (Gullone 2000). The practice of architecture after World War II was radically different from historic design because there was no longer a dependence on nature to solve human problems (Ramzy 2015).

Edward Wilson's book, Biophilia, was significant because it was one of the first attempts to develop an explicit understanding of the benefits of biophilia. In 1993, The Biophilia Hypothesis, edited by Edward Wilson and Stephen Kellert, connected biophilia to the developing fields of environmental and evolutionary psychology. A chapter by Roger Ulrich suggests that the root of biophilic tendencies lies in human evolution. Aesthetic preferences and emotional responses to natural stimuli are linked to survival instincts. For example, people exhibit attraction to tall trees with large canopies that provide shade and views and do not allow threats to hide behind them (Ulrich, 1993) (Kellert and Wilson, 1993).

In the early 2000s, architects began drawing on biophilia to inform novel frameworks for architectural practice. Bob Berkebile and Jason McLennan wrote The Living Building: Biomimicry in Architecture, Integrating Technology with Nature inspired by Janine Benyus and Stephen Kellert. They outline a process and goals for developing biophilic buildings that act as living structures, interacting with nature and their environments to form mutually beneficial hybrid systems (Berkebile and McLennan, n.d.). This framework does not go into specific detail regarding climates, building typologies, scale, or region.

In 2008, more researchers began applying the principles of biophilia to the design field. Stephen Kellert, Judith Heerwagen, and Martin Mador edited writings from a group of architects and designers and published Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life. This collection began to focus on more scientific and architectural approaches to biophilia. In this book, Janine Benyus writes about biomimicry and the reintroduction of nature as a guide and inspiration for architectural form and function. She agrees with Ulrich's argument that aesthetic preferences stem from thousands of years of evolution and suggests that biomimicry presents a biophilic design strategy to satisfy contemporary architectural practice's functional and aesthetic needs (Benyus, 2008). Nikos Salingaros and Kenneth Madsen II corroborate her claims and draw from neuroscientific theory to argue that subconscious biophilic tendencies loosely inform all architectural designs. Capitalizing on a conscious understanding of biophilia can increase its potential benefits for mental and physical wellbeing (Salingaros and Madsen, 2008).

At the same time, architects and designers started exploring specific architectural details that provide the benefits of biophilia. Also in Biophilic Design, Vivian Loftness and Megan Snyder discuss the functions of windows beyond just daylighting and views. They claim that windows offer opportunities for a more intimate connection to nature even within the confines of architectural space. Open windows allow for breezes, scents, temperature variation, sounds, and more indirect natural stimuli to reach people inside buildings. Loftness and Snyder argue that

natural elements such as these create passive survivability (the potential for a building to maintain life-support conditions without reliance on power, water, and despite extreme weather events), sustainable ventilation methods, and increased wellbeing (Loftness and Snyder, 2008). Martin Mador makes a similar case for the inclusion of water in the built environment. He applies a framework developed by Stephen Kellert in the early 2000s to analyze the benefits of visible water in architectural spaces (Mador, 2008). Terry Hartig, Tina Bringslimark, and Grete Grindal Patil unpack the implications of water, windows, and other biophilic architectural features in discussing the restoration perspective of biophilia. They say that as humans' environments change following technological advancement, there grows an increasing need for continuous adaptation. Excessive demands can undermine that adaptation, so periodic restoration is necessary to mitigate the impact of those demands and enhance opportunities for adaptation (Kellert, Heerwagen, and Mador 2008).

Biophilic Design was a novel analysis of the implementation of biophilia in architecture, but its research lacked objectivity and scientific support. In 2015 Stephen Kellert wrote The Practice of Biophilic Design with Elizabeth Calabrese to fill that gap. Kellert and Calabrese draw upon psychological studies of fear to argue that human behavior and mental health are closely tied to adapted and evolved responses to natural stimuli. They cite a study conducted by Arne ÖHman published in 1986, proving that people respond more strongly to perceived dangers in the natural environment, like snakes or spiders than dangers in the engineered environment, like frayed wires or handguns (ÖHman 1986). Calabrese and Kellert claim that this biological response indicates that human behavior is strongly influenced by evolved and adapted responses to natural stimuli. After establishing this scientific basis for the effectiveness of biophilia in the architectural context, Kellert and Calabrese proposed three meaningful experiences and attributes of biophilic design: direct experience of nature, indirect experience of nature, and experience of space and place. They argue that although people experience nature with all of their senses, the most prominent human interaction with nature is visual (Kellert and Calabrese 2015). Kellert and Calabrese go more in-depth into each of the outlined attributes of biophilic design, discussing the benefits of each and presenting some examples in architecture. Kellert and Calabrese's three attributes of biophilic design are derived from Jennifer Cramer's and William Browning's three categories of biophilic design – nature in the space, natural analogs, and nature of the space – proposed in 2008.

The word 'biophilia' is often misused or misunderstood. It is frequently associated with simply the inclusion of plants and life in design, which does not offer suggestions for biophilic spaces in cold climates. This thesis will explore design strategies implemented in climates that cannot rely on live vegetation for year-round access to mental health benefits. Most of the existing research about biophilia pertaining to architecture is based on subjective studies and theory. The term "wellbeing" is used frequently without a precise definition, which I believe is one of the reasons biophilic design is not standard practice in architecture and landscape architecture (Browning, Ryan, and Clancy 2014; Gillis and Gatersleben 2015; DeVault 2015; Joye 2007; Abdelaal 2019; Ryan et al. 2014; Kellert, Heerwagen, and Mador 2008; Krčmáčová, n.d.; Kellert and Wilson 1993). The research in this thesis attempts to first understand biophilia through the lenses of

psychology and physiology before applying it to design.

Beginning in the early 2010s, Browning and Terrapin Bright Green began articulating 14 patterns of biophilic design which have been used almost exclusively as a guide for designing and determining the biophilic success of built spaces. They address different features of biophilia and their benefits, supported by scientific research and analysis of a few case studies. The 14 patterns of biophilia are as follows:

Visual connection with nature is a direct view of natural elements, systems, or processes. This can be either from within a building or simply being outside.

Non-visual connection with nature is the experience of nature through senses other than sight. This includes auditory, haptic, olfactory, or gustatory stimuli that reference natural elements, systems, or processes.

Non-rhythmic sensory stimuli describe "stochastic and ephemeral connections with nature that may be analyzed statistically but may not be predicted precisely" (Browning, Ryan, and Clancy 2014).

Access to thermal and airflow variability is variation in air temperature, humidity, perceivable airflow, and surface temperatures that reflect natural patterns.

Presence of water is the sight, sound, or feel of water in a space.

Dynamic and diffuse light refers to changing intensities of light and shadows that follow a circadian process or other conditions that occur in nature.

Connection with natural systems is the awareness and experience of natural processes, such as seasonal or temporal changes that reflect healthy ecosystems.

Biomorphic forms and patterns are references to naturally occurring textural, patterned, or numerical arrangements.

Material connection with nature is the experience of minimally processed local materials that reflect local life and geology and generate a sense of place.

Complexity and order describe "rich sensory information that adheres to a spatial hierarchy similar to those encountered in nature" (Browning, Ryan, and Clancy 2014).

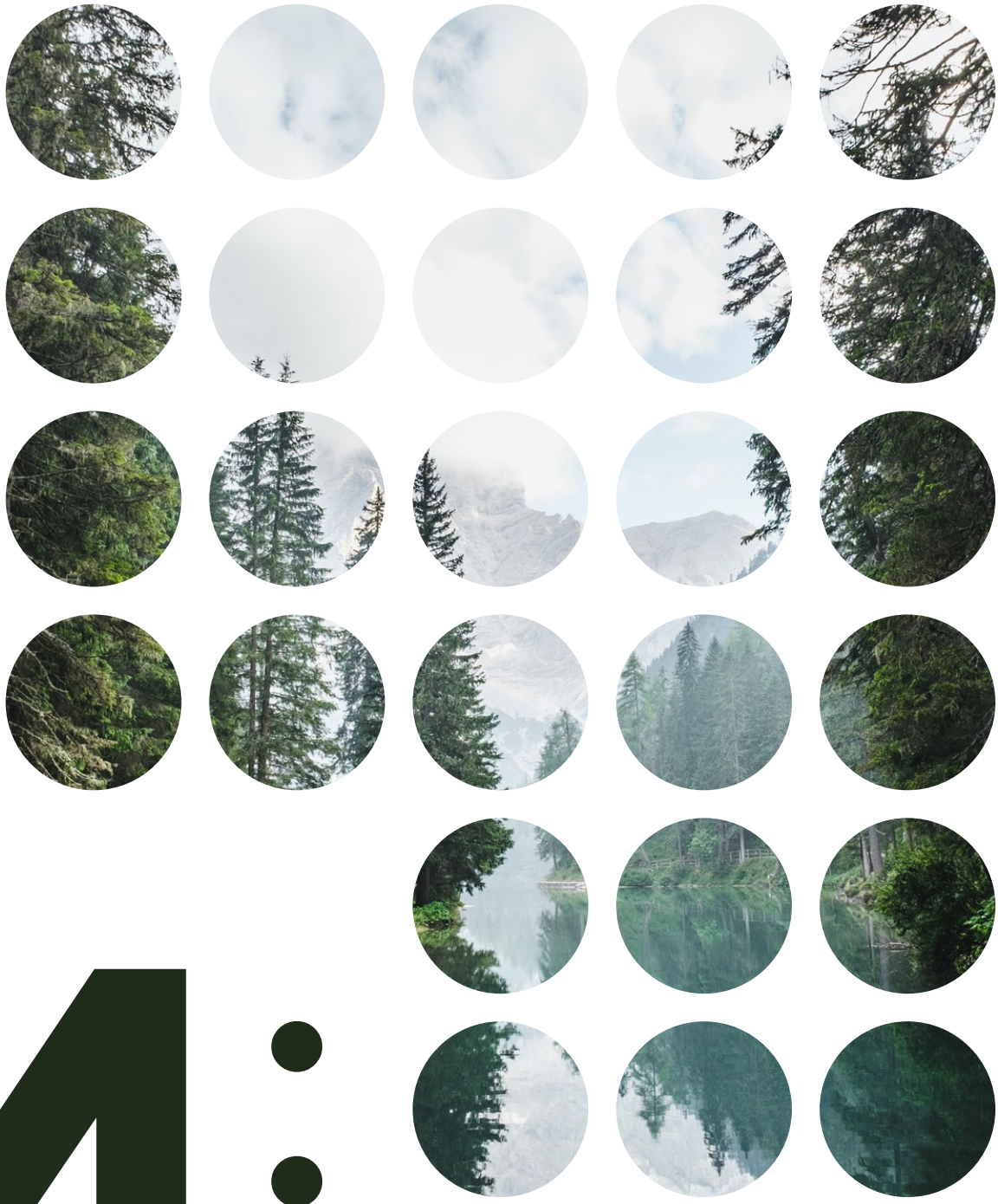
Prospect is distant views without obstacles that allow for surveillance and planning. This pattern has been found to aid in heart rate recovery, attention restoration, and stress reduction.

Refuge is the seclusion from the main flow of activity or prevailing environmental conditions with protection from behind and overhead.

Mystery is "The promise of more information, achieved through partially obscured views or other sensory devices that entice the individual to travel deeper into the environment." (Browning, Ryan, and Clancy 2014)

Risk and Peril are a perceived threat and present protection.

Most of the recent work relating environmental design to biophilia has used Browning's and Clancy's 14 patterns as a framework for evaluating successful spaces. (Browning, Ryan, and Clancy 2014; Loftness 2020) Some would argue that these patterns are underdeveloped and lack significant scientific support. (Peters and D'Penna 2020) My methodology draws upon attention restoration psychology and physiology as the sources of my framework to resolve this gap.



4: METHODS

4. Methods

Initially, I planned to use the 14 Patterns of Biophilia as a guide for measuring how restorative different campus environments are. It quickly became apparent that this set of conditions was too vague to be observed without bias or subjectivity. Additionally, the 14 patterns are not explicitly focused on the mental health benefits of biophilic design, meaning they are not entirely relevant to my question. To resolve this issue, I developed a new set of objectively identifiable, measurable, scientifically supported principles of natural connectedness for restorative design. This new matrix translates Browning's and Clancy's 14 patterns into a more applicable and defensible list of conditions. Rather than using abstractions of experimental psychological findings to defend my ideas, the items included in my principles are directly founded in attention restoration and stress recovery psychology and informed by the 14 patterns of biophilia. Using these criteria as a framework for ideal design, a set of 34 sites on five college campuses were observed with the intent of determining whether or not they present certain biophilic conditions that allow for attention restoration and stress recovery.

Visual connection with nature: Daniel Brown, Jo Barton, and Valerie Gladwell examined parasympathetic patterns after a stressful activity with and without a visual connection to nature. They discovered that parasympathetic activity was significantly higher in recovery after the stressor that followed viewing a natural scene. This research suggests that a visual connection to nature improves the recovery process after enduring stresses (Brown, Barton, and Gladwell 2013).

An article by Agnes van der Berg, Terry Hartig, and Henk Staats published in 2007 explored the psychological reasoning behind the preference for nature in urban settings. Their research concludes with a proposal to introduce nature to ensure social and environmental sustainability in dense and urbanized areas (van den Berg, Hartig, and Staats 2007).

A study conducted by Yuko Tsunetsugu and Yoshifumi Miyazaki in 2005 used near-infrared time-resolved spectroscopy to measure hemoglobin concentration in the prefrontal region in different environments. They found that the prefrontal region was calmer in forest environments than in cities. Participants' cortisol levels were lower during and after being in a forest than in a city (Tsunetsugu and Miyazaki 2005).

Xiaomin Yue, Edward Vessel, and Irving Biederman used magnetic resonance imaging to observe activity in the parahippocampal cortex, which was higher after viewing natural scenes than less preferred environments. Their findings suggest that visually experiencing nature is cognitively pleasurable, which is supported by more significant blood-oxygen levels after looking at the images of nature (Yue, Vessel, and Biederman 2007).

A multi-study analysis by Jo Barton and Jules Pretty in 2010 examined the effects of activity in nature. Barton and Pretty determined that green exercise significantly increases self-esteem in young people, with a similar but less extreme effect in older age groups (Barton and Pretty 2010).

A visual connection to natural elements is an essential component of biophilic campus design. It is often present because it is challenging to entirely remove nature from an environment. Browning's "visual connection with nature" is too broad and ambiguous to be objectively quantified in site observation.

This pattern informs the sight category of my matrix. It is also the primary source of my visible presence of live vegetation principle.

Non-visual connection with nature: Yuko Tsunetsugu, Bum-Jin Park, and Yoshifumi Miyazaki wrote a paper about the Japanese practice of "Shinrin-Yoku," or forest bathing, in 2009. Their research found that the smell of a forest and the sound of rustling leaves trigger the same physiological results as Yue's, Vessel's, and Biederman's studies of responses to visual stimuli involving natural elements. Their results also found a reduction in stress hormones and systolic blood pressure in people experiencing wood with a tactile sensation (Tsunetsugu, Park, and Miyazaki 2010).

A study comparing psychophysiological stress recovery and attention restoration in urban and natural environments by Terry Hartig et al. found that anger decreased and positive affect increased while experiencing nature with more senses than just visual (Hartig et al. 2003). A similar study by Elizabeth Orsega-Smith et al. focusing on older adults found that perceived physical and mental health impacts of nature are dependent on the frequency of sensory exposure to nature. In contrast, physiological health measures depend on the context of the natural experience (active vs. sedentary, alone vs. with one or more people.) (Orsega-Smith et al. 2004).

A 2012 paper exploring the impacts of ambient noise on creative cognition by Ravi Mehta, Rui Zhu, and Amar Cheema examined the results of five studies on ambient noise. Their research found that low and moderate natural ambient noises promote abstract processing and enhance performance on tasks involving creativity (Mehta, Zhu, and Cheema 2012).

A study conducted at the New York University Medical Center observed the effects of lavender essential oils on postoperative patients compared to patients who had undergone the same surgery but were not treated with lavender oil. The study found that the lavender group required significantly less morphine during recovery than the control group. These results suggest that the olfactory experience of natural elements can assist pain management (J. T. Kim et al., 2007).

Like a visual connection to nature, a non-visual connection is difficult to remove in any environment entirely. In the same way, it is impossible to quantify. Because of this, my research will create separate categories for non-visual senses with sub-items to determine which non-visible elements are most often present in campus design. The principles in this category will be drawn from specifically proven restorative stimuli that have been researched and proven effective in the studies above.

Non-rhythmic sensory stimuli: Peter Kahn et al. worked on a study in 2009 that compared heart rate recovery from stress when viewing nature through a window, looking at a screen with a real-time stream of the same natural scene, or looking at a blank wall. They discovered that while looking at the screen and through the window both caused heart rates to recover faster than looking at a blank wall, the effect of the window was more significant (Kahn et al. 2008). This study's findings suggest that unpredictable and unmeasurable factors contribute to the benefits of exposure to nature that are not mimicked by an exclusively visual connection.

My research will not include this pattern due to the difficulty of objectively identifying non-rhythmic sensory stimuli. Future studies on

this topic with more resources would be better equipped to incorporate this idea.

Access to thermal and airflow variability: A paper by K. Tham and H. Willem analyzed the performance of call center workers in the tropics in different temperature and airflow conditions. They found that when exposed to increased outdoor air, the workers' performance improved between 7% and 9%, even without a temperature change (Tham and Willem 2005).

Hans Wigö conducted a study that aimed to examine the impact of dynamic indoor climates on humans' psychological and physiological health. The research found that intermittent air velocity variation can make people more comfortable with higher temperatures, reducing the need for excess air conditioning. He also determined that performance on a short-term memory test was better with people who had experienced variations in airflow than people under consistent airflow conditions (Wigö 2005).

The studies mentioned here establish that any noticeable variation in airflow and temperature has a measurable positive effect if not uncomfortable. This pattern is an objectively identifiable specific condition, so it will be included without change as one of my principles of natural connectedness. Because my matrix is divided into categories based on senses, this pattern will be grouped in with other items in the "touch" category because airflow and thermal variability are experienced haptically.

Presence of water: Jesper Alvarsson, Stefan Wiens, and Mats Nilsson conducted a study in 2010 that tested skin conductance levels in participants who completed a stressful test and then listened to natural sounds like running water. They found that the sounds help facilitate recovery from sympathetic activation after a psychological stressor (Alvarsson, Wiens, and Nilsson 2010).

A study by Robert Pheasant et al. observed the effects of vision and audition of water on tranquility. They found that the presence of water in a space can significantly increase an occupant's perceived tranquility both during and after their time in the space (Pheasant et al., 2010).

Yue's, Vessel's, and Biederman's study of blood-oxygen levels while experiencing nature supports these findings with empirical evidence. Their study found that exposure to a natural scene with water contributed to lower heart rate and improved pleasure (Yue, Vessel, and Biederman 2007).

An experiment to determine whether or not these results were accurate for water outside of a natural scene was conducted in 2010 by Mathew White et al.. The study explored affect towards water in urban settings and natural ones, finding that the general presence of water in either setting results in higher preference and higher perceived restoration than both natural and urban scenes without water (White et al. 2010).

Bernhart Ruso and Klaus Atwanger argue that this preference for water stems from evolutionary adaptation. They claim that water has consistently indicated the presence of necessary resources, and as such, humans are biologically drawn to it (Ruso and Atzwanger, n.d.).
Water is one of the most challenging patterns to implement in cold climates because freezing temperatures complicate manufactured water features. This research suggests that water is beneficial when experienced visually, haptically, and auditorily. Therefore, my matrix will include items for experiencing

water in each sensory category. This categorization will help determine which sensory water experience is most present on college campuses.

Dynamic and diffuse light: M. Beckett and L. C. Roden discuss literature that claims disruption of circadian rhythm may lead to cancer and other adverse health effects. They argue that human evolution in a rhythmic environment has established circadian rhythms in our metabolism, behavior, and physiology. Disrupting this rhythm can cause negative impacts on mental and physical health through the misregulation and uncoupling of cellular and physiological processes (Beckett and Roden 2009).

An experiment conducted by S. Y. Kim and J. J. Kim found that artificial light systems can cause annoyance and increase eye fatigue and distraction (S. Y. Kim and Kim 2007). Since my case studies will be outdoors, this pattern should always be present. Even so, it will be included as an item in my sight-based category for the possible event that a site is so enclosed that its users cannot experience circadian systems.

Connection with natural systems: Research in this category is founded entirely on perceived and subjective responses. I cannot include this pattern in my matrix because I can neither defend nor objectively identify it.

Biomorphic forms and patterns: This pattern is supported by the research presented in the visual connection with nature section. It is translated into an item in the sight category of my matrix with a strict definition for replicability.

Material connection with nature: A study by Tsunetsugu et al. observed the effects of wood in a space by measuring people's responses to varying amounts of wood in a room. There was no observed change in autonomic nervous activity in a room with no wood. In contrast, in a room with 45% of the visible area as wood, there was a significant decrease in diastolic blood pressure and an increase in pulse rate. Participants also identified the room with 45% wood as the most subjectively comfortable. In a room with 90% of the visible area being wood, a significant decrease in systolic blood pressure was noted, and over time a decrease in brain activity was observed (Tsunetsugu, Miyazaki, and Sato 2007).

An experiment conducted by Stephanie Lichtenfeld et al. tested the effects of green light on creativity. They briefly exposed participants to a glimpse of achromatic and chromatic green light before assigning them a creative task. The findings suggest that green improves creative cognition and has implications beyond aesthetics (Lichtenfeld et al., 2012).

My research will include material connections with nature in sight and touch categories. This categorization will allow me to determine which sensory experience of natural materials is most often present

Complexity and Order: This pattern is nearly impossible to identify objectively without more resources, time, and ability. I will not include an item for complexity and order in my matrix because it would be biased and subjective.

Prospect: Birgitta Gatersleben and Matthew Andrews conducted a study in 2013 that observed heart rate recovery and perceived restoration in environments with high levels of prospect versus low levels of prospect. Participants were given a mentally fatiguing task before walking along one of two trails, one with a large amount of prospect and

one with minimal prospect. The order in which participants took the different trails was randomized, and their heart rates were measured before and after each procedure step. Gatersleben and Andrews found that heart rate recovery happened significantly faster after participants walked along the prospect trail instead of the low prospect trail, regardless of the order they took them in. Their study also gauged perceived attention restoration, affect, and stress levels. The results indicate that prospect increases attention restoration, lowers stress, and promotes positive affect (Gatersleben and Andrews 2013)

My research will not include prospect because it cannot be objectively defined. The results of experiments studying the effects of prospect vary by person depending on their backgrounds and familiar environments, making it impossible to quantify.

Refuge: Because the experience of refuge is subjective, and there is minimal concrete evidence supporting its potential for attention restorative properties, my matrix will not include this pattern.

Mystery: Mystery is experienced subjectively, and there is not enough existing research to define it in a way that allows me to measure its presence objectively. Therefore, I will not include mystery as an item in my matrix. There is also minimal research that empirically proves that mystery in the built environment is psychologically beneficial.

Risk/Peril: This pattern cannot meaningfully be included in my research for the same reasons as mystery.

4.1 Categorization of New Conditions

The development of these conditions provides an objective framework for quantifying the biophilic success of built environments. These principles of natural connectedness will be used to determine whether or not college campuses provide opportunities for attention restoration and stress recovery based on proxy research in psychology and physiology. The conditions I looked for are sorted into three categories based on senses. I will focus on features that can be experienced with sight, hearing, and touch. Taste and smell will not be a part of my research because there is not enough existing scientific data to define tastes and smells that objectively provide the benefits I am studying.

4.2. Conversion from the 14 Patterns of Biophilic Design to Principles of Natural Connectedness:

14 PATTERNS OF BIOPHILIC DESIGN:	INFORMED PRINCIPLES OF NATURAL CONNECTEDNESS
 VISUAL CONNECTION WITH NATURE	1 2 3 4 5 6 7
 BIOMORPHIC FORMS AND PATTERNS	1 5 7
 DYNAMIC AND DIFFUSE LIGHT	7 14
 PRESENCE OF WATER	2 9 13
 CONNECTION WITH NATURAL SYSTEMS	3 4 7 10 11 14
 MATERIAL CONNECTION WITH NATURE	5 15
 ACCESS TO THERMAL AND AIRFLOW VARIABILITY	11 14
 NON-VISUAL CONNECTION WITH NATURE	8 9 10 11 12 13 14 15

UNUSED PATTERNS:

 PROSPECT

 MYSTERY

 COMPLEXITY AND ORDER

 RISK/PERIL

 NON-RHYTHMIC SENSORY STIMULI

 REFUGE

4.3. PRINCIPLES OF NATURAL CONNECTEDNESS:

Sight Category

1 PRESENCE OF LIVE VEGETATION

This condition is solely visual, so its success in any given site will be determined by whether there is visible plant life. It's important to note that plants presented in small doses are significantly less impactful than consistent vegetation, so this condition will be met only if there is live vegetation visible at all points along the path.

2 VISIBLE WATER

This condition will be met if water can be seen from anywhere along the chosen path. Since it will be impossible to observe each site during the exact same weather, I'll also look for precipitation management strategies that retain water on a site rather than draining it as quickly as possible. These strategies will be explicitly described in my findings, but there is still the possibility of observational error in this category. Water present on sites in places where it is not intended to be won't count, because it does not signify a designed condition. For example, a wet sidewalk on its own does not count, but snowmelt dripping down a gutter does. Additionally, there is little research which effectively proves that snow offers the same benefits as liquid water, so snow will not meet this condition.

3 VISUAL INDICATION OF WILDLIFE

In the sight category, this condition is only met if there are visible signs of wildlife presence on the site. Birds' nests, animal tracks, or visible animals are examples of success in this condition.

4 EVIDENCE OF WEATHER AND SEASONALITY

Visual indication of seasonal change, such as fallen leaves, dormant trees, or seasonal weather. This condition will be considered met if the visual appearance of the site during winter when I observe it is significantly different from its appearance during other seasons. Since I am only collecting data in the winter, I will note the indications of seasonal change that I believe meet this condition in my findings.

5 VISIBLE NATURAL MATERIALS

This condition will be met if natural materials are visible along the entire extent of the selected path. "Natural materials" refers to minimally processed materials that appear similarly to the way they would if found in a natural environment. This condition will not be met if the only visible natural materials are vegetation. Given that there is a possibility for observational bias, I will identify examples of the natural materials I encounter in my findings.

6 BIOMORPHIC FORMS

References to naturally occurring textural, patterned, or numerical arrangements. Because the success of this condition could be influenced by my personal opinions, I'll document specific features that I believe do or don't meet this criterion.

7 DYNAMIC AND CIRCADIAN LIGHT

This condition will be met if the lighting of the site changes throughout the day. An example of a situation in which this pattern would not be present is in an entirely shaded site with artificial or no lighting, like a tunnel or path along a north facing wall without breaks.

Sound Category

8 AUDIBLE VEGETATION

Rustling leaves, tree branches, or other sounds created by plant life. This could be either dormant or non-dormant plants. Noises caused by a person or animal behaving regularly in the space, like stepping on leaves or branches, will count for this condition. Artificial vegetation sounds satisfy this condition

9 AUDIBLE WATER

This condition is not dependent on visible water. It will be met by any type of audible experience of water, including naturally running water, fountains, drips, etc. Artificial water sounds satisfy this condition.

10 AUDIBLE WILDLIFE

Audible indications of wildlife. This condition will be met if any form of animal is audible from any point along the path. Artificial animal sounds satisfy this condition.

11 WIND/WEATHER

This condition does not have to be felt, only heard. It will be successful if wind or weather phenomena are audible at any point along the selected path.

Touch Category

12 HAPTIC EXPERIENCE OF VEGETATION

A tactile connection to plants at any point along the selected path. This could be either dormant or non-dormant vegetation, if it can be interacted with without leaving the path.

13 HAPTIC EXPERIENCE OF WATER

A tactile connection to water at any point along the selected path. This condition includes precipitation, so even if there is no way to touch water along the path I will note opportunities for experiencing rain or snow.

14 THERMAL AND AIRFLOW VARIABILITY

Noticeable changes in temperature or airflow at any point along the path. This could involve walking in and out of shade, through different microclimates, or past windy spots.

15 HAPTIC EXPERIENCE OF NATURAL MATERIALS

This condition is met by the presence of natural materials that can be touched without deviating from the selected path. Benches, gravel, and rough stones are examples of features that would meet this criterion. This condition will not be considered met if the only tactile connection to natural materials is through vegetation.

4.4. Limitations:

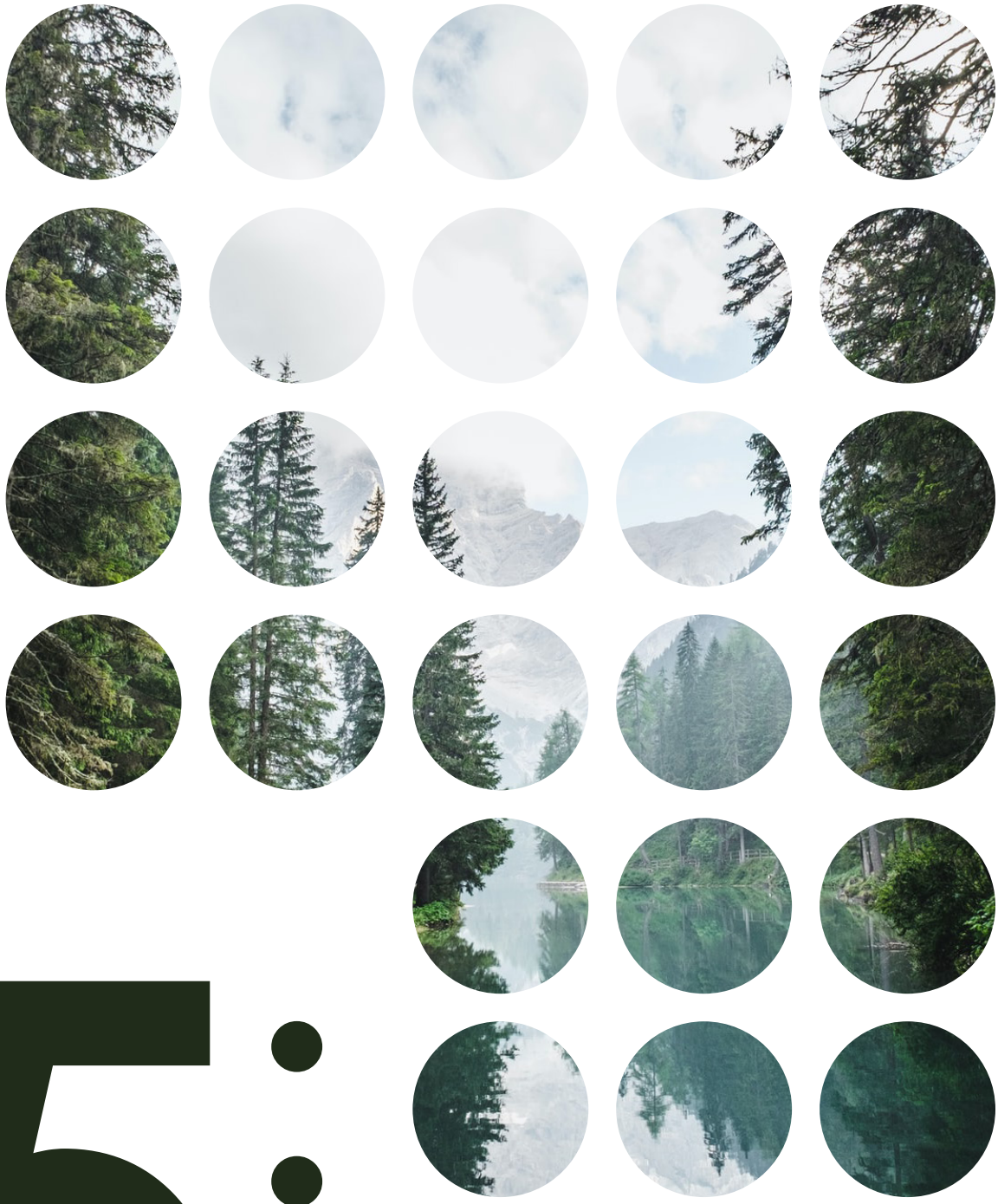
Resources, time, and ability limit this methodology. An ideal research process would involve firsthand measurements of people's physiological responses to the observed sites. However, I have neither the qualifications nor the funding to complete that type of endeavor. The chosen method takes advantage of existing research to maximize the impact of my data and make the most of the time available without needing to complete redundant research.

The conditions outlined in my methodology prioritize the benefits of natural environments on college-aged people. This prioritization means that ideas are presented that are either not proven to have the same effects on different age groups or even have established adverse effects. An example of this is thermal variability. Transitions between sunlit and shaded spaces are often required to achieve variable temperatures along a path. Such a pattern is a positive stimulus for a young person but can make it difficult for older users of the path to see well.

4.5. Case Study Selection and Data Collection Process:

My data collection includes six to seven sites for each of five different college campuses, for a total of 35 sites. The campuses observed are the University of Colorado Boulder, University of Denver, Regis University, Colorado State University, and the Auraria Campus (University of Colorado Denver, Community College of Denver, and Metropolitan State University). These campuses represent a collection of large, small, public, and private schools in high-density urban, low-density urban, and suburban contexts. All five schools are located in Colorado in climates with consistently freezing temperatures during the winter. The chosen paths on each campus connect different academic and essential programs. These programs include lecture halls, classrooms, and research environments. The paths are distributed throughout the majority of the academic regions on each campus. All observed sites are ADA accessible, open to the public, and within high pedestrian traffic areas. The observation process for each path involved walking the extent of every route four times; once forward, once backward, and once forward again for all the sites in order, then one time walking through all of the sites again later in the day. My observations took place at various times between November 20th, 2021 and February 7th, 2022. All of the campuses were visited from approximately 10:00am to 6:30pm on days without overcast conditions or precipitation.

Maps of the selected campuses and the paths observed on them can be found in the appendix alongisde the data collected at each location.



5: FINDINGS

5. Findings:

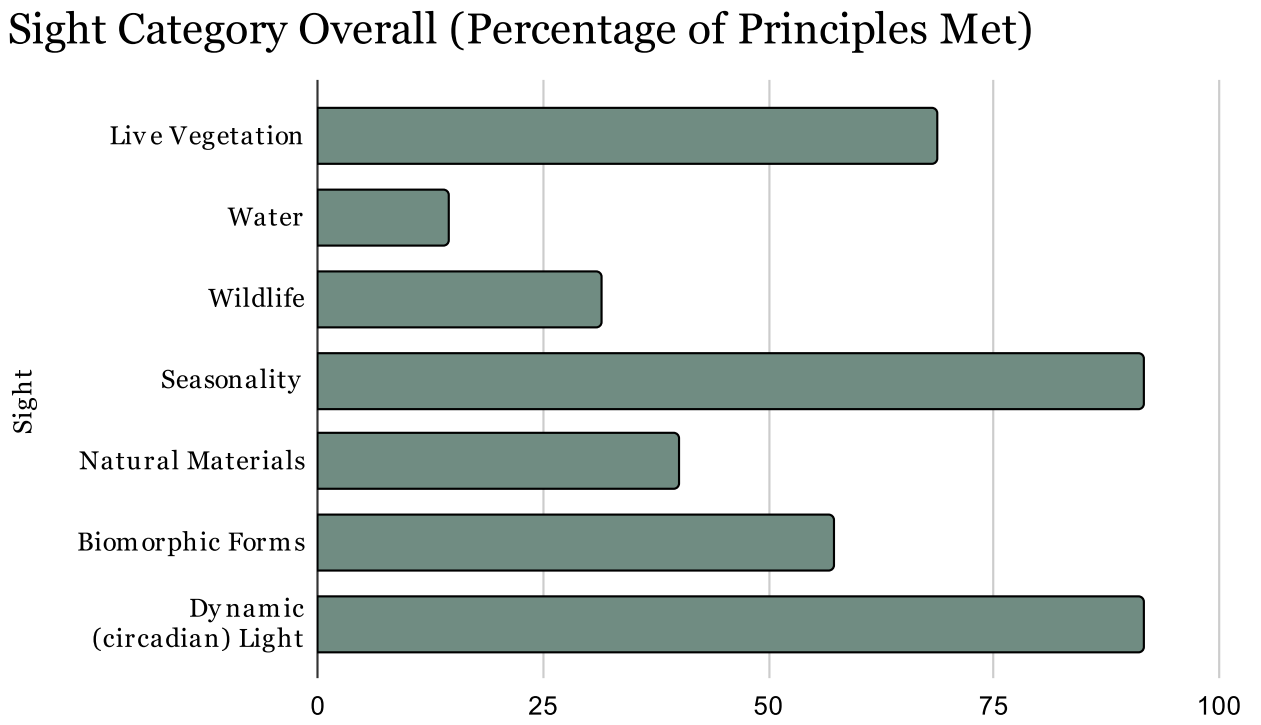


Figure 5.1.1: Graph of Sight Principles

5.1 Sight:

The most surprising finding is that only 68.5% of the observed sites met the criteria for the presence of live vegetation. While this is still a reasonably high number compared to most of the other results, it is still much lower than expected given visible plants' well-known and well-researched benefits. I will note that 91.4% of the sites had some form of vegetation present, but the ones that failed to meet the outlined conditions all failed because there were no non-dormant plants. This criterion should be prioritized in designing and retrofitting universities in cold climates.

14.3% of the sites had visibly present water. This statistic is not difficult to understand because intentional water features are a challenge to implement and maintain in regions where temperatures often drop low enough for water to freeze and damage pipes and other infrastructure. The places where water was most often visible were stormwater management systems like gutters and channels, which still meet the requirements for this principle.

There were visible indications of wildlife in 31.4% of the sites observed. The most frequently present animals were geese and squirrels.

Weather and seasonality were evident in 91.4% of the sites. The only ones that did not meet this condition were those without vegetation. Most of the failing sites had some form of enclosure, likely to protect from wind and precipitation.

Unfortunately, only 40% of the paths met the natural materials requirements. In some cases, building guidelines can explain this, like CU Boulder. The school prohibits wood and any other materials that cannot last 100 years without maintenance in outdoor environments.

57% of the sites met the requirements for biomorphic forms, which is surprising. While planning the routes I observed, I noted that most paths on the selected campuses are rectilinear, which led me to believe biomorphic forms would not be very present. Interestingly, most sites with one instance of biomorphic forms had many others, and they often appeared in regions of campuses that look to be the oldest parts.

94% of the sites exhibited dynamic light. While this is a substantial majority, it is still disappointing given how difficult it is to remove evidence of the sun along a path entirely. The single site that failed to meet this criterion was a narrow but popular path on the north side of a long building with an overhang on the Auraria campus.

5.2 Sound:

Audible vegetation was present in 42.9% of the observed sites, significantly less than the percentage of sites that included visible live vegetation. Because coniferous trees do not make much noise, the most prevalent sound of vegetation was rustling dead leaves from deciduous trees.

28.6% of sites had audible water, twice as many as those with visible water. Not all of the instances of visible water were audible, and most of the sites with audible water had no visible water. This discrepancy is because

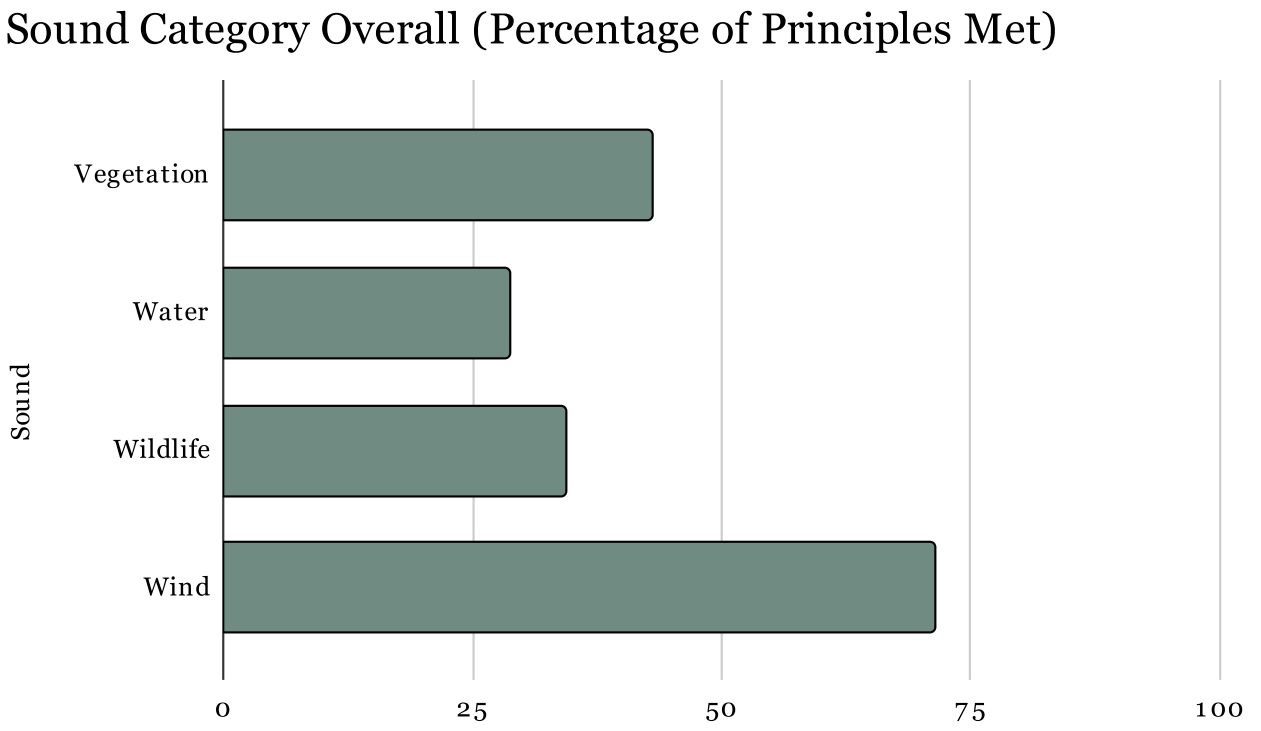


Figure 5.2.1: Graph of Sound Principles

almost every audible water feature was drainage infrastructure like channels under sidewalks or closed gutters.
34% of the sites presented audible wildlife, and in every case, the audible wildlife was geese. This finding is interesting because geese are most present during fall and winter and less evident during the summer, which is the opposite of most of the other conditions in this list.

The wind was audible in 71.4% of the sites I observed.

5.3 Touch:

There was no tactile connection to vegetation on any of the observed sites. This finding is not surprising because forced or encouraged interaction with plants is perceived as an inconvenience in most cases.

The only haptic experience of water was splashes from snow melt dripping out of a gutter.

Thermal variability was evident in 62.9% of the sites. The places that did not meet the criteria for this principle were those with either consistent shade or no shade at all.

28.6% of the observed sites offered a haptic experience of natural materials. This statistic means that most natural materials on the selected campuses are located close to paths, which is ideal.

The full tables of my observations are included in an appendix.

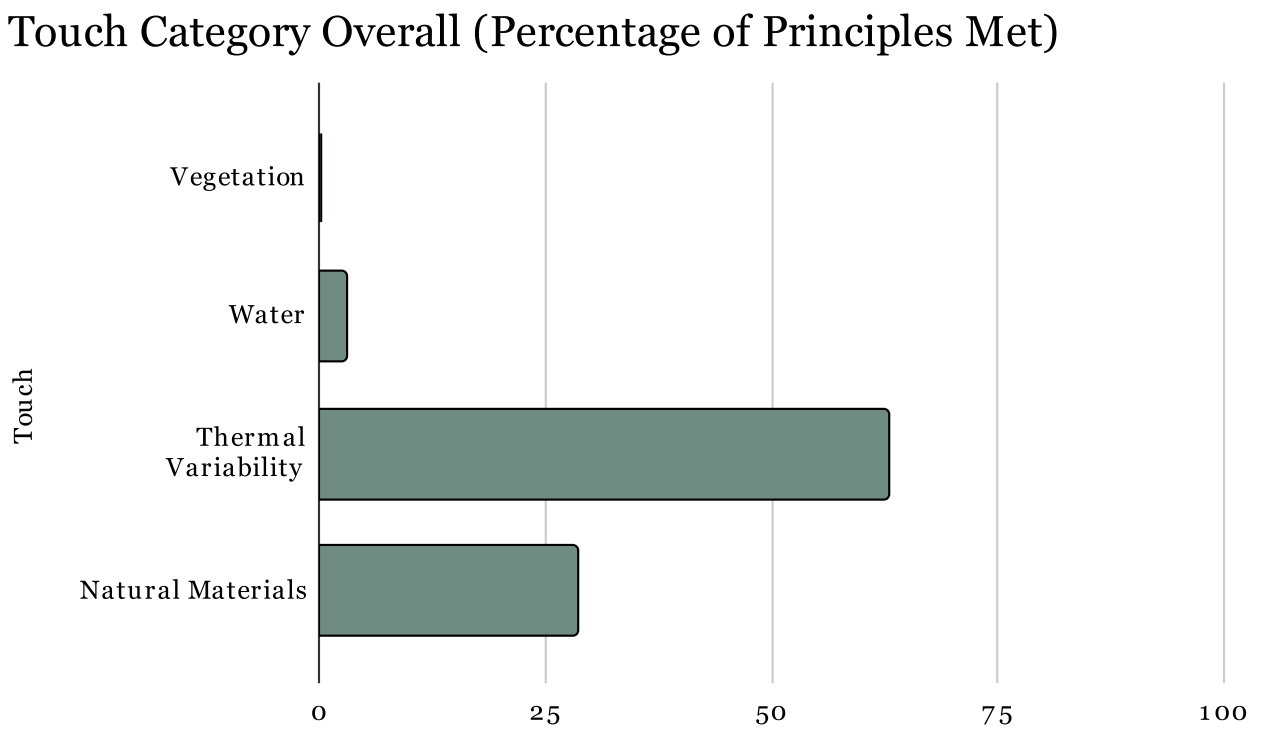
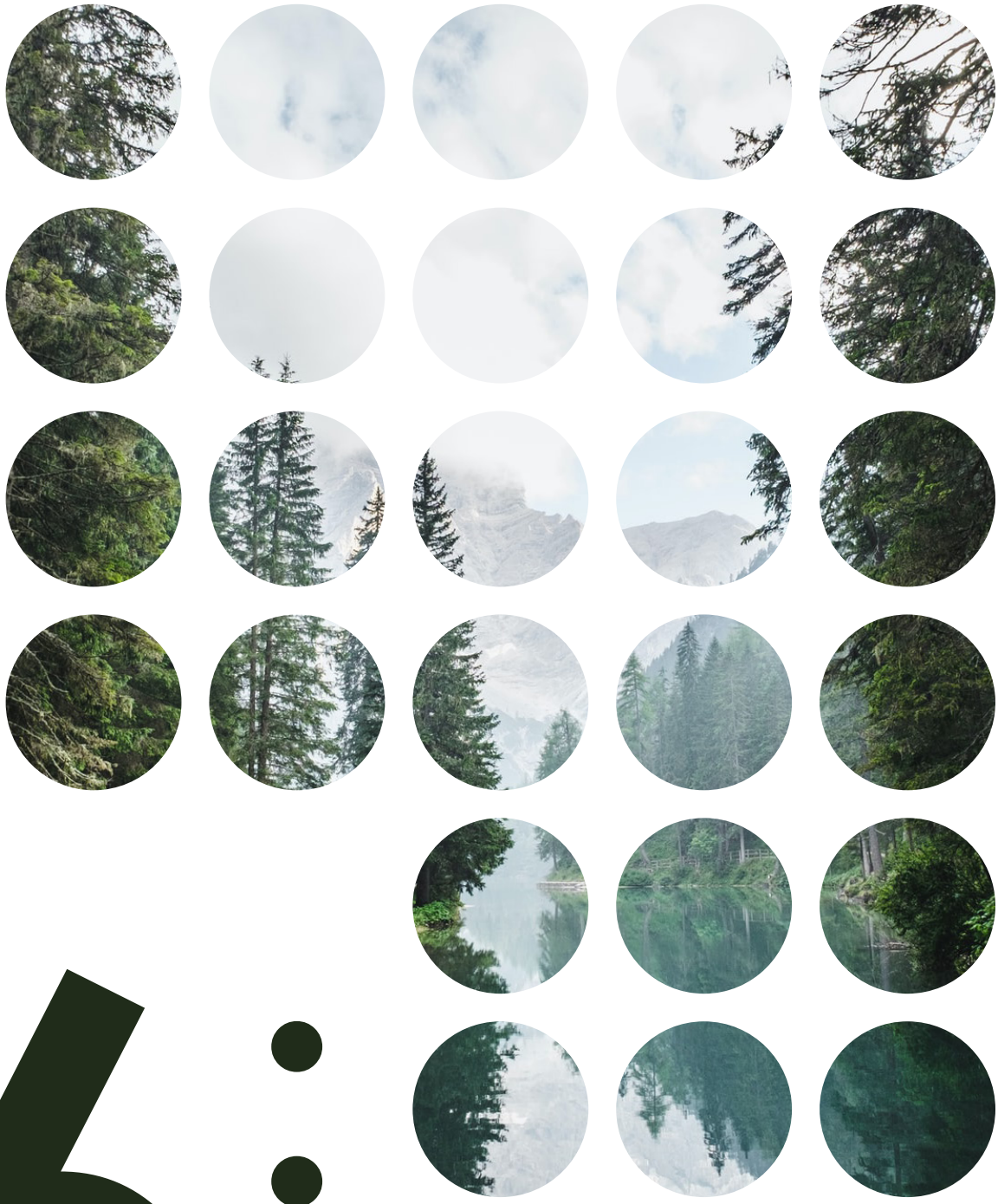


Figure 5.3.1: Graph of Touch Principles



6: DISCUSSION

6. Discussion:

This research is intended to determine whether or not college campuses offer students opportunities for attention restoration. Based on the findings above, the short answer is yes. However, these observations also found that campus environments could be better. One flaw in the methodology of this project is the lack of a process for weighing the principles of natural connectedness. Since there is not yet a system that enables the objective comparison of the success of these principles to one another, it is impossible to determine which sites are the most successful.

Regardless, the findings presented in the previous section indicate a need for significant changes in the way universities are designed. The studies discussed in developing the 15 principles for natural connectedness prove that a higher quantity of soft stimuli is more effective in psychological health restoration. Therefore, since no single site presented all 15 of the proposed principles, every site observed has the potential to be improved. This trend across different types of campuses in various contexts suggests that most university campuses in the region lack some of the conditions necessary to restore students' cognitive facilities.

Because all but one of the principles of natural connectedness were present on at least one of the observed sites, this thesis offers suggestions for the practical implementation of restorative stimuli in built environments based on the successful instances of natural connectedness observed.

One of the features with the highest impact on the observation process was stormwater and snowmelt management infrastructure. Since the experience of water is an item in each of the three sensory categories, water features that can be experienced visually, haptically, and auditorily are essential. Water is a problematic element to include in environments where the temperature often drops below freezing, so built water features must satisfy all three principles of natural connectedness that involve it. This overlap was not usually accomplished on the observed sites. The only instance of visible, audible, and haptically experienceable water was a gutter dripping close to a sidewalk that splashed my legs as I walked by. As simple as this feature is, it still meets the criteria for all three water-related principles of natural connectedness.

While the principles involving water could all be satisfied with a single design feature in most cases, the vegetation items are not as simple. The instances of live vegetation on the observed sites were never audible or haptically experienceable. All of the cases of audible vegetation were dormant trees, bushes, and dead leaves. This means that campus settings should include various plant types that respond differently to seasonality. There must be a majority of evergreen vegetation, meaning the site looks alive all year, but there is also a need for trees to place the site in time and make noise. Light and shade must also be considered in tree placement, as they can be important in regulating thermal variation.

The natural materials principle was most often met by outdoor furniture, such as benches or large rocks along paths. Despite almost every site having some form of seating, just over 25% of the paths included seating made from natural materials. The majority of benches were metal, a durable material but one that is uncomfortable during extreme cold and extreme heat. Natural materials like stone or wood are more comfortable than metal and provide psychological benefits to people who see or sit on them. Wooden benches and large rocks should be implemented as often

as possible in outdoor settings for various benefits. Paving also offers an opportunity for the inclusion of natural materials. Universities are generally reliant on hardscape paths because of their resilience and accessibility, but adding optional gravel or dirt paths can positively impact students.

The only principle never present on the observed sites was a tactile connection to vegetation. This lack of plants in the way of paths is likely due to accessibility requirements and reliance on hardscape. Similar to dirt and gravel paths, this condition can be included as an optional circulation feature. Paths through vegetation that can be experienced haptically and are not too far out of the way could provide an excellent opportunity for restoration.

6.1 *Audible Water in a Drainage Channel*

Most experiences of water on the observed sites were audible. This trend is likely because water is often drained from urban settings as quickly as possible to prevent flooding or inconvenience. In cases where such a drainage strategy is necessary, channels set into walkways that allow people to hear water passing underneath can allow for a maintained connection to water without compromising on

6.2 *A Single Visible, Audible, and Tactile Water Feature*

the function of the site. Whenever practical, features that encourage or force a haptic experience of water should be included in campus design. Gutters close to paths facilitate touching falling water as it splashes while making noise and being visible without requiring too much maintenance or being an inconvenience.

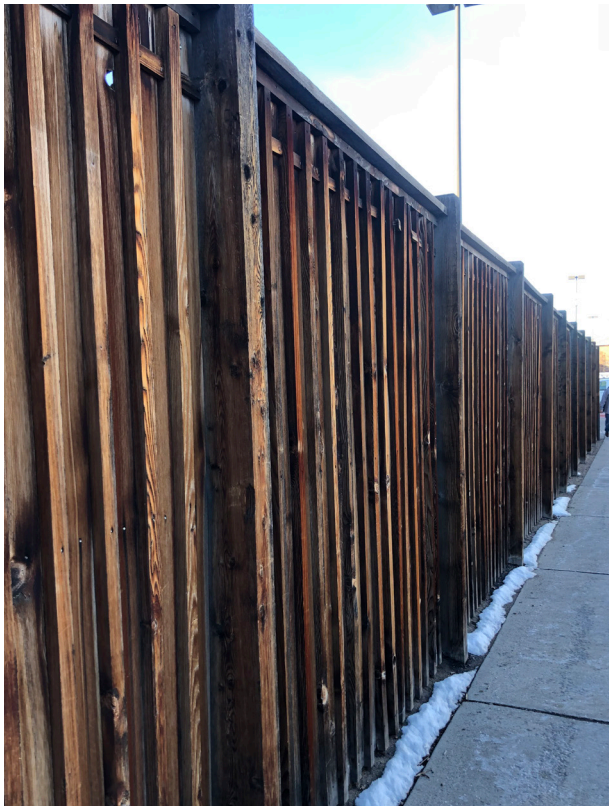
6.3 *Audible but Dormant Vegetation*

Since the most prevalent audible vegetation on the observed sites was dormant and dry grasses and leaves, some of the plants on campuses must continue to be affected by seasonal change. This allows for an experience

5

6.4 *Variation Between Audible and Live Vegetation*

of seasonality and an audible connection to vegetation. Because it is also important that non-dormant vegetation be present along paths, a variety of evergreen and deciduous plants should be included.



6.5 *Visible Natural Materials*

Natural materials do not need to be the primary structural material of architecture on college campuses, but they should be included in the design of human experiences. Objects that people interact with should be made out of minimally processed natural materials

6.6 *Haptic Experiences of Natural Materials*

whenever possible. This includes handrails, benches, doors, gates, and paths. Including natural materials in places where people will touch them means they only need to be implemented once to allow for both a visual and haptic experience of natural materials.

6.7 *Visible Water Features During the Winter*

As seen above, small ponds and other static water features can be aerated to prevent freezing over completely. Despite being possible and beneficial, such installations can be wasteful and inefficient. It should be encouraged if it is practical to include water features like the one pictured. If it is not efficient, more low impact features like gutters and channels should be present.

6.8 *Geese, the Most Prevalent Visible and Audible Wildlife*

It can be difficult to design intentionally for wildlife, but designers should avoid compromising existing wildlife habitats during retrofitting or new construction. This can be accomplished by observing a site before altering it to ensure a project does not disrupt an existing sensitive habitat.

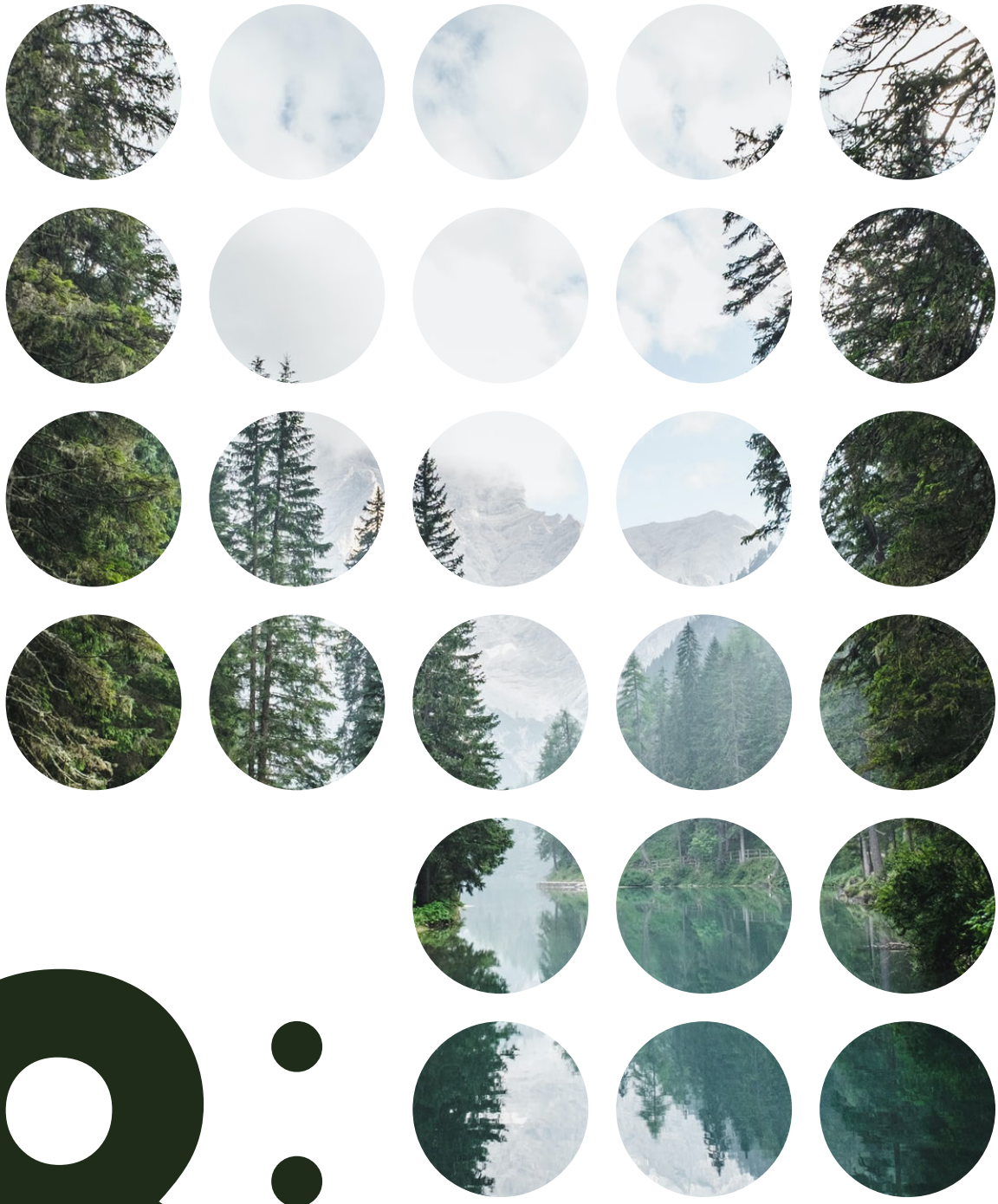
7: CONCLUSION

7. Conclusion:

In summary, there is a need for the development of new strategies to combat mental health issues prevalent in college students. Biophilic design and attention restorative conditions have been suggested as a potential solution to this problem by researchers in the fields of social ecology and environmental psychology. My research and findings resolve some of the issues with existing frameworks for biophilic design, propose a novel method for quantifying the restorativeness of built environments, and guide future research that ties attention restoration theory to architecture in cold climates, all with the intent of creating environments that foster happiness and performance.

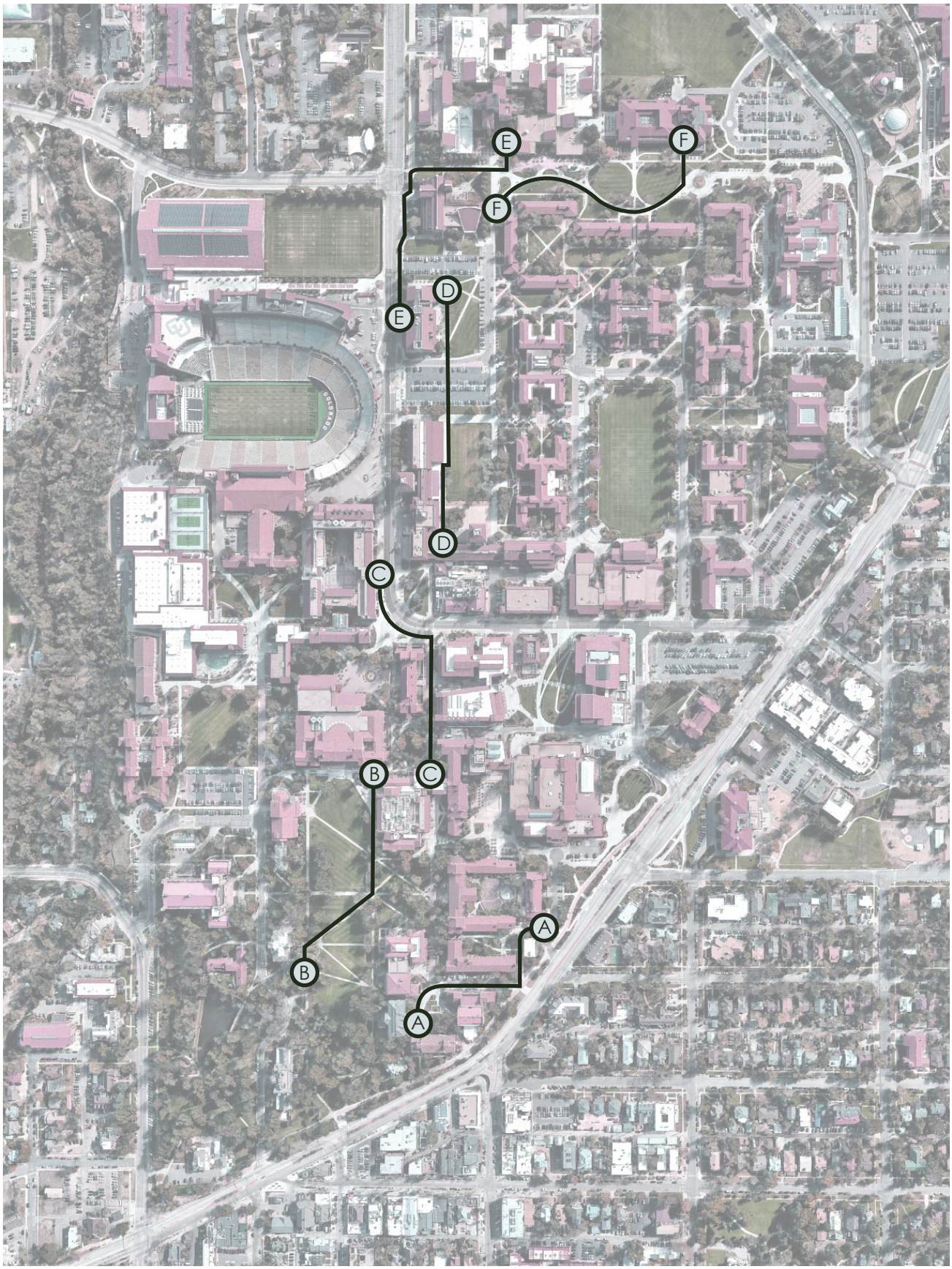
7.2. Implications:

This research is only the first step in creating practical and objective biophilic design frameworks. More research must be done in different environments to establish whether my findings are consistent across other typologies. Such research would also either validate or challenge the conclusions I have discussed. With more time and resources, studies can directly measure physiological responses to specific environments. A more advanced methodology would allow for a much more thorough analysis of the impacts of the conditions I have presented. Once the benefits of biophilic design can be inarguably proven, architects and designers should begin implementing these ideas in their work.



8: APPENDIX

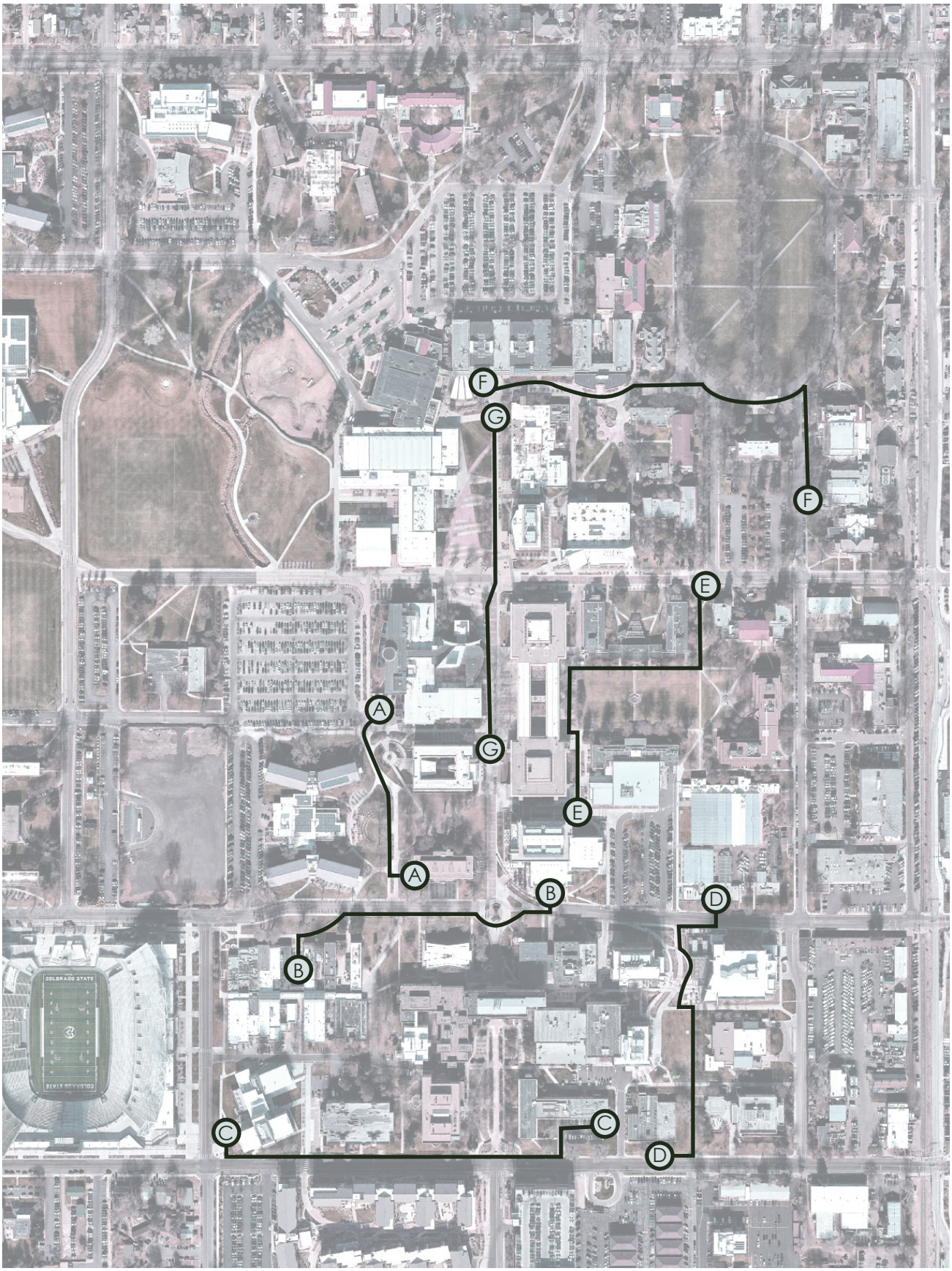
8.1: Sites at CU Boulder



CU Boulder

	1A	1B	1C	1D	1E	1F
Sight						
Live Vegetation	1	1	1	1	1	1
Water	0	0	0	0	0	0
Wildlife	1	1	1	0	0	0
Weather/Seasonality	1	1	1	1	1	1
Natural Materials	1	0	1	0	0	1
Biomorphic Forms	0	0	1	1	0	1
Dynamic (circadian) Light	1	1	1	1	1	1
Total (Sight):	71.42	57.14	85.71	57.14	42.85	71.42
	1A	1B	1C	1D	1E	1F
Sound						
Vegetation	1	0	1	0	0	0
Water	0	0	0	0	0	0
Wildlife	1	1	1	0	0	0
Wind	0	1	0	0	1	0
Total (Sound)	50	50	50	0	25	0
	1A	1B	1C	1D	1E	1F
Touch						
Vegetation	0	0	0	0	0	0
Water	0	0	0	0	0	0
Thermal Variability	1	0	1	0	1	0
Natural Materials	0	0	0	0	0	0
Total (Touch):	25	0	25	0	25	0
Total Overall:	53.33	40	60	26.66	33.33	33.33

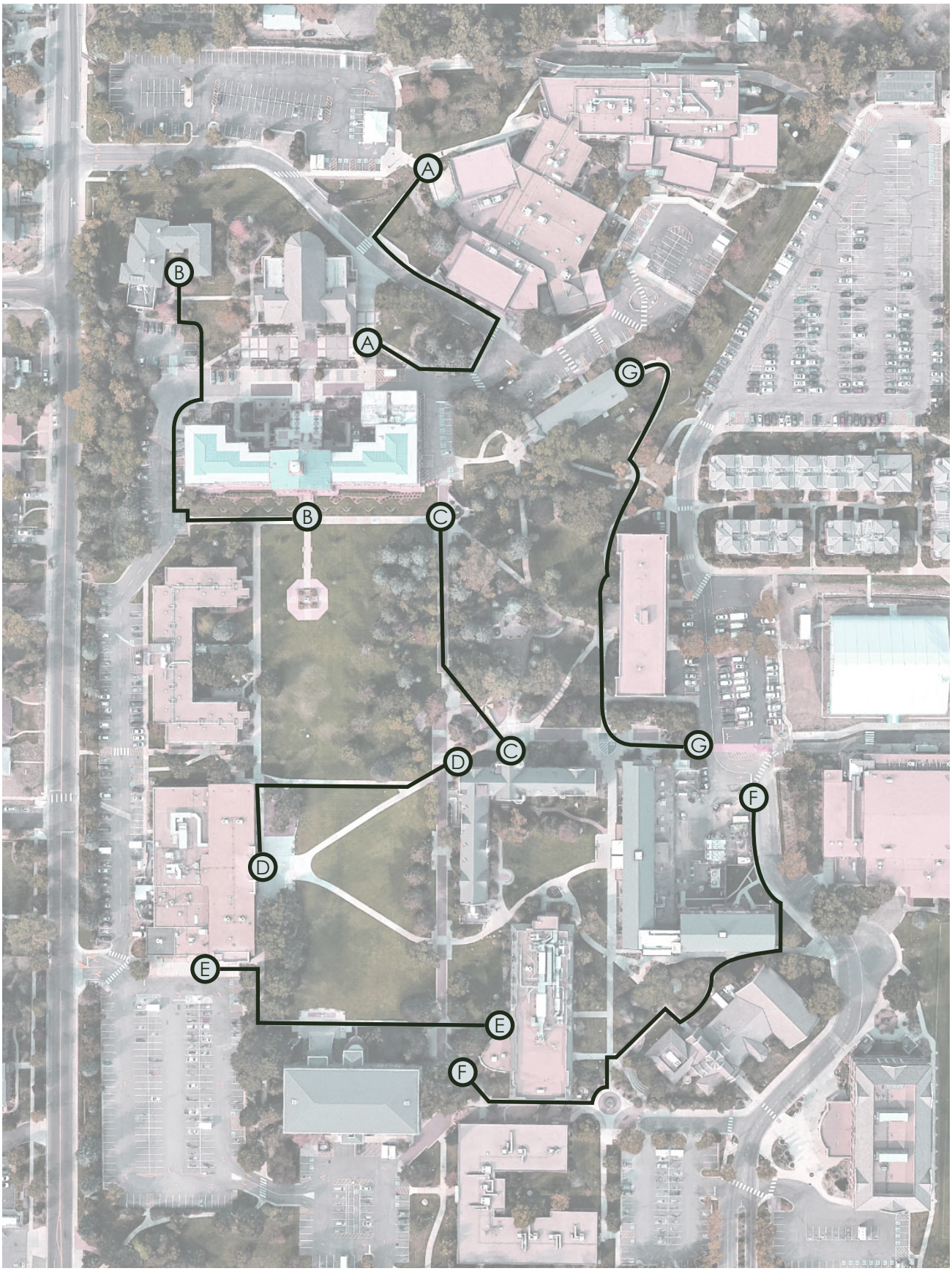
8.3: Sites at CSU



Colorado State University

	2A	2B	2C	2D	2E	2F	2G
Sight							
Live Vegetation	1	1	1	1	0	0	0
Water	0	0	1	0	0	0	0
Wildlife	0	0	1	1	0	0	0
Weather/Seasonality	1	1	1	1	1	1	1
Natural Materials	1	0	1	0	1	0	0
Biomorphic Forms	1	1	0	1	0	1	1
Dynamic (circadian) Light	1	1	1	1	1	1	1
Total (Sight):	71.42	57.14	85.71	71.42	42.85	42.85	42.85
	2A	2B	2C	2D	2E	2F	2G
Sound							
Vegetation	1	0	0	1	1	0	0
Water	0	1	1	0	0	0	0
Wildlife	0	1	1	1	0	1	0
Wind	1	1	1	1	1	1	1
Total (Sound)	50	75	75	75	50	50	25
	2A	2B	2C	2D	2E	2F	2G
Touch							
Vegetation	0	0	0	0	0	0	0
Water	0	0	1	0	0	0	0
Thermal Variability	1	1	1	0	1	1	1
Natural Materials	0	0	1	0	0	0	0
Total (Touch):	25	25	75	0	25	25	25
Total Overall:	53.33	53.33	80	53.33	40	40	33.33

8.5: Sites at Regis University



8.6: Results of Observations at Regis University

Regis University

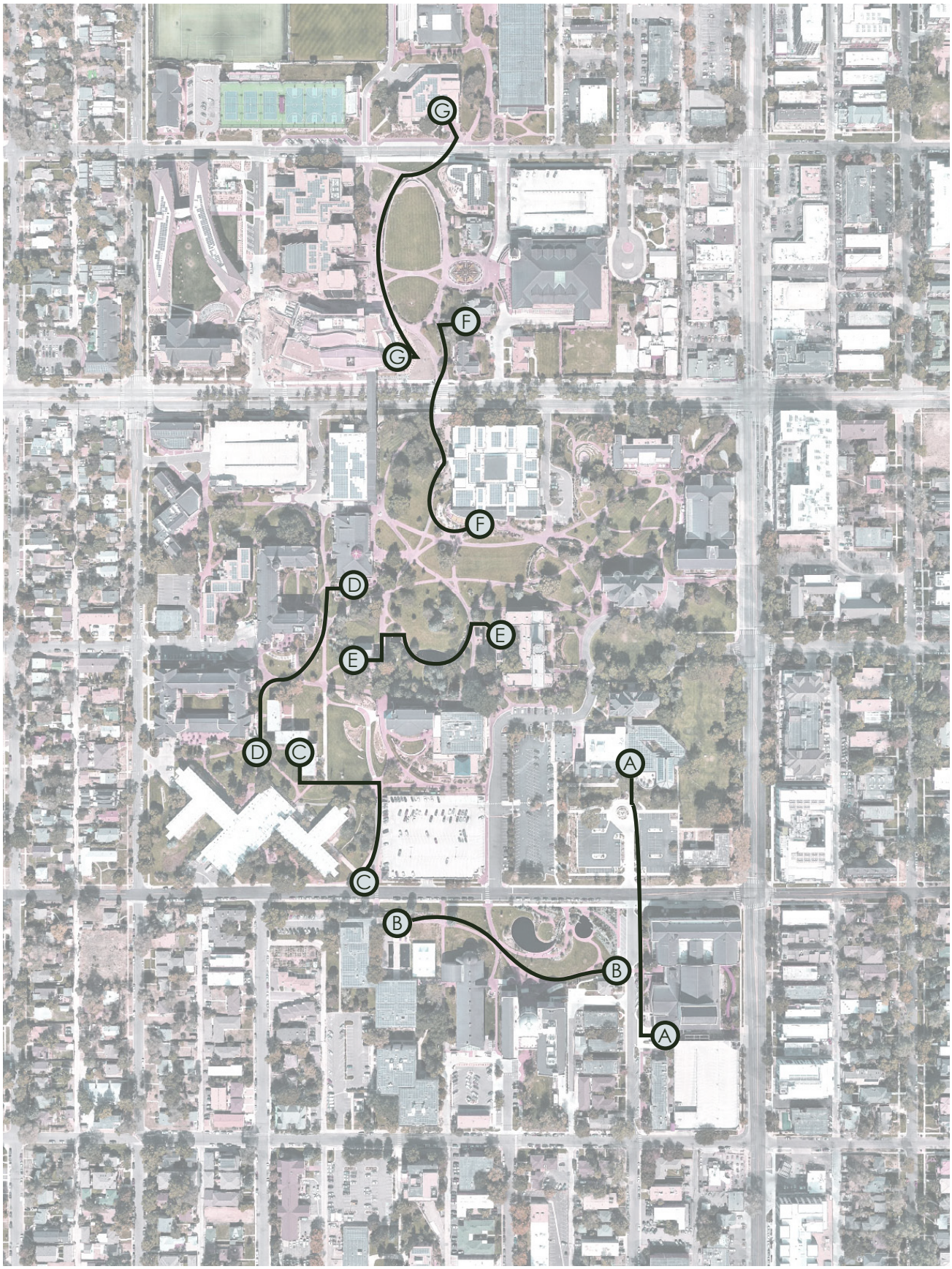
	3A	3B	3C	3D	3E	3F	3G
Sight							
Live Vegetation	1	1	1	1	1	0	1
Water	0	0	0	0	0	0	0
Wildlife	0	1	1	1	1	0	0
Weather/Seasonality	0	1	1	1	1	1	1
Natural Materials	0	0	1	0	1	1	1
Biomorphic Forms	1	1	1	1	1	0	1
Dynamic (circadian) Light	1	1	1	1	1	0	1
Total (Sight):	42.85	71.43	85.71	71.43	85.71	28.57	71.43
	3A	3B	3C	3D	3E	3F	3G
Sound							
Vegetation	0	0	1	1	0	0	1
Water	0	1	0	0	0	0	1
Wildlife	0	0	1	1	1	0	0
Wind	1	0	1	1	1	1	0
Total (Sound)	25	25	75	75	50	25	50
	3A	3B	3C	3D	3E	3F	3G
Touch							
Vegetation	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0
Thermal Variability	0	1	1	0	1	0	1
Natural Materials	0	0	1	1	1	1	1
Total (Touch):	0	25	50	25	50	25	50
Total Overall:	26.66	46.66	73.33	60	66.66	26.66	60

8.7: Sites at the Auraria Campus

Auraria Campus

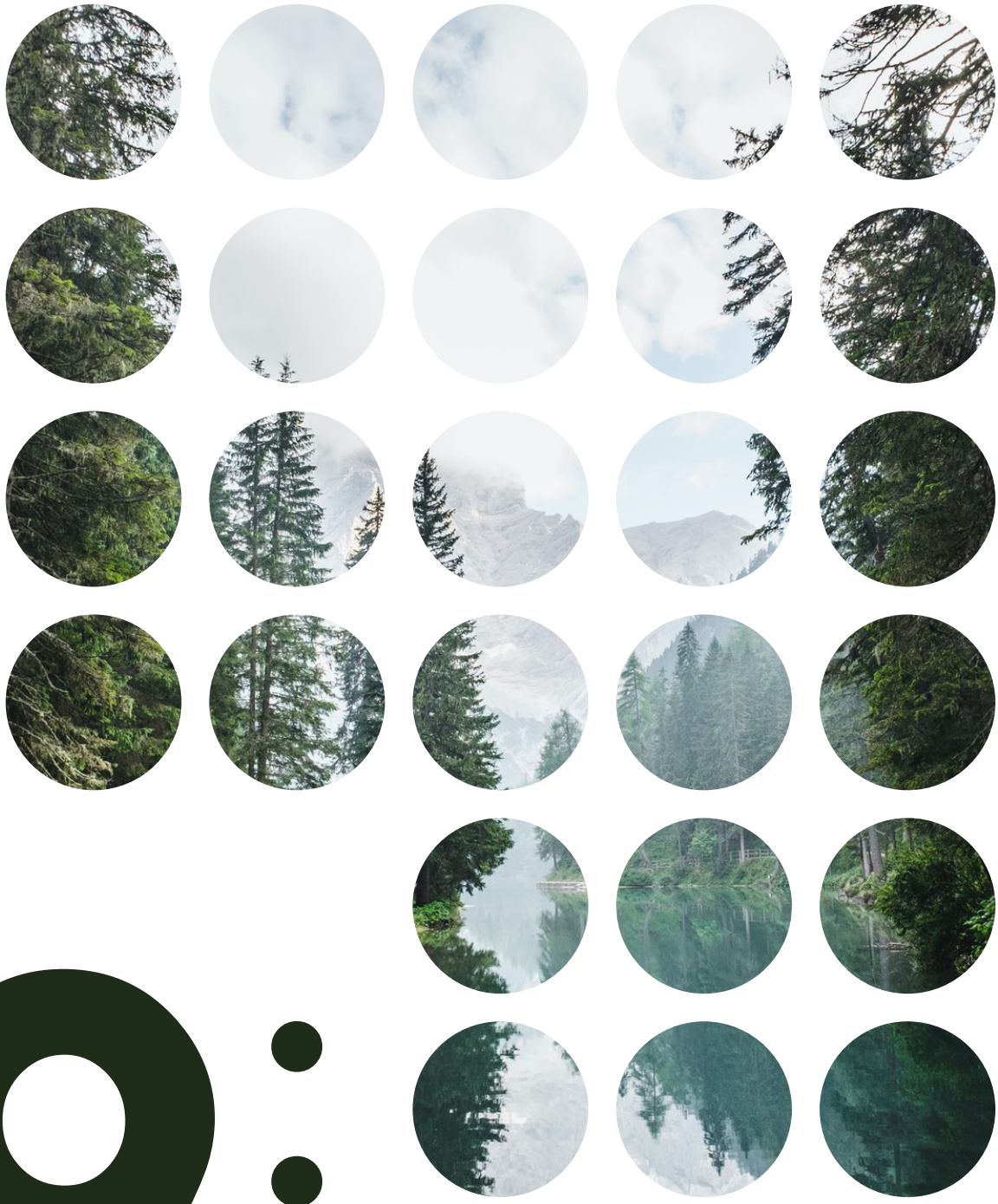
	4A	4B	4C	4D	4E	4F	4G
Sight							
Live Vegetation	0	0	1	0	1	0	0
Water	0	1	0	1	0	0	0
Wildlife	0	0	1	1	0	0	0
Weather/Seasonality	1	1	1	1	1	1	1
Natural Materials	0	0	0	1	1	0	0
Biomorphic Forms	0	1	1	1	1	0	0
Dynamic (circadian) Light	0	1	1	1	1	1	1
Total (Sight):	14.28	57.14	71.42	85.71	71.42	28.57	28.57
	4A	4B	4C	4D	4E	4F	4G
Sound							
Vegetation	0	0	1	0	1	0	0
Water	1	1	1	0	0	0	1
Wildlife	0	0	1	1	0	0	0
Wind	0	1	1	1	1	0	0
Total (Sound)	25	50	100	50	50	0	25
	4A	4B	4C	4D	4E	4F	4G
Touch							
Vegetation	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0
Thermal Variability	0	1	1	1	1	0	0
Natural Materials	0	0	1	0	1	0	0
Total (Touch):	0	25	50	25	50	0	0
Total Overall:	13.33	46.66	73.33	60	60	13.33	20

8.9: Sites at DU



University of Denver

	5A	5B	5C	5D	5E	5F	5G
Sight							
Live Vegetation	1	1	1	1	1	0	1
Water	0	1	1	0	0	0	0
Wildlife	0	0	0	0	0	0	0
Weather/Seasonality	1	1	0	1	1	1	1
Natural Materials	0	1	1	0	0	0	0
Biomorphic Forms	0	1	1	0	0	0	0
Dynamic (circadian) Light	1	1	1	1	1	1	1
Total (Sight):	42.85	85.71	71.42	42.85	42.85	28.57	42.85
	5A	5B	5C	5D	5E	5F	5G
Sound							
Vegetation	0	1	1	1	1	1	0
Water	0	1	1	0	0	0	0
Wildlife	0	0	0	0	0	0	0
Wind	1	1	1	1	1	1	1
Total (Sound)	25	75	75	50	50	50	25
	5A	5B	5C	5D	5E	5F	5G
Touch							
Vegetation	0	0	0	0	0	0	0
Water	0	0	0	0	0	0	0
Thermal Variability	0	1	1	1	1	1	0
Natural Materials	0	1	0	0	0	1	0
Total (Touch):	0	50	25	25	25	50	0
Total Overall:	26.66	73.33	60	40	40	40	26.67



9: BIBLIOGRAPHY

9. Bibliography

Abdelaal, Mohamed S. "Biophilic Campus: An Emerging Planning Approach for a Sustainable Innovation-Conducive University." Journal of Cleaner Production 215 (April 1, 2019): 1445–56. https://doi.org/10.1016/j.jclepro.2019.01.185.

Alvarsson, Jesper J., Stefan Wiens, and Mats E. Nilsson. "Stress Recovery during Exposure to Nature Sound and Environmental Noise." International Journal of Environmental Research and Public Health 7, no. 3 (March 2010): 1036–46. https://doi.org/10.3390/ijerph7031036.

Barton, Jo, and Jules Pretty. "What Is the Best Dose of Nature and Green Exercise for Improving Mental Health? A Multi-Study Analysis." Environmental Science & Technology 44, no. 10 (May 15, 2010): 3947–55. https://doi.org/10.1021/es903183r.

Basu, Avik, Jason Duvall, and Rachel Kaplan. "Attention Restoration Theory: Exploring the Role of Soft Fascination and Mental Bandwidth." Environment and Behavior 51, no. 9–10 (November 1, 2019): 1055–81. https://doi.org/10.1177/0013916518774400.

Beckett, M., and L. C. Roden. "Mechanisms by Which Circadian Rhythm Disruption May Lead to Cancer : Review Article." South African Journal of Science 105, no. 11 (November 1, 2009): 415–20. https://doi.org/10.10520/EJC96860.

Bennett, Michael A., and Stephen L. Benton. "What Are the Buildings Saying? A Study of First-Year Undergraduate Students' Attributions About College Campus Architecture." NASPA Journal 38, no. 2 (January 1, 2001): 159–77. https://doi.org/10.2202/1949-6605.1140.

Berg, Agnes E. van den, Terry Hartig, and Henk Staats. "Preference for Nature in Urbanized Societies: Stress, Restoration, and the Pursuit of Sustainability." Journal of Social Issues 63, no. 1 (March 2007): 79–96. https://doi.org/10.1111/j.1540-4560.2007.00497.x.

Berkebile, Bob, and Jason McLennan. "The Living Building: Biomimicry in Architecture, Integrating Technology with Nature," n.d., 9.

Berto, Rita. "The Role of Nature in Coping with Psycho-Physiological Stress: A Literature Review on Restorativeness." Behavioral Sciences 4, no. 4 (October 21, 2014): 394–409. https://doi.org/10.3390/bs4040394.

Brown, Daniel K., Jo L. Barton, and Valerie F. Gladwell. "Viewing Nature Scenes Positively Affects Recovery of Autonomic Function Following Acute-Mental Stress." Environmental Science & Technology 47, no. 11 (June 4, 2013): 5562–69. https://doi.org/10.1021/es305019p.

Browning, William D, Catherine O. Ryan, and Joseph O Clancy. "14 Patterns of Biophilic Design: Improving Health and Well-Being in the Built Environment," 2014, 64.

Mayo Clinic. "Chronic Stress Puts Your Health at Risk." Accessed October 15, 2021. https://www.mayoclinic.org/healthy-lifestyle/stress-management/in-depth/stress/art-20046037.

Deno, William R. "CU-Boulder Main Campus Design Guidlines." Accessed December 22, 2021. https://www.colorado.edu/campusplanning/sites/default/files/attached-files/cu-design_guidelines_final_3-14.pdf.

Determan, Jim. "THE IMPACT OF BIOPHILIC LEARNING SPACES ON STUDENT SUCCESS," n.d., 27.

DeVault, J. Ross. "Active and Restorative Campus: Designing a Garden Street for Student's Mental and Physical Well-Being." Report. Kansas State University, 2015. https://krex.k-state.edu/dspace/handle/2097/19238.

Felsten, Gary. "Where to Take a Study Break on the College Campus: An Attention Restoration Theory Perspective." Journal of Environmental Psychology 29, no. 1 (March 1, 2009): 160–67. https://doi.org/10.1016/j.jenvp.2008.11.006.

Gatersleben, Birgitta, and Matthew Andrews. "When Walking in Nature Is Not Restorative—The Role of Prospect and Refuge." Health & Place 20 (March 1, 2013): 91–101. https://doi.org/10.1016/j.healthplace.2013.01.001.

Gillis, Kaitlyn, and Birgitta Gatersleben. "A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design." Buildings 5, no. 3 (September 2015): 948–63. https://doi.org/10.3390/buildings5030948.

Gordan, Richard, Judith K Gwathmey, and Lai-Hua Xie. "Autonomic and Endocrine Control of Cardiovascular Function." World Journal of Cardiology 7, no. 4 (April 26, 2015): 204–14. https://doi.org/10.4330/wjc.v7.i4.204.

Grahn, Patrik, and Ulrika K. Stigsdotter. "The Relation between Perceived Sensory Dimensions of Urban Green Space and Stress Restoration." Landscape and Urban Planning 94, no. 3 (March 15, 2010): 264–75. https://doi.org/10.1016/j.landurbplan.2009.10.012.

Greenberg, Allan. "CAMPUSES WITH MEANING," 2007, 4.

Gullone, Eleonora. "The Biophilia Hypothesis and Life in the 21st Century: Increasing Mental Health or Increasing Pathology?" Journal of Happiness Studies 1, no. 3 (September 1, 2000): 293–322. https://doi.org/10.1023/A:1010043827986.

Hartig, Terry, Gary W Evans, Larry D Jamner, Deborah S Davis, and Tommy Gärling. "Tracking Restoration in Natural and Urban Field Settings." Journal of Environmental Psychology, Restorative Environments, 23, no. 2 (June 1, 2003): 109–23. https://doi.org/10.1016/S0272-4944(02)00109-3.

Huang, Shuping, Jinda Qi, Wei Li, Jianwen Dong, and Cecil Konijnendijk van den Bosch. "The Contribution to Stress Recovery and Attention Restoration Potential of Exposure to Urban Green Spaces in Low-Density Residential Areas." International Journal of Environmental Research and Public Health 18, no. 16 (January 2021): 8713. https://doi.org/10.3390/ijerph18168713.

Johnson, Jon. "Hypothalamus: Function, Hormones, and Disorders," August 22, 2018. https://www.medicalnewstoday.com/articles/312628.

Joye, Yannick. "Architectural Lessons from Environmental Psychology: The Case of Biophilic Architecture." Review of General Psychology 11, no. 4 (December 1, 2007): 305–28. https://doi.org/10.1037/1089-2680.11.4.305.

Kahn, Peter H., Batya Friedman, Brian Gill, Jennifer Hagman, Rachel L. Severson, Nathan G. Freier, Erika N. Feldman, Sybil Carrère, and Anna Stolyar. "A Plasma Display Window?—The Shifting Baseline Problem in a Technologically Mediated Natural World." Journal of Environmental Psychology 28, no. 2 (June 1, 2008): 192–99. https://doi.org/10.1016/j.jenvp.2007.10.008.

Kaplan, Stephen. "The Restorative Benefits of Nature: Toward an Integrative Framework." Journal of Environmental Psychology, Green Psychology, 15, no. 3 (September 1, 1995): 169–82. https://doi.org/10.1016/0272-4944(95)90001-2.

Kellert, Stephen R., and Elizabeth F. Calabrese. "The Practice of Biophilic Design - A Simplified Framework," 2015. https://www.biophilic-design.com.

Kellert, Stephen R, Judith H Heerwagen, and Martin L Mador. "Biophilic Design," 2008, 434.

Kellert, Stephen R., and Edward O. Wilson. The Biophilia Hypothesis. Island Press, 1993.

Kim, Jung T., Christine J. Ren, George A. Fielding, Abhishek Pitti, Takeo Kasumi, Michael Wajda, Allen Lebovits, and Alex Bekker. "Treatment with Lavender Aromatherapy in the Post-Anesthesia Care Unit Reduces Opioid Requirements of Morbidly Obese Patients Undergoing Laparoscopic Adjustable Gastric Banding." Obesity Surgery 17, no. 7 (July 1, 2007): 920–25. https://doi.org/10.1007/s11695-007-9170-7.

Kim, S. Y., and J. J. Kim. "The Effect of Fluctuating Illuminance on Visual Sensation in a Small Office," 2007. https://journals.sagepub.com/doi/abs/10.1177/1420326X06079947.

Kr_má_ová, Jana. "E.O. Wilson's Concept of Biophilia and the Environmental Movement in the USA," n.d., 14.

Li, Dongying, and William C. Sullivan. "Impact of Views to School Landscapes on Recovery from Stress and Mental Fatigue." Landscape and Urban Planning 148 (April 1, 2016): 149–58. https://doi.org/10.1016/j.landurbplan.2015.12.015.

Lichtenfeld, Stephanie, Andrew J. Elliot, Markus A. Maier, and Reinhard Pekrun. "Fertile Green: Green Facilitates Creative Performance." Personality and Social Psychology Bulletin 38, no. 6 (June 1, 2012): 784–97. https://doi.org/10.1177/0146167212436611.

Loftness, Vivian, ed. Sustainable Built Environments. New York, NY: Springer US, 2020. https://doi.

org/10.1007/978-1-0716-0684-1.

Lu, Ming, and Jingwan Fu. "Attention Restoration Space on a University Campus: Exploring Restorative Campus Design Based on Environmental Preferences of Students." International Journal of Environmental Research and Public Health 16, no. 14 (January 2019): 2629. https://doi.org/10.3390/ijerph16142629.

Mehta, Ravi, Rui (Juliet) Zhu, and Amar Cheema. "Is Noise Always Bad? Exploring the Effects of Ambient Noise on Creative Cognition." Journal of Consumer Research 39, no. 4 (December 1, 2012): 784–99. https://doi.org/10.1086/665048.

ÖHman, Arne. "Face the Beast and Fear the Face: Animal and Social Fears as Prototypes for Evolutionary Analyses of Emotion." Psychophysiology 23, no. 2 (1986): 123–45. https://doi.org/10.1111/j.1469-8986.1986.tb00608.x.

Orsega-Smith, Elizabeth, Andrew J. Mowen, Laura L. Payne, and Geoffrey Godbey. "The Interaction of Stress and Park Use on Psycho-Physiological Health in Older Adults." Journal of Leisure Research 36, no. 2 (June 1, 2004): 232–56. https://doi.org/10.1080/00222216.2004.11950021.

Peters, Terri, and Kristen D'Penna. "Biophilic Design for Restorative University Learning Environments: A Critical Review of Literature and Design Recommendations." Sustainability 12, no. 17 (August 30, 2020): 7064. https://doi.org/10.3390/su12177064.

Pheasant, Robert J., Mark N. Fisher, Greg R. Watts, David J. Whitaker, and Kirill V. Horoshenkov. "The Importance of Auditory-Visual Interaction in the Construction of 'Tranquil Space.'" Journal of Environmental Psychology 30, no. 4 (December 1, 2010): 501–9. https://doi.org/10.1016/j.jenvp.2010.03.006.

Ramzy, Nelly Shafik. "Biophilic Qualities of Historical Architecture: In Quest of the Timeless Terminologies of 'Life' in Architectural Expression." Sustainable Cities and Society 15 (July 1, 2015): 42–56. https://doi.org/10.1016/j.scs.2014.11.006.

Ruso, Bernhart, and Klaus Atzwanger. "Measuring Immediate Behavioral Responses to the Environment." . . P. 4 (n.d.): 2.

Ryan, Catherine O., William D Browning, Joseph O Clancy, Scott L Andrews, and Namita B Kallianpurkar. "BIOPHILIC DESIGN PATTERNS: Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment." International Journal of Architectural Research: ArchNet-IJAR 8, no. 2 (July 12, 2014): 62. https://doi.org/10.26687/archnet-ijar.v8i2.436.

Stigsdotter, Ulrika, and Patrik Grahn. "Experiencing a Garden: A Healing Garden for People Suffering from Burnout Diseases." Journal of Therapeutic Horticulture 14 (January 1, 2003): 38–48.

Tham, K. W., and H. C. Willem. "Temperature and Ventilation Effects on Performance and Neurobehavioral-Related Symptoms of Tropically Acclimatized Call Center Operators Near Thermal Neutrality." ASHRAE Transactions 111, no. 2 (October 2005): 687–98.

"The Healthy Minds Study," 2020, 26.

Tindle, Jacob, and Prasanna Tadi. "Neuroanatomy, Parasympathetic Nervous System." In StatPearls. Treasure Island (FL): StatPearls Publishing, 2021. http://www.ncbi.nlm.nih.gov/books/NBK553141/.

Tsunetsugu, Yuko, and Yoshifumi Miyazaki. "Measurement of Absolute Hemoglobin Concentrations of Prefrontal Region by Near-Infrared Time-Resolved Spectroscopy: Examples of Experiments and Prospects." Journal of PHYSIOLOGICAL ANTHROPOLOGY and Applied Human Science 24, no. 4 (2005): 469–72. https://doi.org/10.2114/jpa.24.469.

Tsunetsugu, Yuko, Yoshifumi Miyazaki, and Hiroshi Sato. "Physiological Effects in Humans Induced by the Visual Stimulation of Room Interiors with Different Wood Quantities." Journal of Wood Science 53, no. 1 (February 2007): 11–16. https://doi.org/10.1007/s10086-006-0812-5.

Tsunetsugu, Yuko, Bum-Jin Park, and Yoshifumi Miyazaki. "Trends in Research Related to 'Shinrin-Yoku' (Taking in the Forest Atmosphere or Forest Bathing) in Japan." Environmental Health and Preventive Medicine 15, no. 1 (January 2010): 27–37. https://doi.org/10.1007/s12199-009-0091-z.

Ulrich, Roger S. "Aesthetic and Affective Response to Natural Environment." In Behavior and the Natural Environment, edited by Irwin Altman and

Joachim F. Wohlwill, 85–125. Human Behavior and Environment. Boston, MA: Springer US, 1983. https://doi.org/10.1007/978-1-4613-3539-9_4.

———. "Natural Versus Urban Scenes: Some Psychophysiological Effects." Environment and Behavior 13, no. 5 (September 1, 1981): 523–56. https://doi.org/10.1177/0013916581135001.

WADESON, RALPH W., JOHN W. MASON, DAVID A. HAMBURG, and JOSEPH H. HANDLON. "Plasma and Urinary 17-OHCS Responses to Motion Pictures." Archives of General Psychiatry 9, no. 2 (August 1, 1963): 146–56. https://doi.org/10.1001/archpsyc.1963.01720140042006.

White, Mathew, Amanda Smith, Kelly Humphryes, Sabine Pahl, Deborah Snelling, and Michael Depledge. "Blue Space: The Importance of Water for Preference, Affect, and Restorativeness Ratings of Natural and Built Scenes." Journal of Environmental Psychology 30, no. 4 (December 1, 2010): 482–93. https://doi.org/10.1016/j.jenvp.2010.04.004.

Wigö, Hans. "Technique and Human Perception of Intermittent Air Velocity Variation," 2005. http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-423.

Yue, Xiaomin, Edward A. Vessel, and Irving Biederman. "The Neural Basis of Scene Preferences." NeuroReport 18, no. 6 (April 16, 2007): 525–29. https://doi.org/10.1097/WNR.0b013e328091c1f9.