UNIVERSAL VISUAL QUALITY FINDING LOW-STRESS PERCEPTIONS ACROSS INTERIOR BUILT AND EXTERIOR NATURE ENVIRONMENTS

By

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ABSTRACT

As humans spend more time inside built environments, as evidenced by recent COVID 19 pandemic mandates, attention to how the built environment affects human health with stress is increasing (Núñez-González, et al., 2020). Recent literature investigating the built environment found improved occupant health with greenbuilding rating systems (GRS) certified buildings. However, statistical research and literature about the built environment attributes shown to improve mental health by decreasing stress through interaction with nature environments remains limited. This study investigates the relationships of the built environment attributes (some stated in WELL Mind Concept criteria) with Attention Restorative Theory (ART) (Kaplan & Kaplan, 1989) engagement components for the effects of environmental stress on human mental health. Three questions are addressed: 1) Are there significant spatial attributes surrounding built environments, nature environments, or a combination of both, that can be consistently recognized to lower human stress within the built environment? 2) What spatial attributes are identified from a predictive model suggesting a ranking of significant low-stress attributes? 3) Are the participants' feelings of low stress shown in differential word antonyms associated with their visual perceptions of low-stress photographs? A significant predictive model (p<0.05) is originated with independent variables investigating photographs of MountainScape, ForestScape, WaterScape, Agricultural, RuralScape, Urban and Industrial, Ceiling Heights, Inside Views of Nature, Outside Views of Nature from inside, Inside Nature Engagement, and Outside Nature Engagement. Random surveys using Q-Sort Visual Quality Assessment method are created asking participants to rank ten variable photographs for perception of least stress (#1) to most

stress (#10) on a scale of one to ten. The Semantic Differential method survey questions ask participants to rank their feelings with word antonyms from viewing specific variable photographs. Disclosure of data analysis reveals MountainScape, ForestScape and Outside Nature Engagement attributes as the most low-stress attributes. New knowledge is provided for low-stress mental health criteria necessary for architects and designers to implement with built environments, building policies and procedures, and educating others.

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CHAPTER 1: INTRODUCTION

1.1 Overview

With the awareness that the average person can spend up to 90% of their time inside (Coffin & Young, 2017; SnowBrains, 2018; Xie Clement-Croome & Wang, 2017), the interest for additional research on how the indoor built environment affects occupant health is increasing (Coffin & Young, 2017; Mitchell et al., 2007; Na, Palikhe, Lim, and Kim, 2016; Xie, Clements-Croome, and Wang, 2017). Literature declares that sustainable (greenbuilding rating systems) certified buildings need to include new knowledge with consideration for the effects of the built environment on improving occupant health (Xie, et al., 2017). For this study, the built environment represents man-made structures and systems that provide places for people to live, to work and play in and around.

Greenbuilding rating systems (GRS) are voluntary sustainable certification standards currently recognized in the industry as built environment design and construction criteria to promote healthy occupants. The first development of the Greenbuilding rating systems focused on a built environment assessment method to decrease environmental resource impacts on building materials, construction, and operations. The Building Research Establishment Environmental Assessment Method (BREEAM), a greenbuilding rating system, initially published in 1990 from the UK, began as a GRS standard for assessing the environmental impacts of building design and construction (Building Research Establishment Environmental Assessment Method [BRE Global], 2011). The United States Green Build Council (USGBC) developed and initiated Leadership in Energy and Environmental Design (LEED) credit criteria in 2000 with the goal of preserving natural resources for *sustainable* *construction and design* (Kibert, Sendzimir, and Guy, (Eds.), 2002; Rosa, 2016; U.S. Green Building Council [USGBC], 2016). In 2006, International Living Future Institute (ILFI) published *Living Building Challenge* Standard with consideration for the symbiotic relationship between humans and the ecology by decreasing operational energy combustion that increases air quality (International Living Future Institute [ILFI], 2017).

In September 2015, the International WELL Building Standard (WELL), published by the International WELL Building Institute (IWBI), was the first voluntary greenbuilding rating system certification standard to consider the building architecture and building function for specific design criteria secondary to promoting occupant health. Each WELL Concept provides human health design criteria specific to the built environment recognized to improve human health (International WELL Building Institute [IWBI], 2015). In 2018, WELLv2 was officially released with new Mind Concepts criteria claiming to improve human mental health by implementing specific biophilic design criteria and creating restorative spaces (IWBI, 2019).

Common literature trends for research investigating the built environment effects on human health include comparing LEED certified buildings and other greenbuilding rating systems with non-LEED certified buildings for environment effects on occupant physical health. Physical Health is not only the elimination of disease, but the ability of the body to fight disease so as to continue to show optimal health (USD-HHS, 1996).

Some examples include measuring employee productivity and engagement in work environments (Hedge, Miller, and Dorsey, 2014). The benefits of nature interaction on human health are recognized in some green building rating systems, with inside nature views and outside nature views from inside the built environment, to improve mental health and decrease stress (Berto, 2005; 2014; Hartig & Staats, 2003; Lottrup, Grahn, and Stigsdotter, 2013).

Research conducted by Investigating outdoor environments reveals that views and engagements with nature can reduce human stress (Berto, 2005; Hartig, et al., 2003; Kellert, 2016; Lottrup, et al., 2013; Wilson, 1984). Research conducted by Kaplan, R. and Kaplan, S. (1989) found that visual exposure to nature, with activities in nature, can decrease mental fatigue and increase cognitive attention. The theory of biomimicry, imitating life, is widely used for finding sustainable building material solutions used with architects (Xue et al., 2019). The golden ratio, perfect proportion found in all nature, is known for providing visual beauty when seen (Trautmann, 2021). Literature finds that there are diverse results and testing methods for evaluating the effects of the built environments influencing occupants' mental health for low stress.

1.2 Knowledge Needed from Literature Gap

The occupant healthy design and construction criteria found in the GRS standards are recognized by sustainable practitioners as the most reputable certification criteria for improving occupant health. However, the definition of "health and wellbeing" is not consistent across all greenbuilding rating systems (BRE Global, 2018; ILFI, 2017; IWBI, 2019; U.S. Green Building Council, 2016). Recent BREEAM, Living Building Challenge, and LEED certification standards include recognizing good indoor air quality, daylight views, and some human-nature interaction and ergonomics when referring to health and wellbeing (BRE Global, 2018; ILFI, 2017; U.S. Green Building Council, 2020). WELLv2 is the first GRS certification standard to include "restorative spaces" when focusing on the effects of human mental health by including the Mind Concepts certification criteria (IWBI, 2019).

Research of built environment attributes that can decrease occupant stress perceptions is needed. A clear assessment method for Identifying the most significant built environment attributes recognizing low mental stress has yet to be found.

1.3 Research Questions

Based on the above discussion, the researcher proposes the following research questions:

1.3.1 Question #1:

Are there significant spatial attributes surrounding built environments, nature environments, or a combination of both, that can be consistently recognized to lower human stress within the built environment?

1.3.2 Question #2:

What environmental attributes are identified from a predictive model suggesting a ranking of significant low-stress attributes?

1.3.3 Question #3:

Are participants' feelings of low stress shown in differential word antonyms associated with their visual perceptions of low-stress photographs?

1.4 Research Hypotheses

To accurately respond to the literature gap and research questions, this study will test three hypotheses. The first hypothesis tests the visual ability of the survey participant to identify attributes surrounding the built environment that they perceive as low stress.

The second hypothesis finds significant environmental preferences for low stress by creating a predictive regression model equation. The third hypothesis finds the participants' word antonyms that describe their feelings associated with low-stress scores.

To find the answer to the questions for the purpose of this research and to complete the objectives, the three hypotheses stated below will be tested.

HA_1: = The descriptive analysis of plotted mean scores finds a ranking from the best low-stress variable environments to the worst low-stress variable environments.

HA_2: = The predictive model results find a hierarchical ranking the independent variables that are statistically significant to predict a response for at least 40% of variance of the independent variables.

HA_3: = The ordination and ranking of the word antonym eigenvector scores associate with the independent variables to find the relationship of the best low-stress variable environments with the best low-stress word antonym eigenvector scores.

1.5 Goals and Objectives

This study seeks to answer the question of what built environment and design characteristics are associated with a reduction in human stress surrounding the built environment. The research framework includes a quantitative methods approach for investigating the human perception of low stress by ranking photographs of the built environment, the built environment with and without nature interaction, and outside nature environments. These results can suggest which significant independent variables contribute to finding the most recognized attributes for preferred low stress with the built environment.

1.5.1 Research Objectives with Tasks

1.5.1.1 Objective One

Objective One: Investigating the gaps and affiliations between relevant literature and theories for their effects on occupant stress when including nature and not including nature surrounding the built environment.

This objective is accomplished by implementing the following research tasks:

Task 1 - Examine scholarly and literature reviews for identifying key words, theories, and knowledge gaps: human mental health, stress, stress reduction, greenbuilding rating systems, built environments, and nature.

Task 2 – Develop a theoretical framework by identifying the relationships between the effects of nature environments on mental stress, the effects of built environments on mental stress, and the effects of built environments with and without nature attributes on mental stress.

1.5.1.2 Objective Two

Objective Two: Developing and implementing a conceptual framework from evaluation of the relationships between occupant mental stress, nature interactions, and the built environment.

This objective is accomplished by implementing the following research tasks:

Task 1 - Identify the most relevant literature and theories for finding the knowledge gaps about stress reduction surrounding the built environment.

Task 2 - Develop and formulate a research framework from the knowledge gaps.

1.5.1.3 Objective Three

Objective Three: Developing and implementing a research method model to gather, measure, and statistically analyze data from participants' perception for low stress.

This objective is accomplished by implementing the following research tasks:

Task 1 - Develop research hypotheses from knowledge gaps.

Task 2 - Identify and develop research analytical model for survey implementation.

Task 3 - Test and conduct survey model for collecting and analyzing data.

1.5.1.4 Objective Four

Objective Four: Developing and conducting statistical analysis to find variable(s) with the highest statistical relevancy recognized to answer research goal and hypotheses.

This objective is accomplished by implementing the following research tasks:

Task 1 - Conducting descriptive, regression and PCA analysis.

Task 2 - Evaluate findings for statistical significance with hypotheses.

Task 3 - Determine variable(s) with the highest statistical relevancy.

1.5.2 Summary

To summarize the conceptual model of this research, this study will include three new research procedures that have not been previously conducted in one investigation.

- Literature review identifying theory gaps for built environments, built environments with and without nature, and nature environments is investigated in one survey to find the most statistically significant attributes recognized to reduce mental stress surrounding the built environment.

- Statistical evaluation for comparison of Attention Restorative Theory (Kaplan & Kaplan, 1989) concepts with restorative concepts for stress-reduction responses surrounding the built environment and nature.
- A recognized method in landscape architecture, Q-sort with Visual Quality Assessment, is used for three questions in the survey questionnaire. The semantic differential method is also included for three survey questions. These two methods have not previously been included together in one study for investigating the effects of the built environment and nature on mental stress.

1.6 Scope and Limitations

The scope of this research is of interest to sustainable greenbuilding rating systems experts and stakeholders interested in this knowledge for future developments. Survey participants asking for results from this survey include architects, designers, and sustainability experts. Additionally, pending the results, homeowners and business owners could also show an interest in improving their own mental health.

Some limitations can be identified that need further investigation. First, all the built-environment photographs show outside nature views of highly green vegetation, which is typically seen during the spring or summer months from the mid-west region of the United States. A person from another country or nationality could view a green vegetated garden as ugly and not like it. Typically, individuals looking at nature environments want to connect what they are seeing with something they are familiar with from the past (Kaplan & Kaplan, 1989). Therefore, a connection with nature for preferred images of low stress may or may not be consistent with the results of this study.

Secondly, the differential antonyms chosen, representing an individual's expression of their feelings about viewing their surrounding environment (Thurlow, 1971), can have different word meanings for participants where English is not their primary language. Therefore, the survey responses may or may not vary. Studies using large sample sizes with random participants could find consistent data results due to the large participant size.

1.7 Importance of this Study

These research results provide new knowledge identifying and comparing the built environment with and without nature environments found to prefer low stress. To fill the knowledge gap, this study will identify the highest ranking, statistically significant, attribute(s) and/or component(s) revealed for low-stress responses surrounding the built environment. This study uses "nature" to represent attributes found in nature. The term "Natural" is not used since "natural" can be anything that is made from natural materials. Cement is a nature material since it is made from natural minerals, yet cement is not considered part of nature.

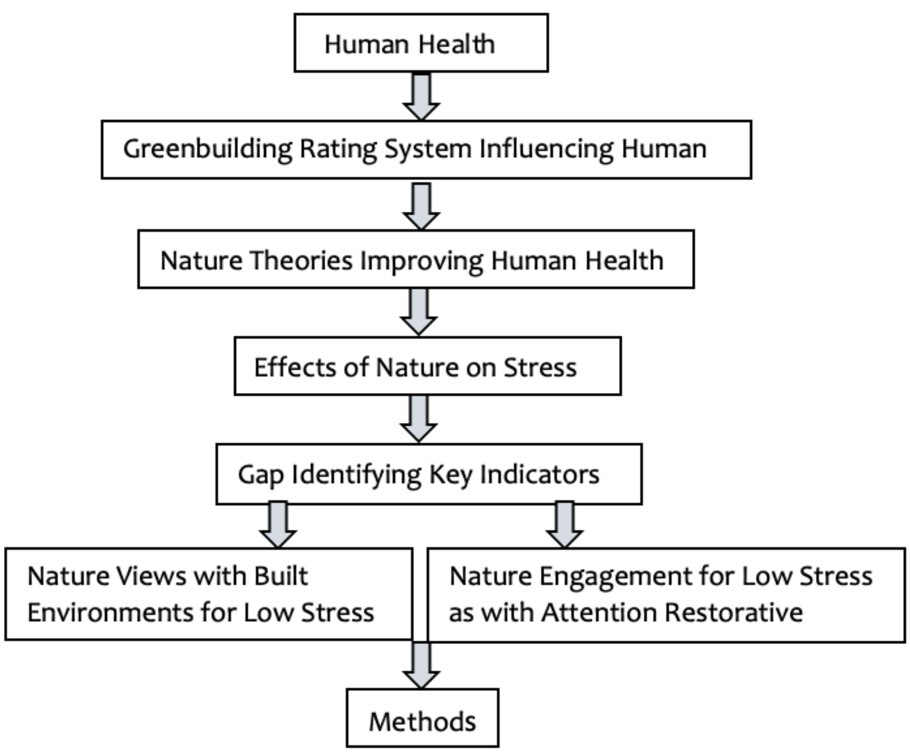
Once recognized, healthy interior architecture attributes identified from this study can be implemented in various sizes, costs, and functions of the built environment for promoting occupant mental health. The results of this study can provide statistical evidence to suggest that built design attributes and concepts can be implemented to improve sustainable building policies and procedures for architects, builders, contractors, designers, and developers who would be able to design and construct buildings that can significantly impact their client's mental health toward a healthier lifestyle. Finally, future studies can be conducted with greater clarity and diversity as recognition of clear and consistent healthy design and construction criteria is implemented.

CHAPTER 2: LITERATURE REVIEW

This chapter offers an overview of human health and stress, influences of nature on stress, and interaction with the built environment, and investigates how this triad of associations relate together to reduce mental stress. Details about Greenbuilding rating systems (GBRS) certification criteria specified to improve human health are introduced. In particular, the role of nature surrounding the built environment is explored. Next, this chapter will present stress-reduction theories associated with nature, nature environments, and built environments. From this literature review, independent variables will be identified and described in detail to investigate stress reduction. Finally, literature about this study's analytical method is presented in Figure 2.1.

Figure 2.1

Outline of Literature Review Topics Discussed in Chapter Two



2.1 Human Health and Well-Being

2.1.1 Human Health

People interact and gather information from their surrounding environments using their five senses: sight, sound, smell, taste, and touch (Guzowski, 2000). The information that an individual gathers is critical to how they will interact with their environment and fundamental to their ability to thrive and be their best. Most environmental information is gathered from communication with friends, family, social media, and interactions with interior buildings and exterior activities in nature (Kaplan, Kaplan, and Ryan, 1998). Understanding one's environment with cognitive awareness provides a sense of security (Kaplan, et al., 1998) and can promote individual health and well-being.

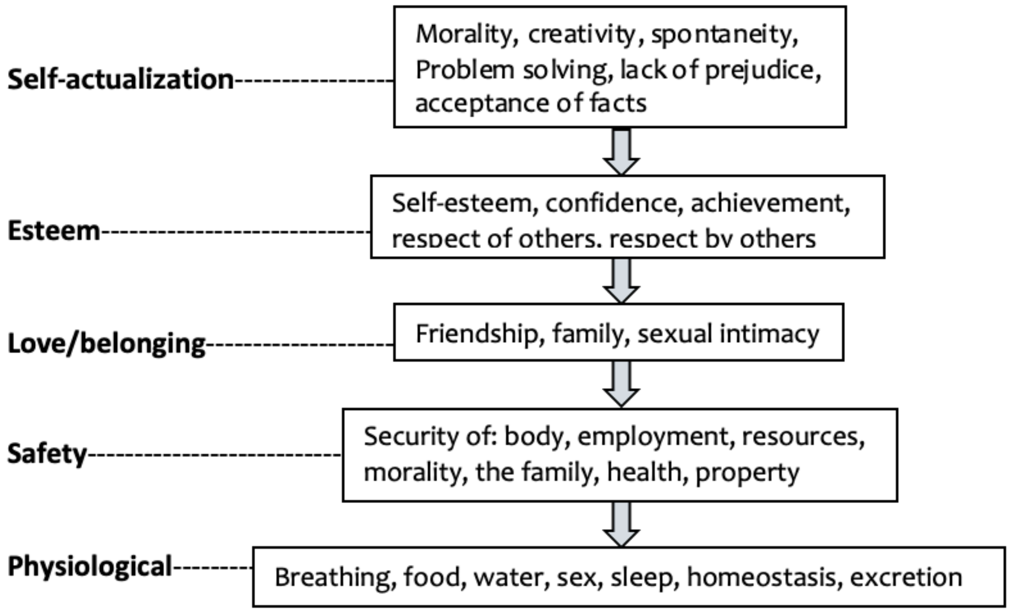
Individual health can be described in many ways. Human health is characterized as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (World Health Organization [WHO], 1948, p.1). It is also related with the ability to live to one's full potential with less stress (Centers for Disease Control and Prevention [CDCP], 2019). Human health and well-being are a continuous process with movement towards the balance of a healthy equilibrium while engaging through life events and challenges (Dodge, Daly, Huyton, and Sanders, 2012). Social Health is when individuals can adapt in a variety of social situations and develop satisfying interpersonal relationships (Study.com, 2019). As individuals continue to adapt to life changes, their well-being is affected.

Though various interpretations for health and subjective well-being are continuously changing, what a person thinks about their own well-being is consistently evident when reviewing the various interpretations (Desmet & Pohlmeyer, 2013; Zheng, Zhu, Zhao, and Zhang, 2015). There are well-being indicators that include feelings of satisfaction and happiness (e.g., self-esteem) and other environmental indicators relating to life events, including personal growth and endurance (Diener, 2000; Nisbet, Zelenski, and Murphy, 2011). Behavioral health represents a person's mental well-being as it relates to their self-emotions, behaviors and physical health when functioning in everyday activity (Insight, 2019). An individual can evaluate their own well-being through a subjective well-being that includes fulfillment with financial activities, such as a job, and cumulative emotional experiences from events associated with happy memories or events associated with unpleasant memories (CDCP, 2019; Diener, 2000, 2006; Zheng, et al., 2015). Yet, individuals who continue to adapt their lives to the fullest and adapt for positive influences can be recognized by researchers to project a happy feeling of subjective well-being (Desmet & Pohlmeyer, 2013; Sweida & Sherman, 2020; Veenhoven, 2011).

Positive human health and well-being can lead individuals to meaningful growth and self-acceptance (Zheng, et al., 2015). As each individual tries to balance life events to maintain positive well-being, they look for internal and external resources to help them regain their positive well-being equilibrium (Cummins, 2010). Some of the recognized external resources have been identified as financial gain and close relationship support (Cummins, 2010). Health care professionals recognize Maslow's Hierarchy of Needs when evaluating human growth and mental health at various stages of human development. Figure 2.2 below shows Maslow's Hierarchy of Needs commonly used by health care professionals.

Figure 2.2.

Representing Pyramid of Maslow's Hierarchy of Needs (Harrington & Commons, 1976)



Maslow's Hierarchy of Needs explains the progression of human needs and satisfaction as an individual continues to be motivated to a higher need identified by Maslow (Graham & Balloun, 1973; Maslow, 1943). Maslow identified the foundational need for health as physical requirements such as food, shelter, and protection. Maslow insists that previous levels must be applied before one can advance to the next level of the pyramid ladder to self-actualization. It has been implied that Maslow's Hierarchy of Needs can be identified as human psychological needs for human growth and development (Harrington & Commons, 2015; Xie, Clements-Croome, and Wang, 2017). This model can aid in the measurement of positive well-being for the ability to promote human health.

A current literature review finds that some researchers equate a positive subjective well-being (SWB) with an individual's thoughts and feelings of being happy (Desmet & Pohlmeyer, 2013; Diener, 2000) and use these terms interchangeably (Desmet & Hassenzahl, 2012; Lee, Je, and Byun, 2011; Petermans, 2019; Veenhoven, 2011). The focus of this study is to investigate the definition of mental well-being as the ability to have less stress for a full and productive life (CDCP, 2019; Kopec, 2017).

2.2 Effects of Built Environment on Human Health with Greenbuilding Rating Systems

The desire to learn more about the influence of the built environment attributes on human experiences and health is growing, thanks to the construction and design criteria included in greenbuilding rating systems (Ergan, Shi, and Yu, 2018). With the awareness that the aesthetic effects from natural attributes can promote good human health, the inclusion of natural attributes within the built environment is fundamental to the design process (Coburn, et al., 2019). Some literature claims that this is not a commonly recognized building practice (Oberti & Plantamura, 2017). However, architects and designers participating in WELL and Living Building Challenge (LBC) building certification projects claim improved occupant health results in healthcare facilities by integrating nature attributes and design criteria that promote interaction with nature (Peters, 2017).

Shortly after the Leadership Environmental and Energy Design (LEED), a greenbuilding rating systems standard that was published in 1999, interest in the influence of the built environment on individual health and performance was found in more literature (Fleming, 2015; Xie, et al, 2017). Kellert (2012) claims that LEED certification criteria did not include consideration for the effects of the built environment nor the inclusion of nature with the built environment on occupant physical and mental health.

Recent examination of literature reveals that studies that examine the effects of occupant "health" in sustainable LEED certified buildings evaluate "health" with different criteria (Dorsey & Hedge, 2017). One study that included ergonomic impacts on human functions when measuring occupant health (Soares, Jacobs, and Allaianese, 2012). A Hedge, Miller, and Dorsey study (2014) determined that higher productivity and better occupant health was equated with outdoor-air ventilation, daylight views, low acoustical environmental impacts, and occupant privacy. A study conducted by Tham, Wargocki, and Tan (2015) found that environmental impacts of acoustics, daylighting, ergonomics, and the indoor environmental quality (IEQ) are large influencers of overall occupant health. A study conducted by Xie, et al. (2017) was one of the first to mention mental health with findings that beautiful scenery and exterior landscape views can also improve occupant well-being and productivity.

Research also finds that built environments for the office can equally influence employees' productivity (Allen, et al., 2015) with improved occupants' health and well-being (MacNaughton, et al., 2016; Xie, et al., 2017). Recent studies suggest that the most significant greenbuilding design and construction criteria recognized worldwide for evaluating the effects of occupant health and productivity includes good indoor air quality, thermal comfort, natural lighting, and noise control (Xie, et al., 2017). Employee health investigated in a non-greenbuilding rating systems building found that poor employee health can relate to higher absenteeism and lower work efficiency (Xie, et al., 2017). Absenteeism can cost the employer

$3,600 per employee per year (Investopedia, 2021). Recent research by McGraw-Hill Construction (2010) investigating employee health in greenbuilding rated commercial buildings found 1% to 5% reduced employee healthcare costs, 21% higher employee productivity, and 56% lower absenteeism. Results of this study influenced the industry professionals to incorporate known greenbuilding rating systems design and construction criteria to promote higher occupant health and productivity (Xie, et al, 2017).

Given that there are various greenbuilding rating systems with different certification criteria and foci, it is difficult to consistently evaluate individual built environment attributes that can positively impact occupant health. The criteria for what one greenbuilding rating system calls "health" or "beauty" can be a totally different criteria than other Greenbuilding rating systems' criteria for the same terms (e.g., health). Further investigation is needed to evaluate which environmental attributes are most influential in impacting human health.

Greenbuilding rating systems (GBR), categorized as sustainable building standards, came into existence as a building assessment tool to verify that building construction and operational performances have less environmental impacts than a typical non-sustainable constructed building ([USGBC], 2016). As greenbuilding rating systems standards are being revised, they are adding more sustainable design and construction attributes specifically intended to improve human health, which is needed (Anåker, Heylighen, Nordic, and Elf, 2017).

The most highly recognized greenbuilding rating systems standards described below reveal more information about their certification criteria on mental health for stress reduction. These greenbuilding rating systems are Building Research Establishment

Environmental Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Living Building Challenge (LBC), and the International WELL Building Standard (WELL).

2.2.1 BREEAM

Greenbuilding rating systems standards started in the United Kingdom (UK) in 1990 with Building Research Establishment Environmental Assessment Method (BREEAM as a sustainability assessment tool. BREEAM provides measurable benchmark criteria for the environmental performance of a building through design, construction, and operation phases (BREEAM, 2021). As the first built-environment assessment tool, BREEAM promoted energy efficiency during construction and building operations (Danivska, et al., 2019). Currently, BREEAM has thirteen sustainable assessments that are diversified depending on the function of the building. The BREEAM UK NC V6 standard was released on August 24, 2022. BREEAM's nine assessment environmental categories include Energy, Health and Well-being, Land Use and Ecology, Materials, Management, Pollution, Transport, Waste, And Water (SRE, 2023). Their Health and Well-being assessment includes safety measures for building indoor air quality and lighting (SRE, 2023). However, built environment assessment criteria for mental health with stress was not included.

2.2.2 US Green Building Council (USGBC)

In 1993, the United States Green Building Council (USGBC) initiated the greenbuilding movement to promote sustainable construction for built environments by conserving natural resources such as energy and water consumption (Kilbert et al., 2002; Rosa, 2019; Sussman & Hollander, 2015). In 1999, USGBC created a voluntary greenbuilding rating system standard, Leadership in Energy and Environmental Design (LEED), to promote sustainable building construction by decreasing natural resources consumed during new construction (Kibert et al., 2002; Rosa, 2016; USGBC, 2016). The voluntary LEED greenbuilding rating systems evaluated six environmental impact areas for certification that could decrease environmental resource consumption during new construction: 1) Sustainable Site, 2) Water Efficiency, 3) Energy and Atmosphere, 4) Materials and Resources, 5) Indoor Air Quality, and 6) Innovation in Design (Attaianese, 2012; USGBC, 2009).

With the growth of LEED building certifications, in 2009 USGBC increased and diversified their LEED Rating Systems with building types including: BD+C New Construction, BD+C Core & Shell, BD+C Schools, ID+C New Construction, and Existing Buildings OM (USGBC, 2009, 2016). In 2016, USGBC developed a new greenbuilding rating system, namely LEEDv4, that diversified LEED Rating Systems based on building functions to include: Healthcare, Hospitality, Warehouse and Distribution Centers, Homes, Multifamily Midrise, Neighborhood Design, and Schools. In 2019, USGBC published the LEEDv4.1 Reference Guide that included updated compliance requirements, easier credit expectations, and additional reference guides for cities and communities (e.g., LEED Cities: Plan and Design; LEED Cities: Existing; LEED Communities: Plan and Design; and LEED Communities (USGBC, 2019).

The USGBC currently asserts that LEED certification criteria with sustainable construction can improve and promote human health (Allan, et al, 2015; USGBC, 2016; USGBC, 2019; Xie, et al., 2017). They assert that LEED building certification criteria improves occupants' health with the use of low chemicals found within construction materials and indoor material finishes for better indoor environmental quality (IEQ), natural daylight views, and thermal comfort (USGBC, 2019). However, investigative research still needs to be found to demonstrate that LEED certified buildings will result in improved occupant health (Dorsey & Hedge, 2017; USGBC, 2016). The current LEED v4.1 includes Quality Views Credit criteria, found in section Environmental Quality (USGBC, 2023), that includes "natural environments" language in the certification criteria. This is the closest criteria in LEED that includes the assessment of nature within the built environment for mental health.

2.2.3 Living Building Challenge

The International Living Future Institute (ILFI) is a non-profit organization that developed and published the Living Building Challenge (LBC) Standard (2006) with the intent to measure the sustainable attributes and environmental impacts by lowering building operational carbon footprints. This standard considers coordinating the relationships between people, nature, and the built environment (ILFI, 2019). The Living Future Institute requires a twelve-month performance metric to meet the voluntary certification requirements for any of the seven standards, namely: 1) Living Building Certification, 2) Core Green Building Certification, 3) Petal Certification, 4) Living Product Challenge, 5) Living Community Challenge, 6) Zero Energy Certification, and 7) Zero Carbon Certification. Additionally, some of the LBC certification requirements include annual sustainable label programs (Reveal, Declare and Just) for strict material chemical transparency. Together, these third-party verified certification programs are stricter than LEED because they require less carbon, fossil fuel influences, and more organic, ecofriendly construction and product materials and design processes (ILFI, 2020).

The LBC standard has seven performance areas called *Petal*. The performance category for each *Petal* includes: 1) Place, 2) Water, 3) Energy, 4) Health+ Happiness, 5) Materials, 6) Equity, and 7) Beauty with core requirements that must be completed to achieve *Petal* Certification (ILFI, 2019). The ILFI partnered with Janie Benyus (co-founder of the Biomimicry Institute) in a biophilic design initiative to help create the concept of *Petal*, a flower metaphor, for connecting humans with nature, and nature with the built environments and community (ILFI, 2019; Schnitzer, 2010). There are twenty Imperatives included with the seven Petals. Each Imperative focuses on a specific scope of influence for certification. From the twenty Imperatives combined in the seven Petals, two of them include nature. The *Health + Happiness* Petal includes an Access to Nature imperative that recognizes occupant access to indoor fresh air, daylight views, and outside views from inside the building (ILFI, 2020). The *Beauty* Petal includes a Beauty + Biophilia imperative that requires an indoor connection with beauty and nature, as Biophilic Design, claiming to enrich the lives of building occupants (ILFI, 2020). However, evaluation of occupant mental health with stress within the built environment was not stated in the LBC criteria.

2.2.4 WELL

The International WELL Building Standard (WELL), published by the International WELL Building Institute (IWBI) in September 2015, was the first voluntary greenbuilding rating systems certification standard to consider the building architecture and building function behind specific human-centered design criteria proven to increase occupant health (IWBI, 2015; Song, Lau, Lau, and Song, 2023) and promote healthy built environments (WELL, 2019). The International WELL Building Institute conducted years of literature and medical research on environmental health, behavioral factors, demographic risk factors, and other relevant standard guidelines (IWBI, 2015).

With the intent of occupant stress reduction, WELLv1 Mind Concept 99 *Beauty and Design* includes visual appeal with higher ceiling heights and art images of nature (IWBI, 2015; USGBC, 2019; Van den Berg, et al., 2003). Expanding visual appeal relating to nature, WELLv2 includes built environment design criteria that includes Mind Concept M02 *Access to Nature* and Mind Concept M09 *Enhanced Access to Nature* (WELL, 2019). Additionally, unique to WELL, the mention of "restorative spaces" are included with Mind Concept M07 *Restorative Spaces*, recognizing the importance of the built environment's impacts for human's mental health. The conformance criteria for the WELL Mind concepts include space interaction with nature on the interior and exterior of built environments.

There are ten Concepts, or built environment focus areas, within WELLv2 that features human health. These Concepts include: 1) Air, 2) Water, 3) Nourishment, 4) Light, 5) Movement, 6) Thermal Comfort, 7) Sound, 8) Materials, 9) Mind and 10) Community. Each Concept has several different Features (compliance areas) with measurable requirements needed for certification. Each Feature in WELL states which human body systems are affected, and knowledge about which human physical behavior changes can lead to better lifestyle choices (IWBI, 2015). For example, the Mind Concept has fifteen Features and includes certification points for mental health, stress support, restorative spaces, and access to nature (WELL, 2019).

LEED and WELL building certification criteria have similar compliance requirements within similar areas. One example is LEED water requirements and WELL Water Feature.

However, research about the occupant health effects of WELL certified buildings remains limited for the consensus criteria on the effects of mental health (Xie, et al., 2017). Most research finds that occupant satisfaction and health in WELL certified buildings are higher than for conventional and other sustainable certified buildings (Birgisdottir, 2019; Danivska, et al., 2019; [IWBI], 2015; Kamaruzzaman, Ashiqin, EM, and Riley, 2016; Xie, et al., 2017; Zimmerman, et al., 2019) and that psychological health is addressed more with WELL certification criteria than other greenbuilding rating systems (GBR) (McArthur & Powell, 2020; Potrč Obrecht, Kunič, Jordan, and Dovjak, 2019; Zimmerman, et al., 2019). Even though IWBI requires post-occupant evaluation surveys for WELL certification, to date there are few published studies examining the effectiveness of WELL certification criteria (Ildiri, et al., 2022).

2.2.5 Comparing BREEAM, LBC, LEED, WELL, LBC Similarities and Differences

Though sustainable construction is important for addressing environmental impacts and can affect occupant physical health, only WELL published the first voluntary greenbuilding rating systems to include consideration for occupant mental health before architecture and design criteria. The different certification criteria for the four greenbuilding rating systems sustainable standards mentioned above are outlined in Table 2.1. Since there are multiple certification requirements for each criterion mentioned, a table below is shown as a general overview with the intention of focusing on certification criteria stated to influence human mental health with stress.

Table 2.1

Comparing LEED, WELL, LBC, and BREEAM Compliances

GBRS CERTIFICATION CRITERIA	BREEAM (Building Research Establishment Environmental Assessment Method)	LEED Leadership in Energy and Environmental Design: USGBC	LBC Living Building Challenge: IFLI	WELL: Delos
Date Initiated	1990	1999	2006	2015
Certification Evaluation Process	Online questionnaire-based approach, improvements then third-party assessor (Building Research Establishment)	Document review with third-party certification (GBCI) and performance metrics	Document Review and performanc e metrics	Document review and on-site Performance Testing-Agent and third-party document review (GBCI) with performance metrics
Multiple Certifications	Yes, with building functions	Yes	Yes	Yes, with building functions
Sustainable Sites	Yes, Ecology	Yes	Yes	Yes
Indoor Environmental Quality	No asbestos and encourages natural ventilation for compliance with WHO guidelines	Must demonstrate indoor air ventilation meets minimum ASHRAE 65.1	Yes. Includes use of natural ventilation.	Yes
Light & Daylight	Yes	Yes	Yes	Yes
Beauty	No	Yes, v4.1 IEQ Outside Views	Yes. Air + Biophilic	Yes. Biophilic
Mental Health	No	No	Yes. Visual + Biophilic	Yes. Biophilic + Restorative
Ceiling height	No	No	No	Yes. WELLv1
Noise	Yes, pollution	Yes v4.1	No	Yes v2
Certification valid	One time	One time except OM; pending certification program	Annual pending certificatio n program	Recertification every 3 years with annual data collection
On site assessment	Yes	No	No	Yes
Total Projects Certified	Over 600,695	Over 6,000	Over 300	Over 24,000

WELLv2 is the only standard to directly address the consideration for the effects of the built environment on occupant mental health with stress. Exclusive claims stated in WELL include the following:

1. Being the first sustainable building standard that focuses on criteria to promote occupant health and wellness before sustainable construction. Claiming the first "human-centered design" criteria for promoting healthy built environments (WELL, 2019).
2. Stating the human body impacts in the introduction of each WELL Concept.
3. Have undergone seven years of research prior to writing WELL investigating relative industry standards, medical experts, physical and psychological research about environmental health, human behaviors, and demographic impacts. Development of Wellographies as performance-based compliance criteria to promote occupant health as cited from trusted scientific literature and best-practice guidelines (e.g., EPA) known in the industry (WELL, 2019).

It is recognized that GRS certification criteria focus on engineering measurements and building performances for their influences on occupant health and consider criteria for indoor environmental quality (IEQ) to suffice (Al horr, et al., 2016; Xue, et al., 2019). IEQ includes the relationship between indoor materials and their relationship with occupant health measuring air quality, humidity, temperature, luminosity, and sound levels (Steinemann, et al., 2017). Few studies investigating occupant health include comparisons between the different certification criteria including WELL Living Building Challenge and other greenbuilding rating systems (Danivska et al., 2019; IWBI, 2015; Kamaruzzaman, Ashiqin, EM, and Riley, 2016; and Xie, et al., 2017). One research study found higher occupant satisfaction and health in WELL certified buildings when compared with conventional buildings and other greenbuilding rating systems certified buildings (Zimmerman, et al., 2019). This study stated the contributing WELL criteria was found to have healthier results by implementing biophilic design, as stated in WELL, for occupant well-being in healthcare facilities (Peters, 2017).

Not many studies focus on the affiliation of the built environment with mental health for stress (Evans & McCoy, 1998; Xie, et al., 2017); therefore, further investigation is needed (Licina & Yildirim, 2021). Consideration for mental health with stress as an effect from the built environment was first introduced in WELLv2 Mind Concept with restorative spaces. However, there remains limited study on the effects of the WELLv2 Mind Concepts criteria on mental health for stress.

2.3 Nature Theories Promoting Human Health with the Built Environment

It can be difficult to identify which built environment attributes can contribute to increasing occupant health within the built environment (Yufan, Tzortzopoulos, and Kagioglou, 2018). Literature suggests that human interaction with nature supplies health benefits such as decreasing human stress (Aristizabal, et al., 2021). Three concepts for nature interaction with the built environment are discussed here by the introduction of biomimicry design, the Golden Ratio, and Frank Lloyd Wright's architectural design philosophy that convers nature with the built environment.

2.3.1 Biomimicry Design with the Built Environment

The term *Biophilia* was first coined by psychologist Erich Fromm who identified the effect of nature for improving human mental health (Kellert, 2012). *Biophilia*, meaning "love of life," emphasizes the scope of the human emotional connection to nature (Sahralyanjahromi & Lodson, 2017; Coburn, et al., 2019; Xue, et al., 2019). Humans are drawn to nature and desire other "life" features within built and non-living environments (Sahralyanjahromi & Lodson, 2017). Research concurs that human visibility to nature can positively impact occupants' health (Sahraiyanjahromi & Lodson, 2017) and decrease stress, fatigue, and some mental disorders in urban areas (Lederbogen, et al., 2011). Human mental fatigue is displayed as cognitive exhaustion precipitated by continuous voluntary mental focus on a task or objective (Parsons, 1991).

The word *Biomimicry* originates from two Greek words: *bios,* for "life" and *mimesis* meaning "to imitate" (Mirniazmandan & Rahimianzarif, 2018). The co-founder of Biomimicry, Janie Benyus, published a book, *Biomimicry: Innovation Inspired by Nature,* in 1997. Janie Benyus intended for biomimicry to become a science that studies nature to "imitate life" for the purpose of finding design solutions to human problems (Sahraiyanjahromi & Lodson, 2017; Mirniazmandan & Rahimianzarif, 2018). In 2006, she founded The Biomimicry Institute that strives to promote natural solutions to products and processes for sustainable building materials with the use of biophilic design (Faludi, 2005; Xue, et al., 2019) with form, materials and structures that are environmentally friendly (Attia, 2015).

Architects are using biomimicry within built environments as an effective source for sustainable design innovations (Benyus, 1997; Mirniazmandan & Rahimianzarif, 2018; Vincent, 2016; Xue, et al., 2019; Zhong, Schrö der & Bekkering, 2022). Biomimicry can assist engineers in solving technical issues and construction impacts to decrease energy consumption (Mirniazmandan & Rahimianzarif, 2018) and affect occupant health with the use of plants and daylight views (Sahraiyanjahromi & Lodson, 2017).

There are two different types of biomimicry processes used to assist architects and engineers with implementing sustainable designs. The first one is problem solving with nature, "top-down approach" (Knippers & Speck, 2012) or "problem-driven" approach for using biological designs found in nature for solving a problem (Helms, Vattam, and Goel, 2009; Mirniazmandan & Rahimianzarif, 2018). The concept of imitating nature to solve problems for technical solutions has been used for many years as evident with Leonardo da Vinci's imitating bird's wings, when formulating an idea for humans to fly (Sahraiyanjahromi & Lodson, 2017). Figure 2.3 shows the author's artistic rendition of Leonardo da Vinci's imitation of bird wings that could be used for humans to fly.

Figure 2.3

Author's rendition of Leonardo da Vinci's imitation of Bird Wings for Humans to Fly

The second one begins with knowledge about biomimicry. The "Bottom-up approach" (Knippers & Speck, 2012), or solution driven approach (Helms et al., 2009), begins with knowledge from biological research (Mirniazmandan & Rahimianzarif, 2018; El-Zeiny, 2012) for mimicking organic designs and techniques found in nature for use with design and technical approaches that offer bioimicry solutions (Benyus, 1997; Mirniazmandan & Rahimianzarif, 2018; Sahraiyanjahromi & Lodson, 2017; Xue, et al., 2019). Chairman Ray Anderson, Interface manufacturing FLOR carpet, used the bottom-up biomimicry approach with inspired images of leaves and river stones when looking to create new carpet design patterns (El-Zeiny, 2012). Figure 2.4 shows an example of the bottom-up biomimicry approach inspired by forest leaves for Armstrong's Fallen Leaves vinyl flooring pattern.

Figure 2.4

Armstrong vinyl flooring (left) created from biomimicry inspirations

To summarize, biophilic design, the concept of designing an environment to encourage human engagement with nature, can provide positive experiences to humans (Kellert, 2016, 2018; Kellert & Wilson, 1993; Wilson, 1984). Integrating biophilia into the built environment can reduce physiological and psychological stress (Hung & Chang 2022; Panagopoulos, Sbarcea, and Herman, 2020; Sahraiyanjahromi & Lodson, 2017). However, further investigation is needed to define and evaluate the psychological effects of nature with the built environment for occupant stress.

2.3.2 Golden Ratio with Nature

Natural shapes and proportions are known to be aesthetically pleasing and harmonious to the human eye (Trautmann, 2021). A geometric ratio, the Golden Ratio, has the Length to Height ratio around 3/2 proportion; that equals 1.618 (Sussman & Hollander, 2015). The equation for the Golden Ratio is x = (1 + Square root of √5)/2 (Bejan, 2009) and is widely thought to be identified as "the most perfect and beautiful proportion" (Trautmann, 2021). The Golden Ratio can be recognized in nature in the form of a smaller square and a rectangle, which then continues into smaller squares and rectangles forming a spiral shape (Akhtaruzzaman & Shafie, 2011). The Golden Ratio spiral shapes are recognized in nature, Figure 2.5, through living organisms such as the physical proportions of the human body (a human face on the left), vegetated proportions in plants and trees, animals, birds, and other creatures (a nautilus shell on the right) in the universe (Akhtaruzzaman & Shafie, 2011).

Architects, artists, engineers, and designers have researched the Golden Ratio when considering a foundation for their work (Akhtaruzzaman & Shafie, 2011). Ancient Greek and Roman architects promoted the Golden Ratio by use of columns in their porticos as shown in the architectural design of the Parthenon of Athens in Figure 2.6 (Sussman & Hollander, 2015).

Figure 2.5

Golden Ratio of a human face and a Nautilus shell (Permission of Company Folders)

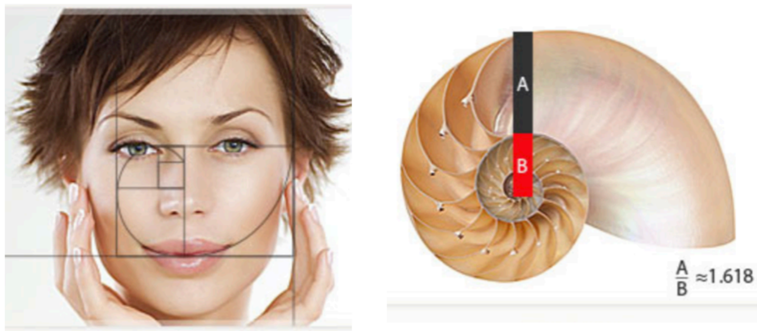


Figure 2.6

Image of Golden Ratio of Parthenon in Athens (Permission of Plus Maths)

2.3.3 Architectural Design with Nature

Identifying the adjacent relationship between the built environment and human experience is imperative (Ergan, et al., 2018) for design practitioners when solving design problems that can strengthen occupant health and productivity (Heba-Talla, 2017). Research conducted by Ergan, et al. (2018) with 400 participants found that immediately noticed architectural designs and features can have a large influence on an individual's awareness of spaces, their preferences, and experiences within those spaces. The highly influenced architectural influences found include exposure to nature with open ease of access, openness and density of accessible space, presence of windows and daylighting, and availability of socialization or isolation when needed (Ergan, et al., 2018). Recognizing that these highly influenced features are related to inside and outside nature interactions further demonstrates that characteristics of nature within the built environment can have the potential to promote human restoration (Hartig, et al., 2003).

Research finds that aesthetic attributes in nature with organic patterns, shapes, and colors can be more visually attractive than straight manufactured lines (Vartanian, et al., 2013). Even before the design and construction of *Fallingwater*, Frank Lloyd Wright was known for architectural design strategies connecting architectural forms with forms found in nature (Vaughan & Ostwald, 2022).

Frank Lloyd Wright implemented nature into his built environment design at Fallingwater (Figure 2.7 below) with the use of naturally, organically shaped attributes of nature beside the straight design lines (Wright, 2021). The architecture of Wright's Fallingwater residence is seen as projecting out of the outside nature landscape, extending the cantilever terraces in the horizontal plane, and the vertical stone facade blending into the vertical forest to invade nature, thus contributing to a feeling of connectedness with outside nature (Kellert, 2012) also called organic design (Kellert, 2005). Frank Lloyd Wright is known for order and pattern within the built environment evidenced by the normal height entryway expanding into a larger, more active living space with a higher ceiling, a formal fireplace, and large windows for a view of the outside (Designing positive psychology, 2011; Wright, 2021). Wright was aware of occupant satisfaction for views of nature inside and outside the built environment (Designing Positive Psychology, 2011).

Figure 2.7

Image of Frank Lloyd Wright's Fallingwater (Permission of Dr. Jon Burley)

The role of built environments, including interior design attributes, has the potential to cause stress and affect human health (Evans & McCoy, 1998). It is evident that not all built environments include nature attributes as the ancient Greeks did with the Golden Ratio or Frank Lloyd Wright's incorporation of bringing outside nature attributes into his building designs. All four levels of Fallingwater's architectural design allows nature views of water, rocks, the valley, and trees (Vaughan & Ostwald 2022). Further investigation is needed to find what nature attributes are perceived to decrease occupant mental stress for any built environment. Such an investigation is based on a foundation of previous research to identify and test specific independent variables surrounding the built environment.

2.4 Human Stress

The mind has a significant role in an individual's health and well-being (IWBI, 2015). Mental disorders, or poor mental health, can be defined as an upheaval in an individual's regular thoughts, emotions, and behavior (WHO, 2022). Mental health is a cognitive state of mind and focus. Positive mental health is where a human state of mind can restore and regenerate cognitive focus. Mental health accounts for 13% (one out of every eight individuals) of the global disease, with depression alone ranking as the leading cause of disability worldwide (WHO, 2022). In 2019, there were around 301 million individuals living with anxiety related to fear and increased worry (WHO, 2019).

Research shows that there are different causes of stress responses. Stress, as one type of mental disorder, can be caused by a thought or actual situation that can be perceived to cause individual harm (WHO, 2022). Kaplan & Kaplan (1989) define the cause of stress as voluntary mental focus on tasks of low interest over prolonged periods of time. Increased psychological stress responses can happen with environment circumstances such as physical crowding, noise, industry air pollutants, and higher temperatures as seen with heat island effects (Cohen, 2004). A stress response can also increase with a learned memory from a specific environment that has caused an increased stress response in the past (Parsons, 1991). The three factors within life's events or circumstances that can trigger a stress response, identified by Evans & McCoy (1998), include: first, an individual's perception or actual unexpected change in life events; second, when an individual is alone during the disrupted life events; and third, when a resource coping solution is difficult or unavailable to adapt to unexpected change.

There are physical and psychological manifestations of an individual stress response (Evans & McCoy, 1998; Kaplan & Kaplan, 1989; Parsons, 1991; Ulrich, et al., 1991). When an individual is perceived to be stressed, physiological chemicals from the neurotransmitters in their body go through the nerves, then to the cells to interact with the physical body to make physical changes including increased blood pressure, dilated pupils, tense muscles, and increased breathing (Evans & McCoy, 1998). This physical response is sometimes called a "Fight or Flight" response (Evans & McCoy, 1998; Parsons, 1991;). Experiencing a "Fight or Flight" response for prolonged periods can lower an individual's immune response to prevent infections (Sternberg, 2009). Kaplan (1983) realized that the cognitive ability of the brain to focus and solve problems decreases when an individual is performing a task under stress. Individuals can have greater physical and psychological damage with repeated episodes of stress if they are not able to recover from the symptoms of stress after a single response (IWBI, 2015).

In 2020, individual anxiety and stress increased 26% of the world's population in just one year in response to the COVID-19 pandemic (WHO, 2022). This environmental stressor disrupted individuals' lives, jobs, and health from the strict regulations placed on them. This rise in mental disorders from COVID-19 encouraged public interest for further evaluation on the effects of the built environment on human stress and what strategies are needed to decrease stress (Weber & Trojan, 2018). During these COVID 19 lockdowns, research found that increased interaction with natural environments provided individuals with better psychological responses induced by the pandemic (Haasova, Czellar, Rahmani, and Morgan, 2020). This relatively new topic (Núñez-González et al., 2020) is the focus of this study, which investigates the influence of nature environments on human stress responses surrounding the built environment. In this study, the built environment is defined as an environment that includes man-made materials or attributes.

2.5 Effects of Nature on Stress

Connection with the natural exterior environment is valuable for promoting positive human health and subjective well-being (De Vries, Verheij, Groenewegen, and Spreeuwenberg, 2003; Gifford, 2014; Kaplan, 2001; Kaplan, Kaplan, & Ryan, 1998; Nisbet, et al., 2011; Sachs, 2018; Van den berg, Maas, Verheij, and Groenewegen, 2010; Wells & Rollings, 2012;). Literature finds strong statistical evidence connecting nature with stress reduction (Evans & McCoy, 1998; Fischl & Gärling, 2008; Hartig, et al., 2003; Herzog, Maguire, and Nebel, 2003; Hung & Chang, 2022; Kaplan & Kaplan, 1989; Lottrup, et al, 2013; Thompson, et al., 2012; Ulrich, 1983; Ulrich, et al., 1991; Van den Berg, et al., 2010). When human stress responses are decreasing, then mental attention is increasing (Berman, Jonides, and Kaplan, 2008; Berto, 2005; Chang, et al., 2008; Coburn, et al., 2019; Emfield & Neider, 2014; Evensen, 2015; Felsten, 2009; Herzog, Chen, and Primeau, 2002; Kaplan, 1995; Thompson, et al., 2012; Wells & Rollings, 2012;). Literature finds that cognitive attention can be increased, or restored, when mental stress is reduced (Ulrich, 1991).

Interaction with nature is known to have positive effects on human health (Lovell, et al., 2015). Humans have a psychological love of nature (definition of biophilia), and they desire a close physical association (Kellert & Wilson, 1993) with nature. Nisbet, et al. (2011) speculated that there are three reasons why humans are intrinsically drawn toward nature. One reason includes a human mental and physical innate attraction towards nature (Hartig, et al., 1996; Kaplan & Berman, 2010; Mayer & Frantz, 2004; Ulrich, 1991), also called Nature Relatedness. The second reason is humans desire being removed from the adverse effects of ambient urban environments (e.g., loud noises and air pollution) and desire interactions with natural environments where they can find visual beauty and relaxation (Nisbet, et al., 2011). The third reason is for the potential to increase physical activity and leisure recreation that can be fun and encourage social interaction (Nisbet, et al., 2011; Thompson, et al., 2012).

A review of the literature has resulted in many interpretations of nature. Kaplan & Kaplan (1989) define nature components as vegetated landscaped areas with natural attributes that can be found in familiar spaces, such as a garden or pond, promoting an increase in human visual interest and satisfaction. Visual attributes found in nature include green plants, forests and mountains, animals on land and in the air, and blue water in rivers and oceans engulfed with living creatures (Sahni & Kumar, 2021), as seen in Figure 2.8. Nature environments does not include materials that are manmade or manufactured (Kaplan & Kaplan, 1989). Research about the effects of stress from road views finds that man-made building materials, as seen more in urban environments, do not promote stress restoration (Parsonset, et al., 1998).

Figure 2.8

Photograph of common attributes found in nature (Permission of Dr. Jon Burley)

With the visual beauty found in nature, one is expected to discover that environments with nature are preferred when comparing them to the built environment (Kaplan & Kaplan, 1989). Yet, built environments are an intrinsic component of all human existence as buildings offer shelter for safety (Gifford, 2014), and shelter is recognized as a basic need when promoting human health from Maslow's Hierarchy of Needs (Harrington & Commons, 2015). The architectural design and construction materials provide opportunities to include attributes of nature that can impact human health and decrease stress.

2.6 Gap: Identifying Key Indicators for Measuring Low-Stress Environments

A comprehensive literature review of current theories, standards, and concepts related to the effects of mental stress with the built environment and nature environment reveals a gap in identifying which attributes in different environments are perceived to have low stress. This study compares key indicators with built environments and outside nature environments. The five key indicators chosen to relate to the built environment are: 1) Ceiling Height, 2) Viewing Nature Inside, 3) Viewing Nature Outside from Inside, 4) Inside Nature Engagement, and 5) Outside Nature Engagement. Inside Nature Engagement and Outside Nature Engagement variables chosen for this study follow similar criteria included in Attended Restorative Theory.

2.6.1 Ceiling Heights

Visual interpretations of interior built environments can influence an occupant's psycho-social health and physical health. The compliance intent for WELLv1 Mind Concept 99 Beauty and Design II is for the interior room to feel spacious by including the ceiling height dimensions with a ratio of room-to-wall dimensions (IWBI, 2015). Literature concurs, acknowledging that individuals can perceive density of a space with respect to room size (square feet) and ceiling height (Vartanian, et al., 2015; Winchip, Inman, and Dunn, 1989).

A common ceiling height before 1990 was eight feet high, largely due to the normal dimensions of required building materials, such as wall studs and sheetrock boards (Weekend Builds, 2024). Rooms with ceiling heights of eight feet can be perceived as being more crowded and stressful (Meyers-Levy & Zhu, 2007; Vartanian, et al., 2015). Adults can perceive the same room dimensions as being bigger and more spacious when the ceiling height is *over* eight feet than when the ceiling height *is* eight feet (Savinar, 1975).

Rooms with ceiling heights higher than the standard eight feet can be perceived as spacious and less stressful (Fich, et al., 2014; Meyers-Levy & Zhu, 2007; Vartanian, et al., 2015). After 1990, newly constructed buildings routinely included nine-foot ceiling heights recognizing that a higher ceiling height could "make any room feel larger" (Weekend Builds, 2024). One study investigating architectural features with high ceiling heights suggests that the participant's preferred ceiling height is a maximum of ten feet (Baird, Cassidy, and Kurr, 1978).

2.6.2 Viewing Nature Inside the Built Environment

Influences of nature within the built environment can affect occupants differently; either positively, negatively, or not at all. All literature and research conducted for this study included real vegetation and no artificial vegetation. Individual responses to nature are different depending on their previous experiences, cultural patterns, frequency, and duration of the interaction with nature, and their perception at the time of interaction (Ryan, et al., 2014). However, evidence suggests that a lack of visual interaction with nature for interior built environments can decrease occupant well-being (Evans, 2003; Grinde & Patil, 2009; Martin, et al., 2015; Shalev, 2016; Spencer & Baum, 1997; Stigsdotter, 2005). Accessible visual interaction with nature can improve mental health with decreased stress (Berto, 2005; 2014; Grinde, & Patil, 2009; Hartig, et al 2003; Kaplan, 1985; Lottrup, et al., 2013; Ronalds, et al., 2010; Tenneessen & Cimprich, 1995; Yin, et al., 2020).

Nature attributes found to decrease workplace stress includes indoor potted plants, access to natural sunlight, and outside views of nature (Largo-Wright, et al., 2011). Office environment studies suggest that occupant exposure to nature attributes can reduce stress symptoms in the workplace (Beil & Hanes, 2013; Grinde & Patil, 2009; Herzog, et al, 2003; Kaplan & Kaplan, 1989; Lohr, Pearson-Mims, and Goodwin, 1996; Lottrup, et al.,2013; Mackerron & Mourato, 2013; Ulrich, et al., 1991). Some literature suggests diverse findings.

One research investigating the effects of indoor plants within a work environment found no significant occupant performance or occupant health improvements between having indoor plants and not having indoor plants within the same work environment (Thatcher, Adamson, Block, and Kalantzis, 2020).

The WELL standard certification criteria for low stress are consistent with most literature found. WELLv2 Mind Concepts M02 *Access to Nature* and M07 *Restorative Spaces* criteria incorporates specific design access to nature with inside plants and views of nature inside and outside (IWBI, 2018) which is proven to increase occupant mood in the work-place (Brown, Barton, and Gladwell, 2013; Largo-Wright, et al., 2011; Larsen, et al., 1998).

2.6.3 Viewing Nature Outside from Inside the Built Environment

Stress Recovery Theory (SRT; Ulrich, 1983; Ulrich, et al., 1991) claims that nature views can transfer human brain activity to a more relaxed state promoting stress reduction and positive emotion. An occupant's inside window view of outside nature can have a positive human health effect due to the perceived openness of the view (Grinde & Patil, 2009) and is essential for stress restoration (Berto, 2005, 2014, 2020; Brown, Barton and Gladwill, 2013; Gladwell, et al., 2012; Hartig, et al 2003; Korpela, et al., 2015; Lottrup, et al., 2013; Tennessee & Cimprich, 1995; Yin, et al., 2020), especially when there is no outside window view of nature vegetation from within the built environment (Coon, et al., 2011; Van den Berg, et al., 2003). Evidence is found that nature views can reduce occupant stress symptoms in the workplace (Beil & Hanes, 2013; Grinde & Patil, 2009; Herzog, et al, 2003; Kaplan & Kaplan, 1989; Lohr, et al., 1996; Lottrup, et al., 2013; Mackerron & Mourato, 2013; Nisbet, et al., 2011; Ulrich, et al., 1991).

Occupants viewing nature environments (e.g., lakes, trees, or mountains) are prone to higher task performances than viewing non-nature environments (Berto, 2005; Hartig and Staats, 2006; Herzog, et al., 2002). Urban planners and landscape architects understand the importance of views of nature by designing visibly beautiful nature environments outside and adjacent to the built environment for promoting human health (Peters, 2017; Sachs, 2018), well-being (Kopec, 2017), and stress reduction (Berman, Jonides, and Kapla, 2008; Berto, 2005; Gascon, et al., 2015; Herzog, et al., 2003; Staats, Jahncke, Herzog, and Hartig, 2016). However, limited research is found that identifies which specific outside landscape attributes contribute most occupant mental health for stress reduction (Velarde, Fry, and Tyeit, 2007).

An older landscape design theory, Salutogenesis, (*salus* is health in Latin) with genesis (origin), was first used by Aaron Antonovksy in 1979, with the intention of promoting human health and not disease (pathogenesis) (Abdelaal & Soebarto, 2019). Including salutogenic designs within the workplace, using indoor plants and close walking distance to gardens (Sachs, 2018), is found to decrease stress and promote occupant health (Gillis & Gatersleben, 2015; Reijula, lahtinen and Rubhomaki, 2015; Stoltz & Schaffer, 2018) and improve occupant productivity more than workplace environments with no plants (Thatcher, et al., 2020). Close association to outside nature, such as a vegetated park, healing garden is also recognized to decrease occupant stress for workplace environments (Largo-Wright, et al., 2011).

When comparing inside water attributes with outside vegetative views, one study finds that interior panoramic water wall murals lowered stress more than interior murals without water, and with outside window views of nature with commonplace vegetation (Felsten, 2009). However, participant's perceptions of the most low-stress views are found when interacting with actual interior water attributes, such as water fountains, over photographic views of water and over an inside aquarium (Nevzati, Demirbas, and Hasirci, 2021). Although research suggests that indoor environments are generally less restorative than outdoor nature environments (Fischl & Gärling, 2008), indoor nature environments and outdoor built environments have equal restorative effects (Hartig, et al., 1997). A variation in the sizes of the murals and sizes of the images could explain the resulting differences (Felsten, 2009). Further investigation is needed to clarify these literature discrepancies.

The WELL Mind Concept M09 *Enhanced Access to Nature* to decrease stress claims positive human health impacts through experiences of nature inside and outside the built environment. Compliances to M09 Concept includes close association with 25% exterior vegetation, or viewing 75% of nature inside, or outside green or blue space within a 1,000-foot walking distance (IWBI, 2018). When comparing other greenbuilding rating systems compliance credits for their emphasis on biomimicry with WELL, criteria connecting the built environment with nature views inside and nature views outside are lacking (Xue, et al., 2019). In summary, conclusive statistical evidence about the types of nature environments that can best promote occupant health need further investigation.

2.6.4 Inside Nature Engagement and Outside Nature Engagement

Literature on two of the five independent variables chosen for this study are reviewed in this section. The Inside Nature Engagement and Outside Nature Engagement independent independent variables follow similar environmental criteria as with Attention Restorative Theory that was discovered by Kaplan & Kaplan (1989).

2.6.4.1 Environmental Psychology

Over fifty years ago, a new branch of psychology was created, termed *Environmental Psychology*, emphasizing the significance of studying the relationships between individuals and their surrounding environments (Steg, van den Berg, and De Groot, (Eds.), 2013). Egon Brunswik (1903-1955), as one of the first environmental psychologists, claims that studying the behavior of an individual surrounding their familiar inside and outside built environments can provide insight into the individual's actions (Steg, van den Berg, and de Groot, (Eds.), 2013). The importance in the field of environmental psychology has grown to include the investigation of relationships between human mental effects with their physical environments, including stress and stress reduction (Kang, Ou, and Mak, 2017).

Architects and psychologists are recognizing the importance that space can have within the built environment to influence human mental health and behavior (De Paiva, 2018). An interior design professional, Cheryl Durst, FIIDA, recently professed that interior designers can influence human behavior and their experiences within the built environment (Williamson, 2020). Current literature claims that when an individual connects with nature in their environments, a concept called human-nature relationship, the effects on the occupant within the built environment can exhibit a positive health influence as with Attention Restorative Theory attributes, suggesting a decrease in mental stress (Hung & Change, 2022). Therefore, understanding human thoughts and behavior while within their natural environments can be relevant to a better understanding of human interactions with nature and the built environments (Gifford, 2014).

2.6.4.2 Attention Restorative Theory (ART)

Kaplan and Kaplan (1989) conducted research in wilderness environments to better understand the process of how individuals gather information and how they interpret their surroundings. They found that individuals associate what they see from what they have seen in the past to better understand their current environment (Kaplan & Kaplan, 1989). Having a "favorite place" in an environment means that there is an emotional connection not found in other environments. A favorite place can be analogous to a restorative environment (Korpela & Hartig, 1996; Korpela, et al., 2008).

While conducting research they concluded that visual exposure and engagement with nature can decrease mental fatigue and increase cognitive attention (Kaplan & Kaplan, 1989). They called this new concept *Attention Restorative Theory* (ART; Kaplan & Kaplan, 1989; Kaplan, 1995). Attention Restorative Theory's philosophy recognizes two types of mental attention (Kaplan & Kaplan, 1989, 1995, 2001). Voluntary attention, or controlled attention, requires an intense focus on a task that has the potential to increase mental fatigue and stress over prolonged periods of time (Berman, Jonides and Kapla, 2008; James, 1892; Kaplan & Kaplan, 1983, 1989;). The second, involuntary attention, is where an individual uses mental focus without controlled intent (James, 1892; Kaplan & Kaplan, 1983, 1989). An individual's focus on an intriguing task or objective, as not seen with voluntary engagement, can allow the mind to wonder without mental fatigue (Kaplan & Kaplan, 1983; 1989).

Four aspects of ART discovered by Kaplan & Kaplan (1989; Kaplan, 1995) that can reduce mental stress when interacting with nature are: 1) being away, 2) fascination,

3) extend, and 4) compatibility. These four contributing aspects can be present in non-nature environments and nature environments. However, studies have stated that nature environments are most reliable when researching the effects of mental fatigue and restorable health (Wells & Rollings, 2012), especially for comparing these effects from urban environments (Felsten, 2009; Herzog, et al., 2003; Kaplan & Kaplan, 1989; Kaplan, 1995; Parsons, 1991).

The first component of ART is with a feeling of "being away" from ordinary and routine experiences that can increase stress over time (Kaplan & Kaplan, 1989, 1998). This can be a combination of physical movement to different environments or through visual acuity of a different environment (Kaplan & Kaplan, 1998). A feeling of being away allows an individual the freedom to explore nature and create their own experience and memory from their current environment (Hung & Chang, 2022; Kaplan & Kaplan, 1989).

The second component of ART is for human "fascination" and engagement with nature allowing the mind to process visual pleasing attributes without any intense focus, as with involuntary attention (Hartig, et al., 1997; Kaplan & Kaplan, 1989, 1998). Attention Restoration Theory (ART) claims that "soft fascinations" as stimuli in nature can attract the individual's attention involuntarily with many captivating views and promote feelings of relaxation, calm and contemplation (Sahni & Kumar, 2021) as to allow the mind to recover from stress (Berto, 2014; Chang, et al., 2008; Hartig, Mang, and Evans, 1991; Kaplan & Kaplan, 1983, 1985, 1989; Ulrich, 1993; Wells & Rollings, 2012). Visual examples are tree branches with leaves blowing in the breeze or waves on the water.

Third, "extent" is where an individual's attention is focused on structural details and a visual sense of order in the environment allowing an individual to imagine the view beyond, as a continuation, of what is currently being seen (Fischl & Gärling, 2008; Hartig, et al., 1997; Hung & Chang, 2022; Kaplan & Kaplan, 1989, 1998; Lin, et al., 2014; Nota, et al., 2017). The order found within the design of nature attributes can provide clarity and is called *coherence*. Specific nature design attributes with order, e.g., texture and pattern, can draw individual attention and provide coherence (Evans & McCoy, 1998; Kaplan & Kaplan, 1989). Coherence is found to be a reliable predictor of environmental preference for nature environments (Herzog, Black, Fountaine, and Knotts, 1997; Kaplan & Kaplan, 1989; Ulrich, 1977), if not the most significant predicator for the effects of mental restoration (Parsons, 1991; Kaplan & Kaplan, 1989).

"Compatibility" is the final mental component of ART where an individual engages with nature for a desired achievement or purpose (Fischl & Gärling, 2008; Hartig, et al., 1997; Hung & Chang, 2022; Kaplan & Kaplan, 1989, 1998; Lin, et al., 2014; Nota, et al., 2017). Examples of these environments include golf courses, ski resorts, hiking trails, and lakes for swimming or boating.

Kaplan and Kaplan (1989) note the importance of nature environments for positive psychological influences. They recognize that there can be many levels of human engagement with nature for mental restoration and conclude that these four mental attributes of ART are important for humans to experience mental restoration. Much research suggests that Attention Restorative Theory reveals the positive effects of interactions with nature environments for improving human mental alertness and reducing mental stress (Berman, et al., 2008; Berto, 2014; Fischl & Gärling, 2008; Hartig, et al., 2014; Herzog, et al., 1997; Hung & Chang, 2022; Kaplan & Kaplan (1989, 1998); Lin, et al., 2014; Parsons, 1991; Pasanen, Johnson, Lee, and Korpela, 2018; Tennessen & CImprich, 1995).

Attributes of Biomimicry can also contribute to decreasing stress and some mental disorders in urban areas through interactions with nature (Lederbogen, et al., 2011). Table 2.2 below summarizes the similarities and differences between the two theories influencing human mental health with nature inside and outside of the built environments.

Table 2.2

Similarities with Attention Restorative Theory and Biomimicry

	Attention Restorative Theory	Biomimicry Design Theory
Origins	Kaplan & Kaplan, 1989	Janie Benyus, 1997
Definition	Research conducted to better understand the process of human mental interaction with nature. Four mental aspects identified to decrease mental stress and increase mental alertness through engagement with nature outside.	Humans are intuitively attracted to living things. Includes attributes of nature for human interaction using nature technology for solutions and nature design attributes surrounding the built environments.
Health Benefits	Decrease mental stress and increase mental alertness through engagement with nature environments.	Promoting human health and stress reduction through interaction with nature.
What environment is it best used for and how	Engagement and interaction with outside nature environments.	Views and interaction with nature for interior built environments.
Similarities	Interaction with nature.	Interaction with nature.
Use in the built environments	This has not been done in the past.	Mimic designs and attributes of nature inside the built environment.

In part, this current research study investigates the perceived effects of varied views of nature, views of nature engagement with landscapes, and varied views of nature with the built environment for the restorative influences stated in Attention Restorative Theory (Kaplan & Kaplan, 1989) and purported in Biomimicry Design as referenced in WELLv2 (IWBI, 2018). These theories have not been previously investigated together, nor have they been used to compare indoor and outdoor nature and built environments.

2.6.5 Outside Nature Environments

Research was conducted investigating visual and environmental attributes of nature environments (Burley & Machemer, 2016) when evaluating landscape environments for land and map assessments (Yilmaz, et al., 2021). A study for comparing human preferences of landscape environments is evident with Kaplan & Kaplan's (1989) early research for developing Attention Restorative Theory. The results of Kaplan & Kaplan (1989) research compared spatial environments of nature settings with human influence and spatial environments with human influence without nature settings. This suggests that nature settings without any human influence is preferred over urban settings (Kaplan, et al, 1989). Another study that is consistent with Kaplan's nature engagement research finds increasing mental restoration and decreasing stress in highly vegetated neighborhood spaces (Sahni & Kumar, 2021).

Despite these studies, there is still limited knowledge on which built environment attributes are associated with perceiving low stress. Literature suggests that views, interactions, or engagement with nature environments finds a high percentage of participants perceiving low stress. However, research for perceptions of low stress surrounding the built environments, including interaction with these nature environments, remains limited. This study will investigate the views of different attributes of outside nature environments for comparison with the inside and outside views of nature surrounding the built environment.

2.7 Literature on Methods

2.7.1 Q-Sort Method Literature with Comparison to Likert Scale Method

The Q-sort method originated by William Stephenson (1902-1989), a physicist and psychologist, detailed the Q-sort process through many publications (Brown, 1993). Additional researchers described their Q-sort method process for psychological studies (Stephenson, 1953). Early Q-sort method was used for individual personality assessment by ranking a participant's personality from *least* liked to *most* liked (called Q-sorting), comparing results, and then analyzing the results for the *most* liked with the most statistical significance (Partin, Burly, Schutzki, and Crawford, 2012).

Q-sort is a more accurate visual assessment method than the Likert scale for participant self-disclosure and expression of feelings (Anderson, Hamlin, Purdum, and Heflin, 2007; Ho, 2017). As described in Table 2.3, the Q-sort Visual Quality Assessment method is a measuring technique wherein the respondents are asked to sort the presented photographs into a ranked order based upon their feelings and perceptions. Literature suggests that mental stress can be measured by subjective ranking scales (Beil & Hanes, 2013). Hence, this ranking method is used for this research to provide subjective data about the participants' perception responses through visual assessment.

Additionally, a Q-Sort survey method is good for quantitative research and comparative analyses in large groups with cultural diversity (Anderson, et al., 2007, Cross, 2005), as seen with this study. This study will implement a quantitative research approach commonly used for testing objective theories by examining the relationships between variables (Creswell & Creswell, 2018).

Table 2.3

Q-Sort Method Comparison with Likert scale

	Likert Scale	Q-sorting
Origins	Created by psychologist Rensis Likert in 1932 for a doctoral thesis (whatis.com, 2014) to measure attitudes (Cross, 2005).	Q-methodology began in 1935 by William Stephenson (Anderson, et al., 2007) for use in psychology describing feelings and beliefs. His works were published into 1960s. Started out as rank-ordering with numerical sorting.
Development	Updated in October 2014.	Ranking Methodology by Stainton Rogers.
Similarities	Self-rating scale: rating objectives to agree or disagree from marking best to worst (Cross, 2005)	Self-rating scales: ranking objectives to agree or disagree with comparisons for best to worst (Cross, 2005).
Differences	Normative data; numerical data rating; most used for psychological self-reporting; single response required; standard data collection; lacks quantitative selection; item (task) centered approach (Ho, 2017); access strength of agreement or disagreement (Cross, 2005).	Self-sorting images; relative linear relationships; individual's subjective perception and attitude responses capturing cognitive thoughts; allows for individual image assessments and judgements; holistic; easier to compare results with each other (Ho, 2017); measures the effect of the image; samplings vary by study; different patterns are seen with data interpretations through comparisons of each study (Cross, 2005).
Advantages	Short time frame to administer; good for baseline perception; economic and easy to give; easy to transfer data to descriptive statistics (Ho, 2017).	Hierarchical arrangement variables better indicate perception and subjective responses (Ho, 2017); provide more accurate data collection/analysis across cultures (Anderson, et al., 2007); both quantitative and qualitative research; most accurately measures attitude; good for health-based research (Cross, 2005).
Disadvantages	Difficult to translate score with meaning (Ho, 2017); mean score results can vary when "no opinion" is included more so than when it is excluded (Ryan, 1980).	General perception for participant based on stimuli provided; takes more time to administer and gather data; need large sample sizes to compare to population; instructions needed for participant (Ho, 2017); replication with 85% consistency one year later; exact sampling needed for accurate participant results. (Cross, 2005).

2.7.2 Visual Quality Assessment

Research suggests that visual connection with nature can decrease stress and fatigue (Berto, 2005; Beute & de Kort, 2018; Hartig & Staats, 2003; Herzog, et al., 2002; Kaplan, 1995; Wells & Rollings, 2012). The visual sense is commonly known as the sense that humans perceive that what they are seeing is real (Carbon, 2014). An individual's perception encompasses visual attention and awareness from neurotransmissions sending messages to the brain for mental focus on specific information and knowledge (Lin, et al., 2014). An individual can have a negative or positive emotional perception from the configuration and qualities of what they are visually aware of when looking at an outside environment (Zadra & Clore, 2011; Ulrich, 1981).

Knowing the importance of human visual acuity increases the validity of the Q-sort Visual Quality Assessment research method, created by Shafer (1969), who used it to better understand a person's perception of landscape design.

Studies find the Visual Quality Assessment method as a reliable and valid visual quality method to study an individual's perceptual response for statistical analysis by using photographic images for visual acuity (Pitt & Zube, 1979). Studies using photographs as a substitution for landscape site visits found a strong respondent similarity between the authentic landscape and photographs (Boster & Daniel, 1972; Burley, Deyoung, Partin, and Rokos, 2011; Evans, & Gärling, 1997; Hartig, Korpela, Evans, and Gärling, 1997; Partin, 2011; Partin, et al., 2012), as well as with digital visual images (Partin, et al., 2012). Coeterier's research (1983) found that photographs are valid substitutions when comparing the participants' reactions to visually viewing an actual landscape scene and viewing pictures of the same landscape scene. Another study finds that interacting with nature environments and urban or built environments can elicit the same fatigue response as when viewing photographs of nature environments and urban or built environments (Berman, 2014).

When conducting research, acknowledging the strength of this correlation between visual perceptions of the same on-site settings and as with the simulated settings eliminates the time needed to transport participants to the specific sites and view the selected nature environment criteria (Hartig, et al., 1997). Studies using photographs for Visual Quality Assessment could provide more viewed sites, include more specific nature attributes, and diversify the images to include specific evaluation criteria for more accurate research.

2.7.3 Predictive Model Equation Assessing Visual Quality Assessment

Shafer's research (1969) finds a predictive model equation by evaluating a participant's visual quality preferences for photographs of outdoor nature environments. This development can be used to correlate an individual's visual perception with their physical behaviors from the variables shown in photographs and can help to better manage outdoor environments (Burley, 1997). After viewing and ranking photographs of each factor in the environment, the researcher then gathers and evaluates the participant's preferences. Burley calls this normative theory *Patterns of Behavior Theory* (1997).

There are no recent predictive model studies found using the Q-Sort Visual Quality Assessment method for evaluating occupant stress surrounding the built environment. Similar research for built environments state that measuring spatial quality through visual distance and viewing angle can dictate building function using rectilinear dimension measurements for private and public spaces (Indraprastha & Shinozaki, 2012). Other closely related visual quality assessment studies for individual visual perceptions can include interior and architectural design models with scientifically detailed measurements from AutoCAD software programs, physics, and math; to name a few (Partin, et al., 2012).

2.7.4 Semantic Differential Scale Survey Model

Semantic differential survey method is a good research tool proven to be very reliable and valid (Cloquell-Ballester, del Carmen Torres-Sibille, Cloquell-Ballester, and Santamarina-Siurana, 2012), and can measure differences in an individual's perception, hidden cognitive opinions, and feelings (Divilová, 2016). Words can portray a perception of what one is viewing, and the definition of words can represent a negative or positive response (Xiong, Logan, and Franks, 2006). Literature shows that individuals describe or perceive an object or situation differently, hence the use of this method known to measure the psychological meaning of individual objects or concepts (Divilová, 2016).

The semantic differential survey method is used in this study to provide another analytical method to examine the participants' overall impression or emotions of the environment they are viewing (Acking & Sorte, 1973; Cloquell-Ballester, et at., 2012; Divilová, 2016). The participants rank the two paired word antonyms with the random photograph they are viewing. The collected data then compares the Q-sort visual quality assessment survey photographs perceived to show the least stress with the word antonyms. This is the first one study to use semantic differential word antonym method with the Q-sort visual quality assessment method for finding preferences of low-stress environments surrounding the built environment.

2.8 Theoretical Summary

This study will evaluate and compare the theories stated above by means of the Q-sort visual quality assessment survey method with photographs of the key indicators mentioned to investigate perceived stress reduction surrounding nature and built environments. The goal of this study is to investigate the relationships between the built environment, nature, and human perception of stress using variables identified from the literature gap and greenbuilding rating systems certification criteria for the effects of mental stress. This gap closely identifies with WELL Mind Concepts including ceiling heights, views of nature inside, and views of nature outside from the inside. The Attention Restorative Theory philosophy for direct nature engagement is included in this study by viewing photographs of individuals engaging with nature inside and engaging with nature outside.

This is the first study finding the effects of the built environment with nature by comparing the perceptions of low stress with views of outside nature environments, inside built environments with nature, and inside and outside nature engagement environments.

CHAPTER 3: RESEARCH METHODS

3.1 Introduction

This study aims to identify the most significant low-stress attributes visually perceived from a continuum across landscapes, architecture with the built environment, and nature surrounding the built environment. The visual quality assessment Q-Sort survey method results in participant photograph ranking and ordination of data from the low-stress photograph attributes to the high-stress photograph attributes. The term "attribute" for this study refers to traits or characteristics of an environment. A stepwise linear regression predictive model ranks specific spatial attributes that can facilitate new universal theoretical knowledge for low-stress environments. A semantic differential method identifies participants' feelings of stress and is used to compare the participants' low-stress feelings with the individual photographs perceived to have low stress. Comparing these environments, using Q-Sort VQA and semantic differential methods, has not been done before in one study.

3.2 Questions and Hypotheses

Research Question #1.1:

> Are there significant spatial attributes surrounding built environments, nature environments, or a combination of both that can be consistently recognized to reduce human stress within the built environment?

Hypothesis #1:

The descriptive analysis of plotted mean scores finds a ranking from the best low-stress variable environments to the worst low-stress variable environments.

Method: Descriptive Scatterplot showing a ranking of mean scores

Research Question #2.1:

What environmental attributes are identified for a predictive model suggesting a ranking of significant low-stress attributes?

Hypothesis #2:

The predictive model results find a hierarchical ranking the independent variables that are statistically significant to predict a response for at least 40% of variance of the independent variables.

Method: Multilinear Stepwise Regression for a model equation of significant variables

Research Question #3.1:

Are the participants' feelings of low stress shown in differential word antonyms associated with their visual perceptions of low-stress photographs?

Hypothesis #3:

The ordination and ranking of the word antonym eigenvector scores associate with the independent variables for finding the relationship of the best low-stress variable environments with the best low-stress word antonym eigenvector scores.

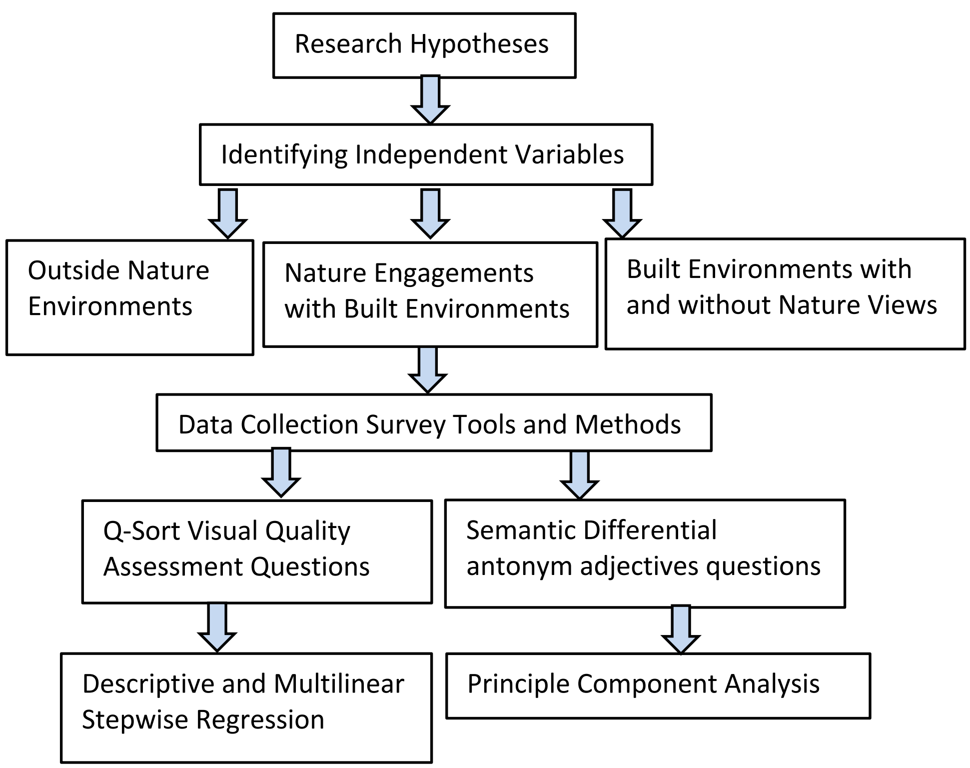
Method: Principal Component Analysis associating antonym and eigenvector scores

3.3 Research Investigative Framework

To test the research questions and hypotheses identified, Q-sort data collection method, a highly robust approach for assessing cognitive perceptions and attitudes (Brown, 1993; Cross, 2005) is adopted for this study. The research framework shown below in Figure 3.1 outlines the investigative steps of this study discussed in this chapter. Research questions and hypotheses are stated first. An introduction to the eleven independent variables includes the use of data collection from the survey tool implemented. Research methods examine the analytical data with finding statistically significant results for low-stress environments.

Figure 3.1

Research Investigative Framework



3.4 Independent Variables Identified and Measured

3.4.1 Photograph Characteristics

To ensure clearly recognizable variables, this study uses a total of 120 high-quality photographs (Appendix B) chosen for their images of the eleven independent variables. All photographs are presented in original colors, horizontally and vertically aligned, and scaled to between 700 to 900 pixels, depending on the alignment. Additionally, measurement of fractals and influences of color are not included in the scope of this study.

3.4.2 Outside Nature Independent Variables Identified

The different types of outside landscape environments chosen for the independent variable photographs were selected for diversity and for similarity with other studies using the same Q-sort method (Burley, 1997; Burley & Yilmaz, 2014; Burley, et al., 2011; Lu, et al., 2012). Sixty landscape photographs are selected from different locations within the United States, some depicting only outside nature environments and some depicting outside nature environments incorporating built environments. From the sixty landscape photographs included, six independent variable groups are created from recognition of a visual percentage of one physical landscape attribute (independent variable). These diverse physical attributes are mentioned in landscape literature when investigating nature attributes with man-made attributes. The six independent variables are stated in Table 3.1 below. Figure 3.2 shows one picture example of each of the six independent groups. These groups are: MountainScape, ForestScape, WaterScape, Agriculture, RuralScape, and Urban and Industrial.

Table 3.1

Six Physical Element Groups found Outside Nature

Independent Landscape Variables	Percentage of Outside Physical attributes	Count
1a_MountainScape	Mountain >50%	4
1b_ForestScape	Trees 70% - 100%	7
1c_WaterScape	Lakes + Water 30% - 80%	8
1d_Agricultural	Dirt / vegetation 50% - 70%	16
1e_RuralScape	Vegetation 20% - 100%	11
1f_Urban and Industrial	Concrete 30% - 80%	12

Figure 3.2

One Picture example of the Six Outside Landscape Independent Variables

MountainScape

ForestScape

Figure 3.2 (cont'd)

WaterScape

Urban and Industrial

Agricultural

RuralScape

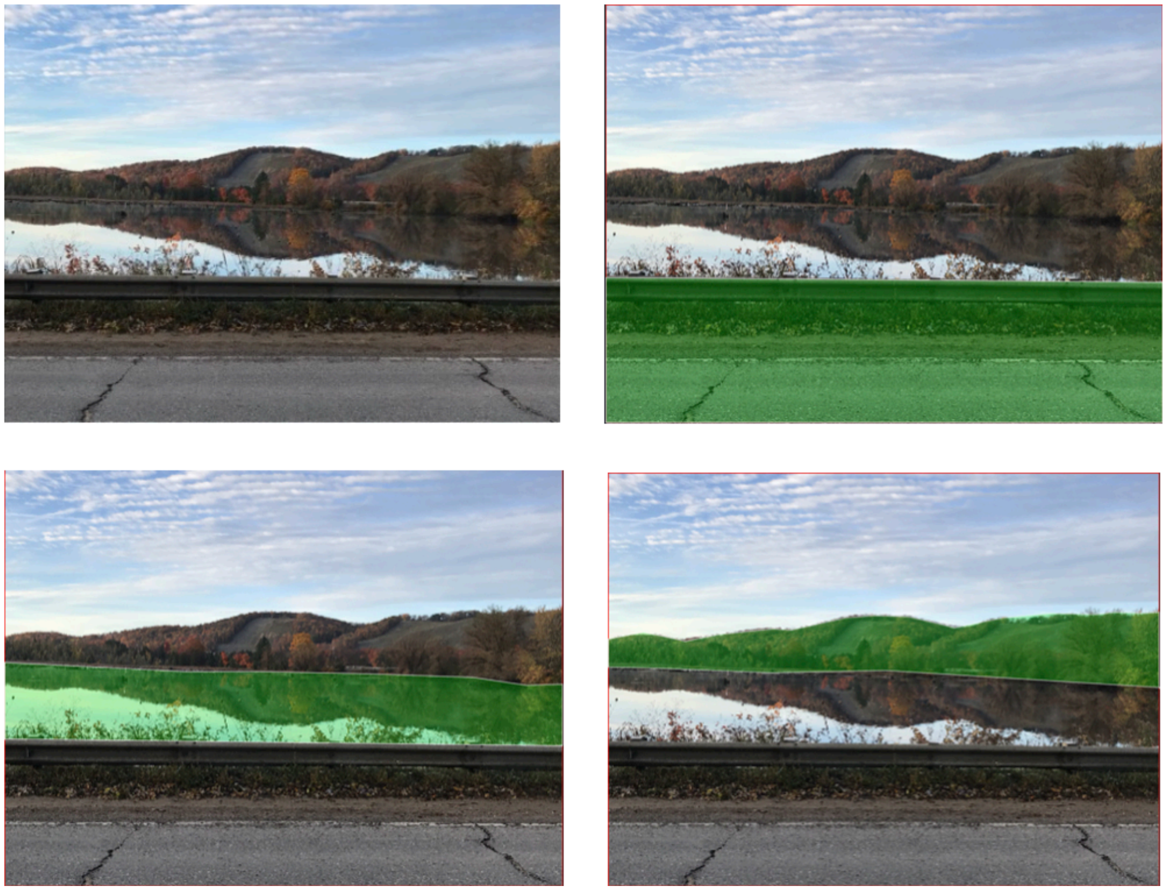
3.4.2.1 Outside Independent Variables Measured

Clearly recognizing the key phenomena, or unit of measure, is vitally important for this study. The percentages of each independent variable the participant is viewing within the total image is calculated using AutoCAD.

The percentage of the independent variable area is determined from the total area of the overall photograph (variable percentage = variable area / total image area). One photograph shows an example of this process below in Figure 3.3. The percentages of the key phenomena within the independent variables are measured in photograph (#47) and include 19% water, 35% concrete, and 12% vegetation. The sky percentage was not calculated since it is not included as an independent variable. Additionally, another study using this research method finds that views of the sky are considered a nonsignificant variable that brings about scores in the neutral range (Burley, 1997).

Figure 3.3

Measuring the Key Phenomena in one Outside Independent Variable Photograph



3.4.3 Built Environment Independent Variables Identified (Appendix B)

The independent variables included in the sixty photographs for the built environment are found at seven different sites (Table 3.2). Seven of these sites are residential and office buildings that are also greenbuilding rating systems certified. The Meyer May House, designed by Frank Lloyd Wright, is a non-greenbuilding rating systems certified residence. It was chosen because of FLW's architectural design style for bringing nature into the building.

Table 3.2

Built Environment Photograph Locations and Certifications

Businesses of Photograph Environments taken	Locations	Building Certification
Aquinas College	Grand Rapids, MI	LEED Gold 2021
Beacon Springs Farm	Ann Arbor, MI	LBC 2017
Catalyst Partners	Grand Rapids, MI	LEED Platinum
Haworth	Holland, MI	LEED 2011
Herman Miller Showroom	Chicago, IL	WELL Health Safety 2021
Meyer May House	Grand Rapids, MI	Frank Lloyd Wright
OFS Manufacturing	Jasper, IN	WELL Platinum 2020
Perkins Eastman	Chicago, IL	WELLv2 Platinum 2020

Photographs are taken of five independent variables found in literature, namely ceiling heights, interior nature views, exterior nature views from inside the built environment, inside nature engagement, and outside nature engagement. These photographs are images easily recognized as office and residential environments of interior and exterior built environments with and without nature, and outside nature environments.

3.4.4 Built Environment Independent Variables' Characteristics

The following independent variables are derived from similar certification criteria found in WELL, ART, and literature investigating biomimicry and landscape influences on human health. Table 3.3 below states the independent variables, percentages of the independent variables seen, and the number of photographs showing the same independent variables. Few literature reviews include the sizes or areas of the independent variables within the viewed photographs when investigating visual perceptions of health.

Only the criteria for greenbuilding rating systems certification require a percentage of occupant outside views.

This study includes five variables (Ceiling Height, Interior Nature Views, Exterior Nature Views from Inside, Inside Nature Engagement, and Outside Nature Engagement) within photographs to investigate the significance of different nature interactions surrounding the built environment for low stress.

Table 3.3

Independent Variables and Characteristics

Independent Variables	Independent Variables' Characteristics	Photo Count
6_Ceiling Height	Heights 8'-0" to 47'-6"	12
7_Inside Nature Views	Variable Images 9% to 91%	12
8_Outside Nature Views	Variable Images 2% to 85% from inside	12
9_Inside Nature Engagement	Nature Engagement Inside	12
10_Outside Nature Engagement	Nature Engagement Outside	12

One photograph of Ceiling Height, Inside Nature Engagement and Outside Nature Engagement for the built environment independent variables are shown in Figure 3.4. The Inside Nature Views and Outside Nature Views built environment variables are shown in Figure 3.5 and Figure 3.6 respectively.

Figure 3.4

Three Built Environment Independent Variable Photographs

Ceiling Height

Inside Nature Engagement

Outside Nature Engagement

3.4.4.1 Built Environment Variables Measured

To measure the independent variable areas, each photograph was uploaded into AutoCAD to calculate the area (Variable percentage = independent variable area / total image area). Shown in Figure 3.5 below, the photograph on the left is the original Inside Nature Views variable photograph (#78). The photograph on the right shows an example of how the vegetation area for Inside Nature Views is measured. The dotted outline on the right surrounding the plant (green color) shows the measured area of the plant as 25% vegetation.

Figure 3.5

Built Environment Independent Variable Measured

In Figure 3.6, the percentages of independent variables measured for the Outside Nature Views photograph below (#92) are shown in a green color below. This includes 14% Outside Nature Views from Inside, 1% inside Nature Views, and Ceiling Height.

Figure 3.6

Built Environment Independent Variables Measured

3.5 Research Survey Tool

3.5.1 Institutional Review Board (IRB) Approval

The Institutional Review Board (IRB) at Michigan State University approved the correlational survey for this study (Appendix A) prior to any distribution to the participants. All participants completed and approved a consent form prior to any survey participation.

3.5.2 Determining Sample Size

An internet research software calculating program, GPower version 4.0, was used to calculate *a-priori* sample size for this study (Hibberts, Johnson, and Hudson, 2012) for multiple regression analysis. This program is used to estimate a required sample size factoring in the alpha level of significance, statistical power, and the effect size. The probability for a statistical test that will show differences between groups tested is called the power ($1-\beta$) of a test (Bowling, 2005). With a level of significance (alpha) set at 0.05, the minimum recommended power (1-β) of a test should be 0.8 (Hibberts, et al., 2012). The effect size indicates the strength of the relationship between the independent variable and the dependent variable. Research sample sizes are different for each of the three possible effect sizes: small, medium, and large (Hibberts, et al., 2012). This study will calculate medium and large as the strength of the relationship for six groups with twelve total predictors.

The target sample sizes are calculated:

For 95% Confidence:

The 95% confidence (*Z*-score = 1.96) = 122 for medium, and 59 for large relationship

Level of Significance = 0.05

Minimum power (1-β) = 0.8

For 99% Confidence:

The 99% confidence (*Z*-score = 2.576) = 165 for medium, and 79 for large relationship

Level of Significance = 0.01

Minimum power (1-β) = 0.8

The goal of this study is to reject the *null hypotheses,* also known as *Type 1 error.* Rejecting the *null hypotheses* suggest that there is a relationship with the population.

3.5.3 Research Sample Size Needed

To decrease sampling bias, the survey instrument was distributed to random participants to ensure accurate evaluation of the investigation intent and to mimic the population with a simple random sample selection. Yet there is no concise answer in research for determining a reliable sample size to ensure reliable survey results (Fowler, 2012). Since this quantitative correlational study will be using a survey as the investigation tool, it is highly likely that the survey mean will be different than the total population mean (Bowling, 2005).

Standard response for research sample size is the bigger the sample, the better the detecting significant differences between variables (Bowling, 2005). Previous research finds that data collection using Q-Sort method for 32 or more complete survey sets for all variations is reliable; providing three variations of a total survey with 120 photographs would be best to ensure randomization. (J. Burley, personal communication, November 3, 2022). To ensure reliable research results, this study set a minimum of n = 36 complete survey sets with 120 photographs. Even with a predetermined sample size value, calculating a required sample size is followed to ensure reliable research results with the data analysis models that sample size is followed to ensure reliable research results with the data analysis models that are created.

3.6 Q-Sort and Semantic Differential Methods and Survey Instrument

3.6.1 Q-Sort Visual Quality Assessment Method

The Q-Sort Visual Quality Assessment ranking method provides a framework for sorting subjective data representing participants' feelings (Brown, 1993) by asking participants to rank their perceptions of viewed images from looking at multiple environments (Schroeder, 1989; Shafer, 1969). As a recreation planner and manager, Shafer (1969) created a Q-Sort predictive model equation to correlate specific landscape attributes with certain behaviors. He began investigating participant preferences for real landscape views with those of landscape photographs (Burley, 1997).

Shafer's study using landscape photographs found a more accurate and reliable research for a perception-based assessment (Burley, 1997). Researchers using visual quality assessment method reveals that participants' responses to site photographs correspond to actual landscapes (Boster & Daniel 1972; Burley, et al. 2011; Hartig, et al., 1997; Partin, et al., 2012). Additionally, viewing photographs, rather than the real landscape location, can promote the desired effect for viewing only the physical factors while keeping conditions for distraction (e.g., weather, noise) as a constant (Hofmann, Westermann, Kowarik, and van der Meer, 2012).

Other uses of Q-Sort research method can be when researchers examine diverse landscape images as variables in looking for close variable associations for recognizing a high visual quality (Lu, et al., 2012), as with landscape planning projects with roadways (Burley, 1997), environmental aesthetics, and ecological concerns (Lu, et al., 2012). Currently, Q-Sort predictive model equation method has not been used when evaluating the effects of built environments on human stress responses, including views of nature and views of nature surrounding the built environment, as with this study.

3.6.2 Q-Sort VQA Survey (Appendix C)

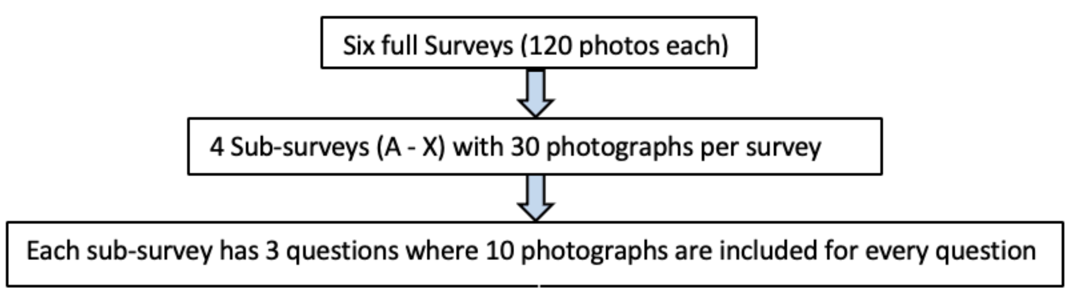
This study uses Q-Sort Visual Quality Assessment method survey that allows for random photographs to be scale ranked with participants' perceptions. Each survey participant is asked to rank one set (ten photographs) per question for perception of low stress. They will rank ten different photographs three times (three sets) with three questions from most satisfied (#1 = low stress) to least satisfied (#10 = highest stress).

This study is comparing independent variables from the distribution of two different survey approaches: in person and digitally using Qualtrics. To prevent survey participant fatigue when ranking photographs, each participant is asked to rank three questions with ten random photographs per question. A previous study using Q-Sort method investigating landscape images asked participants to rank preferences with five subgroups of ten photographs each (Partin, et al., 2012). Therefore, this study created multiple surveys to increase the opportunities for each photograph to be compared and ranked with other photographs.

To ensure that independent variables are randomized, both in-person and online surveys are conducted. One full survey (120 photographs) consists of four sub-surveys (letters A through X) that include three questions (ten photographs per question) with thirty photographs per survey and three questions using the semantic differential method. The combination of four sub-surveys will be equal to one full survey (30 photographs x 4 = 120) and three semantic differential questions. Figure 3.7, below, provides the full Q-sort survey structure.

Figure 3.7

Summary of Full Surveys and Sub-Survey Structure



3.6.3 Semantic Differential Survey Method

The semantic differential method originated as a psychometric tool to measure human behavior and cognitive perceptions based on sensory data (Dettmar, Peltier, and Schlich, 2020). This analytical method is specifically selected to measure the total appearance of an environment by using expressive word adjectives (Acking & Sorte, 1973) to describe feelings. This method is specifically relevant for measuring a participant's thoughts and feelings while viewing photographs of diverse environments (Cloquell-Ballester, et al., 2012; Divilová, 2016; Karlsson, Aronsson, and Svensson, 2003; Kuller, 1975). Semantic Differential as extensively used in architecture and product design (Karlsson, et al., 2003), however, limited use for research with landscape assessments (Acking & Sorte, 1973).

The differential antonyms chosen for this study represent an individual's expression of their feelings about their surrounding environment (Thurlow, 1971), with the inclusion of the words *stressful* and *unstressful.* The Semantic Differential survey results will be compared with the Q-Sort participant's low-stress survey results finding the antonyms associated with the low-stress photographs. These two research methods have not been used together in the same study.

3.6.4 Semantic Differential Survey (Appendix D)

In addition to asking survey participants to rank ten photographs per question, three semantic differential scale questions are included. For each semantic differential question, one random photograph was presented asking the participant to select a word in each of the eleven-word antonyms that best describes an emotional meaning elicited from viewing the selected photograph. The semantic differential survey questions include a five-point Likert scale with ranking from 1 = "a great deal" to 5 = "not at all" for each eleven-antonym adjectives that best describes their feelings of the one photograph.

3.7 Survey Administrative Process

Data gathering for all surveys is in the same survey format described above; with a mixture of in-person and digital Qualtrics surveys. Administering a Q-Sort survey method requires little training since the participants normally conduct the survey themselves by way of photograph ranking (Pitt & Zube, 1979). A total of 650 survey participants randomly voluntarily agreed to participate in this study.

3.7.1 Participant Demographics

The target demographic for the sample size participants ranges between the ages of 18 to 70 of the general population. Data for gender influence, nationalities, and cultural differences are not included in this survey and therefore not collected data for this study. Additionally, Kaplan & Kaplan (1989) did not find any environmental setting preferences between knowledgeable experts and the layperson, therefore, individuals with sustainable design expertise are not separated from the data findings of this study.

3.7.2 In-person Survey Distribution

Limited time and funding precipitates the administration of random in-person surveys conducted at the following three events on Michigan's west side during the fall of 2022. These events are:

- Gaylord Living Well and Healthy Craft and Vendor Expo 2022, September 10, 2022

- Kalamazoo Home Builders Association Fall Home Community Expo, September 23-25, 2022
- Charlevoix Apple Fest, October 14-16, 2022

Survey participants were not selected by a pattern or demographic. The in-person survey explains the intent of the survey and states participant's permission and approval is totally voluntary. The in-person Q-Sort VSA method is the same as with the electronic survey distribution using the same 120 photographs. Participants then rank ten photographs of nature and built environments from the lowest perception of stress (#1) to the highest perception of stress (#10), as with each question in the sub-surveys. The unit of easurement is the survey document ranking order from a set of ten random photographs. The survey administrator adds the photograph number in the ranked order from the participant's selection.

To gather data on the participant's feelings, the semantic differential survey instrument listing eleven antonyms was also conducted. One random photograph was selected for each participant to view while checking their perceived word antonym for completing one semantic differential question.

3.7.3 Online Qualtrics Survey Distribution

Qualtrics Survey Software data collection tool is being used as a secure online survey option for collecting research data (Rudolph, 2022). Using Qualtrics for a survey questionnaire delivery method can increase the reliability of this study.

Qualtrics S-Sort VQA surveys were randomly distributed from September 28, 2022, until December 5, 2022. Emails were sent out to over 650 students from general education and introduction classes and from office employees who voluntary agreed to participate. The researcher administered access to the online Qualtrics surveys through direct emails by sending the participant an "anonymous link" that directly connects them to a specific Qualtrics survey so that each participant's survey response remained anonymous.

As with the in-person surveys, participants then complete a Qualtrics sub-survey where each of the three questions have ten photographs. The participants rank the ten photographs of nature and built environments from the lowest perception of stress (#1) to the highest perception of stress (#10) by dragging individual photographs in a ranked order.

To be consistent with the in-person surveys, the survey instrument includes three questions for the semantic differential method listing eleven antonyms. One random photograph is selected for each participant to view while marking each word antonym when completing one semantic differential question.

3.8 Statistical Analysis

The statistical analysis methods implemented include Descriptive, Multivariate Linear Regression, Stepwise Linear Regression, and Principal Component Analysis.

3.8.1 Data Preparation

Each participant's survey responses are recorded, as the unit of measurement, for data documentation, collection, and reference. Reliable data analysis of the survey questionnaire responses is inputted into a SPSS spreadsheet format for conducting IBM SPSS Statistics 28 for Mac (www.spss.com) software statistical analysis.

This study uses a regression standardized predicted value scatterplot of the standardized residuals (errors) to test for homoscedasticity and can show a normal distribution of variables to disclose the variable linearity (Osborn & Waters, 2002). Homoscedasticity assumes that different samples have the same variance for regression analysis. A slight heteroscedasticity can have little effect on statistical testing, yet marked heteroscedasticity can lead to distorted statistical analysis and possible increase in Type I error (Osborne & Waters, 2002).

Additionally, the continuous survey response data is applied to SPSS database to determine standard error deviation and evaluate internal consistency using Cronbach's alpha values (Pallant, 2016). Cronbach's alpha will be used to test internal consistency, reliability, of outcome data (Mao, Qi, Li, and Tan, 2017). Acceptable Cronbach's, alpha correlation scale is between 0 and 1 with an acceptable value of more than 0.7 (Aigbavboa & Thwala, 2014).

3.8.2 Descriptive Analysis

The collected data collection was uploaded to IBM SPSS Statistics 28 Data for descriptive analysis to state the means, standard deviations, and variance statistics for data assessment of outcome variables. These statistical results provided a visual representation of the mean differences from the photographs representing the participant's perceptions of high-stress versus low-stress. A visual inspection with a scatterplot displayed distinct clusters of the mean differences and can show distribution of variables to disclose the variable linearity.

3.8.3 Multiple Regression Analysis

Multiple Linear Regression analysis is used for this study to determine the strength of the relationships between multiple variables and the relationships within variable groups to make predictions about the knowledge gaps (Uyanik & Guler, 2013) and to correctly evaluate the independent and dependent variables linear relationships (Osborne and Waters, 2002).

Multiple regression analysis can answer three research questions (Pallant, 2016). They are as follows:

1) How well can a set of variables predict the model outcome?
2) Which variable in a group of variables is the best predictor of an outcome?
3) Is there a particular variable that can still be a predictor when controlling for effects of other variables?

This study uses stepwise multiple regression method for linear modeling using SPSS Statistics that calculate the model by removing the least useful predictor when another predictor enters the model looking for the variable that best statistically predicts the model outcome (Field, 2018; Pallant, 2016). The predictive model equation can help other researchers assess the significance of environmental spaces without visiting them (Yilmaz, Wang, and Burley, 2023) . The best independent (predictor) variable is selected by having the highest simple correlation with the outcome. If this predictor significantly improves the model's ability to predict the outcome it is then retained. A removal test also is made of the least useful predictor (Field, 2018). This continues until there are no more predictors entered to improve the predictor model (Field, 2018).

3.8.4 Principal Component Analysis

Principal Component Analysis is used in this study as a variable reduction technique for large numbers of variable data sets by eliminating insignificant results and conducting statistical analysis (Suhr, 2005). This ordination technique produces patterns from multivariate data (Mao, et al., 2017) into a set of linear components (Field, 2018) and increase the significance of the resulting principal components collected (Sadek & Willis, 2020; Suhr, 2005). Each principal component dimension includes individual vector coefficients that are independent of other component dimensions (Bartholomew, 2010; Field, 2018).

The totaled-up sum of squared distances (variable dimensions) across all variables for each component is determined and an eigenvalue is calculated (Field, 2018). The larger eigenvalues are more significant as they correspond to the larger sizes of variance explained (Field, 2018; Yue & Burley, 2022). The principal components with eigenvalue scores over the value of 1.0 are considered significant (Yue & Burley, 2022). The principal component eigenvalues explain the variance influence and the direction of the eigenvalues are shown as the eigenvector (Fields, 2018).

A 2-D linear plot shows each word antonym from the significant principal component eigenvectors. An independent variable scatterplot shows the relationships with the word antonym eigenvectors with the independent variable photographs. These results can display which independent variable environments are perceived as the best low-stress nvironments associated with the low-stress word antonyms.

3.9 Evaluating Research Quality

Determining the features of the statistical measure provides confidence to the researcher (Field, 2018). This study tested the validity and reliability of the research instrument, as both are critical to empirical studies.

3.9.1 Validity

Validity of scientific research shows the degree by which the measurement instrument measures what it is supposed to measure (Pallant, 2016). Internal Validity is determined on how efficient the research was conducted for finding out if one variable could cause a change in another variable where the measurement of the dependent variable is valid (Hammersley, 1991). Reliable internal validity is established in this study by ensuring that interactions with the treatment did not happen before the survey was conducted and that two different survey methods (stratified and random) are conducted to ensure more accurate findings (Creswell & Creswell, 2018). Additionally, there were no diverse participant interactions prior to survey participations (Cuncic, 2019; Creswell & Creswell, 2018).

External validity is the extent of the results of the research that can be applied to the wider population of interest (Bowling, 2005), hence generalizability. Confident external validity is addressed in this study by using different random sample participant selections and using two different survey administrative techniques involving multiple participants (Cuncic, 2019). This helps to ensure that the sample size represents the demographic population and that the participants understand the study so that they can see this as a real-life event.

Three types of validity are needed for quantitative research: content validity (measure what was intended), predictive validity (data can predict a measured criteria), and construct validity (hypothetical concepts are measured) (Creswell & Creswell, 2018). Content validity for this study includes the Q-sort method supported by literature stating that these studies found more meaningful results with Q-sort method than others for measuring subjective opinions, compare results (Cross, 2005; Ho 2017), and the ability to collect more accurate data (Anderson, et al., 2007; Burley, 1997; Cross, 2005). Additionally, all committee members reviewed the Qualtrics online survey as pilot testing for face validity including understanding of survey intent, clarity of research questions, ease of use for question responses, visuality of photographs, manipulation of photographs and time allowance for completing the survey.

Predictive validity is found for this study by using a stepwise regression analysis model for finding the largest correlation of predicted variables. Predictive validity is supported by the size of correlation ® coefficient value, where high correlation can find that the measure can correctly predict an expected outcome. As found in previous research studies using Q-Sort method, participant's hierarchical ranking of variables provides a better perception and response (Burley, 1997; Cross, 2005; Ho, 2017).

Construct validity can be found from using an existing survey instrument proven to establish construct validity in the past with Q-sort survey method for measuring participant's perceptions. The Q-sort method has been used in research for multiple disciplines over the years including psychology, planning, education, nursing, and sociology (Partin, et al., 2012). The constructs for this study, found in survey responses, has not been researched before using Q-sort method. However, considering the vast amount of statistical research using Q-sort method, it is highly likely that construct validity can be found by the ability of the data collection analysis to answer the selected hypotheses for this research. However, validity by itself cannot be a good unit of measuring the research data without reliability (Field, 2018).

3.9.2 Reliability

High reliability in scientific research is important to demonstrate the ability of an instrument to consistently repeat the same results with the same conditions (Field, 2018). An instrument must first be reliable to be valid (Creswell & Creswell, 2018; Field, 2018). The online Qualtrics web-based software tool used in this study to administer the surveys and collect the data provided a secure, undisclosed participant option. Another study using Qualtrics found similar results (Rudolph, 2022).

Equivalency reliability is when two separate measurements are correlated to determine how consistent they are (Pallant, 2016). The standard error deviation is a way of measuring the reliability of the sample mean within the general population. The smaller the standard error deviation is, the more reliable the statistical evidence is consistent with the general population (Gravetter & Wallnau, 2017). In quantitative correlational research, a correlation coefficient $R2$ value is calculated to show the relationship between the predictor (independent) variables and the dependent variables.

Internal consistency is another way to determine reliability of the research instrument or the research procedure. Cronbach's alpha, developed by Cronbach in 1951, is the most common scale measurement used to measure reliability by evaluating the correlation coefficients among all the values (Pallant, 2016; Field, 2018). Acceptable values for Cronbach's alpha are found in this study to measure internal consistency with ranges between 0.7 to 1 indicating reliable results (Field, 2018).

3.10 Summary

The best investigative model created for this study uses visual perception survey tools, Q-sort VQA and semantic differential, for examining low stress spatial attributes in the built environment and nature environments. Greenbuilding rating systems' concepts and theories for the built environment are compared with recognized nature theories for finding the most statistically significant low-stress spatial attributes. These attributes are found from methods finding a clustering of variable means, comparing all variable attributes in a linear regression model, and comparing significant word association scores with low-stress photograph attributes.

CHAPTER 4: ANALYTICAL FINDINGS

4.1 Introduction

Results find the relationships between the built environment, design characteristics associated with nature environments, and outside nature environments for perceptions of low stress. The strongest results were gained through use of perceived mean averages and comparative stepwise regression analysis, while all methods showed some support for the research hypotheses.

4.2 Data Preparation

This chapter depicts the statistical analysis results utilizing descriptive, multilinear stepwise regression, and principal component methods for investigating the relationships and the characteristics of the independent variables.

4.2.1 Sample Size

For this study, the total number of completed surveys is n = 543. Data were collected to achieve a confidence level of 95% for representation of the true population. Participant data for gender influence, nationalities, and cultural differences are not collected for this study. The research sample size was calculated from *a-priori* software program to require a sample size of 165. The resulting sample of 543 responses provides a greater granularity of analysis.

4.2.2 Initial Analysis

The reliable continuous outcome data from the independent variable photographs were collected and measured. The outcome data numbers starting with 1 (1, 2, etc.) demonstrate participants' perceptions for low-stress environments and the higher data numbers (9,10, etc.) demonstrate participants' perceptions for high-stress environments where a score of 10 indicates the highest stress environments. For statistical analysis, the average scores were multiplied by 12 to easier visualize the data findings and to compare these findings with other studies using the same research methods (Burley, 1997; Burley, et al., 2011; Yilmaz, et al., 2021). The photograph data scores are shown in Appendix F under "Dependent" column.

A variety of statistical tests were applied to determine the reliability of results, including Cronbach's Alpha, Homoscedasticity, Shapiro-Wilk Test, and Cook's Distance.

4.2.1.1 Cronbach's Alpha

Cronbach's Alpha is a common measurement used for indicating a scale of reliability by computing two sets of correlation coefficients between two items in multiple ways to find the average (Field, 2018). Testing for Cronbach's alpha statistical reliability found the data (.916), and standardized items data (.904) for eleven items to be in the acceptable value (value of more than 0.7) for measuring internal consistency (Aigbavboa & Thwala, 2013).

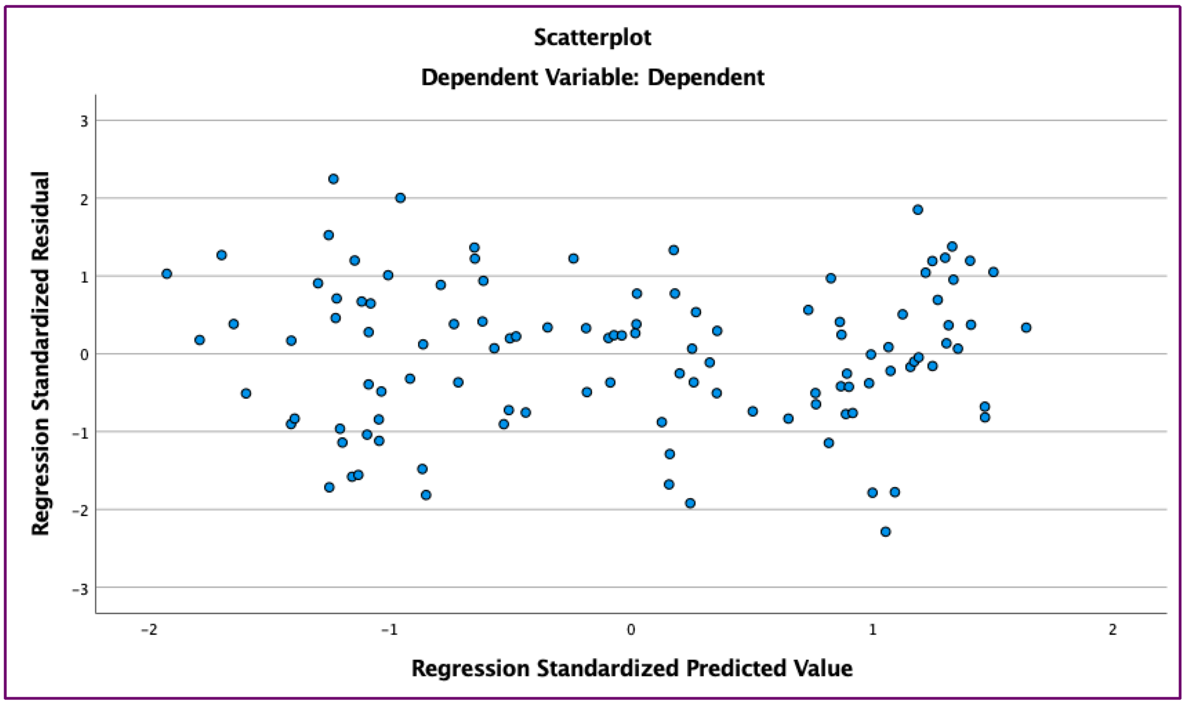
4.2.1.2 Homoscedasticity

Homoscedasticity assumes equal or similar variances in different groups being compared where the variance of the outcome (dependent) variables is constant in each of the independent variables for all data (Field, 2018). A scatterplot of standardized residuals can show a normal distribution of variables to disclose the variable linearity (Osborne & Waters, 2002). Any unequal variance results are likely to be skewed or biased.

To test for homoscedasticity, this study uses a visual examination of a scatterplot of standardized residuals (errors) and the predicted values (Figure 4.1 below). A Random scattering around the horizontal line (0 value) can indicate comparative even distribution for a linear relationship between the dependent and independent variables including that none of the points fall outside of - 3 to + 3 on the x or y axis (Osborne & Waters, 2002).

Figure 4.1

Scatterplot of Outcome Variables



4.2.1.3 Shapiro-Wilk Test and Cook's Distance

The Shapiro-Wilk test is used to compare sample scores to normally distributed scores with the same mean and standard deviation (Field, 2018). A significant Shapiro-Wilk test ($p < 0.05$) indicates that the sample distribution is significantly different from a normal distribution where the Null hypothesis can be rejected (Field, 2018).

The Shapiro-Wilk test in this study finds the same standardized and unstandardized significance of p = .128. These results suggest that a non-significant Shapiro-Wilk test ($p > 0.05$) shows that the sample distribution is the same as the normal distribution (Field, 2018).

Cook's Distance is a measure of how much the residual data points influence the model for measuring model validity. Cook's Distance values less than 1 are recommended (Field, 2018). Cook's distance for this study finds a minimum value = .000, maximum value = .112 and the mean value = 0.011.

4.3 Descriptive Analysis

This study assesses the average mean score results of the independent variables for showing the ranking of the low-stress environments.

4.3.1 Variable Means

The results are presented in Table 4.1 and show the independent variable average mean scores from the lowest mean average score (low stress starts at 1) to the highest mean average score (high stress starts at 10). These results (Table 4.1) show the ranked scores starting with the least stress: 1) MountainScape, 2) ForestScape, 3) Outside Nature Engagement, 4) WaterScape, 5) RuralScape, 6) Inside Nature Engagement, 7) Ceiling Height, 8) Agricultural, 9) Outside Nature Views, 10) Inside Nature Views, 9) and 11) Urban and Industrial.

Table 4.1

Variable Mean Scores[a]

Variables	Average Variable Mean
MountainScape	38.97
ForestScape	42.97
Outside Nature Engagement	44.89
WaterScape	52.55
RuralScape	56.10
Inside Nature Engagement	63.04
Ceiling Height	72.33
Agricultural	75.40
Outside Nature Views	77.06
Inside Nature Views	78.11
Urban and Industrial	94.50

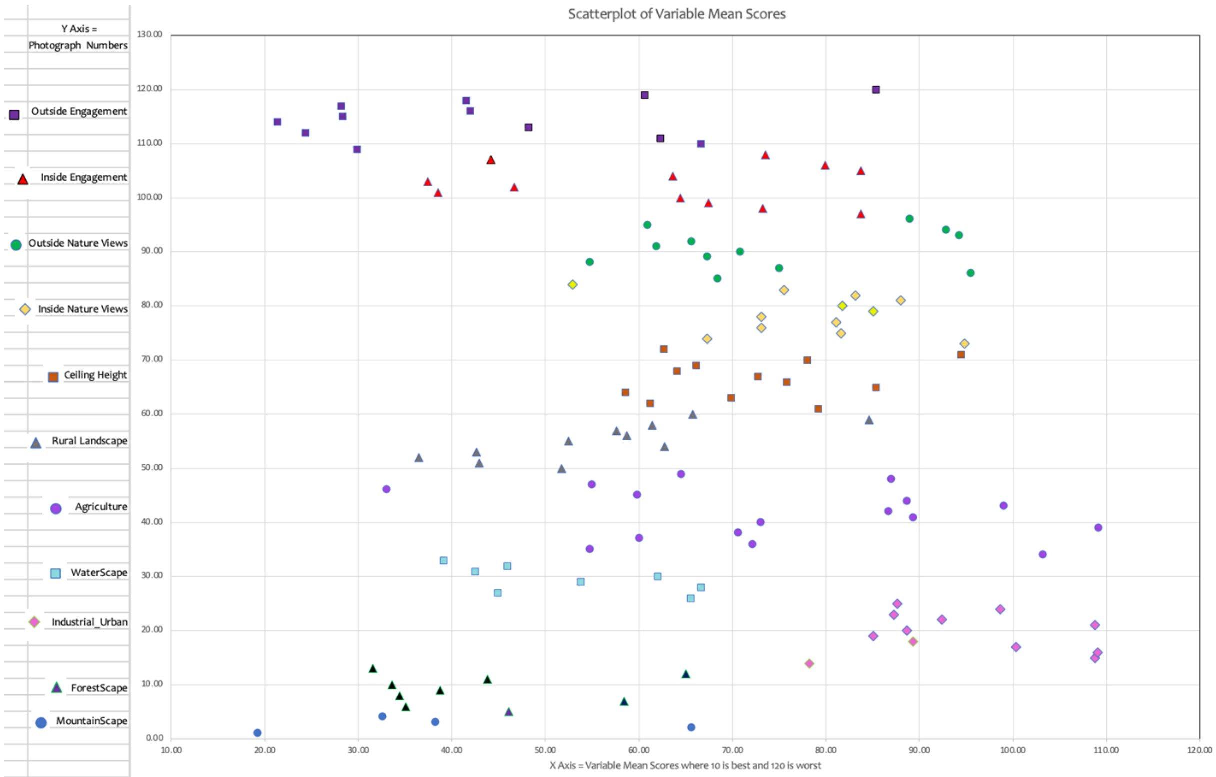
a. Results list variable environments means from low stress to high stress.

4.3.2 Scatterplot of Independent Variable Scores per Photograph

A scatterplot of each independent variable shows the corresponding ranked photograph with the mean scores that participants perceive for low-stress environments (Field, 2018). Figure 4.2 shows a ranking of which environmental attributes are perceived as the best low-stress environments (lowest score) to the worst low-stress environments (highest score). The independent variables are stated on the Y-axis and the ranking of the photographs on the X-axis. The ranges and variations of the scores vary.

Figure 4.2

Scatterplot of Independent Variable Scores



Key

	Independent Variable	Identifying Shape & Color
11	Outside Nature Engagement	dark purple square
10	Inside Nature Engagement	bright red triangle
9	Outside Nature Views	green circle
8	Inside Nature Views	yellow diamond
7	Ceiling Height	dark orange square
6	RuralScape	grey triangle
5	Agricultural	purple circle
4	WaterScape	light blue square
3	Urban & Industrial	pink diamond
2	ForestScape	black triangle
1	MountainScape	blue circle

As shown in Figure 4.2, the MountainScape and Outside Engagement environment scores rank closest to a score of 10 (low stress), where Agricultural and Urban and Industrial environment scores rank closer to a score of 110 (higher stress). Most independent variable scores show a clustering between scores of 60 and 80. The variables scores that range close to 70 are likely to be in the neutral range (Burley, 1997) and can be perceived as neither low-stress environments nor high-stress environments.

4.4. Stepwise Multivariate Linear Regression Analysis

A stepwise linear regression analytical method is chosen for finding the largest variable coefficients with statistical significance as the best predictor (independent) variables (Field, 2018) from the multiple variables used in this study.

4.4.1 Coefficients

The coefficient Table 4.2 below shows the individual variables' contribution to the regression model. The significance of the independent variables' engagement to the outcome of the predicted model can be detected by the column labeled *Sig.* for statistical significance (Field, 2018). Significant values of $p < 0.05$, for a 95% confidence level, show more significant with the variables' engagements in predicting the model's outcome than $p > 0.05$.

The coefficient *B* values explain one variable's proportion of variance that is impacted by another variable (Field, 2018). The largest coefficient values show the most significant independent variable impacts. For this study, the negative coefficient values find a better predictive model equation for low-stress environments. Table 4.2 shows a range of variable coefficient values from 0.006 (Agricultural) as the worst low-stress environments to -0.456 (Outside Nature Engagement) as the best low-stress environments.

Standard Error of the Mean (SE) is found by finding the differences between each sample mean and the total sample means, squaring the differences, adding them up and dividing by the total means for finding the average (Field, 2018). A small SE suggests that differences between sample means, centered around zero, are closely associated with the normal population. Large sample mean values can depict sampling variations suggesting differences in the normal population (Field, 2018).

Table 4.2

***Coefficients*[a]**

Model 1	Standardized *B*	Std. Error	Sig.	Collinearity Tolerance	Statistics VIF
Constant	124.213	14.858	<.001**		
MountainScape	-.178	.377	.019*	.881	1.135
ForestScape	-.415	.069	<.001**	.522	1.915
Urban and Industrial	.271	.095	.001**	.713	1.403
WaterScape	-.260	.164	.001**	.807	1.239
Agricultural	.006	.221	.935	.883	1.133
RuralScape	.031	.139	.681	.853	1.173
Ceiling Height	-.054	.300	.541	.631	1.584
Inside Nature Views	-.013	.105	.874	.760	1.317
Outside Nature Views	-.010	.105	.904	.724	1.381
Inside Nature Engagement	-.201	6.480	.029*	.594	1.683
Outside Nature Engagement	-.456	6.480	<.001**	.594	1.683

a. Dependent Variable: Perception of stress rank
* $p < 0.05$. ** $p < 0.001$

To ensure that there are no multiple correlations between variables, variance increase factors (VIFs) and Tolerance values are examined. As shown in Table 4.2, VIF factors less than 10.0 indicate that there are no multiple relationships between variables. Tolerance values greater than 0.10 indicate that there are no multiple relationships between the variables (Uyank & Güler, 2013) which are shown in Table 4.2 for this study.

4.4.2 Stepwise Regression Model

The best predictive model is found when an independent variable is added to the equation and a removal of the least significant variable is conducted at the same time (Field, 2018). A stepwise regression analysis determines which equation shows the highest statistical significance ($P < 0.05$) for finding the best predictive model by using the most variables with the highest coefficient values (Field, 2018).

4.4.2.1 Predictive Linear Model Results

The predictive model equation summary results seen in Table 4.3 explain 46.6% of the significant variance. These are the results of eleven independent variables added in the stepwise regression analysis using main effect terms for finding statistical significance (with $p < 0.001$) with the highest R-Square (R^2) values. The R^2 values can show the strength of the relationships between the variables and is calculated by dividing the sum of squares of model (SS_M) by the total sum of square (SS_T) (Field, 2018; Uyanık & Güler, 2013).

The Mean Square measures the average variation of the model that is found by dividing the Sum of Squares by the degrees of freedom (df). The degrees of freedom value represent the maximum number of independent values the samples are free to vary (Field, 2018). The df is shown as (N -1), where N is the number of variables within the data sample. The Total df are shown in Table 4.3.

The F-statistic measures how much the model increases the accuracy when compared to the model errors. This shows the fit of the regression model and is best to be greater than 1.0 (Field, 2018), as shown in Table 4.3 below.

Table 4.3

Predictive Model Summary

Model[a]		Sum of Squares	df	Mean Square	F	Sig
1	Regression[b]	25,825.387	11	2,346.853	8.710	< 0.001**
	Residual	29,099.745	108	269.442		
	Total	54,915.132	119			

a. Dependent Variable: Perception of stress rank

b. Predictors: (Constant), MountainScape % of photograph, Agricultural % of photograph, RuralScape % of photograph, Inside Nature Views % of photograph, Outside Nature Views % of photograph, Urban and Industrial % of photograph, WaterScape % of photograph, ForestScape % of photograph, Ceiling Heigh, Inside Nature Engagement, and Outside Nature Engagement

** $p < 0.001$

The multivariate linear regression model shown in Table 4.4 shows the six independent variables with statistical significance for acceptance within the predictor equation. An increase in the R values is shown with the addition of the significant independent variables. The R value is the square root of R-Squared (R^2) value. The *coefficient of determination,* or R^2 value, measures how much variance in one variable is explained by another variable (Field, 2018; Uyanık & Güler, 2013).

For a regression model, R^2 shows the degree that the variance of the dependent variables can be explained by the model. The R^2 values get bigger as the best independent variables are added. A positive value increase in R^2 means that there is an increase in the contribution of the dependent variable to the independent model (Field, 2018).

Table 4.4

Multivariate Linear Regression Model

Independent Variables	R	R^2	Coefficient *B*	Std Error	Pr > F
Intercept			76.035	2.343	<.001**
Urban and Industrial	.380[a]	.144	.324	.081	<.001**
Outside Nature Engagement	.476[b]	.227	-31.140	5.206	<.001**
ForestScape	.577[c]	.332	-.274	.053	<.001**
WaterScape	.642[d]	.412	-.524	.154	<.001**
Inside Nature Engagement	.663[e]	.439	-13.014	5.206	.014*
MountainScape	.683[f]	.466	-.880	.367	.018*

* $p < 0.05$. ** $p < 0.001$

This predictive model equation finds main effect terms for maintaining higher variable coefficient values and R^2 values with significance for effecting the dependent variables. Main effect terms are better than using squared effect terms and interaction effect terms for finding a good predictive model. Therefore, variable squared effect terms and interaction effect terms are not included in the predictive model equation.

The six independent variables, environmental attributes, and the coefficient values shown in Table 4.5 are included in the regression model. The independent variables include Urban and Industrial, Outside Nature Engagement, ForestScape, WaterScape, Inside Nature Engagement, and MountainScape.

Table 4.5

Predictive Variable Model Attributes and Coefficients

Independent Variables	Environmental Attributes	Coefficient
Urban and Industrial	Concrete + Trees + Buildings	00.324
Outside Nature Engagement (ONE)	Engagement with Outside Vegetation	-31.140
ForestScape	View of Multiple Green Trees + Dirt	-00.274
WaterScape	Views of Water + Dirt	-00.524
Inside Nature Engagement (INE)	Engagement with Vegetation Inside	-13.014
MountainScape	Views of Mountain Landscapes	-00.880

4.4.2.2 Predictive Model Equation

The stepwise regression analysis finds six interaction variables for creating the best predictive model. Negative beta coefficient variables suggest a higher preference for low-stress environments, where positive beta coefficients suggest perceptions of high-stress environments. A hierarchical listing of negative and positive variable coefficient values ranging from 0.284 to -0.437 are shown in Table 4.5 Independent variable Outside Nature Engagement shows the largest negative coefficient value where Urban and Industrial variable coefficient shows the only positive coefficient value.

The predictive model equation shows the dependent variable (Y) results from the calculations of the independent variable coefficients. The model equation Intercept (B_0) standard error of the estimate is 76.035, which is the value of the dependent variable when all independent variable coefficients equal zero (Fields, 2018). The predictive equation shows a better predictive model equation for low-stress environments (Y value) when all independent variable coefficients are included. This results in a lower dependent variable value (Y) suggesting better low-stress environments.

Model equation:

$$Y = 76.035 + (0.324*Urban) - (31.140*ONE) - (0.274*Forest) - (0.524*Water) - (13.014*INE) - (0.880*Mountain)$$

The dependent variable result from including all the predictive coefficients is:

$Y = 30.527$

The largest coefficient values impact on the predictive equation the most. The negative coefficient values in this study shows a better predictive model equation for low-stress environments. Outside Nature Engagement shows the largest negative coefficient value and thus the most significant low-stress environment found followed by Inside Nature Engagement, MountainScape, WaterScape and ForestScape.

4.5 Principal Component Analysis (PCA) with Semantic Differential Scores

For this study, a semantic differential survey method is used for finding the meaning of similar scores to represent the meaning of the environmental characteristics viewed from the survey photographs shown (Osgood, Suci, and Tannenbaum, 1957). The principal component analysis (PCA) method is used for finding the word-antonym associations with the low-stress photographs. The semantic differential survey scores are sorted and clustered in an ordination following the Principal Component Analysis (PCA) method. The PCA method provides graphic positions from a few data points that result from finding the most significant variables that have the greatest variability on the same axis. This data will show up in a component, or principal component.

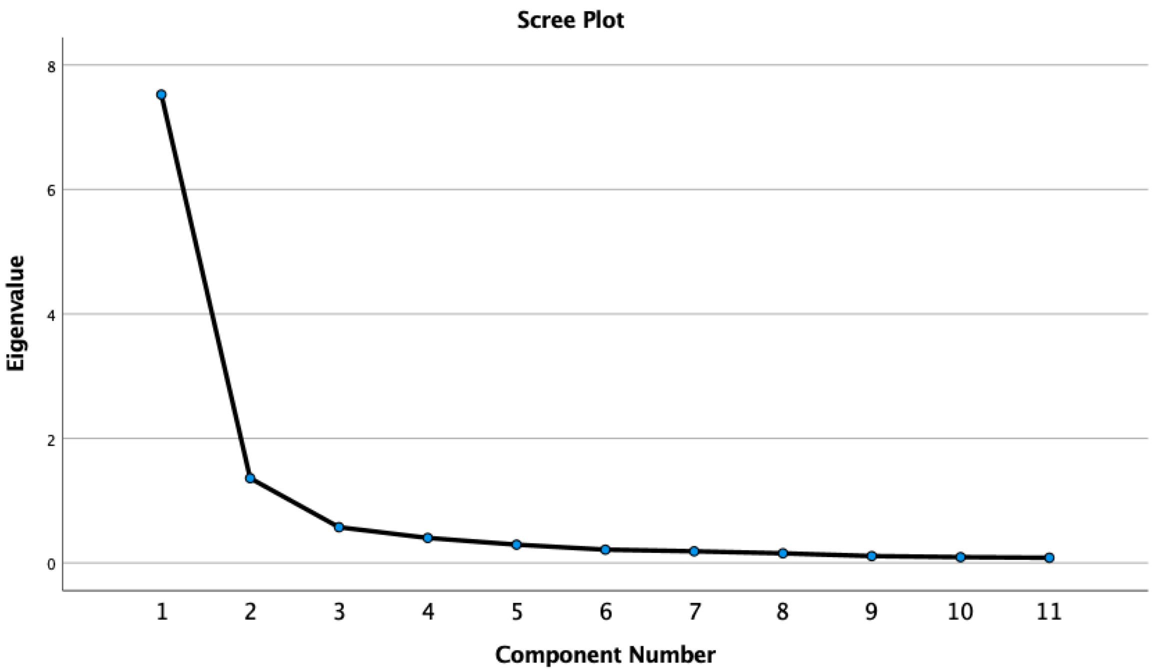
Cronbach's Alpha values (.952) used for testing internal consistency of the semantic differential survey data is found to be within the acceptable value for all independent variables (Aigbavboa & Thwala, 2013).

4.5.1 Spree Plot of Eigenvalues

Each component has an eigenvalue that shows the total of the sum of squared factors for all variables. The eigenvalues greater than 1.0 in a component shows significance. A scree plot (Figure 4.3) is used to plot each eigenvalue (Y-axis) against the associated factor (X-axis) and to show the relative importance of each factor (Field, 2018). The scree plot for this study finds two components with significantly high eigenvalues. The scree plot below shows that PC1 has the largest eigenvalue followed by PC2, where both eigenvalues are greater than 1.0 and represent further investigation.

Figure 4.3

Scree Plot of Eigenvalues



4.5.2 Principal Component Eigenvalues

Total variance explained for Principal Component Analysis extraction method shown in Table 4.6 below depicts the eigenvalues for each principal component. The biggest eigenvalue similarities signify the percentage of the variable accounted for by the principal component. As shown in the scree plot, two components that are extracted find high eigenvalues with significance for values greater than one. The first principal component (PC1) explains 68.6 % of the observed variance in the data. The second principal component (PC2) explains 13.477 % of observed variance. In total, the first two components explain 82.078 % of data variance and will require further analysis.

Table 4.6

Eigenvalues of the Principal Components

Principal Component	Eigenvalue	Cumulative Percentage	Sum of Squared Percentage of Variance
1	7.526	68.419	68.601
2	1.362	80.798	14.477
3	0.574	86.019	
4	0.402	89.673	
5	0.294	92.344	
6	0.213	94.284	
7	0.187	95.985	
8	0.155	97.393	
9	0.1107	98.397	
10	0.093	99.243	
11	0.083	100.00	

4.5.3 Eigenvector Component Coefficients

The PC1 and PC2 eigenvector component coefficients shown in Table 4.7 finds all positive numbers under principal component 1 and negative and positive numbers under principal component 2. The two values of the eigenvector (length and width) for each independent variable tell the maximum amount of the variance's matrix and can show how evenly, or not, the variances covary together as linear components.

Table 4.7

Eigenvector Table of Component 1 and Component 2

Antonyms	Component 1	Component 2
Energic_Lethargic	0.592	0.653
Interesting_Boring	0.666	0.494
Cheerfrul_Gloomy	0.884	0.250
Refreshing_Weary	0.931	0.017
Pleasant_Unpleasant	0.885	-0.016
Satisfying_Frustrating	0.916	-0.035
Fearless_Fearful	0.835	-0.128
Unstressful_Stressful	0.936	-0.139
Carefree_Anxious	0.906	-0.141
Relaxed_Tense	0.925	-0.227
Calm_Excitable	0.460	-0.721

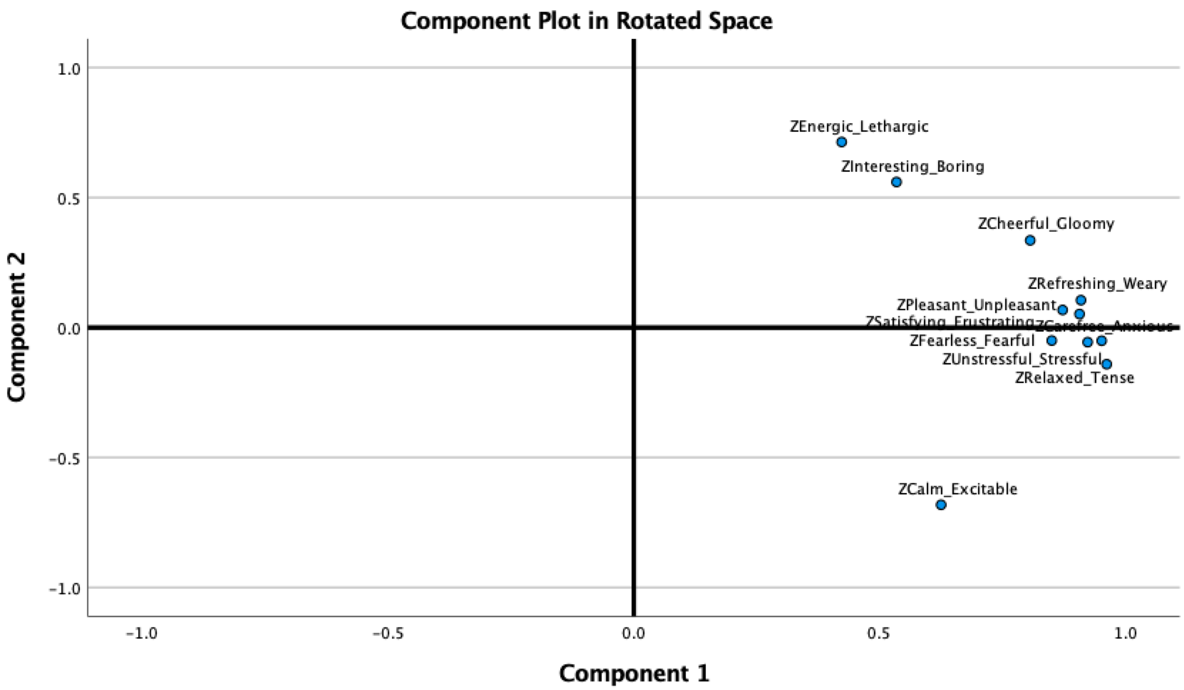
The PC1 eigenvectors scores are all positive and range from 0.460 (Calm_Excitable) to 0.936 (Unstressful_Stressful). PC1 is the axis (X) where eigenvectors span the most variation. The positive and negative eigenvector scores showing in PC2 is the second most varied axis (y) with eigenvector scores ranging from -0.721 (Calm_Excitable) to 0.653 (Energic_Lethargic). The word antonym scores with the larger values (< -0.4 or > 0.4) have more influence than the word antonyms with eigenvector scores closer to zero.

4.5.4 Word Association Eigenvector Plot

The PC1 and PC2 eigenvector scores plotted in the 2-D linear graph below (Figure 4.4) represent the locations of the word-associated eigenvector correlations (Field, 2018). The large positive eigenvector scores for word antonyms, Energic_Lethargic, and Interesting_Boring are shown in the upper right quadrant. A decrease of the PC2 eigenvector scores can be seen diminishing from the top right quadrant (Y-axis) to the bottom right axis recognizing Calm_Excitable antonym as the most negative PC2 eigenvector score. All the PC1 eigenvector scores are shown in the right quadrants (X-axis) as they are all positive variance scores.

Figure 4.4

A 2-Dimensional Graph Plotting PC1 and PC2 Eigenvectors



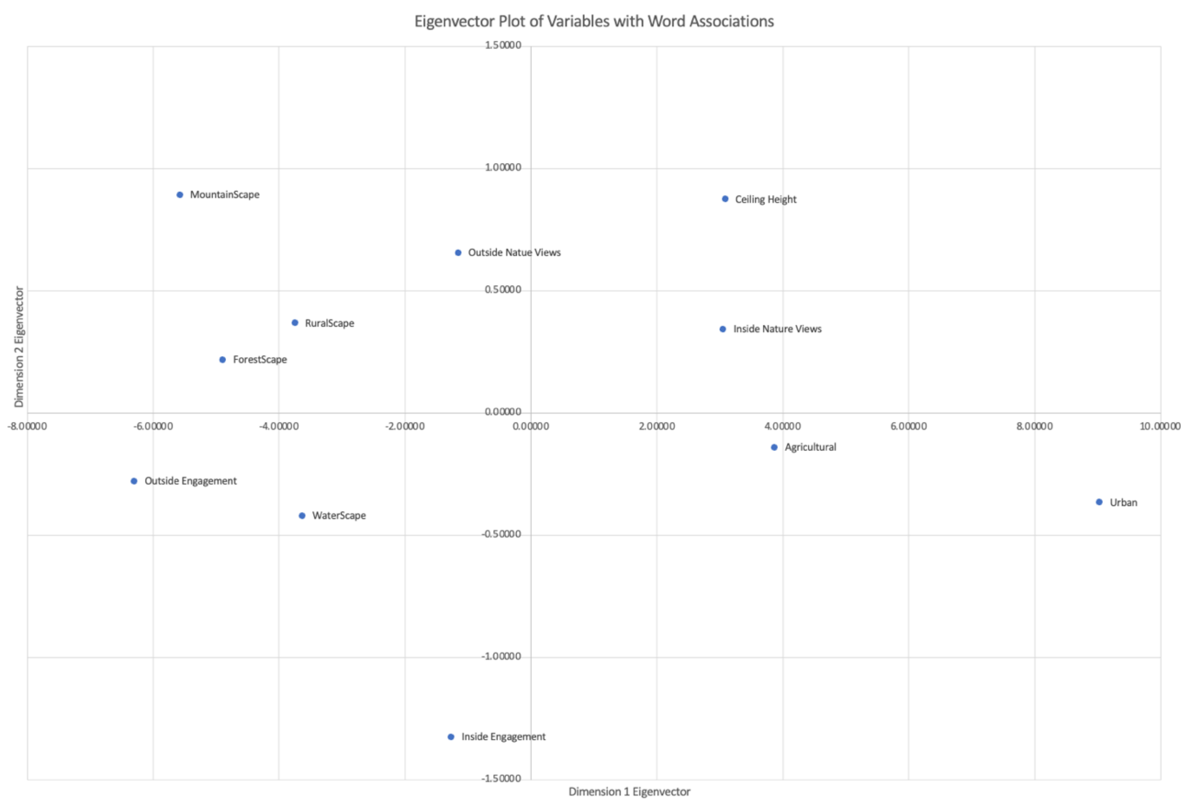
4.5.5 Eigenvector Plot of Variable Group Means with Word Associations

Word antonym eigenvalues are plotted on a 2-Dimensional graph (Figure 4.5) showing the relationships of the word antonyms eigenvectors associated with the eleven independent variable means. The PC1 (X axis) eigenvectors with 68.6% of variance are therefore more important than eigenvector differences along PC2 (Y axis) explaining 13.48% of variance.

The larger eigenvector scores (more significant) show for PC1 (X-axis) where the top left quadrant represents a higher preference for low-stress independent variables than in the bottom right quadrant. The independent variables shown in the outer quadrant borders represent high eigenvector scores and are thus more influential.

Figure 4.5

Eigenvectors Plotted from Variable Means with Word Associations



Eigenvector scores that are similar can represent similar perceptions for low-stress variable attributes. The perceptions of low-stress variables shown in Table 4.8 state #1 as the most low-stress variables and #5 at the least low-stress variable.

Table 4.8

Variable Eigenvectors with Word Antonyms

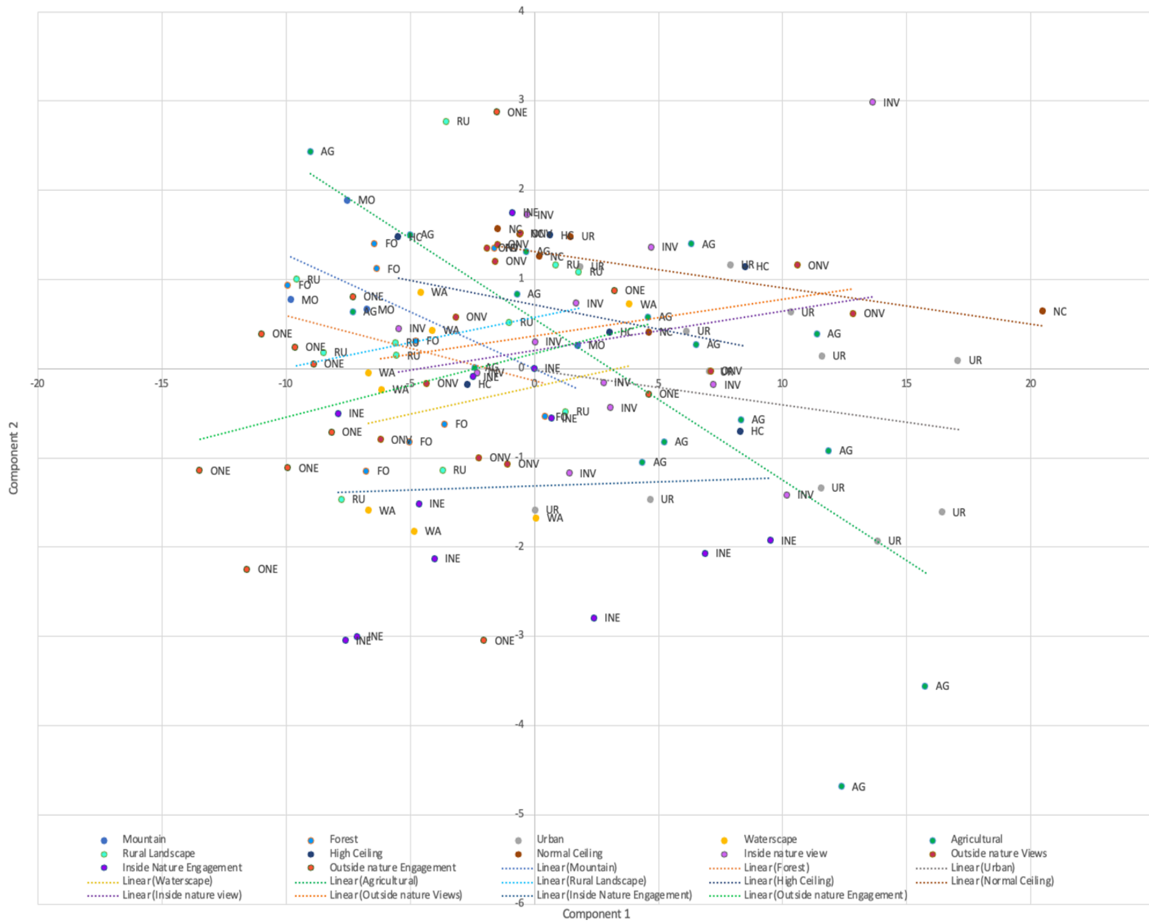
Independent Variable Environments	Perceptions of stress (1 Lowest Stress – 5 Most Stress)
Outside Nature Engagement	1
MountainScape	1
ForestScape	1
RuralScape	2
WaterScape	2
Outside Nature Views	3
Inside Nature Engagement	3
Ceiling Height	4
Inside Nature Views	4
Agriculture	4
Urban and Industrial	5

4.5.6 Vector Plot of Variable Means with Word Associations

As seen in Figure 4.6 below, a scatterplot of the 120 built environment and nature environment photograph means, representing the eleven independent variables, are shown for associations to each other and for associations with PC1 and PC2 word antonym eigenvectors. A drop line for each independent variable is shown connecting the photograph mean scores with the independent variables (Field, 2018).

Figure 4.6

Linear Vector of Variable Means with Word Associations



The plotted variable means clustering of low PC1 and PC2 eigenvector scores around zero on the X-axis illustrating similar scores with less variable influence. The best low-stress variable vector scores show for PC1 (X-axis) ranking are found in the top left quadrant to the lower right quadrant along PC1 axis for low-stress environments. This shows that the more negative numbers in PC1 were perceived as low-stress environments.

Table 4.9 shows the ranking of the best low-stress variables to the worst low-stress variables. The best low stress variables are Outside Nature Engagement, ForestScape, MountainScape, and RuralScape. These perceived results show RuralScape as a better low-stress environment than the other methods. The variable eigenvector scores clustering closer to zero are shown to be WaterScape and Inside Nature Engagement. Similar lustering eigenvector scores as with the other research methods are High Ceiling Height, Outside Nature Views and Inside Nature Views. The worst low-stress environments with wide variance are Normal Ceiling Heigh, Agricultural, and Urban and Industrial. The drop line for the Agricultural variable is shown from the top left to the bottom right quadrant representing the largest variable variance.

Table 4.9

Variable Linear Vectors Associated with Word Antonyms

Independent Variable Environments	Variable and Eigenvalues for PC1 (X-axis)
Outside Nature Engagement	-14.0 to -0.5
ForestScape	-10.0 to 0
MountainScape	-10.0 to 0
RuralScape	-9.0 to 2.0
WaterScape	-7.0 to 3.0
Inside Nature Engagement	-7.0 to 9.0
High Ceiling Height	-5.0 to 8.0
Outside Nature Views	-5.5 to 13
Inside Nature Views	-5.0 to 13
Normal Ceiling Height	-2.0 to 20
Agriculture	-9.0 to 20
Urban and Industrial	0.0 to 15

4.6 Summary

The diverse methods used for this study allow for a detailed examination of the hypotheses and answer the research questions investigating environmental attributes that can be perceived to reduce human mental stress. The three statistical methods employed provide significant results that can advance understanding of the research subject. Chapter 5 will discuss the contributions of these findings in terms of the study hypotheses and emerging patterns.

CHAPTER 5: DISCUSSION

5.1 Introduction

The statistical results of this study investigating low-stress perceptions from the effects of the built environment (some stated in WELL Mind Concept criteria) and with nature environments (as with Attention Restorative Theory) answer the three research hypotheses. Seven emerging patterns along with design innovations are discussed below.

5.2 Hypotheses

Hypothesis #1:

The descriptive analysis of plotted mean scores finds a ranking from the best low-stress variable environments to the worst low-stress variable environments.

Accepting Hypothesis #1

This data analysis answers Research Question 1.1 and uncovers data for accepting Hypothesis #1 (*HA*1) by finding that there are built environments and nature environments that cluster and group together. MountainScape, Outside Nature Engagement, and ForestScape variables are found to be the strongest low-stress variables with mean scores from 20 to 45. The average low-stress variables clustering with scores from 50 to 70 are WaterScape, Inside Nature Engagement, and RuralScape. The average to worst low-stress variables scores from 70 to 80 are Outside Nature Views, Ceiling Height, Inside Nature Views and Agriculture. Urban and Industrial variable score ranks over 80 as the worst low-stress environment.

Hypothesis #2:

The predictive model results find a hierarchical ranking of the independent variables that are statistically significant to predict a response for at least 40% of variance of the independent variables.

Accepting Hypothesis #2

The results of the stepwise multilinear regression model answers Research Question 2.1 and uncovers data for accepting Hypothesis #2 (*H*A2) by finding a statistically significant hierarchical ranking of the independent variables for 46.6% of the variance. The predictive model shows Outside Nature Engagement with the largest negative coefficient value (-31.140) as the most significant low-stress environment, followed by Inside Nature Engagement (-13.014). The following ranking of the best low-stress environments are MountainScape (-00.880), WaterScape (-00.524), and ForestScape (-00.274). Urban and Industrial environment ranks as the worst low-stress environment (00.324).

Hypothesis #3:

The ordination and ranking of the word antonym eigenvector scores associate with the independent variables for finding the relationship of the best low-stress environments with the best low-stress word antonym eigenvector scores.

Accepting Hypothesis #3

The principal component analysis ranking the best low-stress variables with the best low-stress word antonym eigenvector scores find Outside Nature Engagement, MountainScape, and ForestScape as the best low-stress environments. The best to worst low-stress environment ranking order are as follows: RuralScape, WaterScape, Inside

Nature Engagement, Outside Nature Views, Ceiling Height, Inside Nature Views, Agricultural, and Urban and Industrial. The most significant word antonyms are Energic_Lethargic, Interesting_Boring, and Calm_Excitable, yet principal component 1 and principal component 2 explains 82.078 % of the observed variance in the data. These findings answer Research Question 3.1 and uncovers data for accepting Hypothesis #3 (*HA*3) by finding a statistically significant hierarchical ranking.

5.3 Seven Emergent Patterns

As is common with other research findings, participants can see nature from different perspectives due to diverse backgrounds, cultures, and experiences (Kaplan & Kaplan, 1989; Nisbet, et al., 2011). One example is the various design attributes used for creating an experience within a Japanese garden may not be commonly seen in a European or English garden (Chen, et al., 2021). Knowing that individual interpretations and preferences vary, these findings represent the most significant patterns and themes for most of the participants.

The discussion of these emergent patterns includes references for comparison to earlier landscape studies that also use Q-Sort method and for expanding knowledge with this study's ranked perceptions of low stress while viewing outside nature environments, inside built environments with nature, and inside and outside nature engagement environments. These patterns are listed in a ranking order of the best low-stress environments first, followed by then next and so on, where the worst low-stress environment is discussed last. The ranked listing are statistical results of low-stress independent variable environments and their closely associated (cluster) variables.

5.3.1 Pattern One: Outside Nature Engagement as Best Low-Stress Environment

The statistical results of this study verify the value of outside nature engagement environments surrounding a built environment for reducing stress. Kaplan & Kaplan (1989) claim that higher feelings of low stress are seen with Attention Restorative Theory (ART) as an individual engages in involuntary focus interacting with outside nature environments.

The Outside Nature Engagement variable photographs are based upon Attention Restorative Theory (ART) claims that involuntary focus can increase when interacting with nature by mentally being away, engaging with interest, perceive extended views, and enjoy compatibility with the nature environment (Kaplan & Kaplan, 1989). Much literature claims that human involvement in nature promotes mental health for decreasing stress (Aristizabal et al., 2021; Kaplan & Kaplan, 1989; Lederbogen et al., 2011; Sahni & Kumar, 2021; Sahraiyanjahromi & Lodson, 2017) and for providing mental restoration for attention (Kang & Kim, 2019; Kaplan, 1995).

The results of Outside Nature Engagement variable for this study are consistent with other literature suggesting that physical access to outside vegetation has more stress reducing effects than only a visual access (Beuet & Kort, 2018; Lothrup et al., 2013; Van de berg et al., 2010). Figure 5.1 shows a photograph example of Outside Nature Engagement variable that includes views of green grass, trees, flowers and rolling hills. Small interspersed man-made views of roof tops, a fence, a chair, and china than can be seen. The photograph's concept of being surrounded by nature while eating a continental breakfast can supersede the views of the man-made attributes. The measured percentages of nature and man-made attributes in Outside Nature Engagement variable photographs are beyond the scope for this study. Future research is needed to evaluate what influences the different percentages that man-made attributes and nature attributes can have, if any, on Outside Nature Engagement photographs.

Figure 5.1

Outside Nature Engagement Variable as Best Low-Stress Environment

Recommended Design Innovations:

1. Specifying high-occupancy locations with percentages and types of nature attributes for occupants to engage with near the built environment.
2. Include a subjective pre-engagement and post-engagement survey measuring the participants' perception of stress to determine the effectiveness.

5.3.2 Pattern Two: MountainScape and ForestScape Next Best Low-Stress Environment

This study finds participants' perceptions for the next best low-stress variable environments to be MountainScape and ForestScape. From the six outside nature environment variables, these two environments rank significantly better for low stress. Consistent with another study identifying the *Biospheric Preference Theory*, participants prefer visual environments with living attributes found in nature such as plants, flowers, trees, and diverse landscapes (Burley, 1997; Ives, et al., 2021). Three reasons for MountainScape and ForestScape as best low-stress ranking are discussed next.

5.3.2.1 Visually Rare and Appealing Nature Views

Views of nature attributes can be rare and visually more appealing. *Temporal Enhancement Theory* defines these as specific attributes or experiences with landscape environments that are preferred (Burley & Yilmaz, 2014). Examples can be with outside nature views as with a sense of adventure and/or vacation venue that typically includes traveling to an appealing outside environment. A vacation to a tropical environment, such as Hawaii or Florida, can be favored with individuals living in colder climates during winter months. A previous memory of a favorite vacation location can change an individual's landscape perception. Kaplan and Kaplan (1989) found that past emotional experiences can influence perceptions of more recent environments.

5.3.2.2 Larger Horizon Views

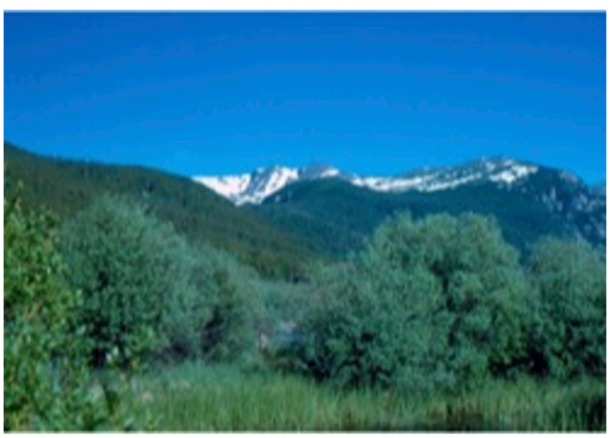
Larger horizon views are perceived as more spacious (Stamps, 2011), which can potentially decrease stress (Yin et al., 2020), and feel like being outside (Beurte & de

Kort, 2018). Mountain views are found to be a strong preference for low-stress environments in other studies using Q-sort Visual Quality Assessment method (Ives, et al., 2021; Shafer, et al., 1969).

Most of the MountainScape variable photographs provide views of distance horizons as viewing mountains from a distance. However, not all the ForestScape variable photographs provide distant horizon views of the forest. Figure 5.2 shows examples of MountainScape and ForestScape variable photographs used in this study. The MountainScape photograph shows a view of mountains and hills in the distance, and the ForestScape photograph shows a view of dark green trees in the foreground and the distant background. Both photographs are good examples of larger horizon views.

Figure 5.2

MountainScape and ForestScape as Best Low-Stress Environment



Both photographs include views of the sky on the horizon line. Previous landscape studies using the same Q-Sort method finds common nature features (sky, vegetation, and water) with neutral environmental scores (Burley, 2006; Lu, et al., 2021). Therefore, the effects of sky preference views and the effects of the distant horizon lines are beyond the scope of this study. Future studies can investigate the effects the sky views and horizon line views have on perceptions of nature and built environment low-stress environments.

5.3.2.3 High Percentages of Nature Environments for the Best Low-stress Environments

This study finds that high percentages of highly populated nature views (MountainScape and ForestScape) can provide a higher quality of low-stress environments when surrounding the built environment. A study investigating landscapes finds that Individuals who are in contact with large areas of rich nature environments are highly correlated with lower stress (Thompson et al., 2012). The best nature rich environments for lowering stress are suggested to include ForestScapes, vegetation parks, or water sites (Korpela & Hartig, 1996; Korpela, et al., 2015).

Another study finds that vegetated areas surrounding the built environment within 1.86 miles is found to lower occupant stress (Van den Berg, et al., 2010). It is not known what the best percentage and distance of nature rich vegetation is for promoting low stress with the built environment. This is beyond the scope of this study. Future research is needed.

Recommended Design Innovations:

1. Include rich green vegetation parks created by a landscape architect close to the busy built environments.
2. Add multiple nature rich vegetated areas within 1.86 miles of occupied built environments.

5.3.3 Pattern Threes: WaterScape, RuralScape, and Interior Nature Engagement Ranking

The data clustering for perceptions of medium low-stress environments includes two outside nature variables (WaterScape and RuralScape) that score in the 50s and one built environment variable (Inside Nature Engagement) that scores in the 60s. The clustering suggests a close association of middle low-stress scores shows common nature attributes that are typically viewed in everyday living (vegetation, water, clouds, and sky). The combination of these diverse environment scores can show average scores from the best scores (scores of 20 to 40) with the worst scores (scores of 70 to 90). The resulting average scores (scores in the 60s) are the middle of the ranking scale of 1 to 120. These medium low-stress environments with scores in the 60s can be included in the *Neutral Theory*, a normative theory developed by other landscape studies (Burley & Yilmaz, 2014; Lu, et al., 2012).

5.3.3.1 WaterScape Ranking

Results from this study rank the WaterScape photographs as a better medium low-stress environment than the built environment photographs with man-made attributes, as seen with the RuralScape and Inside Nature Engagement photographs. Figure 5.3 shows one WaterScape example with views of vegetation and mountain surrounding the water. This study includes WaterScape variable photographs showing a combination of water landscapes with views of buildings, people, and boats surrounded with nature views of trees, dirt, and rocks.

Figure 5.3

WaterScape Variable as Medium Low-Stress Environment

This finding is consistent with literature suggesting that water views in nature can improve human health, though green landscape environments can improve human health better than water views in nature (Velarde, Fry, and Tveit, 2007). However, another landscape study shows that outside nature water views are preferred over typical green vegetation views (Ives et al., 2021).

These diverse literature results show a need for future research to clarify and to answer the following questions: What percentage of water views find the best low-stress environment? Could any of the water surrounding views of vegetation, mountains, or human activity be perceived as the best low-stress environments? What are the perceptions for low-stress environments between inside water views and outside water views?

5.3.3.2 RuralScape and Inside Nature Engagement

The results of RuralScape and Inside Nature Engagement variable photographs as medium low-stress environment can suggest that these variable environments show more man-made attributes than with WaterScape variable environment photographs. These results are the first evidence that outside nature environments are closely associated with inside nature environments, though this study finds the inside nature environment to be Inside Nature Engagement.

Figure 5.4 shows examples of RuralScape and Inside Nature Engagement variable environments. The RuralScape variable photograph example shows about 10% less view of trees than man-made materials of concrete, stone, steps, and a house. This nature to man-made ratio is similar with the other RuralScape variable photographs where views of nature are less than views of man-made attributes.

The Inside Nature Engagement variable photograph (depicted in Figure 5.4 on the right) includes views of trees, plants, and a water fountain. However, the percentage of nature attributes and man-made attributes are not measured in this study with Inside Nature Views. When comparing the views of both photographs, the Inside Nature Engagement photograph shows more man-made attributes and no sky views. Future research is needed to better identify, measure, and compare the different percentages of nature attributes and man-made attributes with RuralScape for perceptions of the best low-stress environments.

Figure 5.4

RuralScape Compared to Inside Nature Engagement as Medium Low-Stress Environment

Recommended Design Innovations:

1. Add rich green vegetation in close association with rural built environments from a landscape plan created by a landscape architect.
2. Include nature attributes inside the built environment for occupant interaction and engagement.

5.3.4 Pattern Four: Ceiling Height, Outside Nature Views, Inside Nature Views, and Agricultural Environments

This study finds a close ranking (clustering) between middle to worst low-stress variable environment scores as Ceiling Height, Outside Nature Views, Inside Nature Views, and Agricultural. These rankings include the three built environment variables used in this study (except for Inside Nature Engagements and Outside Nature Engagement) with one outside nature variable (Agricultural).

5.3.4.1 Ceiling Height

The ceiling height variable used in this study shows a close association of Ceiling Height with Outside Nature Views. These results are not conclusive with other studies investigating low-stress ceiling heights. Literature suggests that human perception of ceiling heights over eight feet to be spacious and less stressful (Fich, et al., 2014; Meyers-Levy & Zhu, 2007; Savinar, 1975; Vartanian, et al., 2015). Future research is needed for further investigating a ceiling height that can be perceived as the best low-stress environment with comparison to outside nature views.

5.3.4.2 Outside Nature Views

Outside Nature Views scores rank higher than the Inside Nature Views for perceptions of low-stress environments. One reason can be due to the expansive panorama outside nature views that is suggested to offer more stress reducing benefits (Yin, et al., 2020). However, Outside Nature Views are ranked as middle to worst low-stress environment. This result is contrasted to other literature suggesting that outside nature views through a window can provide similar restorative benefits as being in actual contact with the outdoors (Beurte & de Kort, 2018; Kaplan, 2001).

The Outside Nature Views variable photographs used in this study include average percentages of outside vegetation views. Figure 5.5 illustrates one example of an Outside Nature Views variable photograph with 14% of outside nature views from Inside though the total window view is 40% of this photograph. As seen with this photograph, inside man-made attributes are also viewed. Even with much literature suggesting that outside nature views through a window can decrease stress, it is unclear what percentage of outside nature needs to be seen from the window. Does the window size matter more or does the view of nature matter more for reducing stress? Future research can investigate the percentage of outside nature views and window size for perceptions of the best low-stress environment.

Figure 5.5

Outside Nature Views Variable as Middle to Worst Low-Stress Environment

Recommended Design Innovations:

1. Add a landscape plan that includes high quality outside nature views from all windows created by a landscape architect.
2. Implement what is currently included in three of the more common greenbuilding rating systems certification criteria. The WELLv2 Mind Concepts M07 *Restorative Spaces* include certification criteria for outside access to nature as a new criterion from the previous version for outside access to nature as a new criterion from the previous version (IWBI, 2018). BREEAM published a new standard aligning with WELL for health and wellbeing and includes the same criteria as WELL (BRE Global, 2018). LEEDv4.1 BD+C New Construction certification standard integrates quality views for 75% views of outdoor natural or urban environments (USGBC, 2019). The Living Building Challenge 4.0 standard contains Petal Health + Happiness with 95% daylight views and Petal Beauty + Biophilia include design attributes within the project for promoting Human-Nature relationships (ILFI, 2019).

5.3.4.4 Inside Nature Views

This study shows the perceptions of Inside Nature Views variable as middle to worst low-stress environments when compared to the built environment and outside nature environments. Other literature suggesting that visual connectivity with nature inside the built environment can decrease mental stress (Berto, 2005; Grinde, & Patil, 2009; Yin et al., 2020), improve job satisfaction (Kaplan & Kaplan, 1989), and improve work productivity (Lohr, et al., 1996). Additionally, some greenbuilding rating systems include inside nature views within their certification criteria using biophilic strategies and design attributes (BRE Global, 2018; ILFI, 2019; IWBI, 2018; USGBC, 2019).

As this is the first study ranking outside nature interaction with nature inside built environment, the Inside Nature Views ranking result is not surprising. This study uses average percentages of inside nature views for the Inside Nature Views variable photographs. Still, all the photographs include views of man-made interior building attributes, which can support this ranking. One photograph example of Inside Nature Views variable environment is provided in Figure 5.6 for showing 25% of an inside vegetation view.

Figure 5.6

Inside Nature Views Variable as Middle to Worst Low-Stress Environment

Future research is needed for investigating the percentages of inside nature views with the percentages of man-made attributes for finding the best low-stress environment. These results can be altered when comparing inside nature views to outside nature views, or with built environments with no outside nature views. Other literature suggests that inside nature views can reduce stress when no outside nature views exist.

Recommended Design Innovations:

1. Build an inside courtyard with vegetation, as with the nineteenth-century Egyptian palaces, which can provide continuous nature environments of beauty.
2. Provide additional inside nature environments consistent with the current greenbuilding rating system certification criteria. The WELLv2 Mind Concepts M02 *Access to Nature* and M07 *Restorative Spaces* include certification criteria for inside nature interaction with direct nature contact or photographic representation of nature attributes or using biomimicry design with materials that mimic nature. Additionally, WELLv2 M09 *Enhanced Access to Nature* includes 75% of "Nature Views" inside the built environment (IWBI, 2018). BREEAM published a new standard aligning with WELL for health and wellbeing and includes the same criteria as WELL (BRE Global, 2018). The Living Building Challenge 4.0 standard contains Petal Beauty + Biophilia for including nature features as will biomimicry design for promoting Human-Nature relationships (ILFI, 2019).

5.3.4.5 Agricultural Next *to Worst Low-Stress Variable Photograph Example*

The Agricultural environment ranks as the second to worst low-stress environment with the widest, non-clustered variance scores suggesting that this low-stress ranking is not consistently perceived. These results may be explained from the diverse Agricultural topographic photographs showing man-made attributes of manipulated dirt and vegetation, fences, concrete, and equipment. These views of noospheric attributes (predominately man-made) can be perceived as human intrusions in nature environments.

These results suggest that Agricultural environments can be more stressful than built environment attributes of Inside Nature Engagement, Ceiling Height, and Outside Nature Views. The "Theory of Human Intrusion" is defined as where human activities can intrude upon other humans (Burley, 2006; Hallsaxton, et al., 2023; Lu, et al., 2012). This theory is easily understood for views of the built environment. The results of this study for Agricultural environments suggest that agriculture landscapes are also viewed as spaces “used” by humans. Figure 5.7 shows one photograph example of Agricultural variable environments used in this study with a view of 82% vegetation of dirt and trees. This view of dirt in the foreground shows evidence of the dormant garden season of this garden. Other evidence suggests that a garden can be a designed or a planned space with human creation and intervention in this space.

Figure 5.7

Agricultural Variable as Worst Low-Stress Environment

Are agricultural spaces perceived as low stress when they are viewed as seasonal growing periods for crops, food, flowers, and livestock? What are the perceptions of low-stress environments for views of manipulated dirt? Or for agricultural environments for animals? Future studies can help identify which attributes of agricultural landscapes can be perceived as the best low-stress environments.

Recommended Design Innovations:

1. Include Agricultural views as part of outside nature engagement with the help of landscape architects using *salutogenic* design. Salutogenic design is an older landscape design theory first used by Aaron Antonovksy in 1979 with the intention

of promoting human health by close association to nature (Abdelaal & Soebarto, 2019).

2. Agricultural views are not commonly included within the greenbuilding rating systems. However, LEEDv4.1 Sustainable Site certification criteria includes alterations for environmental impacts with nature for vegetation and water conservation, and to protection and restoration of habitat with a native flowering pollinator garden for at least 30 square feet (USGBC, 2023).

5.3.5 Pattern Five: Urban and Industrial Variable Ranks as Worst Low-Stress Environment

The statistical findings from this study consistently show that Urban and Industrial landscapes are perceived as the worst low-stress and a narrow variance spread. A narrow variance spread suggests that most of the participants perceive Urban and Industrial environments as the same. Nature environments are most reliable for researching the effects of mental fatigue and restorable health (Wells & Rollings, 2012), especially for comparing these effects with urban environments (Felsten, 2009; Herzog, et al., 2003; Kaplan & Kaplan, 1989; Kaplan, 1995; Parsons, 1991; Ulrich, 1979). The results of this current study are consistent with other research investigating the human health effects of urban and nature landscapes claiming preferences to higher vegetated environments (Burley, 1997; De Vries, et al., 2003; Ives, et al., 2021).

This data suggests that Urban and Industrial photographs are showing higher percentages of man-made attributes than nature attributes, if any nature attributes at all. Not all Urban and Industrial photographs include views of nature. Examples of man-made attributes this study uses include brick buildings, concrete buildings, windows, concrete roads, fences, cars, and people. Examples of topographic attributes that could be included in some photographs are dirt, grass, water, green trees, and dead trees.

One example of an Urban and Industrial variable photograph in Figure 5.8 illustrates both a 68% view of an outside mall with concrete buildings and a 27% view of trees in the foreground. Recognizing that some Urban and Industrial photographs include nature, and some do not, with a narrow variance score, suggest that most participants in this study perceive outside built environments as the worst low-stress environments.

Figure 5.8

Urban and Industrial Photograph as Worst Stress Variable Environment Example

Previous literature and the results of this study find the best low-stress environments with views of high percentages of nature and highly vegetated areas. Literature suggests that including nature in urban and industrial environments can decrease mental stress. The amount and position of the vegetated areas (background or foreground) viewed in urban and Industrial environments is beyond the scope of this current study but offers the potential for future research investigations.

Recommended Design Innovations:

1. Include a landscape plan for adding rich green vegetation in close association to the built environments.
2. Communicate with local urban planners for best landscape practices to increase rich green vegetation locations close to Urban and Industrial areas.

5.3.6 Pattern Six: Low-Stress Environments can be with Involuntary and Voluntary Focus

The significant ranking of Outside Nature Engagement over other outside nature environments and Inside Nature Engagement suggests that involuntary focus can provide a more stress reducing environment than a planned nature environment for voluntary focus. As claimed by Kaplan & Kaplan (1989) involuntary focus is defined as when an individual's mind freely wonders, without an intended focus, when viewing their surroundings. Involuntary focus can provide a higher feeling of low stress consistent with Attention Restorative Theory (Kaplan & Kaplan, 1989). Voluntary focus can be defined as when the mind is intentionally focusing on something; not wondering as with involuntary focus.

This study finds that intentional outside nature access and nature views surrounding the built environment provides an individual with a voluntary focus for intentionally viewing nature attributes to reduce stress. Intentional nature views can be when looking at flowers in a garden, or artwork on a wall. The first photograph in Figure 5.9 shows an involuntary example where the vast background nature views of the green valley and mountain can provoke the mind to wonder without intent. The next photograph shows views of an inside butterfly exhibit at Frederik Meijer Gardens in Grand Rapids, Michigan. This exhibit is frequently visited by individuals with voluntary intentions on Seeing views of butterflies and nature. The differences between the perceived stress levels for involuntary and voluntary nature environments are beyond the scope of this study. Future research is needed to further investigate the differences and similarities for the effects of low stress.

Figure 5.9

Involuntary Environment (left) Compared to Voluntary Environment

Recommended Design Innovations:

1. Specifying easy occupancy access to rich green vegetation in close association to the built environments for involuntary nature views and engagements.
2. Include additional inside nature views with biomimicry materials and/or with photographs of nature to promote voluntary engagements with nature.
3. Provide subjective pre-engagement and post-engagement surveys measuring the participants' perception of stress.

5.3.7 Pattern Seven: Not all Outdoor Nature Environments are Low-Stress Environments

The statistical results of this study are not consistent with literature suggesting that outdoor nature environments are more conducive to decreasing cognitive stress. This study ranks the Agricultural variable environment as next to the worst low-stress environment due to higher views of man-made attributes and human activities. Other literature and the results of this study find the best low-stress environments are with engagement and/or views with high percentages of nature and highly vegetated areas (Keralis, et al., 2020).

Two additional explanations for suggesting that not all outside nature environments are low-stress environments can be due to views of seasonal topographic conditions and from diverse human cultural and social perceptions. Further discussion follows.

5.3.7.1 Seasonal Outside Nature Views

Seasonal constraints in specific climates can limit access and views of highly vegetated environments and decrease the positive effects of individual mental restoration with low stress (Hartig, et al., 2007). Photographs for Outside Nature Views and Outside Nature Engagement variable environments during cloudy, rainy, or snowy weather conditions can deter an occupant's desire to view or engage with nature outside.

Figure 5.10 illustrates variable photographs with seasonal differences in the Midwest United States. The first photograph includes highly vegetated views of green trees, pink flowers, and green grass in the foreground. The second photograph was taken in Michigan in the month of March. This specific location is the site of an annual garden. Altered climate conditions and dormant growing seasons can be less aesthetically pleasing and nature engaging without views of highly green vegetation and possible color.

Figure 5.10

Dense Vegetation Compared to Dormant Growing Season Environment

The effects of low stress from views of seasonal landscape differences and diverse climate topography (e.g., deserts) are not included in the investigation of this study. Future research investigating these differences can provide additional knowledge for the effects of Outside Nature Engagement and Outside Nature Views as low-stress environments.

Recommended Design Innovations:

1. Install inside wall murals with images of beautiful, highly vegetated nature landscapes including mountains, forest, water, and dense vegetation.
2. Provide outside nature access and outside nature views with varying images of live nature throughout the year developed by a landscape architect.

5.3.7.2 Individuals have Diverse Perceptions of Best Low-Stress Environments

Not all individuals have the same perceptions for nature views and engagements (H¨agerh¨all, et al., 2018). Participants' perceptions and feelings of viewing nature can vary pending diverse backgrounds, cultures, locations, and experiences (Brown, Barton, and Gladwell, 2013; Kaplan & Kaplan, 1989). Cultural and social diversities can include what the participant is accustomed to viewing and familiar with (e.g., French gardens, statues, etc.).

The influences of cultural and social diversity, and past emotions on perceptions of the best low-stress environments are beyond the scope of this study. Future studies could explore diverse culture preferences for familiar low-stress environments. These results can then be compared with different cultural perceptions of low-stress environments for finding significant similarities and differences.

Recommended Design Innovations:

1. Conduct focus groups with building occupants finding their experiences and beliefs with views of nature landscapes and the built environment for their perceptions of low-stress environments.
2. Interview occupants to include nature attributes that they are most familiar with and can relate to for including familiar photographic views within the survey.
3. Include a nature relatedness scale to guide occupants toward these answers (Nisbert, Zelenski, and Murphy, 2009).

5.4 Summary

This study identifies seven emergent patterns resulting from statistically significant data investigating the effects of nature environments and built environments for the perceptions of low stress. Chapter 6 states how the emergent patterns contribute to new knowledge, recognize research limitations, provide future research recommendations, and advance theoretical understanding to the industry.

CHAPTER 6: CONCLUSION AND NEW KNOWLEDGE

6.1 Introduction

This study brought to fruition emergent patterns, as well as more questions needing research. Research limitations will discuss specifics from the implementation of this study. These emergent patterns contribute the most to the discussion of new knowledge. The advancing theoretical knowledge from this study that is contributing to the built environment industry includes discussion of some inconsistent industry knowledge.

6.2 New Contributions to the Body of Knowledge

Much literature focuses on the effects of the built environment for occupant "health and well-being" by measuring and investigating the building landscape, construction materials, and operations (locations, site, air quality, water, light, etc.). This study contributes new knowledge about the relative effects of the built environment, built environment with nature, and outside nature only environments for human perceptions of mental stress. A summary of this contributing new knowledge for reducing stress is stated below.

- Outside Nature Engagement is the best low-stress environment for comparison with the built environment. This further validates the contribution of Attention Restorative Theory for identifying cognitive focus that can decrease human stress.
- Large horizon lines in nature views are perceived as best low-stress environments.

- High percentages of densely vegetated nature attributes with less or zero percentages of man-made attributes can provide a higher quality of low-stress environments when surrounding the built environment.
- Outside Nature Views rank better than Inside Nature Views for low-stress environments.
- The best low-stress environments can be with both involuntary and voluntary cognitive focus.
- Not all outside nature environments are perceived as low-stress environments.
- The value of outside vegetated nature environments increases from this study by the significant findings of the differences with the low-stress ranking.
- Q-Sort Visual Quality Assessment is a reliable method for investigating the perceived effects of built environments and nature environments on human mental stress.

6.3 Research Limitations

As this study investigates new statistical knowledge for low-stress environments, four limitations connected with this research are mentioned below.

6.3.1 Photographs Representing Different Seasons and Climates

The built environment photographs show most variables within the United States for images of green vegetation and bright sunshine during the warmer growing seasons. Additional variable photographs for Outside Nature Views, Outside Nature Engagement, and other landscape environments representing the spring, fall, and winter seasons are not included. Therefore, the ranking results of Outside Nature Views and Inside Nature Views may not apply to outside nature environments that have less or no green vegetation as during different seasons from the Midwest United States.

6.3.2 Photographs Representing Diverse Participants

Due to the researcher's location, as well as time and cost limitations, most of the survey participants resided in Michigan. Though some survey participants' backgrounds could be from other states and nations, participant inquiry for cultural and social diversity was not included in the scope of this study. Therefore, the findings from this study may not apply to participants living outside of the United States that have varied cultural, social, and racial beliefs and familiarities with outside nature topography.

6.3.3 Limited Quality Photographs

Limited consideration for the quality of the photographs representing the independent variable environments was used. The use of specific photograph sizes for quality image presentations was not included in the scope of this study. Coeterier's (1983) research suggest that using larger photographs can better present background and foreground images. The influence of specific colors and the boldness of color quality for perceptions of the best low-stress environments are not included in this study and therefore, are not known.

6.3.4 Limited to Subjective Data

The use of Q-Sort visual quality assessment and semantic differential methods is subjective data with samples represent participants' visual perceptions of low-stress environments. Objective data obtained from using physical equipment for measuring feelings of low stress was not used in this study. Knowledge about whether physical equipment attached to the human body (blood pressure cuff or EKG machine) can reliably measure human stress responses is not known.

6.4 Future Research Recommendations

Future research ideas and methods can provide greater clarity and knowledge of the most significant architectural and design attributes for creating low stress-built environments. More research can provide new resources and evidence-based theories for architects and designers to implement.

6.4.1 Evaluate Diverse Nature Climates and Seasons

In this study, photographs showing nature attributes (variables) include a medium-to- high ratio of green vegetation. Higher green nature environments can lower stress, and not all views of nature provide feelings of low stress (Twedt, Rainey & Proffitt, 2019). Future research is recommended to include nature environments photographs from diverse seasons and climates in a study like this for their effects on perceptions of low stress.

6.4.2 Evolute Different Cultures and Beliefs

Data for participants' culture and beliefs are not included in the scope of this study. The participant's perceptions and feelings of low stress when viewing nature environments may differ depending on culture and beliefs (Brown et al., 2013). Future studies are needed to collect participants' familiar cultural and social beliefs for providing new environmental attributes and/or design criteria that can influence stress.

6.4.3 Evaluate Horizon Line as Best Low-Stress Environment Attributes

Some MountainScape, ForestScape, and WaterScape views can include a long horizon view with a view of the sky. However, this study finds MountainScape and ForestScape as better perceived low-stress environments than WaterScape though they all have long horizon lines. Future research is recommended to further investigate the size of a horizon line and the effects these views can contribute to low-stress environments.

6.4.4 Evaluate Stress Level Perceptions for Involuntary and Voluntary Environments

This study finds Outside Nature Engagement variable environment ranked as best low-stress environment. As with Attention Restorative Theory, that involuntary focus can decrease human stress allowing an individual's mind freely wonders while viewing their surroundings. Examples of voluntary focus, intentionally seeking nature to decrease stress, can happen when an individual views an inside garden, materials from nature, or an oil painting of flowers. Future research can identify and provide additional knowledge by investigating the effects of low stress between involuntary and voluntary nature environments.

6.4.5 Evaluate Percentages of Man-Made Attributes and Nature Attributes

Literature shows that bigger views of nature are perceived as less stress. This study finds the Agricultural nature environment as a more stressful environment than the inside built environments. Do the different percentages of man-made attributes and nature attributes show different influences between the built environment and nature environments? As with WaterScape environments, are outside water views less stressful than inside water views? Do outside window views need to show all views of nature or can a twelve-foot window decrease human stress regardless of the outside nature views? Future research is recommended for identifying the effects of viewing different amounts of nature attributes and man-made attributers with nature inside and outside the built environment.

6.4.6 Investigate the Effects of the Photographs Size and Color Quality

Consideration for views of larger photograph sizes and views of bold color hues can have on the participants' perceptions of low-stress environments was not included in the scope of this study. Future research is needed to investigate the Q-sort VQA method for the significant effects of viewing photographs with different sizes and viewing photographs with soft and bold color hues found in nature environments and built environments.

6.5 Contributing to the Built Environment Industry

This study shows evidence-based data finding the best low-stress environments and the worst low-stress environments. Recognition of these significant findings suggest the following contributions to the built environment industry.

6.5.1 New Design Knowledge for Low-Stress Environments

Recognizing and implementing new knowledge about low-stress environments can educate interested parties, architects and designers, universities, scholars, and stakeholders. Institutions and universities can educate students from different disciplines, such as construction and landscape architects, to design and plan for healthier built environments.

6.5.2 New Research Method Finding Precipitants' Perceptions

New knowledge provides the use of a new research tool, Q-Sort Visual Quality Assessment, for investigating the participants' visual perceptions of low-stress built environments. Semantic differential word associates survey finds participants' feelings with differential word antonym associations of photographic views for low-stress environments. New research methods and scientific evidence about the effect of the built environment on individual health is needed (Bluyssen, 2014; Xie et al., 2017).

6.5.3 New Building Policies and Procedures

This study provides new information that can update building and construction policies and procedures to include Single Operating Procedures (SOPs) identifying and ranking built environment attributes for promoting restorative effects on occupants. Cities and counties could create new building codes, policies, procedures, and programs for developers to include mental health attributes that promote good occupant mental health.

6.5.4 Cost Effective Building Construction

New knowledge and implementation of healthy building design and construction attributes can become cost effective, efficient, and more significant when multiple disciplines are collaborating in projects with a charrette. Use of healthier built environment attributes can decrease construction time by using known construction materials, decreasing the cost of building operations, and increasing occupant health and productivity.

6.5.5 Significance of Landscape Architects and Urban Planners

The results of this study show the significance of landscape architects and urban planners. Agricultural views and spaces for gardening can be added as part of outside nature engagement with the help of landscape architects using *salutogenic* design. Richly vegetated nature attributes and nature engagement environments that are closely added to ruralscapes, urban and Industrial environments, multiple housing, and neighborhood developments are statistically proven to lower the mental effects of stress.

6.5.6 Future Research Finding Clarity for Low-Stress Environments

This study provides new ideas and methods for future research investigating the most significant architectural attributes for low-stress environments. More conducted research can increase the significance of this study and provide new resources and theories for architects and designers to use for promoting mental health.

6.5.7 New Knowledge for Greenbuilding Rating Systems

The data results from this study provide evidence that can increase the validity of greenbuilding rating systems certification claims for human health criteria and healthy environments. This is evident with LEED and WELL sustainable building certifications criteria which include a percentage of nature inside and nature outside as "nature views" as blue or green spaces, integration of biophilic design strategies, and close outside nature access to the building (IWBI, 2018; USGBC, 2019).

Newly included, LEEDv4.1 Sustainable Site certification criteria includes alterations for soil and habitat restoration by adding soil, vegetation, and a 30-square-feet pollinator garden (USGBC, 2023). However, other outside agricultural views of vegetable gardens and flowering gardens are not included. Additionally, access to outside and inside nature engagement environments are not included in any greenbuilding certification criteria.

6.6 Summary

The built environment is needed and has its place in serving many human functions. Functions such as activities of daily living for eating and sleeping, as well providing a boundary for protection. Identifying what actions individuals can take to improve their mental health with stress reduction is becoming more important (Hartig & Staats, 2006), especially with the awareness that most people can spend more than 90% of their time inside the built environment (Coffin & Young, 2017; SnowBrains, 2018; Xie, et al., 2017).

The goal of this study is to find what built environment and design characteristics are associated with a reduction in human stress surrounding the built environment. The research framework includes investigating the effects of only outside nature environments, of the built environment with views of nature inside and of nature outside, and of inside and outside nature engagement environments on mental health with stress.

Outside landscapes can either reduce human mental stress, have little or no effect on human stress, or increase human mental stress. The results from this study verify the importance of specific attributes of outside nature environments, especially surrounding the built environment, that can reduce stress. This study finds the best low-stress environments to be Outside Nature Engagement with the highest percentages of nature attributes and less percentages of man-made attributes. Large, distant horizon views of densely vegetated nature are also perceived as the best low-stress environments.

Results from this study find that Individuals engaging in nature outside and have highly vegetated outside nature views from inside the built environment can reduce stress more than with inside nature engagements and inside nature views. Interior designers can intentionally create interior spaces promoting low-stress environments. Collaboration with landscape architects and urban planners for providing outside nature engagements and views can promote low-stress options for healthy building design and construction processes. Built environments that can juxtapose with nature environments, as seen with Frank Lloyd Write's Fallingwater residence, and use innovative nature materials inside can offer greater opportunities for nature engagements in reducing mental stress.

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APPENDIX A: Copy of Institutional Review Board (IRB) Approval Letter

MICHIGAN STATE
UNIVERSITY

EXEMPT DETERMINATION
Revised Common Rule

July 12, 2022

To: Patricia Lynn Machemer

Re: **MSU Study ID:** STUDY00007923
Principal Investigator: Patricia Lynn Machemer
Category: Exempt 3(i)(B)
Exempt Determination Date: 7/12/2022
Limited IRB Review: Not Required.

Title: Perceived Restorative Interior Elements for Built Environments

This study has been determined to be exempt under 45 CFR 46.104(d) 3(i)(B)

Principal Investigator (PI) Responsibilities: The PI assumes the responsibilities for the protection of human subjects in this study as outlined in Human Research Protection Program (HRPP) Manual Section 8-1, Exemptions.

Continuing Review: Exempt studies do not need to be renewed.

Modifications: In general, investigators are not required to submit changes to the Michigan State University (MSU) Institutional Review Board (IRB) once a research study is designated as exempt as long as those changes do not affect the exempt category or criteria for exempt determination (changing from exempt status to expedited or full review, changing exempt category) or that may substantially change the focus of the research study such as a change in hypothesis or study design. See HRPP Manual Section 8-1, Exemptions, for examples. If the study is modified to add additional sites for the research, please note that you may not begin the research at those sites until you receive the appropriate approvals/permissions from the sites.

Please contact the HRPP office if you have any questions about whether a change must be submitted for IRB review and approval.

New Funding: If new external funding is obtained for an active study that had been determined exempt, a new initial IRB submission will be required, with limited exceptions. If you are unsure if a new initial IRB submission is required, contact the HRPP office. IRB review of the new submission must be completed before new funds can be spent on human research activities, as the new funding source may have additional or different requirements.

Reportable Events: If issues should arise during the conduct of the research, such as unanticipated problems that may involve risks to subjects or others, or any

Office of Regulatory Affairs
Human Research Protection Program

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www.hrpp.msu.edu

problem that may increase the risk to the human subjects and change the category of review, notify the IRB office promptly. Any complaints from participants that may change the level of review from exempt to expedited or full review must be reported to the IRB. Please report new information through the study's workspace and contact the IRB office with any urgent events. Please visit the Human Research Protection Program (HRPP) website to obtain more information, including reporting timelines.

Personnel Changes: After determination of the exempt status, the PI is responsible for maintaining records of personnel changes and appropriate training. The PI is not required to notify the IRB of personnel changes on exempt research. However, he or she may wish to submit personnel changes to the IRB for recordkeeping purposes (e.g. communication with the Graduate School) and may submit such requests by submitting a Modification request. If there is a change in PI, the new PI must confirm acceptance of the PI Assurance form and the previous PI must submit the Supplemental Form to Change the Principal Investigator with the Modification request (available at hrpp.msu.edu).

Closure: Investigators are not required to notify the IRB when the research study can be closed. However, the PI can choose to notify the IRB when the study can be closed and is especially recommended when the PI leaves the university. Closure indicates that research activities with human subjects are no longer ongoing, have stopped, and are complete. Human research activities are complete when investigators are no longer obtaining information or biospecimens about a living person through interaction or intervention with the individual, obtaining identifiable private information or identifiable biospecimens about a living person, and/or using, studying, analyzing, or generating identifiable private information or identifiable biospecimens about a living person.

For More Information: See HRPP Manual, including Section 8-1, Exemptions (available at hrpp.msu.edu).

Contact Information: If we can be of further assistance or if you have questions, please contact us at 517-355-2180 or via email at IRB@msu.edu. Please visit hrpp.msu.edu to access the HRPP Manual, templates, etc.

Exemption Category. The full regulatory text from 45 CFR 46.104(d) for the exempt research categories is included below. [1234]

Exempt 1. Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Exempt 2. Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

(i) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;

(ii) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

(iii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

Exempt 3. (i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:

(A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;

(B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or

(C) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by 45 CFR 46.111(a)(7).

(ii) For the purpose of this provision, benign behavioral interventions are brief in duration, harmless, painless, not physically invasive, not likely to have a significant adverse lasting impact on the subjects, and the investigator has no reason to think the subjects will find the interventions offensive or embarrassing. Provided all such criteria are met, examples of such benign behavioral interventions would include having the subjects play an online game, having them solve puzzles under various noise conditions, or having them decide how to allocate a nominal amount of received cash between themselves and someone else.

(iii) If the research involves deceiving the subjects regarding the nature or purposes of the research, this exemption is not applicable unless the subject authorizes the deception through a prospective agreement to participate in research in circumstances in which the subject is informed that he or she will be unaware of or misled regarding the nature or purposes of the research.

Exempt 4. Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects;

(iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of ``health care operations'' or ``research'' as those terms are defined at 45 CFR 164.501 or for ``public health activities and purposes'' as described under 45 CFR 164.512(b); or

(iv) The research is conducted by, or on behalf of, a Federal department or agency using government-generated or government-collected information obtained for nonresearch activities, if the research generates identifiable private information that is or will be maintained on information technology that is subject to and in compliance with section 208(b) of the E-Government Act of 2002, 44 U.S.C. 3501 note, if all of the identifiable private information collected, used, or generated as part of the activity will be maintained in systems of records subject to the Privacy Act of 1974, 5 U.S.C. 552a, and, if applicable, the information used in the research was collected subject to the Paperwork Reduction Act of 1995, 44 U.S.C. 3501 et seq.

Exempt 5. Research and demonstration projects that are conducted or supported by a Federal department or agency, or otherwise subject to the approval of department or agency heads (or the approval of the heads of bureaus or other subordinate agencies that have been delegated authority to conduct the research and demonstration projects), and that are designed to study, evaluate, improve, or otherwise examine public benefit or service programs, including procedures for obtaining benefits or services under those programs, possible changes in or alternatives to those programs or procedures, or possible changes in methods or levels of payment for benefits or services under those programs. Such projects include, but are not limited to, internal studies by Federal employees, and studies under contracts or consulting arrangements, cooperative agreements, or grants. Exempt projects also include waivers of otherwise mandatory requirements using authorities such as sections 1115 and 1115A of the Social Security Act, as amended. (i) Each Federal department or agency conducting or supporting the research and demonstration projects must establish, on a publicly accessible Federal Web site or in such other manner as the department or agency head may determine, a list of the research and demonstration projects that the Federal department or agency conducts or supports under this provision. The research or demonstration project must be published on this list prior to commencing the research involving human subjects.

Exempt 6. Taste and food quality evaluation and consumer acceptance studies: (i) If wholesome foods without additives are consumed, or (ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

Exempt 7. Storage or maintenance for secondary research for which broad consent is required: Storage or maintenance of identifiable private information or identifiable biospecimens for potential secondary research use if an IRB conducts a limited IRB review and makes the determinations required by 45 CFR 46.111(a)(8).

Exempt 8. Secondary research for which broad consent is required: Research involving the use of identifiable private information or identifiable biospecimens for secondary research use, if the following criteria are met:

> (i) Broad consent for the storage, maintenance, and secondary research use of the identifiable private information or identifiable biospecimens was obtained in accordance with 45 CFR 46.116(a)(1) through (4), (a)(6), and (d);
>
> (ii) Documentation of informed consent or waiver of documentation of consent was obtained in accordance with 45 CFR 46.117;
>
> (iii) An IRB conducts a limited IRB review and makes the determination required by 45 CFR 46.111(a)(7) and makes the determination that the research to be conducted is within the scope of the broad consent referenced in paragraph (d)(8)(i) of this section; and
>
> (iv) The investigator does not include returning individual research results to subjects as part of the study plan. This provision does not prevent an investigator from abiding by any legal requirements to return individual research results.

[1]Exempt categories (1), (2), (3), (4), (5), (7), and (8) cannot be applied to activities that are FDA-regulated.

[2] Each of the exemptions at this section may be applied to research subject to subpart B (Additional Protections for Pregnant Women, Human Fetuses and Neonates Involved in Research) if the conditions of the exemption are met.

[3] The exemptions at this section do not apply to research subject to subpart C (Additional Protections for Research Involving Prisoners), except for research aimed at involving a broader subject population that only incidentally includes prisoners.

[4] Exemptions (1), (4), (5), (6), (7), and (8) of this section may be applied to research subject to subpart D (Additional Protections for Children Involved as Subjects in Research) if the conditions of the exemption are met. Exempt (2)(i) and (ii) only may apply to research subject to subpart D involving educational tests or the observation of public behavior when the investigator(s) do not participate in the activities being observed. Exempt (2)(iii) may not be applied to research subject to subpart D.

APPENDIX B: Copy of Survey Photographs

Figure B.1

Copy of Survey Photographs

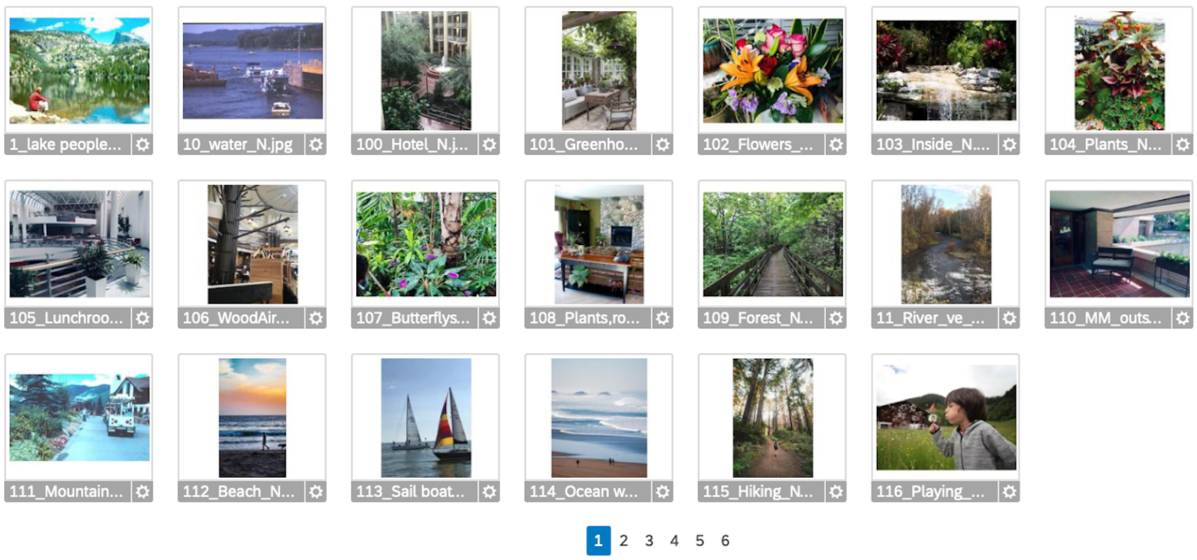
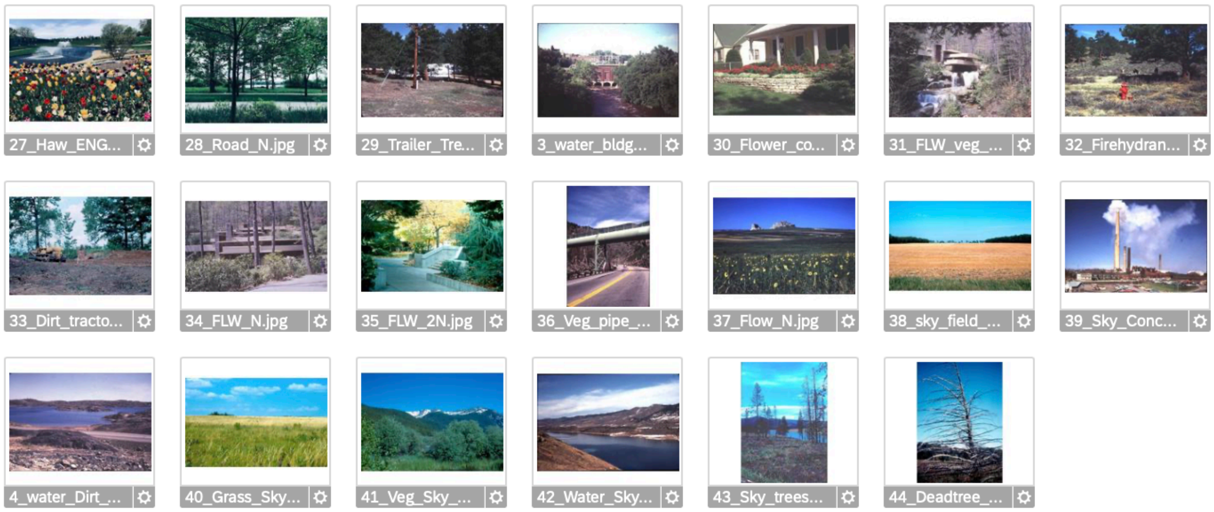


Figure B.1 (cont'd)



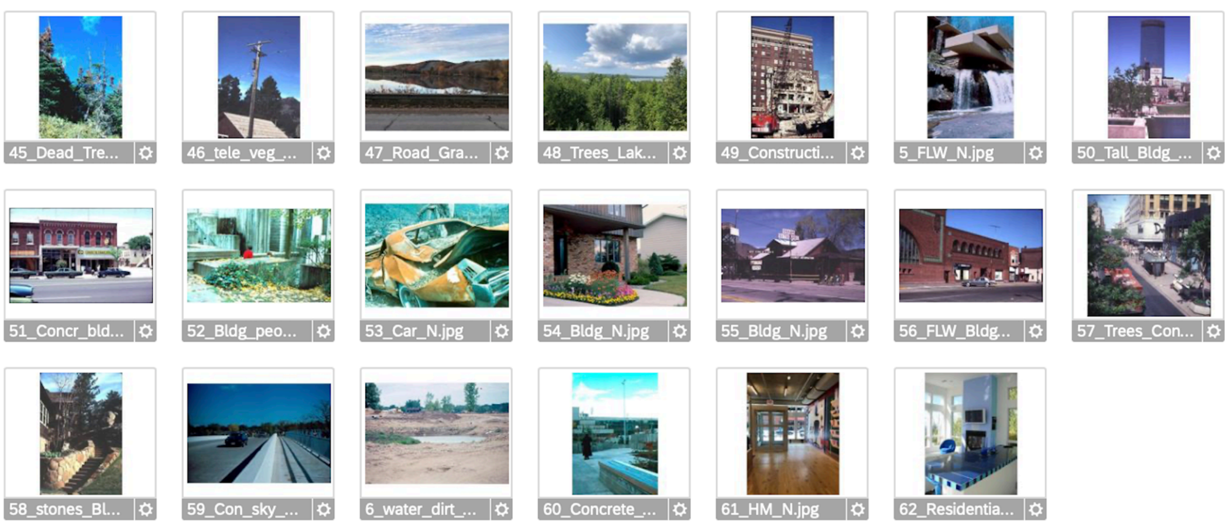
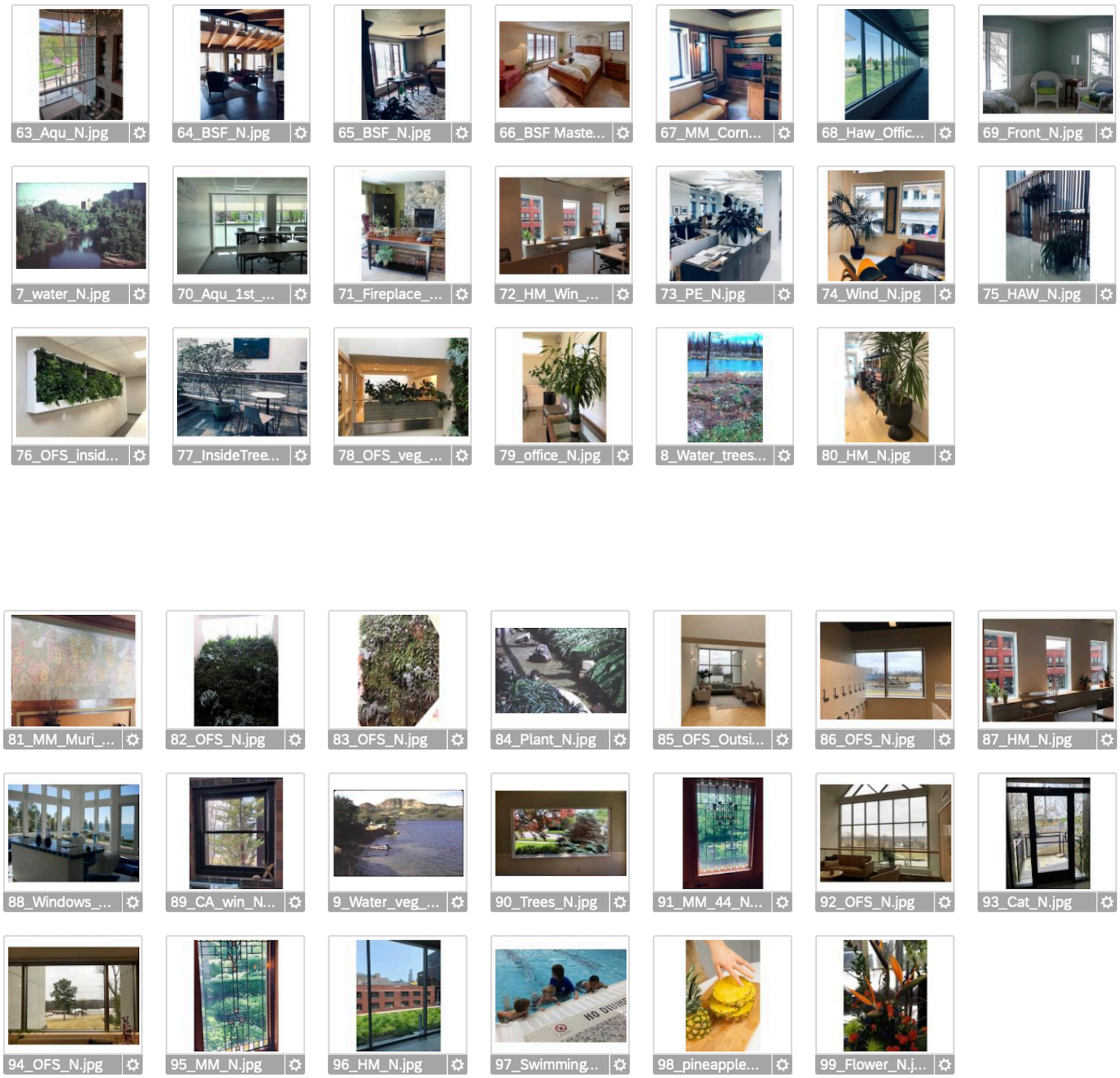


Figure B.1 (cont'd)



APPENDIX C: Copy of Q-Sort VQA Qualtrics Survey Questionnaire

Q1. Thank you for participating in this survey. The purpose of this research is to investigate human perception of healthy design for built environments.

You are asked to complete the following survey that includes two main question types. The first question type will ask you to rank ten photographs from most satisfied (1) with low stress to least satisfied (10) with high stress. Please be sure to view all photographs to complete the final ranking.

The second question type will ask you how you feel about one photograph using semantically opposite adjectives. Mark the circle closest to the adjective you feel when viewing the photograph.

Participation in this survey is totally voluntary. You must be 18 years of age or older. You may skip any questions, withdraw, and /or stop this survey at any time for any reason. For any questions or concerns, please contact hallsaxt@msu.edu. A competed and submitted survey will indicate that you voluntarily agreed to participate. Thank you for your participation!

This question was not displayed to the respondent.

Set 1 Drag and Drop . Ten random photographs have been selected. Rank the photographs from the photograph you are most satisfied with (#1) first, low stress, to the photograph you are leased satisfied with (#10) last, high stress. You can move the photograph you like best to the top and the worst photograph to the bottom by dragging and dropping the photographs.

APPENDIX D: Copy of Q-Sort VQA In-person Survey Questionnaire

Visual Assessment with Q-Sorting

Thank you for participating in this survey. The purpose of this research is to investigate human perception of healthy interior design environments.

This research question is asking you to rank ten photographs from most satisfied (1) to least satisfied (10). Please consider the images in the photographs and not the photograph quality for ranking.

Participation in this survey is totally voluntary. You must be 18 years of age or older. You may skip any questions, withdraw, and / or stop this survey at any time for any reason. For any questions or concerns, please contact hallsaxt@msu.edu. A completed and submitted survey will indicate that you voluntarily agreed to participate. Thank you for your participation!

Photograph numbers below for ranking.

________________	1	________________	1	________________	1
________________	2	________________	2	________________	2
________________	3	________________	3	________________	3
________________	4	________________	4	________________	4
________________	5	________________	5	________________	5
________________	6	________________	6	________________	6
________________	7	________________	7	________________	7
________________	8	________________	8	________________	8
________________	9	________________	9	________________	9
________________	10	________________	10	________________	10

APPENDIX E: Copy of Semantic Differential Survey Questionnaire

Q7

From a randomly selected photograph, please respond to which word best fits your feelings about that image.

pleasant	○ ○ ○ ○ ○	unpleasant
weary	○ ○ ○ ○ ○	refreshing
interesting	○ ○ ○ ○ ○	boring
tense	○ ○ ○ ○ ○	relaxed
frustrating	○ ○ ○ ○ ○	satisfying
stressful	○ ○ ○ ○ ○	unstresssful
gloomy	○ ○ ○ ○ ○	cheerful
calm	○ ○ ○ ○ ○	excitable
anxious	○ ○ ○ ○ ○	carefree
cheerful	○ ○ ○ ○ ○	gloomy
lethargy	○ ○ ○ ○ ○	energy
fearless	○ ○ ○ ○ ○	fearful

Figure F.1

Copy of SPSS Stepwise Multilinear Regression Model Data

0A_NEw_1015AA.sav [DataSet1] - IBM SPSS Statistics Data Editor

33 : PRE_1 65.11339362334878 Visible: 23 of 2

	Dependent	Var01Mt	Var02Fo	Var03Ur	Var04Wa	Var05Ag	Var06Ru	Var07CHH	VAR08CHN	Var09INVS	VAR10INVM	VAR11INVL	Var12ONVS	VAR13ONVM	VAR14ONVL	Var15INE	Var16ONE
1	19.26	46.00	.00	.00	38.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
2	46.12	.00	98.00	.00	2.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
3	78.29	.00	47.00	12.00	10.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
4	65.55	.00	.00	.00	15.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
5	44.89	.00	.00	46.00	47.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
6	103.17	.00	14.00	.00	4.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
7	66.63	.00	46.00	12.00	22.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
8	54.82	.00	.00	.00	11.00	45.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
9	53.77	1.00	36.00	.00	48.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
10	62.09	.00	22.00	.00	56.00	.00	22.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
11	35.01	.00	40.00	.00	44.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
12	42.49	.00	36.00	.00	24.00	.00	5.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
13	58.39	.00	96.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	51.73	.00	97.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
15	42.93	.00	80.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
16	72.27	.00	50.00	.00	.00	27.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
17	60.14	.00	25.00	.00	.00	33.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
18	34.41	.00	100.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
19	70.56	.00	78.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
20	109.16	.00	3.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
21	38.73	.00	42.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
22	33.64	.00	100.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
23	43.76	.00	85.00	.00	11.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
24	65.04	.00	71.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
25	73.03	.00	55.00	.00	.00	.00	34.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
26	65.59	6.00	.00	.00	.00	.00	52.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
27	36.43	.00	73.00	.00	9.00	.00	6.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
28	42.65	.00	93.00	.00	1.00	.00	6.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
29	89.25	.00	47.00	.00	.00	27.00	8.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
30	62.73	.00	32.00	.00	.00	.00	37.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
31	52.42	.00	77.00	.00	10.00	.00	13.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
32	86.65	.00	77.00	2.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

0A_NEw_1015AA.sav [DataSet1] - IBM SPSS Statistics Data Editor

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	Dependent	Var01Mt	Var02Fo	Var03Ur	Var04Wa	Var05Ag	Var06Ru	Var07CHH	VAR08CHN	Var09INVS	VAR10INVM	VAR11INVL	Var12ONVS	VAR13ONVM	VAR14ONVL	Var15INE	Var16ONE
33	98.98	.00	51.00	4.00	.00	25.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
34	58.66	.00	74.00	.00	.00	.00	12.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
35	57.62	.00	75.00	25.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
36	88.64	.00	24.00	44.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
37	38.32	2.00	68.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
38	59.84	.00	6.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
39	108.77	.00	.00	27.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
40	33.14	.00	33.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
41	32.68	5.00	58.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
42	45.99	.00	38.00	.00	23.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
43	54.92	.00	9.00	.00	4.00	37.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
44	86.97	.00	29.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
45	64.51	.00	39.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
46	100.27	.00	28.00	.00	.00	.00	19.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
47	39.07	.00	13.00	.00	16.00	.00	13.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
48	31.54	.00	54.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
49	109.10	.00	.00	75.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
50	89.27	.00	16.00	41.00	9.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
51	85.02	.00	.00	79.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
52	88.68	.00	23.00	77.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
53	108.72	.00	27.00	73.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
54	61.40	.00	29.00	.00	.00	.00	71.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
55	84.61	.00	18.00	.00	.00	.00	62.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
56	92.36	.00	.00	79.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
57	87.28	.00	27.00	68.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
58	65.74	.00	41.00	.00	.00	.00	47.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
59	98.60	.00	8.00	51.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
60	87.63	.00	10.00	54.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
61	79.15	.00	.00	.00	.00	.00	.00	11.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
62	61.19	.00	.00	.00	.00	.00	.00	12.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
63	69.78	.00	.00	.00	.00	.00	.00	48.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
64	58.56	.00	.00	.00	.00	.00	.00	30.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Figure F.1 (cont'd)

0A_NEw_1015AA.sav [DataSet1] - IBM SPSS Statistics Data Editor

33 : PRE_1 65.11339362334878 Visible: 23 of

	Dependent	Var01Mt	Var02Fo	Var03Ur	Var04Wa	Var05Ag	Var06Ru	Var07CHH	VAR08CHN	Var09INVS	VAR10INVM	VAR11INVL	Var12ONVS	VAR13ONVM	VAR14ONVL	Var15INE	Var16ONE
65	72.69	.00	.00	.00	.00	.00	.00	.00	8.00	.00	.00	.00	.00	.00	.00	.00	.00
66	64.09	.00	.00	.00	.00	.00	.00	.00	8.00	.00	.00	.00	.00	.00	.00	.00	.00
67	66.10	.00	.00	.00	.00	.00	.00	.00	9.00	.00	.00	.00	.00	.00	.00	.00	.00
68	85.37	.00	.00	.00	.00	.00	.00	11.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
69	78.01	.00	.00	.00	.00	.00	.00	.00	8.00	.00	.00	.00	.00	.00	.00	.00	.00
70	94.40	.00	.00	.00	.00	.00	.00	.00	9.00	.00	.00	.00	.00	.00	.00	.00	.00
71	62.59	.00	.00	.00	.00	.00	.00	.00	8.00	.00	.00	.00	.00	.00	.00	.00	.00
72	75.82	.00	.00	.00	.00	.00	.00	11.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
73	94.78	.00	9.00	.00	.00	.00	.00	.00	.00	9.00	.00	.00	.00	.00	.00	.00	.00
74	67.29	.00	16.00	.00	.00	.00	.00	.00	.00	16.00	.00	.00	.00	.00	.00	.00	.00
75	81.57	.00	20.00	.00	.00	.00	.00	.00	.00	20.00	.00	.00	.00	.00	.00	.00	.00
76	73.07	.00	24.00	.00	.00	.00	.00	.00	.00	24.00	.00	.00	.00	.00	.00	.00	.00
77	81.10	.00	26.00	.00	.00	.00	.00	.00	.00	.00	26.00	.00	.00	.00	.00	.00	.00
78	73.04	.00	28.00	.00	.00	.00	.00	.00	.00	.00	28.00	.00	.00	.00	.00	.00	.00
79	85.03	.00	39.00	.00	.00	.00	.00	.00	.00	.00	39.00	.00	.00	.00	.00	.00	.00
80	81.72	.00	48.00	.00	.00	.00	.00	.00	.00	.00	48.00	.00	.00	.00	.00	.00	.00
81	87.94	.00	61.00	.00	.00	.00	.00	.00	.00	.00	.00	61.00	.00	.00	.00	.00	.00
82	83.14	.00	77.00	.00	.00	.00	.00	.00	.00	.00	.00	77.00	.00	.00	.00	.00	.00
83	75.51	.00	91.00	.00	.00	.00	.00	.00	.00	.00	.00	91.00	.00	.00	.00	.00	.00
84	52.96	.00	57.00	.00	34.00	.00	.00	.00	.00	.00	.00	100.00	.00	.00	.00	.00	.00
85	68.41	.00	2.00	4.00	.00	.00	.00	.00	.00	.00	.00	.00	15.00	.00	.00	.00	.00
86	95.46	.00	5.00	1.00	1.00	.00	3.00	.00	.00	.00	.00	.00	21.00	.00	.00	.00	.00
87	75.05	.00	15.00	19.00	.00	.00	.00	.00	.00	.00	.00	.00	23.00	.00	.00	.00	.00
88	54.84	.00	4.00	.00	2.00	.00	2.00	.00	.00	.00	.00	.00	27.00	.00	.00	.00	.00
89	67.30	.00	21.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	36.00	.00	.00	.00
90	70.75	.00	28.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	34.00	.00	.00	.00
91	61.88	.00	33.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	48.00	.00	.00	.00
92	65.69	.00	36.00	3.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	89.00	.00	.00	.00
93	94.34	.00	11.00	31.00	.00	.00	8.00	.00	.00	.00	.00	.00	.00	.00	63.00	.00	.00
94	92.86	.00	16.00	27.00	.00	.00	4.00	.00	.00	.00	.00	.00	.00	.00	69.00	.00	.00
95	60.90	.00	80.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	80.00	.00	.00
96	89.02	.00	24.00	.00	.00	.00	38.00	.00	.00	.00	.00	.00	.00	.00	85.00	.00	.00

0A_NEw_1015AA.sav [DataSet1] - IBM SPSS Statistics Data Editor

33 : PRE_1 65.11339362334878 Visible: 23 of

	Dependent	Var01Mt	Var02Fo	Var03Ur	Var04Wa	Var05Ag	Var06Ru	Var07CHH	VAR08CHN	Var09INVS	VAR10INVM	VAR11INVL	Var12ONVS	VAR13ONVM	VAR14ONVL	Var15INE	Var16ONE
97	83.75	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
98	73.17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
99	67.44	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
100	64.41	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
101	38.51	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
102	46.64	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
103	37.39	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
104	63.58	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
105	83.73	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
106	79.97	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
107	44.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
108	73.53	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00	.00
109	29.91	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
110	66.56	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
111	62.22	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
112	24.41	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
113	48.25	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
114	21.39	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
115	28.33	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
116	42.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
117	28.19	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
118	41.57	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
119	60.54	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00
120	85.34	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	2.00