The influence of environmental attributes on indicators of wellbeing across greenspace types in virtual landscapes

by

Carson Michael Scheer

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture and Regional & Community Planning
College of Architecture, Planning, and Design

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Approved by:

Major Professor
Sara Hadavi

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Abstract

Psychological benefits of natural environments have been a driving force behind the design of greenspaces for centuries (Eco, 1994; Montford, 2017; Ward-Thompson, 2011). The impact the presence of greenspace has on an occupant's sense of belonging, safety, and comfort has been broadly investigated (Herzog, 1992; Houlden et al., 2019; Nasar, 1983; Strumse, 1994). However, less attention has been paid to how changes in specific physical attributes of an environment may affect these senses differently across different types of urban greenspaces. The goal of this study is to examine how changes in the temperature of light, vegetation density, and surface texture impact occupants' sense of belonging, safety, and comfort differently in distinct types of greenspaces. The examined types of public greenspaces include manicured park, unmanicured timber-meadow, streetscape, community garden, and green roof. A series of five-point rating scale surveys was used to collect data from 51 participants in the southeast side of Brush Creek, Kansas City, MO. Participants were selected by convenience sampling at the public library extension, diners, restaurants, coffee shops, and community spaces located within the study area. The data collection was assisted using an Oculus Quest 2 stereoscopic virtual reality (VR) headset, through which participants were able to experience three-dimensionally rendered environments. VR has been shown to be more immersive than traditional photo boards for design research (Wilson & Soranzo, 2015). First, each participant was randomly assigned to one of the aforementioned greenspace types and asked to observe a baseline virtual environment as a control. They then rated their levels of comfort, safety, and belonging on a five-point rating scale. Participants then also indicated whether they see similar scenes near their residences. Secondly, one of the above environmental attributes was then modified, and the participant again rated their levels of comfort, safety, and belonging; this second step was then repeated for each of the three environmental attributes. Demographic data (age, race, gender, and education level)

was also collected. This study shows differences in how the participants' sense of comfort, safety, and belonging may change across different types of environments. For example, vegetation amount was beneficial in timber-meadow environments but not in any others, and surface texture was found to have the most negative impact on streetscapes. The findings of this study offer greater insights into the use of design elements across greenspace typologies to improve neighborhood quality of life through increased sense of belonging, safety, and comfort. The broader outcome of this study relates to its implications in community restoration through urban greening and to further develop the use of VR in design research.

Virtual Landscapes

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Department of Landscape Architecture and Regional and Community Planning

College of Architecture, Planning, and Design

Kansas State University

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VIRTUAL LANDSCAPES

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A REPORT

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Keywords:

Virtual reality, Greenspace typology, Sense of comfort, Sense of safety, Sense of belonging, Environmental attributes

Abstract

Psychological benefits of natural environments have been a driving force behind the design of greenspaces for centuries (Eco, 1994; Montford, 2017; Ward-Thompson, 2011). The impact the presence of greenspace has on an occupant's sense of belonging, safety, and comfort has been broadly investigated (Herzog, 1992; Houlden et al., 2019; Nasar, 1983; Strumse, 1994). However, less attention has been paid to how changes in specific physical attributes of an environment may affect these senses differently across different types of urban greenspaces. The goal of this study is to examine how changes in the temperature of light, vegetation density, and surface texture impact occupants' sense of belonging, safety, and comfort differently in distinct types of greenspaces. The examined types of public greenspaces include manicured park, unmanicured timber-meadow, streetscape, community garden, and green roof. A series of five-point rating scale surveys was used to collect data from 51 participants in the southeast side of Brush Creek, Kansas City, MO. Participants were selected by convenience sampling at the public library extension, diners, restaurants, coffee shops, and community spaces located within the study area. The data collection was assisted using an Oculus Quest 2 stereoscopic virtual reality (VR) headset, through which participants were able to experience three-dimensionally rendered environments. VR has been shown to be more immersive than traditional photo boards for design research (Wilson & Soranzo, 2015). First, each participant was randomly assigned to one of the aforementioned greenspace types and asked to observe a baseline virtual environment as a control. They then rated their levels of comfort, safety, and belonging on a five-point rating scale. Participants then also indicated whether they see similar scenes near their residences. Secondly, one of the above environmental attributes was then modified, and the participant again rated their levels of comfort, safety, and belonging; this second step was then repeated for each of the three environmental attributes. Demographic data (age, race, gender, and education level) was also collected. This study shows differences in how the participants' sense of comfort, safety, and belonging may change across different types of environments. For example, vegetation amount was beneficial in timber-meadow environments but not in any others, and surface texture was found to have the most negative impact on streetscapes. The findings of this study offer greater insights into the use of design elements across greenspace typologies to improve neighborhood quality of life through increased sense of belonging, safety, and comfort. The broader outcome of this study relates to its implications in community restoration through urban greening and to further develop the use of VR in design research.

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Acknowledgments

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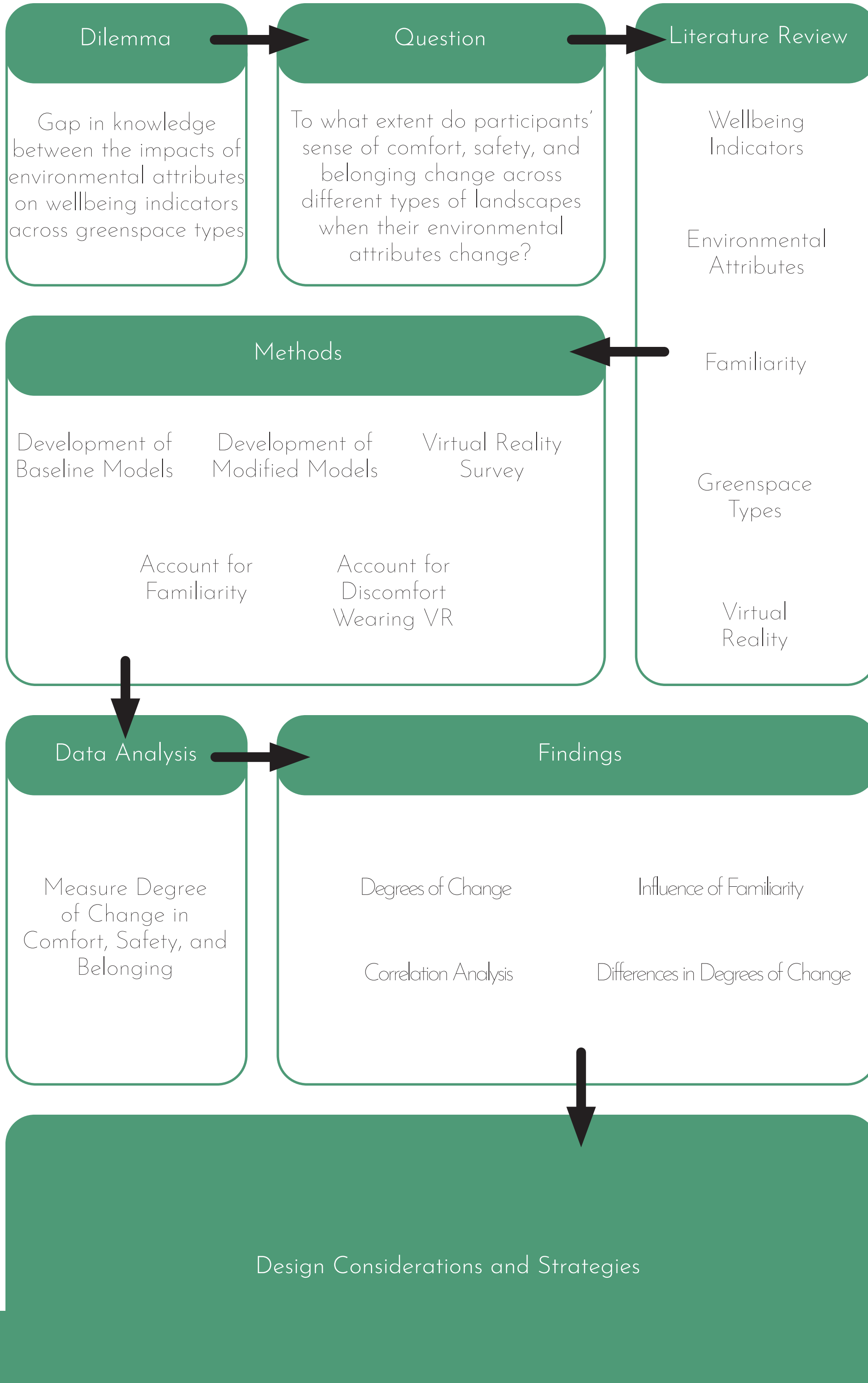
Chapter I: Introduction

The relationship between contact with natural environments and mental wellbeing is an important area of research that landscape architects ought to pay attention to. The ability to benefit the wellbeing of occupants is understandably an area of interest for those designing outdoor spaces. This study examines changes in three indicators of wellbeing when environmental attributes change in five different virtual landscape typologies. These three indicators are the sense of comfort, the sense of safety, and the sense of belonging. By finding ways to have a positive impact on these indicators of wellbeing through changes in environmental attributes in different contexts, this study aims to offer landscape architects insights to design solutions that would ultimately lead to improved sense of wellbeing of users. See Figure 1 for more details on study process.

Figure 1: Study Process.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Problem Definition

There exists a body of research speaking to the connection between many environmental attributes in a greenspace and mental wellbeing (Herzog, 1992; Herzog & Gale, 1996; Ho & Au, 2020; Houlden et al., 2019; Nasar,, 1983; Strumse, 1994). Research has also found a connection between the presence of greenspace and increased health perception (Kardan et al., 2015) and that it is the presence of environmental attributes (i.e., vegetation, color, and material texture) found within greenspaces which are thought to be the source of these benefits—in concert with the landscape type itself (Rohde & Kendle, 1994, pp 66-111). Safety, comfort, and belonging are key aspects of sense of mental wellbeing (Bond et al., 2012). Furthermore, it has been found that there is a connection between the presence of greenspace and improvement of a sense of safety (Groenewegen et al., 2006) and comfort (Ulrich, 1979).

People's engagement with natural environments has been linked to an increased sense of belonging or nature-relatedness (Lawton et al., 2017), which corresponds with decreased levels of reported anxiety (Nisbet & Zelenski, 2013). Surface texture is likewise understood to impact psychological responses of occupants in greenspaces—their emotional and attuitive reactions to the spaces and subsequent mental states (Thieme et al., 2015; Yeh et al., 2015). Furthermore, the color temperature of light has been shown to have an impact on the sense of comfort and safety of occupants (Ekström & Beaven, 2014; Shahidi et al., 2021). Nonetheless, there exists a gap in knowledge about the connection between the presence of these environmental attributes across distinct public greenspace types and occupants' sense of comfort, sense of safety, and sense of belonging. Knowing about these connections will help designers make better decisions when making changes in environmental attributes in different landscape settings.

Literature Review

The Connection between Aesthetic Qualities and Mental Benefits

Stress Reduction Theory holds that humans exhibit emotions as psychological responses to environments with varying levels of naturalness, and that these emotional responses range from a sense of uneasiness to a sense of calm (Hadavi & Sullivan, 2018; Ulrich, 1983). These initial respondent changes in emotional state are determined by the composition and content of a space (Ulrich, 1983: Hadavi & Sullivan, 2018). Furthermore, there appears to be an association between access to the views of natural landscapes and improvements to psychological health (Spano, Dadvand, & Sanesi, 2021; Tsunetsugu et al., 2013; Velarde, Fry, & Tveit, 2007). However, there remains some question as to potential gender disparities in stress reduction (Jiang, Chang, & Sullivan, 2014).

Attention Restoration Theory, on the other hand, is concerned with the cognitive benefits of natural environments (Hadavi & Sullivan, 2018; Kaplan, 1995; Spano, Dadvand, & Sansai, 2021). The theory holds that exposure to nature can help to improve cognitive function (Berman, Jonides, & Kaplan, 2008; Shin et al., 2011; Trammell & Aquilar, 2021) and alleviate mental fatigue (Bratman, Hamilton, & Daily, 2012; Hadavi & Sullivan, 2018; Kaplan &

Berman, 2010; Shin et al., 2011). Additional associated benefits include improvements to mood (Berman, Jonides, & Kaplan, 2008; Shin et al., 2011), working memory (Berman, Jonides, & Kaplan, 2008), and potentially some forms of executive function (Trammell & Aguilar, 2021). Furthermore, testing of Attention Restoration Theory has revealed an association between the presence of greenspace and improved cognitive health (Besser, 2021; Dzhambov et al., 2019); however, this latter finding remains controversial (Besser, 2021).

Wellbeing Indicators

There is, according to past studies, reason to accept that environmental attributes have an impact on the wellbeing of occupants (Francis et al., 2012; Hadavi, 2017; Hur, Nasar, & Chun, 2010). Environmental attributes affect not only the physical wellbeing of residents, but also their mental wellbeing (Hadavi, 2017; Hur, Nasar, & Chun, 2010; Kuo et al., 1998). The perceived quality of open spaces has also been found to play a role in mental wellbeing, particularly with regards to satisfaction (Aiello, Ardone, & Scopelliti, 2010; Francis et al., 2012). Understanding that environmental attributes are associated with mental wellbeing, it is necessary to take a closer look at specific environmental perceptions that contribute to mental wellbeing of occupants. These perceptions include sense of comfort, sense of safety, and sense of belonging. The relationship between environmental attributes and mental wellbeing is shown in Figure 2.

Comfort

Comfort and wellbeing are interrelated concepts. Some studies treat comfort as a contributing factor to mental wellbeing (Elsadek, Liu, & Xie, 2020; Jennings & Bamkole, 2019). Others treat comfort as a related but broader and more wholistic concept, one which nonetheless is linked with mental wellbeing (Pinto et al., 2016). Regardless, that there exists an association between comfort and mental wellbeing is clear (Elsadek, Liu, & Lian, 2019; Elsadek, Liu, & Xie, 2020; Jennings & Bamkole, 2019; Pinto et al., 2016). The sense of comfort in urban greenspaces has also been the subject of past studies (Birenboim, 2017; Hosseini et al., 2021), with research showing that the occupant's sense of comfort is particularly influenced by environmental attributes (Birenboim, 2017). Sense of comfort specifically has also been associated with access to greenspaces (Hosseini, 2021). Comfort, for the purposes of this research, includes both the psychological and the mental aspects, and is a component of wellbeing as it relates to a positive relation to place and relief from pain or distress (Wensley et al., 2020).

Safety

Previous studies have found a connection between the presence of greenspace and an increase in the feeling of social safety (Birenboim, 2017; Groenewegen et al., 2006; Groenewegen et al., 2012; Maas et al., 2009). This sense of safety is an aspect of wellbeing (Baum et al., 2009; Hunter et al., 2019). Environmental attributes have been shown to be particularly impactful on an occupant's sense of safety (Birenboim, 2017)—both negatively and positively. Lighting levels, as an example, greatly impacts perceived safety (Unver, 2009; Wu & Kim, 2016). However, lighting quality does not necessarily equal brighter lighting, and after a certain point brightness begins to negatively impact the perceived level of safety (Unver, 2009; Wu & Kim, 2016).

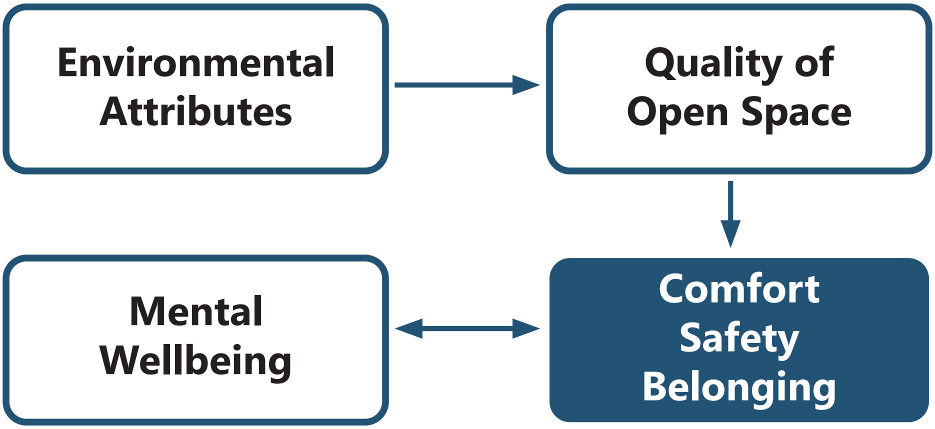


Figure 2: Relationship of Environmental Attributes to Mental Wellbeing.

Belonging

Studies have found that communities with higher amounts of greenspace have higher levels of reported social cohesion and less frequently experienced feelings of loneliness or lack of social support (Groenewegen et al., 2012; Sugiyama et al., 2008; van den Berg, 2017; Viers et al., 2013;). The presence of greenspace has been associated with a greater sense of belonging (Hosseini et al., 2021; Rugel et al., 2019; Viers et al., 2013). Furthermore, the presence of greenspace has been associated with an increase in place attachment, identity, and a boost in neighborhood morale (Hosseini et al., 2021). This increased sense of belonging extends even to patients suffering from dementia (Barton & Rogerson, 2017). Greenspaces which are appropriately placed and designed with comfort—both mental and physical—in mind are more closely associated with increased sense of belonging (Hosseini et al., 2021).

There is also research which supports the idea that belonging is not merely a social need. It is suggested that the need to belong extends to the non-human realm of animals, places, and nature (Baxter & Pelletier, 2019; Kellert and Wilson, 1993; Man Wai Li, Lio, & Ito, 2021; McConnell et al., 2011; Scannell & Gifford, 2016;). Additional evidence suggests that nature relatedness and the need for belonging in nature is independent—or even a substitute for where lacking—social belonging (Brehm, Eisenhauer, & Krannich, 2006; Man Wai Li, Lio, & Ito, 2021; Ryan & Deci, 2017; Zelenski & Nisbet, 2012).

Environmental Attributes and Familiarity

Considering that a wide number of environmental attributes may play a role in mental wellbeing, it is important to look more closely at a narrowed selection of attributes—specifically those which can be influenced by the work of landscape architects and designers. Such attributes include site legibility (Conniff & Craig, 2016; Golledge, 2003; Guiducci & Burke, 2016), light color temperature, amount of vegetation , surface texture, habitat-encouraged wildlife noises, light level, surface color, materiality, location, shade, wayfinding, or design patterns. Amongst these attributes, light color temperature, amount of vegetation, and surface texture were selected for this study (see Figure 3). other possible attributes were discarded either for their limited ability to be influenced by designers, an unsuitability for study in VR, or their limited ability to be self-compared as before-after scenes as single attributes.

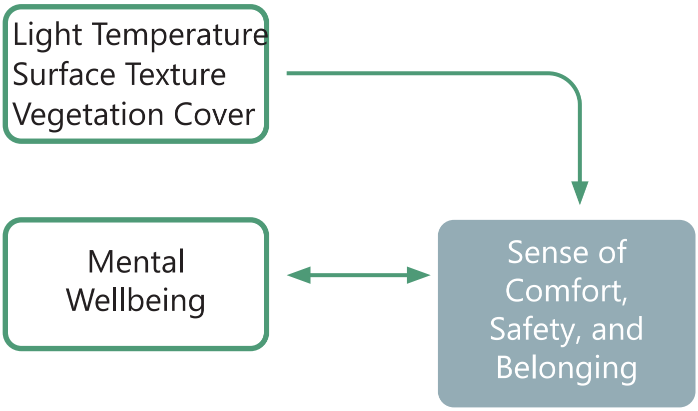


Figure 3: Environmental Attributes Relating to Wellbeing.

Light Color Temperature

In building spaces, the amount of light being too little and too great can have negative effects on occupants' wellbeing and comfort (Araji, 2008; Heerwagen & Hase, 2001). In outdoor pedestrian areas, light levels have been shown to have a significant impact on the sense of comfort of users (Ovsteda & Ryeng, 2002; Vukmirovic, Gavrilovic, & Stojanovic, 2019); however, the existing research focuses on indoor lighting—whereas research into outdoor lighting has been neglected. Furthermore, the sense of safety of individuals within a space is closely related to light quality (Unver, 2009; Wu & Kim, 2016). However, light quality should not be confused with brightness. Overly bright lights can negatively impact occupants' sense of safety (Unver, 2009, Wu & Kim, 2016). Warm temperature lights are said to elicit an increased sense of anxiety and a decrease in sense of safety and comfort as compared to blue and white lights (Ekström & Beaven, 2014; Shahidi et al., 2021). Consequently, cool temperature lights have been shown to increase happiness and comfort while decreasing levels of anxiety and confusion (Ekström & Beaven, 2014; Shahidi et al., 2021).

Amount of Vegetation

Vegetation coverage has been found to have an impact on the restorative benefits of both greenspaces and bluespaces (Fisher et al., 2021). Tree coverage in greenspaces is associated with a temporary increase in mental wellbeing (Bakolis et al., 2018; Fisher et al., 2021). Biodiversity in plant species is associated with increased wellbeing as well (Fisher et al., 2021; Hoyle, Jorgensen, & Hitchmough, 2019), and higher degrees of "wildness" are associated with increased restorativeness (Hoyle, Jorgensen, & Hitchmough, 2019). However, the perception of biodiversity in a space is more closely associated with increased wellbeing of occupants than the actual level of biodiversity (Carrus et al. 2015; Dallimer et al. 2012; Fisher et al. 2021). Because of this, those environmental characteristics that are most beneficial for the comfort and wellbeing of occupants may not necessarily be those that are best for conservation efforts (Fisher et al., 2021; Pett et al., 2016). Additionally, higher colorfulness in vegetation is associated with higher perceived levels of restoration (Hoyle et al., 2018).

Surface Texture

The surface texture of a space greatly impacts the aesthetic qualities of a site (Berlyne, 1960). Additionally, texture is suspected to play a role in the psychological responses people experience—changes in mental wellbeing, emotion, perception, or unconscious understanding—when in nature (Thieme et al., 2015; Yeh et al., 2015). People within a space are drawn to and engaged by texture and patterns of site surfaces. The occupant's engagement or interaction with the space is what drives these psychological responses and, therefore, has a role in addressing what occupants need out of greenspaces (Thieme et al., 2015). Surface texture is thus, an important attribute to consider while designing a space. Through the digital manipulation of textures—either through map selection, baking, filtering, scaling (such as through the use of nearest-neighbor interpolation, bilinear interpolation, box sampling, mipmapping, or deep convolutional neural networks), or other methods—the VR environment can be tailored to the needs of the designer in representing a real world site design or in exploratory design. However, the study of textural changes in a VR environment will lack the haptic feedback of a real-world environment. Likewise, the exact perception of texture being viewed from an unfiltered human perspective could be different than how texture is perceived in the virtual environment (Appel et al., 2007; Cant & Shrubsole, 2000; Catmull, 1974; Dong et al., 2015; El-Khamy, et al., 2005; Kessenich, Sellers, & Shreiner, 2016; Mastyło, 2013; Pagés et al., 2015; Rukundo & Cao, 2012; Sorensen, 2018; Spini et al., 2016; Thieme et al., 2015). See Appendix V for more.

Familiarity

Place attachment is the familiarity of occupants to a particular space they regularly interact with (Scannell & Gifford, 2014). The familiarity of a person to spaces may influence the connection between their perceived mental wellbeing and the environmental attributes of the space (Man Wai Li, Lio, & Ito, 2021; Ryan & Deci, 2017; Scannell & Gifford, 2014). As such, it is important to account for the familiarity of participants with an environment when studying their perception and engagement with the space. Therefore, this study includes familiarity as a control variable (See Figure 4 for the variable relationships visualized).

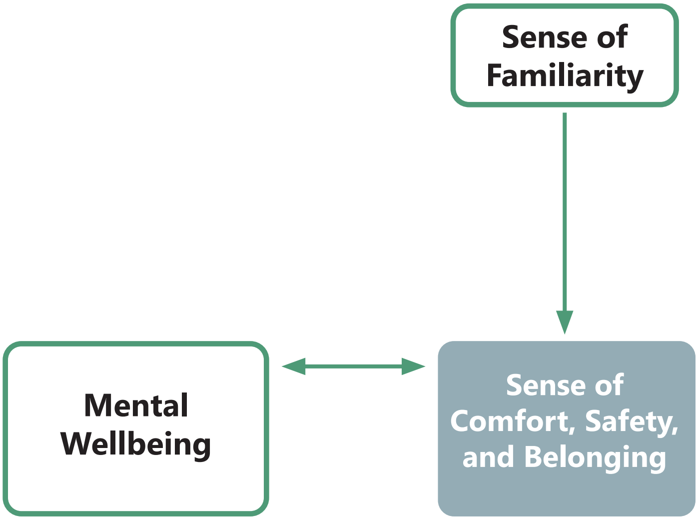


Figure 4: Relationship of Familiarity to Mental Wellbeing.

Greenspace Typology

Studying the character of a variety of greenspace types allows landscape architects and designers to understand how environmental attributes affect users' perceptions in each type of landscape. It also allows one to look at how there might be differences in the ways in which environmental attributes are manifested distinctly across a diverse array of spaces. For this reason, a variety of typologies were researched. These selected greenspace typologies are manicured park, unmanicured timber and meadow, streetscape, community garden, and greenroof. The five greenspace types were chosen due to their relative distinctiveness, their ability to be influenced by designers, and their possession of the environmental attributes being studied. Figure 5 (below) shows the relationship of these variables.

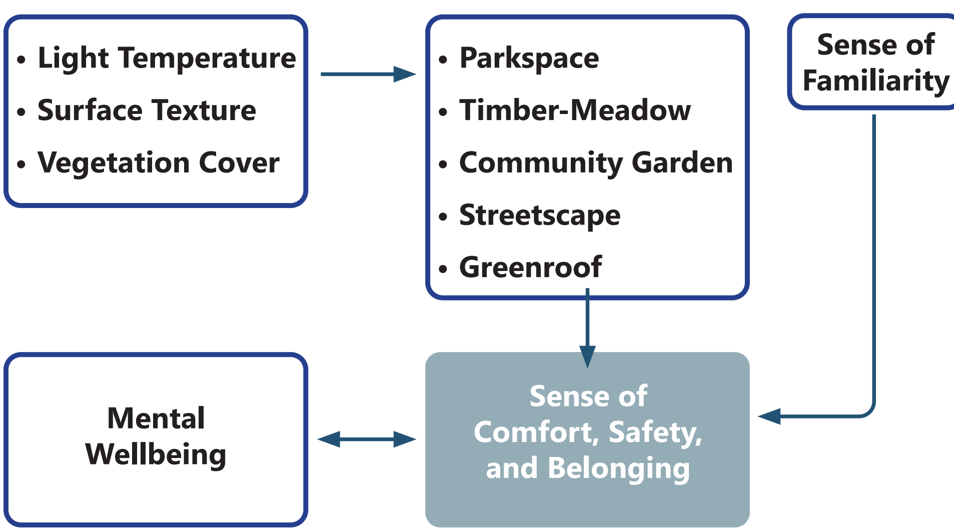
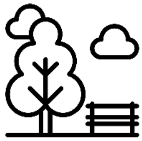
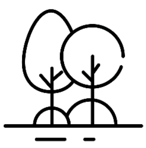


Figure 5: Relationship of Study Variables to Mental Wellbeing.



Parkspace

Manicured park space is commonly used by residents for relaxation, recreation, socializing, refuge from the urban environment, and pet-care, amongst other uses (Chiesura, 2005). As shown in Figure 6, parkspaces oftentimes have a variety of programing elements. Research has shown that park spaces are associated with benefits to mental health and wellbeing (Hosseini et al., 2021; McConnell et al., 2011; Scannell & Gifford, 2016).



Timber-Meadow

Unmanicured Timber and Meadow is oftentimes treated as a nuisance by city officials who seek to develop it or transform its current use. This has the unfortunate side effect that the community uses and associations with the current land use are ignored (Toomey, 2021). Vacant unmanicured land is sometimes treated as public space (Lee & Newman, 2020). However, vacant land is typically seen as merely a stage in a cycle of uses leading up to development or revitalization (Greenberg, Popper, & West, 1990; Lee & Newman, 2020). Nevertheless, some vacant land is left unmanicured intentionally so that, in so doing, it can be used to increase the proportion of urban greenspace (Desimini, 2015; Heckert, Schilling, & Carlet, 2015; Lee & Newman, 2020) such as that depicted in Figure 7. More urban unmanicured space tends to be of poorer quality than suburban and rural spaces (Lee & Newman, 2020; Schetke, Haase, & Breuste, 2010).

Figure 6: A Manicured Recreational Space Used for Relaxation, Recreation, Socializing, Refuge from the Urban Environment, Pet-Care, Etc. (Larkin, 2020)

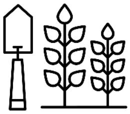
Figure 7: A "Natural" Space Associated with Undeveloped Land and Edges Between Plots of Land. (Harwood, 2021)

Streetscape

Streetscapes are oftentimes defined by the conjunction of landscape with architectural features, the connecting of the public and private spheres, or the meeting of circulatory spaces (streets, sidewalks, etcetera) with the indoor environment (Frank, 2010; Pattacini, 2021) like shown in Figure 8. Design features which delineate the streetscape as a boundary between these two realms include the presence of overhead planes, the integration of infrastructural elements such as stormwater systems, the creation of vertical planes like fences, or changes in the ground plane (Pattacini, 2021). The advent of the automobile and nineteenth century regulations has greatly shaped the subsequent development of streetscapes (Frank, 2010). A resulting feeling of disconnection from the street has led to contemporary design philosophies focusing on increasing transparency (the ability to see into buildings and vice versa) and on improving the cohesiveness of the whole right-of-way as a designed space (Whyte, 1980; Jacobs, 1993; Sucher, 2003; Frank, 2010). The addition of seating elements, shelter, and street trees are important aspects of quality streetscapes (Frank, 2010; Jacobs, 1993; Sucher, 2003; Whyte, 1980). Furthermore, increased levels of street tree canopy coverage have been linked to mental and physical health benefits for residents (Kardan et al., 2015; Pattacini, 2021).

Figure 8: Streetscapes are Defined by the Meeting of Landscape with Architectural Features and the Connecting of the Public and Private Spheres. (Aglo, 2017)

Community Garden



Community gardens, where they have been successfully established, support and provide for communities. They allow for residents to cultivate the land, not just for food production, but also for habitat conservation and aesthetic benefit (Anderson et al., 2019; Burdine & Taylor, 2017) as shown in Figure 9. However, while community gardens provide a useful amenity to the neighborhoods they reside in, they are typically treated as a temporary land uses as vacant lots transition into new developments (Jennette, 2010; Langegger, 2011). Community gardens have been shown to improve the feeling of safety and belonging in vulnerable communities (Ohmer et al., 2009).

Greenroof

Greenroofs are rooftops designed or used for the support of vegetation growth (Dvorak & Volder, 2010; Magill et al. 2011). These structures have an extensive history. Their historic uses included use as temperature regulation, for aesthetic pleasure, as a substitution for more scarce roofing materials, and for fireproofing (Magill et al., 2011). Current greenroof designs focus on habitat production, stormwater management, urban heat island mitigation, and energy efficiency (Dvorak & Volder, 2010; Magill et al. 2011) as well as recreational uses, aesthetic quality (such as the greenroof in Figure 10), noise mitigation, and carbon sequestration (Dunnett & Kingsbury, 2004; Magill et al. 2011).

Figure 9: Community Gardens Help in Providing Food to Communities, Aesthetic Value, Community Engagement, and Invertebrate Habitat. (Adams, 2021)

Figure 10: Rooftops Designed or Used for the Support of Vegetation Growth, Recreation, Aesthetics, and Noise Reduction. (Skabelund, 2021)

What Next?

What is important to explore more? Even with all the knowledge known of these greenspace types, there is a lack of clarity on how changes in environmental attributes impact the indicators of wellbeing differently across greenspace types. This study aims to explore this question further. The importance of further exploration of the connection between indicators of wellbeing (specifically the sense of comfort, safety, and belonging) and greenspace types is key to understanding how design can be used to benefit quality of life of occupants within urban residential areas. Landscape architects and designers, people who have a hand in the shaping of environments and their attributes, have a role to play in the development of greenspaces for benefit of mental wellbeing in occupants. Understanding the differences in response to environmental attributes in various greenspaces may lead to useful design outcomes.

Virtual Reality as a Design Research Tool

The use of virtual reality (VR) within landscape architecture has expanded greatly in recent years (Paar, 2006; Portman, Natapov, & Fisher-Gewirtzman, 2015). The use of VR in studies of mental wellbeing also has several precedents (Jerdan et al., 2020). In a few studies, the use of VR in design was found to have some limitations in group settings. More specifically, verbal communication between group members suffered (Hill, George, & Johnson, 2019; Lin et al. 2018). However, visual communication remained effective for team communication of design ideas (Hill, George, & Johnson, 2019). A benefit of the use of VR in design is an increased awareness of the three-dimensional aspect of a space (Hill, George, & Johnson, 2019; Song & Huang, 2018). Other benefits include the heightened perception of a sense of place (Hill, George, & Johnson, 2019; Song & Huang, 2018) and the development of creative design solutions not possible with conventional design tools (Song & Huang, 2018).

The use of VR technology in human perception research opens some incredible opportunities, however, there are some limitations. While a virtual environment may be much more immersive—and, thereby, more "real"—than conventional two-dimensional techniques, the technology is still not to the point where the VR space feels as real as physical environments. Prudence when attempting to use VR environments as a stand-in for physical spaces in research is warranted (Wilson & Soranzo, 2015). Additional limitations are the costs associated with VR equipment and software, and the technical barriers to entry (Hill, George, & Johnson, 2019; Wilson & Soranzo, 2015). VR technology is anticipated to continue improving in the future, and, in so doing, continue to grow in popularity amongst design professionals and researchers (Hill, George, & Johnson, 2019; Nielsen, 2017; Song & Huang, 2018; Wilson & Soranzo, 2015).

Summary and Research Question

The above literature speaks to a body of knowledge about the impact of greenspaces on mental wellbeing. There is, as shown above, good reason to accept that engagement with greenspace benefits mental wellbeing, particularly through improved sense of comfort, safety, and belonging. Furthermore, three environmental attributes have been identified as both influenceable by landscape architects and impactful in the experience of a space. The impact of the environmental attributes on wellbeing has been evidenced. However, the way changes in environmental attributes impact sense of comfort, safety, and belonging differently across the discussed greenspace types remains unexplored.

This study examines the question, to what extent do participants' sense of comfort, safety, and belonging change across different types of landscapes when their environmental attributes—such as amount of vegetation, surface texture, and light temperature—are modified? The findings of this study are expected to offer greater insights into the use of design elements across greenspace types to positively impact users.

Chapter II: Methods

Study Area

The study area (shown in Figure 11) for this project is located southeast of Brush Creek, Kansas City, Missouri bounded by Brush Creek to the North, Troost Avenue to the West, 63rd Street to the South, and the Big Blue River to the East. This study area was selected due to the shortcomings of the neighborhoods (including high poverty rates, high crime rates, low walkability, low aesthetic value, poor-quality infrastructure, and a low presence of occupiable greenspace) in the hopes that some opportunities for improvement may be presented as a result. Furthermore, the study area was chosen as it allows the study of urban greenspaces in a metropolitan area.

The total population of the study area is 17,577. The study area has significant levels of vacancy, with 765 vacant housing units (9% of the total housing supply), constituting 6% of the total housing vacancy of Kansas City, Missouri. Five of the six neighborhoods studied have declining occupancy rates. The average home value within the study area is 69.7% below the national average. Additionally, the average household income is 45.8% below the national average. However, the cost of living is 16% below the national average. Moreover, unemployment rates are high, especially within the center of the study area. The racial makeup of the site is majority African American with significant White and Hispanic minorities within certain neighborhoods in the study area. The average resident's education level is at a high school level.

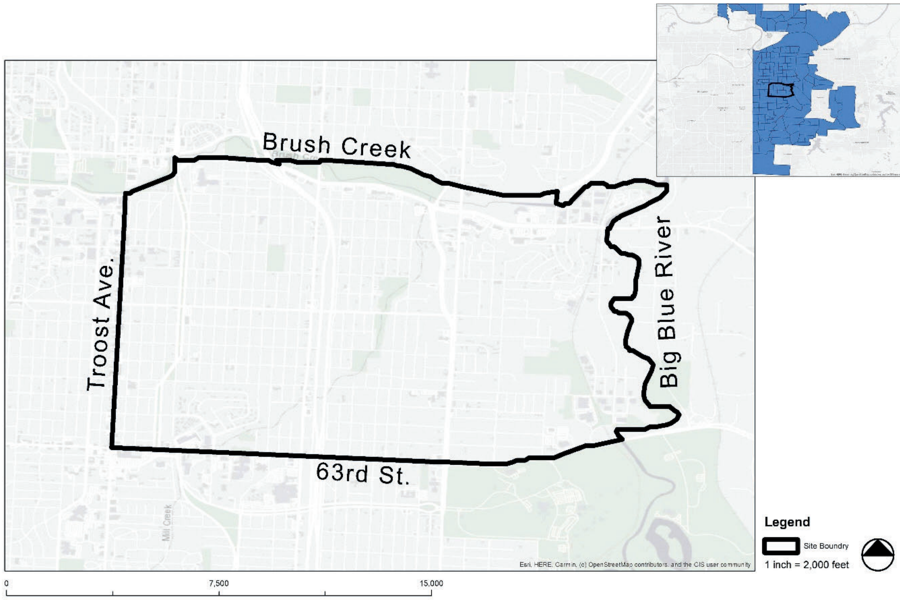


Figure 11: Study Area Boundary and Location within Kansas City, Missouri.

Food Insecurity

The study area suffers from low food access. The majority of the site is within zones considered at high risk for food insecurity. This risk is exacerbated by the economic conditions among many of the neighborhoods. Fresh food is hard to come by on site, with only two full-scale grocery stores within the study area. The northeast and southwest of the site have high concentrations of fast-food locations, contributing to the poor food options available.

Transportation

The site has low pedestrian accessibility. This has led to isolated areas and low streetscape character. Likewise, the study area has only four streets with bicycle access. The majority of the arterial roadways and vehicular access runs north to south with only minor access east to west. Bus routes also predominantly run north to south.

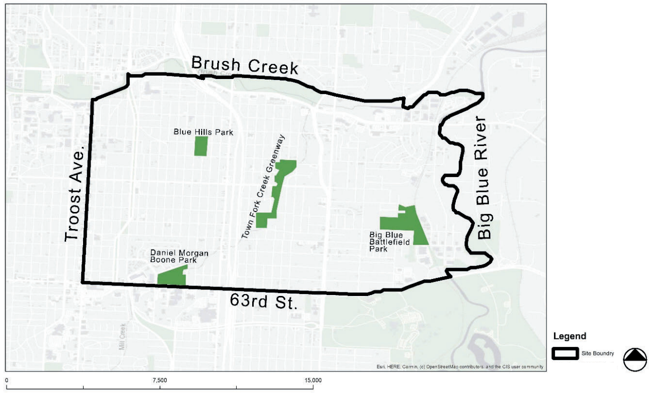


Figure 12: Study Area with Major Greenspaces Identified.

Greenspace

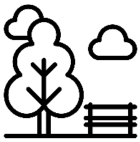
There are three trails within the Kansas City Metropolitan Area MetroGreen system that are for bicyclists. Additionally, the Town Fork Creek Greenway runs from the southwest to the northeast and allows for pedestrian access along a series of greenspaces. There are a handful of parkspaces within the study area, the major examples being Blue Hills Park, Big Blue Battlefield Park, Daniel Morgan Boone Park, and Town Fork Creek. The study area is also home to vulnerable animal and plant species. These species are concentrated along the Big Blue River on the eastern edge of the study area. See Figure 12 for context.

Bluespace

The three primary waterbodies within the study area are the Big Blue River, Brush Creek, and Mill Creek. Each of these are classified as impaired due to their poor water quality and high amounts of contaminants. Brush Creek and Mill Creek both have concrete channeling infrastructure. Additionally, Kansas City's combined stormwater-sewer system opens these waterbodies up to pollution from wastewater. Poor stormwater infrastructure within the study area has also produced flooding issues in parts of these neighborhoods.

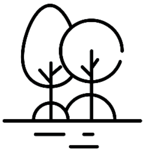
Site Selection

Underutilized spaces within the study area act as bases for VR modeling. This is because these spaces are most vulnerable and most suitable for benefits to the community. The selected site locations were chosen from those available landbank-owned vacant lots within the study area which were suitable for development into the five greenspace types. These five types were explored within the study area at the following locations:



Parkspace: Northeastern Morgan Daniel Boone Park

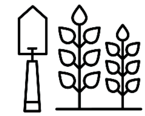
Morgan Daniel Boone Park consists of a large plot of undeveloped land centered around Mill Creek along 63rd Street. The east-southeastern edge of the park contains a short trail terminating in a cemetery dedicated to explorer and Missouri pioneer Daniel Morgan Boone.



Timber-Meadow: Big Blue Battlefield Park

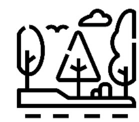
Big Blue Battlefield Park is a large and fragmented forested space that lies north of 63rd Street along the Big Blue River. The surrounding land use is largely industrial to the east and residential to the west. The northwestern part of the park is currently closed to the public and unoccupiable. Roadway connections to the park are currently limited.

Community Garden: 55th Street and Wanye Avenue Vacant Lot



The 55th Street and Wayne Avenue lot is comprised of two adjacent vacant parcels of land in a residential area. The site has a moderate slope from the east to the west and has a retaining wall separating the interior of the site from the right-of-way.

Streetscape: 53rd Street between Rockhurts University and Town Fork Creek Greenway



53rd Street is a two-lane roadway that begins within the Rockhurst campus and runs eastward, intersecting 71 Highway, and continues until it meets the Town Fork Creek Greenway—at which point it jogs southward before continuing to the east. The modeled portion of the street lies immediately west of 71 Highway—intersecting Prospect Ave—and runs a four blocks eastward.

Greenroof: Swope Parkway Vacant Lot

The Swope Parkway Vacant Lot on which the Greenroof model is based is an undeveloped lot lying north of 63rd Street on the western half of the study area. The building on which the roof is built is a proposed business development meant to service the surrounding residential neighborhood. The Greenroof is intended to have semi-public access.

Data Collection

Figure 13 shows a plan view of the selected study sites.

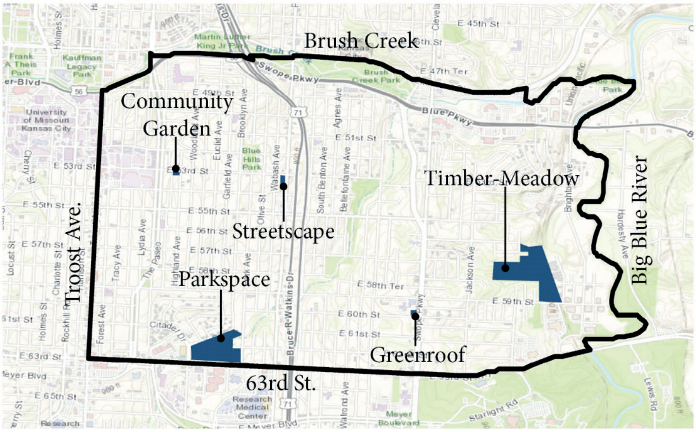


Figure 13: Study Sites Located in the Neighborhoods Southeast of Brush Creek, Kansas City, Missouri.

Social Data

The collection of data from community members is crucial to understanding the relationship between the five greenspace types and their changes of environmental attributes and perceived sense of safety, comfort and belonging. The measurement of difference in the changes between environmental attributes in the environment is paramount in understanding how these attributes differently impact people across greenspace types.

Manicured park, unmanicured timber and meadow, community garden, streetscape, and greenroof represent a collection of disparate greenspace types selected to provide a wide range of environmental attributes. Each of these greenspace typologies were modeled in three dimensions using Rhinoceros 7, SketchUp, and Civil 3D before being rendered for virtual reality (VR) use in Lumion 11. Each render was experienceable with the use of a virtual reality headset with stereoscopic display.

Before the study was conducted, a pilot test was run with volunteering Kansas State University students. The survey design consists of an initial page of two questions asking the participant whether or not they have used a VR headset before and their level of comfort in using a headset. Next, the participants put on the headset and experienced the baseline environment before ranking their subjective levels of comfort, safety, and belonging with the space.

To account for familiarity, participants were also asked if they had any spaces similar to the one depicted near to their place of residence. Participants then put back on the headset and experienced each of the remaining five environments. After each subsequent environment they were again asked to rank their sense of comfort, safety, and belonging. Finally, participants were asked to answer four demographic questions and one question about their experience with the VR headset.

Study participants were recruited in the study area at the public library extension, restaurants, diners, cafes, stores, and community centers. A station was set up at these locations with signage meant to encourage people to volunteer for the survey. Subjects were first asked if they have ever used a VR headset before. They then were asked to rank their level of comfort in using the technology. Next, subjects were randomly assigned a greenspace model to walk through with the VR headset. They were asked to rank their level of safety, level of belonging, and level of comfort each on a five-point rating scale (with five being the highest in sense of safety/belonging/comfort and one being the lowest). See Appendix III for survey questions. After their responses had been recorded for the initial greenspace settings, each environmental attribute was then adjusted in succession with their perceived levels of comfort, safety, and belonging recorded again on the same scale after each. These environmental attributes are lighting color temperature (in a nighttime scene) white lighting, cool lighting, and warm lighting; vegetation coverage, the relative scope of planting in a space as a measure of density; and surface texture, the relative amount of detail in paved surfaces. A potential limitation of this method might be the potential for motion sickness and headaches causing bias in participants. As such, participants were asked if they experienced any of these symptoms at the end of the survey. Participants were offered a free refreshment in gratitude for the volunteering of their time.

A sample size of 51 individuals from southeast Brush Creek neighborhoods of Kansas City was recruited for this study. This gave 10 or 11 participants for each greenspace typology. With this, the degree to which the sense of safety, belonging, and comfort changed within each typology as the environmental attributes changed (as measured by the difference in the mean response before and after each factor was changed) was compared between greenspace typologies. Jeon and Jo's 2020 study used a five-point like to dislike scale to study the satisfaction with different aspects of a virtual urban environment (Jeon & Jo 2020). In this way, the use of the above five-point scale is similar but is distinct in that this study asks for respondents to rate their sense of safety, belonging, and comfort in a space—not mere likes and dislikes. The five-point rating scales are suited for this study because it seeks to compare these factors across different greenspace typologies.

Model Definitions

Vegetation

Amount of vegetation is measured through calculated area covered by plants that are exposed to viewers. Because of the unique qualities which inhere in individual greenspaces as artifact types, the planting requirements for each greenspace reflect the character of their individual functions. As a consequence, greenspace models cannot (across the five types studied) contain equal amounts of vegetation per unit of area while serving their purpose (extrinsically imposed). For this reason, a baseline degree of vegetation for each greenspace type was implemented to the degree appropriate for the purposes of that space in order to authentically represent it in the VR environment. Likewise, because the range of appropriate degrees of vegetation coverage will vary across greenspace types, a suitable increase in vegetation will be different between the five types. Because of this, the vegetation attribute increase view for each greenspace model has different increased percentages. These respective levels of vegetation within close proximity to the viewer for each greenspace are show in Table 1. Vegetation amount was determined through sectioning off 25'x25' plots around the viewer's location and averaging the number of plant models located within a single plot (see Figure 14 for a demonstration).

Table 1: The compared baseline and increase plant densities. Values are plants per 25 square feet.

Model	Baseline	Increase
Parkspace	57 (25'x25')	419 (25'x25')
Timber-Meadow	114 (25'x25')	217 (25'x25')
Community Garden	98 (25'x25')	133 (25'x25')
Streetscape	5 (25'x25')	182 (25'x25')
Greenroof	35 (25'x25')	102 (25'x25')

Figure 14: Vegetation Amount Calculation for Baseline Greenroof.

Texture

Surface texture is measured by the degree of fineness and coarseness; for the purposes of this study, surface texture refers specifically to that of paved surfaces. The requirements for surfaces are different for each of the five greenspace types. As such, the baseline image resolution will be distinct. Additionally, the increased texture models will have their own rates of increase based on what is design-appropriate for each greenspace type and its surfaces (due to the nature of the different texture types being different). Textures were adjusted through image magnification, the rate of which is found in Table 2 for each of the respective sites in the baseline and then the increase models.

Table 2: The magnification rate of surface texture maps for both the baseline and increase views by greenspace type.

Model	Baseline	Increase
Parkspace	1.9x	41.6x
Timber-Meadow	0.8x	4.0x
Community Garden	3.0x	8.4x
Streetscape	1.9x	41.6x
Greenroof	0.2x	1.1x

Lighting

The light color temperature for each greenspace type is divided between a white light, warm light, and cool light for the purposes of studying influence on wellbeing indicators. These lights were placed within lighting elements in the scenes. The Kelvin values for lighting refer to the temperature of the filament in the lightbulb. Higher Kelvin temperatures produce cooler colored light, while lower temperatures produce warmer colored light. Within these scenes, 5,500K is the value referring to white light, 2,800K is warm light, and 8200K is cool light. Warm lights are 2,700K less than the white light, while cool lights are 2,700K more than the white light. These values were chosen to capture a wide range of the spectrum of color temperature so that the influence on the wellbeing indicators can be understood across a wider array of lighting options.

Chapter III: Data Analysis And Findings

The collected data was exported to IBM SPSS software for statistical analysis. Pearson correlation, descriptive means, and regression analysis were conducted so that the associations between variables and response groups could be explored. The findings of the data analysis were then used as the basis for projective design solutions.

Descriptive Means

Whole Sampling Descriptive Means

The total sample size was 51 participants. Each participant was randomly assigned to a particular greenspace type. Those individual greenspace types are separately analyzed and presented below; this section looks at the whole pool of data and details the baseline scene statistics as well as the highest mean environmental attribute scenes for the collection of all greenspace types; additional information is shown in the associated tables and can be found in Appendix IV.

The means of the collective baseline scenes were 4.31 for comfort, 4.39 for safety, and 3.88 for belonging. The highest means for all three wellbeing indicators were the baseline model types. There appears to be two possible explanations for the baseline being so widely preferred. The first of these could be a bias towards the initial model being viewed, in which participants either estimate their initial comfort, safety, and belonging based on what they presume subsequent models to be like, and then compensate based on their expectations as the environmental attributes are changed. The second, simpler theory would be that the environmental attribute changes really did detract from the reported wellbeing indicators. I give more credence to the second theory as it requires fewer assumptions and would seem to be expected given the nature of the various attributes being changed. In order to identify the true reason for why the baseline appears to be favored, future research needs to be done which randomizes the order of scenes to minimize any bias towards the initial scene viewed.

Data Subsets Frequency Statistics and Analysis

For each greenroof type, descriptive frequency analysis was conducted to determine the average—mean—as well as the standard deviation. These represent the sets of participants randomly assigned to each of the five greenspace types (parkspace, timber-meadow, streetscape, community garden, and greenroof). This section details the baseline scene statistics as well as the highest means for the modified environmental attribute scenes from each greenspace type; additional information is shown via the associated tables and can be found in Appendix IV.

Parkspace

The Parkspace greenspace type had 10 total participants randomly assigned to this greenspace type survey. The baseline means were 4.20 for comfort, 4.30 for safety, and 3.80 for belonging. The highest mean comfort was the baseline, while the highest mean safety was for the increased texture scene at 4.40. The highest mean belonging was tied between the baseline and the increased plant density scenes at 3.80. For context, see Figures 15, 16, and 17 below. As presented in Figure 18, this was the only greenspace type in which the increased texture scene had the highest mean across the three indicators of wellbeing; the reason behind this remains unknown, but it may have something to do with the nature of the modeled space. The playground structure sat on a rubber base, and the concrete walking path dominated the model, and so the increase in detail amongst these design elements may lead to increased sense of safety as they become more present in the perception of the occupant. The baseline being the highest mean amongst the sense of comfort is expected given the whole sample analysis detailed previously. The sense of belonging being highest within the increased amount of vegetation—while not the majority outcome across the five greenspace types—is the second most frequent outcome. This may have something to do with the vegetation obscuring the view of the roadway, although the exact nature of the association is unknown without further study.

Literature on this topic suggests that higher degrees of "wildness" in site plantings is associated with increased restorativeness, and so this may account for the favoring of higher vegetation coverage perceived by the participants (Hoyle, Jorgensen, & Hitchmough, 2019).

Figure 15: The Baseline Parkspace Model.

Figure 16: The Increased Coarseness of Surface Texture Model.

Figure 17: The Increased Amount of Surface Vegetation Model.

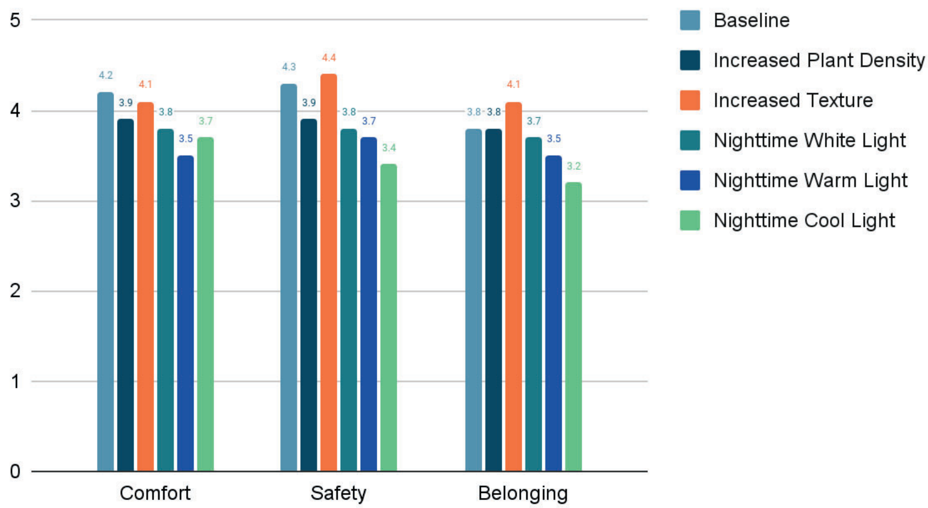


Figure 18: Mean Differences Across Three Indicators of Wellbeing in Parkspace.

Timber-Meadow

The Timber-Meadow greenspace type had 11 total participants randomly assigned to this greenspace type survey. The baseline means were 4.27 for comfort, 4.36 for safety, and 3.82 for belonging. The highest mean comfort was for the increased amount of vegetated area scene at 4.55, while the highest mean safety was related to increased vegetated area scene at 4.64. The highest mean belonging was nighttime white light scene at 4.09. These scenes are shown below as Figures 19 and 20. This greenspace type was dominated by the "natural" planting and heavy tree cover. With this in mind, the scenes with increased amount of vegetation having the highest means for comfort and safety (Figure 21) was somewhat surprising. The decrease in visibility caused by the increase in vegetation coverage was thought to lead to lower levels of comfort and safety, especially in such neighborhoods that are known to have relatively high crime rates. Additionally, the nighttime white light scene being the highest mean level of belonging was also surprising, as it would at first appear counterintuitive that being in a forested area at night would have high levels of belonging. However, it might be due to the high levels of artificial lighting present in the scenes through the lightposts that line the hiking trail and the lit pavilion.

Figure 19: The Nighttime White Light Timber-Meadow Model.

Figure 20: The Increased Amount of Surface Vegetation Model.

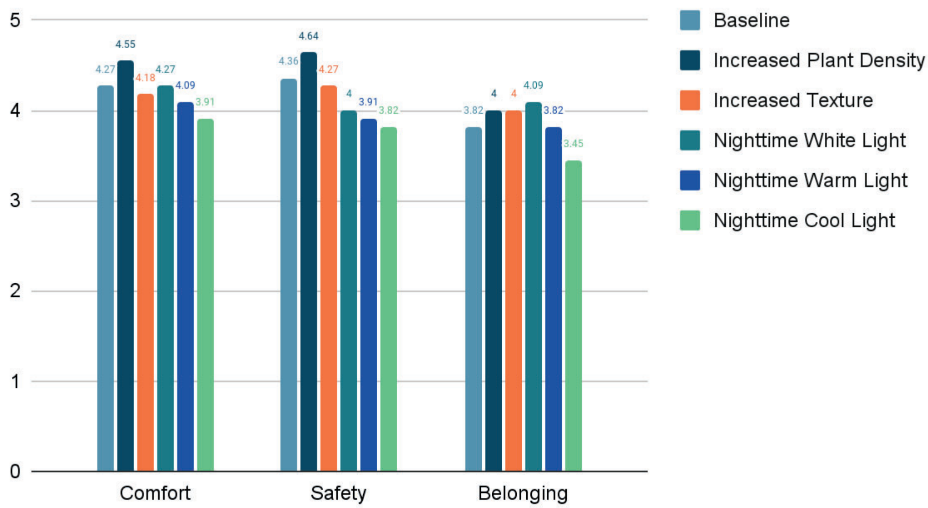


Figure 21: Mean Differences Across Three Indicators of Wellbeing in Timber-Meadow.

Streetscape

The Streetscape greenspace type had 10 total participants randomly assigned to this greenspace type survey. The baseline means were 4.40 for comfort, 4.30 for safety, and 3.90 for belonging. See Figure 22 below for this model. As shown in Figure 23, like with the community garden greenspace, the baseline model type had the highest mean value for all three wellbeing indicators. The fact that all three wellbeing indicators were dominated by the baseline scene is not surprising in light of the whole sampling analysis; however, it seems that this outcome might be in part related to the presence of the street as the dominating factor in the scene. It would appear that the nighttime scenes would be ruled out by the fact that a busy street with houses at night would not be conducive to high levels of comfort, safety, or belonging. Furthermore, the increased vegetation and the increased texture scenes both would have made an already busy environment type busier, and so this may have influenced the results.

Figure 22: The Baseline Streetscape Model.

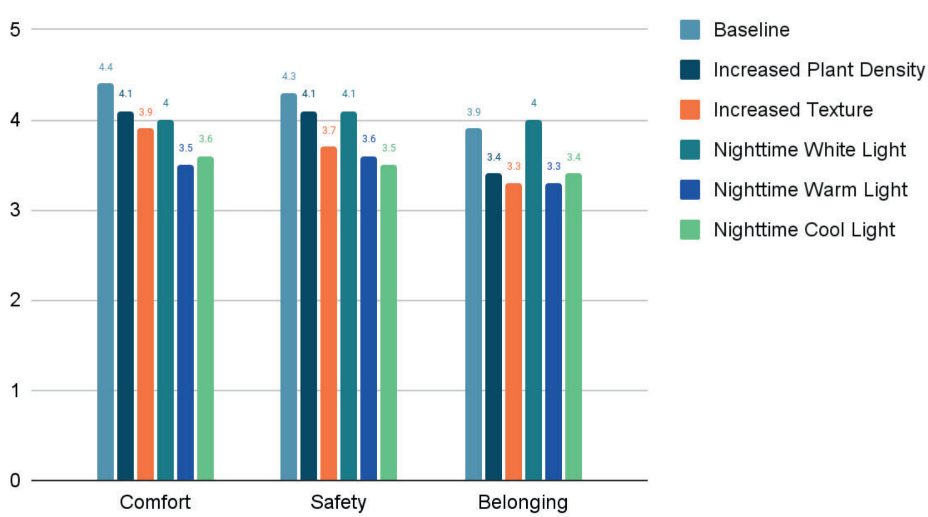


Figure 23: Mean Differences Across Three Indicators of Wellbeing in Streetscape.

Community Garden

The Community Garden greenspace type had 10 total participants randomly assigned to this greenspace type survey. See Figure 24 for this model view. The baseline means were 4.30 for comfort, 4.40 for safety, and 3.80 for belonging. As shown in Figure 25, the baseline model type had the highest mean reported for each of the three wellbeing indicators (comfort, safety, and belonging)—similar to the streetscape model type. This may be for the same reasons as the streetscape, the presence of the street and houses in the scenes. Furthermore, the increased vegetation coverage was closer to the view of the participant in this model than others by virtue of the scene being situated within a vegetable garden. More research into how the presence of streets and housing influences the wellbeing of occupants in a space may give greater insight into the reasons behind the survey data.

Figure 24: The Baseline Community Garden Model.

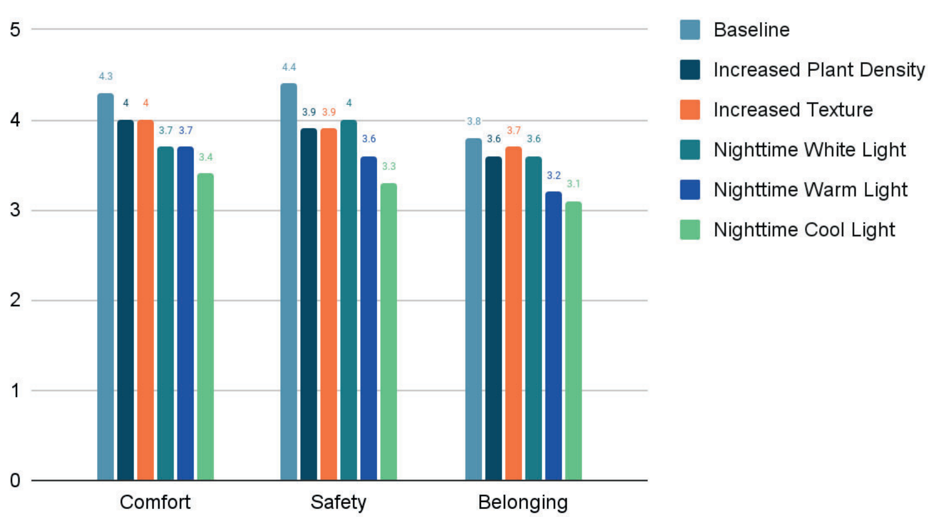


Figure 25: Mean Differences Across Three Indicators of Wellbeing in Community Garden.

Greenroof

The Greenroof greenspace type had 10 total participants randomly assigned to this greenspace type survey. Figures 26 and 27 show the context. The baseline means were 4.40 for comfort, 4.60 for safety, and 4.10 for belonging. The highest mean comfort was for the baseline, while the highest mean safety was tied between the baseline and for the scenes with increased amount of vegetation at 4.60. As presented in Figure 28, the highest mean belonging was for the scene with increased amount of vegetation at 4.40. This greenspace type had an even split amongst wellbeing indicators' means between the baseline and the increased vegetation. Based on what was discovered in the other greenspace type analyses, this might be because of the greenroof type being a sort of hybrid space that takes place within a residential neighborhood (like the streetscape and the community garden) but is also detached from it by being located higher up off the street.

Figure 26: The Baseline Greenroof Model.

Figure 27: The Increased Amount of Surface Vegetation Model.

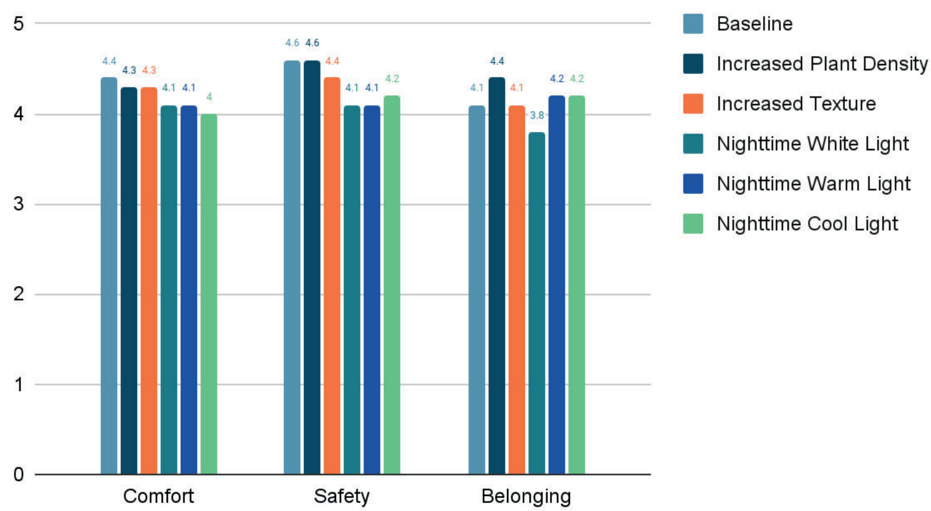


Figure 28: Mean Differences Across Three Indicators of Wellbeing in Greenroof.

Takeaways of Frequency Statistics

For the majority of greenspace types, the highest mean for all three wellbeing indicators was the baseline model. This means that in most circumstances the alterations made to the spaces decreased the mean reported sense of comfort, sense of safety, or sense of belonging. However, the highest mean comfort reported was related to the scene of the Timber-Meadow model with increased amount of vegetation (See Figure 29) at 4.55. Likewise, the highest mean safety reported for the same scene at 4.64. Lastly, the highest mean belonging reported was related to the scene of the Greenroof model with increased amount of vegetation at 4.40. It appears that the increase in vegetation amount may have some bearing on increases in comfort, safety, and belonging in at least some greenspace types.

Figure 29: Timber-Meadow High Amount of Vegetation 360° Panoramic View.

Data Subsets Compared Means

Each of the five greenspace types underwent the same five modifications to environmental attributes from the baseline. The differences in the participant-reported sense of comfort, sense of safety, and sense of belonging between each of the greenspace types were analyzed from the VR survey responses. See Appendix IV for a complete dataset of this comparison.

Increased Amount of Vegetation

The increase in total visible surface area of vegetation within each of these scenes was rendered in such a way that it was appropriate within each of the specific greenspace types and cohered with the overall spatial design and organization. For imagery, see Appendix III. This change in the environmental attribute was measured and compared across the three wellbeing indicators (sense of comfort, safety, and belonging) by subtracting the reported changed level from the baseline (as depicted in Figure 30). See Figure 31A, B, and C for the compared differences between the attribute change and the baseline models. Note that a higher percentage value means a higher difference and thus a greater negative reaction on the part of the participant to the change.

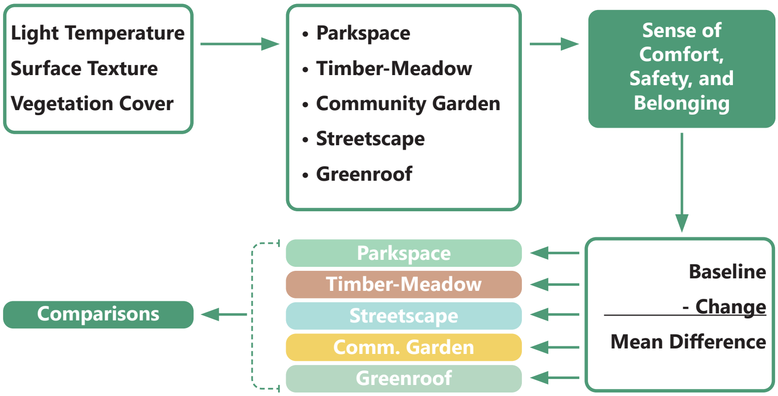


Figure 30: Relationships Between Variables.

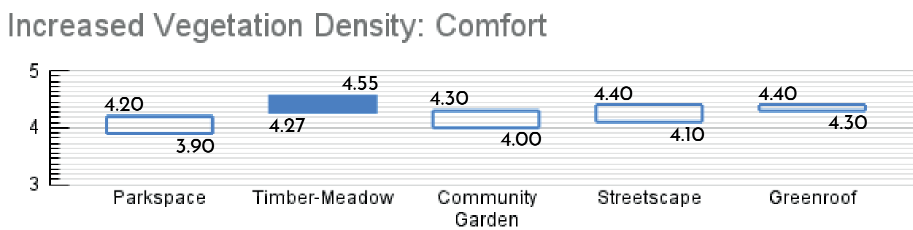


Figure 31A: Mean difference in comfort between baseline and scenes with increased vegetation amount. Solid color blocks are positive changes in reported comfort while hollow blocks are negative changes and lines are no change.

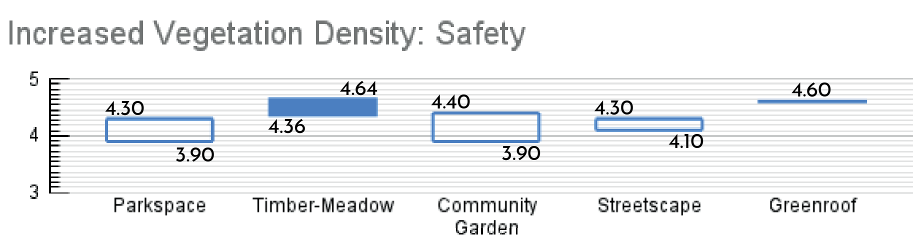


Figure 31B: Mean difference in safety between baseline and scenes with increased vegetation amount. Solid color blocks are positive changes in reported safety while hollow blocks are negative changes and lines are no change.

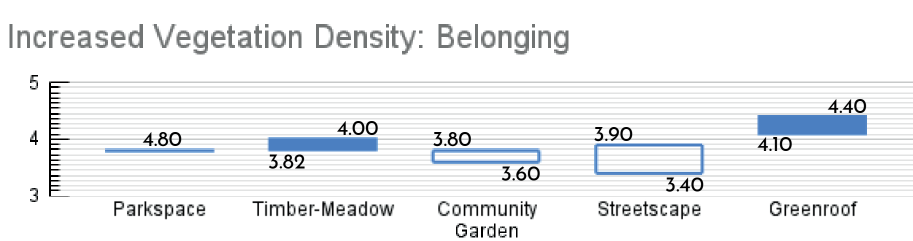


Figure 31C: Mean difference in belonging between baseline and scenes with increased vegetation amount. Solid color blocks are positive changes in reported belonging while hollow blocks are negative changes and lines are no change.

Increased Surface Texture

The increase in surface texture had noticeable disparities across the five greenspace types. Amongst participants who experienced the streetscape model, their mean reported sense of comfort with the increased surface texture scene was 0.50 of that of the baseline scene. The sense of safety those participants who experienced the parkspace model felt, on average, 0.10 safer with the increased textures than the baseline, while those who experienced the streetscape and community garden models respectively felt levels of safety reduced 0.60 and 0.50 that of the baseline. Furthermore, the sense of belonging in the increased texture scene reported for those participants who experienced the streetscape was also reduced by 0.60 from the baseline, while parkspace and timber-meadow participants had greater senses of belonging (changes of 0.30 and 0.1818 respectively). See Figure 32A, B, and C for more information. This data seems to suggest that streetscapes and community gardens are more adversely affected by surface texture increases, while parkspaces (and to a lesser extent timber-meadows) may actually see benefits to their reported levels of wellbeing.

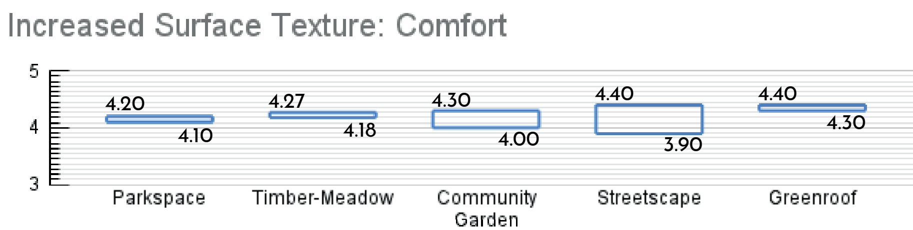


Figure 32A: Mean difference in comfort between baseline and increased surface texture scenes. Hollow blocks are negative changes.

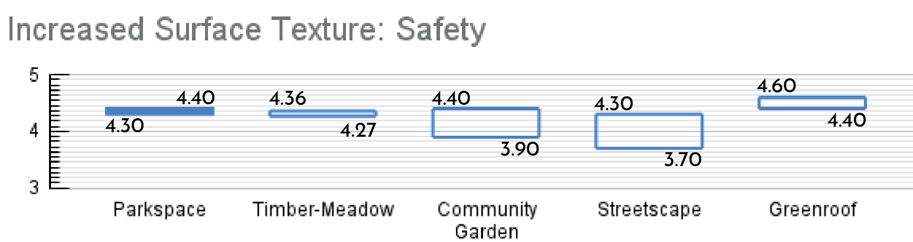


Figure 32B: Mean difference in safety between baseline and increased surface texture scenes. Solid color blocks are positive changes in reported safety while hollow blocks are negative.

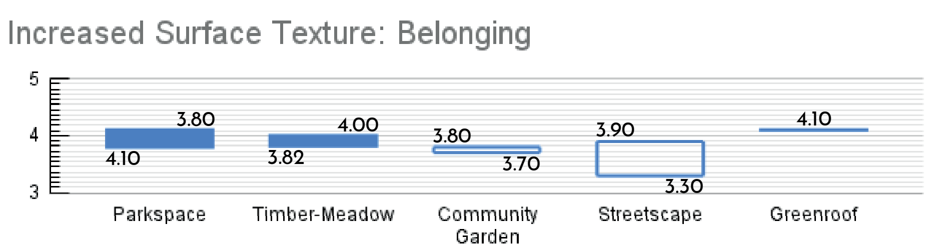


Figure 32C: Mean difference in belonging between baseline and increased surface texture scenes. Solid color blocks are positive changes in reported belonging while hollow blocks are negative changes and lines are no change.

Nighttime White Light

The change from the baseline to nighttime scenes with white light (5,500K) had disparate impacts on the five greenspace types. Those participants who experienced the timber-meadow greenspace model type experienced no change in reported sense of comfort between the baseline and nighttime white light scenes. Conversely, participants who experienced the community garden model type reported levels of comfort 0.60 less than that of the baseline. With regards to reported sense of safety, all participant groups showed reductions. However, the streetscape participants reported the smallest reduction at only 0.20 lower. Moreover, these same participants reported an increase in sense of belonging of 0.10, while all other participant groups reported levels which either decreased or remained steady. This may point to a slight advantage to streetscapes in terms of white light. See Figure 33A, B, and C for more information.

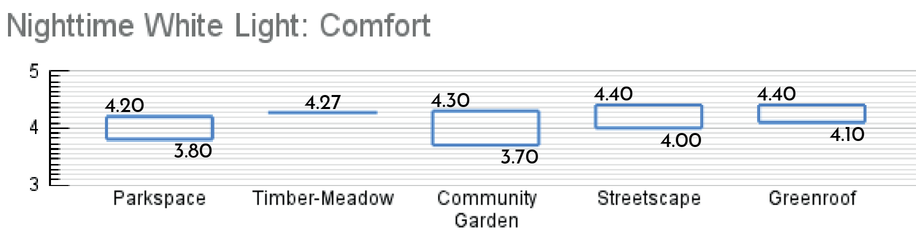


Figure 33A: Mean difference in comfort between baseline and nighttime white light scenes. Solid color blocks are positive changes in reported comfort while hollow blocks are negative changes and lines are no change.

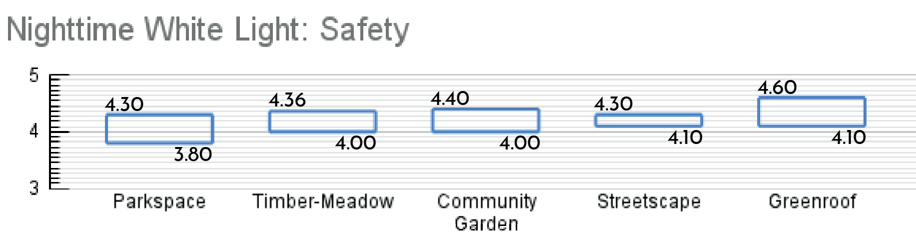


Figure 33B: Mean difference in safety between baseline and nighttime white light scenes. Solid color blocks are positive changes in reported safety while hollow blocks are negative changes.

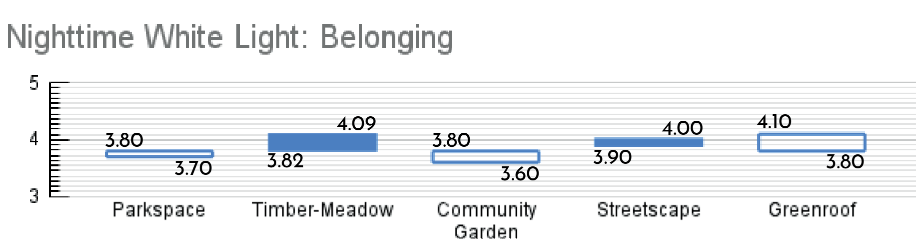


Figure 33C: Mean difference in belonging between baseline and nighttime white light scenes. Solid color blocks are positive changes in reported belonging while hollow blocks are negative changes and lines are no change.

Nighttime Warm Light

The effect of the change in scenes from the baseline to the nighttime warm light (2,800K) differently impacted the various greenspace types. The streetscape model type had a significant decrease of 0.90 in reported sense of comfort; meanwhile, the greenspace types of timber-meadow and greenroof had much lower decreases, at 0.1818 and 0.30 respectively. With the sense of safety, all greenspace types saw decreases in levels of safety. However, the timber-meadow and greenroof scenes again had the smallest decreases at 0.45 and 0.50 respectively. Finally, the sense of belonging reported by participants who experienced the timber-meadow model type showed no change from the baseline while the greenroof participants actually saw an increased sense of belonging for 0.10. This is contrasted with the streetscape and community garden participant groups which both saw a 0.60 decrease in sense of belonging from the baseline. These findings appear to suggest that the use of warm light at night most negatively impacts streetscapes and community gardens while having a much smaller effect on timber-meadows and greenroofs. See Figure 34A, B, and C for more information.

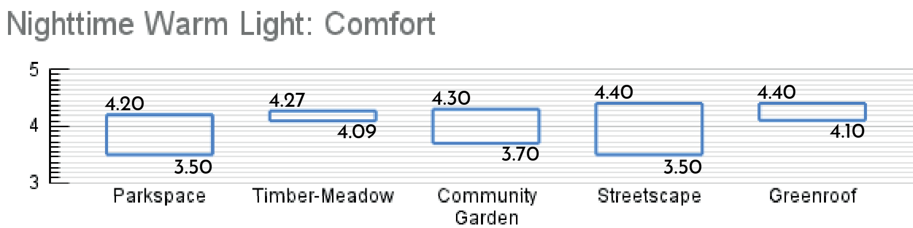


Figure 34A: Mean difference in comfort between baseline and nighttime warm light scenes. Solid color blocks are positive changes in reported comfort while hollow blocks are negative changes.

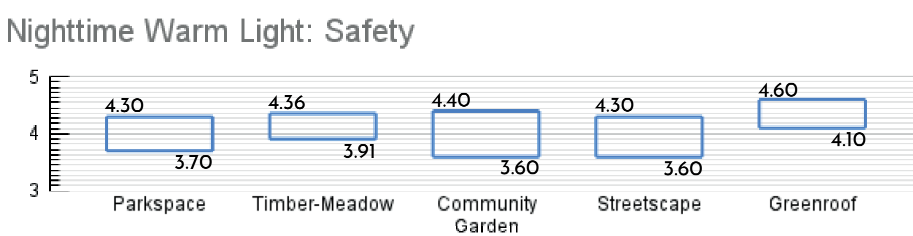


Figure 34B: Mean difference in safety between baseline and nighttime warm light scenes. Solid color blocks are positive changes in reported safety while hollow blocks are negative changes.

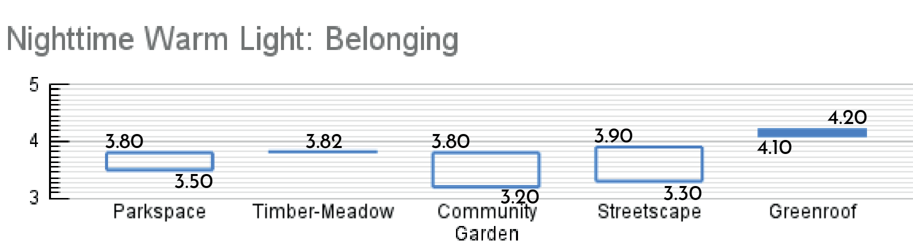


Figure 34C: Mean difference in belonging between baseline and nighttime warm light scenes. Solid color blocks are positive changes in reported belonging while hollow blocks are negative changes and lines are no change.

Nighttime Cool Light

The effects of the change from the baseline to nighttime cool light (8,200K) impacted the different greenspace types in diverse ways. The streetscape and community garden participants were especially negatively affected in their sense of comfort (with 0.80 and 0.90 decreases respectively). Timber-meadow and greenroof participants were less effected; their reported levels of comfort only decreased 36.36% and 40% respectively. With the sense of safety, the community garden participants saw a 1.10 decrease, whereas the greenroof only saw a comparatively smaller decrease (0.40). The sense of belonging reported by those participants who experienced the greenroof model type saw a 0.10 increase with the cool light. All other greenspace types had decreased senses of belonging, especially the community garden. These results seem to suggest that community garden greenspaces are especially negatively affected by nighttime usage of cool lights while greenroofs are less impacted. See Figure 35A, B, and C for more information.

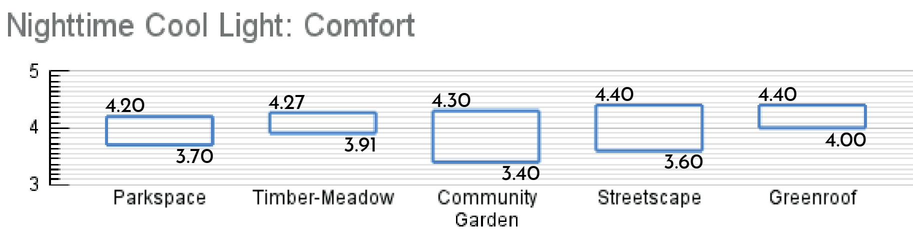


Figure 35A: Mean difference in comfort between baseline and nighttime cool light scenes. Solid color blocks are positive changes in reported comfort while hollow blocks are negative changes.

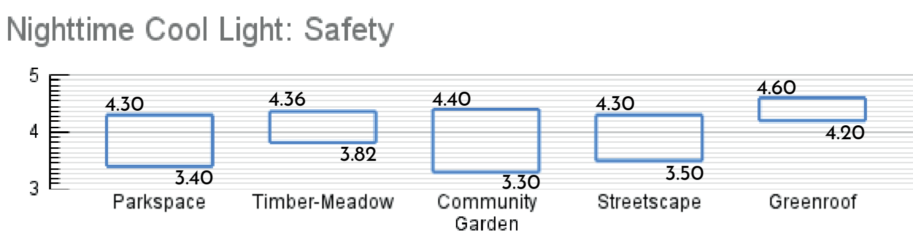


Figure 35B: Mean difference in safety between baseline and nighttime cool light scenes. Solid color blocks are positive changes in reported safety while hollow blocks are negative changes.

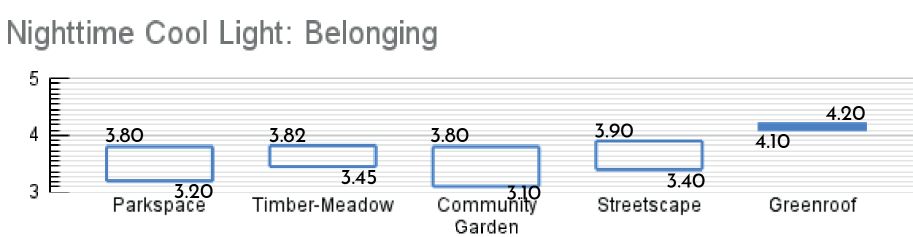


Figure 35C: Mean difference in belonging between baseline and nighttime cool light scenes. Solid color blocks are positive changes in reported belonging while hollow blocks are negative changes.

The Role of Familiarity

To control for the potential role of familiarity with landscape scenes in participants' responses, linear regression analysis with collinearity diagnostics was ran—once for each environmental attribute scene change. The dependent variable in each analysis was the respective scene and the independent variable was the participant's reported sense of familiarity with the greenspace type. No statistically significant association between familiarity and sense of comfort, sense of safety, nor sense of belonging was found for any of the environmental attribute scenes.

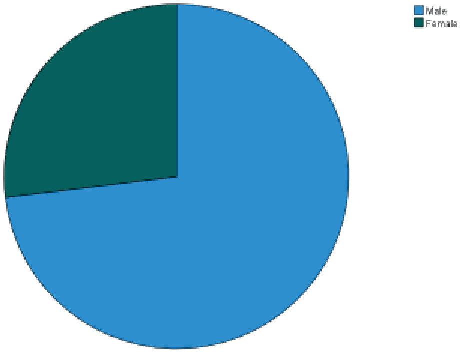


Figure 36: VR Usage by Gender.

Correlations with Model Type

Running a bivariate Pearson correlation analysis on each of the variables studied as whole-samplings, testing for significance was two-tailed, and significant correlations were identified (see Table 14).

Notable correlations include:

Past use of a VR headset was strongly correlated with younger age groups and males (see Figure 36). This was anticipated and matches what was reported by the Nielsen Company (Nielsen, 2017). Furthermore, gender was a factor in changes in wellbeing indicators for four general environmental attributes. It was most strongly correlated (37.2%, p-value<0.01) with comfort in the scenes with increased surface texture—with males being far more likely to experience a sense of comfort in these scenes than females. Likewise, male participants were more likely to experience a sense of safety (28.4%, p-value<0.05) and a sense of belonging (28.8%, p-value<0.05) than female participants.

Interestingly, amongst those scenes with increased vegetation amount, no significant correlation of sense of comfort and sense of safety with gender was detected; however, males were found to have significantly higher levels of a sense of belonging in scenes with increased vegetation amount than females (30.6%, p-value<0.05). Age was not found to have any significant correlation with senses of comfort, safety, and belonging amongst any of the environmental attribute changes.

High levels of a sense of comfort, safety, and belonging amongst the baseline model types was strongly correlated with continued senses of comfort, safety, and belonging across all daytime environmental attribute changes (see Table 14 for more details). In other words, as shown in Figure 37, most participants initially comfortable with the baseline daytime scene remained comfortable in all daytime scenes. However, responses to nighttime scenes were less consistent. High baseline senses of comfort, safety, and belonging were each correlated with high nighttime white light comfort; however, none were correlated with nighttime white light safety, and only high levels of baseline model belonging was correlated with nighttime white light comfort (see Table 14 for more information).

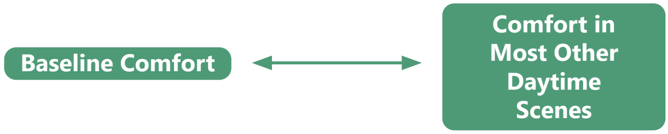


Figure 37: Correlations with Daylight Comfort and Baseline Comfort.

The senses of comfort, safety, and belonging associated with warm light nighttime scenes tended to correlate with the baseline measures of the wellbeing indicators. Baseline model's sense of comfort significantly correlated with nighttime warm light sense of comfort (52.3%, p-value<0.001), sense of safety (31.7%, p-value<0.05), and sense of belonging (31.9%, p-value<0.05). Baseline model for sense of safety correlated with nighttime warm light sense of comfort (41.6%, p-value<0.005) and sense of safety (40.5%, p-value<0.005). Baseline model reported values for sense of belonging correlated with nighttime warm light sense of comfort (37.3%, p-value<0.01) and sense of belonging (40.9%, p-value<0.005). These relationships are shown below in Figures 38 and 39.

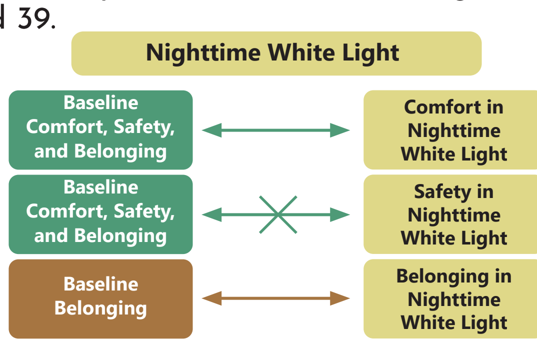


Figure 38: White Light Correlations.

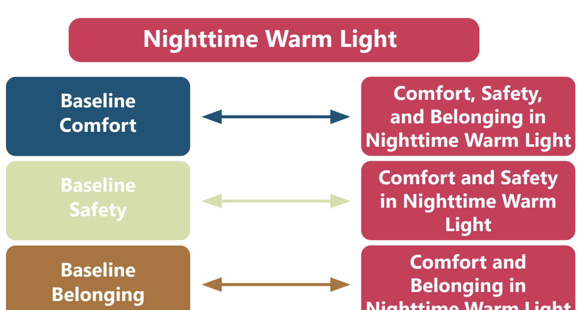


Figure 39: Warm Light Correlations.

Cool light nighttime scenes' sense of comfort was not significantly correlated with any baseline model's wellbeing indicator level, nor was sense of safety in nighttime cool light scenes. Cool light nighttime scenes' sense of belonging was not correlated with baseline participant-reported comfort levels—unlike warm light nighttime scenes. However, the reported sense of belonging associated with nighttime cool light scenes was significantly correlated to a moderate degree with the sense of safety reported (30.9%, p-value<0.05) and to a high degree with the sense of belonging reported (42.2%, p-value<0.01) for baseline models (see Table 14 for details).

Summary

After reviewing the analysis results, it appears that, on average, the environmental attribute changes depicted in the VR models had a negative impact on participants' sense of comfort, safety, and belonging—the collective means being highest in the baseline models when all greenspaces are considered together. However, this is not true of all greenspace types when looked at individually. Notably, within the Timber-Meadow model, the baseline scene was not the highest mean amongst any of the wellbeing indicators. Other greenspaces had their highest indicator means split between particular scenes and the baseline. Additionally, the highest mean for each wellbeing indicator irrespective of greenspace type was accomplished by increased vegetation coverage scenes (despite increased vegetation not being associated with the highest mean of any wellbeing indicator when all greenspaces were considered together collectively).

Chapter IV: Design Strategies

Distilling the collected data from participant responses, design strategies were developed for use by landscape architects and designers in the production of future greenspaces. These strategies seek to address the needs of the five greenspace types individually, so that design can be tailored to the needs of a site as a greenspace type. The goal of implementing these design strategies is the maximization of the occupants' senses of comfort, safety, and belonging through manipulation of vegetation amount, surface texture, and light temperature.

Vegetation

The change in vegetation density particular to each greenspace type has different impacts on occupant's sense of comfort, safety and belonging as important indicators of wellbeing. Taking the reported participant levels of comfort, safety, and belonging, for each of the greenspace types at the baseline and comparing them to the respective increased model types can inform future designs. Of the five greenspaces studied, the timber-meadow and the greenroof model types saw an increase in indicators of wellbeing associated with the higher vegetation levels while the parkspace, community garden, and streetscape model types saw decreases in reported levels of comfort, safety, and belonging. Table 3 contains the associated degree of vegetation (amount of plants per unit of area) correlated with the higher level of reported sense of comfort, safety and belonging for each greenspace type.

Table 3: Vegetation data for models with highest reported indicators of wellbeing by greenspace type.

Model	Type	Amount in 25'x25' area
Parkspace	Baseline	51
Timber-Meadow	Increase	217
Community Garden	Baseline	98
Streetscape	Baseline	5
Greenroof	Increase	102

The distinct expectations people have for different greenspace types may have an impact on the optimum desired vegetation levels for a particular greenspace. Greenspace types such as the Timber-Meadow imply by nature a higher density of plant material, lower visibility, and increased spatial enclosure. Likewise, Parkspaces, for example, tend towards lower plant densities (using beds of contained planting, sporadic tree placements, and high amounts of low-cut turfgrass), higher visibility, and low levels of enclosure. It would seem to be apparent that these readily understood features of a given greenspace may, if absent, influence the occupant's sense of comfort, safety, or belonging. Perceiving this, designers should be conscious of how their manipulation of vegetation amount might disrupt or work counter to the well-grounded assumptions of occupants.

The requirements for the desired plant species, and the desired planting pattern within a greenspace, must also be kept in mind when determining the degree of vegetation amount. As the findings of this study suggests, increased amount of vegetation in the Timber-Meadow greenspace type is associated with increases in senses of comfort, safety and belonging. The use of shade tolerant plants as an understory may increase the perceived vegetation amount of a Timber-Meadow environment, as this greenspace type is suited to the utilization of targeted maintenance practices limited to those areas assigned to pedestrian use. Likewise, increased vegetation amount in Greenroof environments was also found to be associated with benefits to mental wellbeing. Dense use of carpeting plants is able to both achieve a high degree of plant coverage across the roof beds while also accounting for the limitations of the shallow substrate present on a greenroof. Likewise, upright planters can be used, as seen in this study's Greenroof model, to create an increased sense of enclosure within the greenspace. For the other greenspace types studied, the increased vegetation amount had negative associations with the indicators of mental wellbeing. This suggests that designers should take an approach to planting design in these environments where sight lines are not obstructed by planting and where the planting does not overly obstruct pedestrians' movement.

Texture

The perception of texture on a given surface is influenced by a variety of factors depending on the chosen material type used. The granularity of the finish on a concrete surface can be the primary factor in determining how the texture is perceived in that material. This entails that there is one variable at play in that material type. Likewise, the same principle will apply for gravel or decomposed granite surfaces, wherein the perceived texturedness of the surface is determined by the size of pebble or granule. Given the findings of this study, which suggests that the Parkspace and Timber-Meadow greenspace types may derive some benefits from an increase to their surface texture (coarseness), designers should take this into account when making materials choices for these sites. Likewise, for the Streetscape and Community Garden types there was a negative association found with coarser textured surfaces.

The magnification of a texture map is used to approximate the increase in texturedness for a surface between a baseline and the changed view. This allows comparison between the impacts of finer and coarser surfaces (See Table 4). The parkspace greenspace type saw higher reported levels of the indicators of wellbeing with the increased coarseness in surfaces, whereas the community garden, streetscape, and greenroof greenspace types saw higher levels of comfort, safety, and belonging in the baseline texture environments. The timber-meadow environment saw little difference between the two texture levels.

Table 4: The baseline magnification, the changed magnification, and the view attribute with the higher reported indicators of wellbeing by greenspace type.

Model	Type	Baseline Magnification	Increase Magnification
Parkspace	Increase	1.9x	41.6x
Timber-Meadow	Both	0.8x	4.0x
Community Garden	Baseline	1.9x	8.4x
Streetscape	Baseline	3.0x	41.6x
Greenroof	Baseline	0.2x	1.1x

A possible design strategy for these sites is to adjust surface textures in different parts of the site—with finer texture used neared to streets and coarser textures in the interiors of the sites or in heavily treed areas. The level of textures used in a greenspace should be purposeful. The findings of this study suggest that the Parkspace and Timber-Meadow type greenspaces see benefits associated with the coarser surface texture while Streetscape and Community Garden types see detrimental effects. With this in mind, in a composite site with multiple uses across it, using fine-textured surfaces nearer to those spaces where they are detrimental and coarse-textured surfaces in those spaces where they are beneficial may be an effective strategy for maximizing the comfort, safety, and belonging of occupants.

Lighting

Based upon the data collected from survey participants, there is reason to believe that light temperature has influence on the three investigated indicators of wellbeing. Knowing this, there are a variety of design strategies that can be taken to maximized perceived mental wellbeing. The lighting options used in the greenspace models were 5,500K (Kelvin), 2,800K, and 8200K (referred to herein as white, warm, and cool respectively).

Various streetscape options have differing correlated color temperature (CCT) values (Cai, 2015). These lighting options limit the light temperature values available to designers for selection in sites. Some examples of lighting options and their associated CCT can be seen in Table 5.

Table 5: Examples of public outdoor lighting options from the United States Department of Energy (DOE, 2017).

Light Type	Degrees Kelvin (K)
PC White LED	2700-6500
Narrowband Amber LED	1606
Low Pressure Sodium	1718
High Pressure Sodium	1959, 2041
Mercury Vapor	6924, 3725
Incandescent	2836
Halogen	2934
F32T8/830 Florescent	2940
F32T8/835 Florescent	3480
F32T8/841 Florescent	3969

Given the general negative responses participants reported to the cool nighttime light scenes, it is not unexpected that the preponderance of light elements available would have kelvin values lower than 8200K.

The use of varying of light temperature throughout a multi-use site is one way to maximize the perceived senses of comfort, safety, and belonging. For example, participants in Streetscapes were found to have more favorable responses to white light whereas participants in Timber-Meadow environments were more favorable to warm lighting. As such, one strategy that could be undertaken is to transition the light color from white lights on the street to warm lights in the interior of the site.

Finally, PC White LED lights have a wide range of CCT values available, and so their use in influencing the color temperature of lights to influence the wellbeing of participants is better able to meet the light temperature needs of different greenspaces.

Design Strategies

Summary Sheet

Vegetation Amount

Low levels of surface coarsness were favored in Community Gardens, Streetscapes, and Greenroofs while high levels were favore in Parkspaces, and in Timber-Meadows neither was favored.

Parkspace	Timber-Meadow	Community Garden	Streetscape	Greenroof
51 plants/25ft^2	217 plants/25ft^2	98 plants/25ft^2	5 plants/25ft^2	102 plants/25ft^2
Baseline	Increase	Baseline	Baseline	Increase

Surface Texture

Low levels of surface coarsness were favored in Community Gardens, Streetscapes, and Greenroofs while high levels were favore in Parkspaces, and in Timber-Meadows neither was favored.

Parkspace	Timber-Meadow	Community Garden	Streetscape	Greenroof
41.6x	0.8x - 4.0x	1.9x	3.0x	0.2x
Increase	Both	Baseline	Baseline	Baseline

Light Color Temperature

White nighttime lights were favored in Parkspaces, Timber-Meadows, Community Gardens, and Streetscapes while warm lights were favored in Greenroofs.

Parkspace	Timber-Meadow	Community Garden	Streetscape	Greenroof
5,500K	5,500K	5,500K	5,500K	2,800K
White	White	White	White	Warm

Chapter V: Conclusion

Summary

The two theories of human psychological response to natural environments (Stress Reduction Theory and Attention Restoration Theory) both conclude that access to views of natural spaces can benefit the wellbeing of occupants. In Stress Reduction Theory it is thought the changes in emotional states as a response to the composition of natural landscapes which are responsible for the psychological health benefits. Conversely, in Attention Restoration Theory it is held that the views of natural landscapes allow the occupant to restore mental fatigue and improve cognitive function by attention restoration. In each of these theories, there is an association supposed between the aesthetic qualities of a space and the mental wellbeing of the occupant.

The environmental attributes of light temperature, amount of vegetation , and surface texture are three qualities of a greenspace which may influence the mental wellbeing of an occupant through affecting their sense of comfort, safety, and belonging. These three environmental attributes were chosen due to their potential to be influenced by designers, their possibility of being represented in a virtual space, and their ability to be compared against a baseline site model without the need for drastic redesigning of the greenspace. Different greenspaces will have distinct balances of aesthetic attributes, functional ends, and means of interaction with humans and the surrounding context. These greenspace types were chosen due to their ability to be present within an urban setting, their distinctiveness from one another, and their ability to be readily modeled.

The light color temperature was represented using three distinct kelvin values (5,500K, 2,800K, and 8,200K). Information useful for the development of design strategies concerning the appropriate selection of lighting elements for greenspaces was gained from this study. White light was discovered to be associated with higher values of reported wellbeing indicators (sense of comfort, safety, and belonging) than warm and cool light in all greenspaces types except for the greenroof. Within the greenroof type, warm light had higher levels of reported indicators of wellbeing than white light.

The vegetation amount in this study was measured as a density of vegetation within an area around (not including turfgrass). This 3D modeled vegetated area was then projected onto a 2D image displayed on the interior of a 360° panoramic sphere of viewspace within the VR environment. Increases in reported wellbeing indicators were found to be associated with the baseline vegetation levels in all greenspace types except for the timber-meadow, where the increased vegetation amount value was favored by participants. This provides designers with useful information when designing environments for maximizing participant wellbeing.

The surface texture was, similar to vegetation amount, a comparison of a baseline level and an increased level of coarseness. Magnification rates between texture maps for surfaces were compared. The baseline level of texturedness was reported as being associated with higher levels of comfort, safety, and belonging by participants in community gardens, streetscapes, and greenroofs. However, in parkspaces the increased texturedness was reported as being associated with higher levels of wellbeing indicators by participants in the parkspace environment, while neither levels of texturedness were found to be associated with higher levels of wellbeing indicators in the timber-meadow environment. These findings provide insights into texture selection in different types of greenspaces.

Contribution of Work

The use of virtual reality as a tool for studying greenspaces has many advantages over more traditional methods. A VR experience is more immersive than a photo-board or 2D-perspective rendering. This study contributes to a further understanding of the use of virtual reality in design research, and provides a methodology that can be adapted for future study in the representation of landscape architecture in the digital space.

Significant correlations were found to exist between the presence of certain environmental attributes and participants senses of comfort, safety, and belonging in different greenspaces. Table 6 outlines how the findings of this study on vegetation, texture, and lighting apply to each of the five greenspace types to improve sense of comfort, safety, and belonging. Each greenspace was found to have particular associations with how environmental attributes influence the reported wellbeing indicators.

Table 6: Recommendations from Design Strategies.

Model	Vegetation Amount within 25'x25' area	Texture	Night Lighting Temperature
Parkspace	51 plants	Increased (41.6x)	5500K
Timber-Meadow	217 plants	Both (0.8x-4.0x)	5500K
Community Garden	98 plants	Baseline (1.9x)	5500K
Streetscape	5 plants	Baseline (3.0x)	5500K
Greenroof	302 plants	Baseline (0.2x)	2800K

Limitations

Due to the limitations of Lumion 11 and the time available for the development of models and surveys, the light color temperature was represented using only three distinct kelvin values (5,500K, 2,800K, and 8,200K). Nevertheless, useful information about the appropriate selection of lighting elements for greenspaces was gained from this study regarding the influence of light temperature on sense of comfort safety and belonging. Likewise, technological limitations prevented the inclusion and utilization of haptic feedback and audio. Lastly, due to time constraints the sample size of this study was small which limited the generalizable of this study. Despite this, significant correlations were discovered between environmental attributes and the senses of comfort, safety, and belonging that could encourage further study on this topic.

Broader Implications and Future Study

The use of a variety of design strategies within a design in order to maximize the positive impact of the environment on wellbeing of occupants is important. The strategies discussed within this report were limited to those related to the three environmental attributes studied. Future research should look at how additional environmental attributes influence occupant wellbeing in diverse greenspaces. Likewise, the study of how the environmental attributes differently influence wellbeing in other greenspace types is worthy of study so that a wider picture of the relationships between these variables can be understood. Furthermore, future research into the systematic classification of greenspaces is needed, so that they can more accurately and objectively be modeled for study.

A higher resolution spectrum of light with more varied temperatures shown to participants may provide designers with more precise information for deciding upon more specific Kelvin values are best suited for a given space. Future research which develops models using real-world commercially available lighting elements may provide additional data for use by designers.

Moreover, the preponderance of past research on the influences of light temperature on mental wellbeing and human psychology is done in indoor environments with lighting elements intended for indoor use. More research is needed to better understand lighting in outdoor spaces at night. Future research is needed to better understand how light color temperature can influence indicators of wellbeing in outdoor spaces.

Future research where several additional degrees of the amount of vegetation are presented to participants along spectra may provide designers with even more information related to plant coverage. Moreover, research measuring plant volume per unit of land area may shed greater light on how vegetation density is percived. Furthermore, research comparing the impact of texture changes in additional greenspace types could provide further information to designers and help build a greater understanding of the relationship between texture and occupant comfort, safety, and belonging to a higher degree of accuracy. Likewise, research into the impact of material change on percieved texture could help to better understand the subjective amount of texturedness of various surface types. Additionally, research using similar methods with a larger sample size could result in more generalizable findings. Finally, conducting the survey in a variety of locations may affect the responses to the VR environment, so research needs to be done to better understand this potential relationship.

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Appendix I: Timeline

Table 7: Project Timeline

	October				November				December				January				February				March				April				May			
Departmental Deadlines																																
Committee Members Determined (10.28)				*																												Committee Members Determined (10.28)
Final Proposal to Major Professor (11.5)					*																											Final Proposal to Major Professor (11.5)
Revised Draft to full Committee (11.19)							*																									Revised Draft to full Committee (11.19)
Prrogram of Study Submitted (11.19)							*																									Program of Study Submitted (11.19)
Prelimindary MPR Reviews (11.29-12-3)								*	*																							Prelimindary MPR Reviews (11.29-12-3)
Revisions due for spring enrollment (1.14)														*																		Revisions due for spring enrollment (1.14)
Substantial Completion draft (2.14)																		*														Substantial Completion draft (2.14)
Substantial Completion Reviews (2.21-25)																			*	*												Substantial Completion Reviews (2.21-25)
Final MPR draft due (3.22)																							*									Final MPR draft due (3.22)
Approval to Schedule Final Exam (3.25)																								*								Approval to Schedule Final Exam (3.25)
Final Defense Presentations (4.4-8)																									*							Final Defense Presentations (4.4-8)
Final Exam Ballots (4.15)																										*						Final Exam Ballots (4.15)
ETDR Upload (4.15)																										*						ETDR Upload (4.15)
Commencement (5.14)																														*		Commencement (5.14)
													Intersession Classes																			
Tasks																																
• Rhino Model Development					*																											
• IRB Application Completed						*																										
• Write Survey Questions				*																												
• Inquire about VR headset check-out						*																										
• Data collection and survey administration													*	*	*																	
• Data analysis															*	*																
• VR Headset Check-Out										*																						
• Survey Test-Runs										*	*																					
• Lumion Model Completion								*																								
• Rhino Model Completion							*																									
• Ongoing Literature Review				*	*				*	*						*	*	*	*	*												
• Methodology Revisions									*	*																						
• Survey Question Revisions									*																							
• Board Creation																												*				
• Return VR Headset																							*									
• Collaborate with Kirby in Rhino						*	*										*			*												
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Appendix II: IRB Approval

TO: Sara Hadavi Proposal Number: IRB-10986 Landscape Archit & Comm Plan

FROM: Rick Scheidt, Chair

Committee on Research Involving Human Subjects DATE: 01/18/2022

RE: Proposal Entitled, "The Influence of Environmental Attributes on Indicators of Wellbeing Across Greenspace Types within Virtual Landscapes."

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, 45 CFR §104(d), category:Exempt Category 2 Subsection ii.

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

Electronically signed by Rick Scheidt on 01/19/2022 9:17 AM ET

Appendix III: Surveys

Timber-Meadow

Survey: **Participant No.:___________________**

Have you ever used a VR headset before?

- Yes
- No

How comfortable are you using a VR headset? (1 being very low comfort and 5 being very high comfort)

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of safety within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort with the space?

1 - 2 - 3 - 4 - 5

Do you have spaces similar to the one pictured nearby to your home? Please fill in the bubble that applies:

- ○ Yes, similar spaces exist near my home
- ○ No, similar spaces do not exist near my home
- ○ Somewhat similar spaces exist near to my home

After viewing the environment, how would you rate your level of comfort within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of safety within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of belonging within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of safety within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of belonging within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort within the space?

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After viewing the environment, how would you rate your level of safety within the space?

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1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort within the space?

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1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of safety within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of belonging within the space?

1 - 2 - 3 - 4 - 5

Please fill out the following questionnaire

Racial identity (please mark all that apply):

- Black/African American
- White (Europe, Middle East, or North Africa)
- Asian
- American Indian/Alaska Native
- Native Hawaiian/ Pacific Islander

Age

- 18-24
- 25-34
- 35-44
- 45-64
- 65+

Gender Identity

- Male
- Female
- Other

Education Level (please mark the highest level that applies)

- Some High School
- High School Diploma
- Some College/Technical School
- Associates Degree
- Technical Degree
- Bachelor's Degree
- Master's Degree
- PhD/Doctorate Degree
- Post-Doctorate Studies

Did you experience any headache, nausea, or discomfort during the course of this survey?

- Yes
- No

Parkspace

Survey: **Participant No.:____________________**

Have you ever used a VR headset before?

- Yes
- No

How comfortable are you using a VR headset? (1 being very low comfort and 5 being very high comfort)

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of safety within the space?

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort with the space?

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Age

- 18-24
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- 45-64
- 65+

Gender Identity

- Male
- Female
- Other

Education Level (please mark the highest level that applies)

- Some High School
- High School Diploma
- Some College/Technical School
- Associates Degree
- Technical Degree
- Bachelor's Degree
- Master's Degree
- PhD/Doctorate Degree
- Post-Doctorate Studies

Did you experience any headache, nausea, or discomfort during the course of this survey?

- Yes
- No

Streetscape Survey:

Participant No.:___________________

Have you ever used a VR headset before?

- Yes
- No

How comfortable are you using a VR headset? (1 being very low comfort and 5 being very high comfort)

1 - 2 - 3 - 4 - 5

After viewing the environment, how would you rate your level of comfort within the space?

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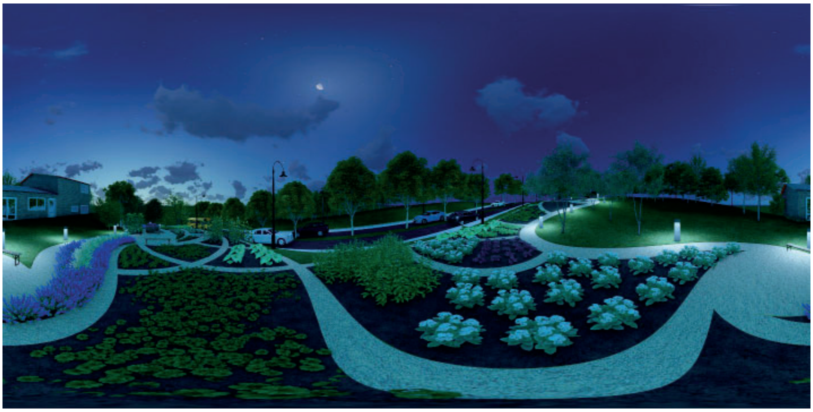

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Age

- 18-24
- 25-34
- 35-44
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- 65+

Gender Identity

- Male
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- Other

Education Level (please mark the highest level that applies)

- Some High School
- High School Diploma
- Some College/Technical School
- Associates Degree
- Technical Degree
- Bachelor's Degree
- Master's Degree
- PhD/Doctorate Degree
- Post-Doctorate Studies

Did you experience any headache, nausea, or discomfort during the course of this survey?

- Yes
- No

Appendix IV: Analysis Results

Table 8: Collective Greenspace Frequency Statistics.

		Baseline Comfort	Baseline Safety	Baseline Belonging	Increased Plant Density Comfort
N	Valid	51	51	51	51
	Missing	0	0	0	0
Mean		4.31	4.39	3.88	4.18
Median		4.00	5.00	4.00	4.00
Mode		5	5	5	4
Std. Deviation		.735	.827	1.194	.793
Variance		.540	.683	1.426	.628
Skewness		-.891	-1.742	-.792	-.581
Std. Error of Skewness		.333	.333	.333	.333

		Increased Plant Density Safety	Increased Plant Density Belonging	Increased Texture Comfort	Increased Texture Safety
N	Valid	51	51	51	51
	Missing	0	0	0	0
Mean		4.24	3.84	4.10	4.14
Median		5.00	4.00	4.00	4.00
Mode		5	5	4	5
Std. Deviation		.929	1.007	.922	1.077
Variance		.864	1.015	.850	1.161
Skewness		-.964	-.283	-1.156	-1.282
Std. Error of Skewness		.333	.333	.333	.333

		Increased Texture Belonging	White Light Comfort	White Light Safety	White Light Belonging
N	Valid	51	51	51	51
	Missing	0	0	0	0
Mean		3.84	3.98	4.00	3.84
Median		4.00	4.00	4.00	4.00
Mode		5	4	5	5
Std. Deviation		1.206	.969	1.114	1.102
Variance		1.455	.940	1.240	1.215
Skewness		-.683	-.645	-.814	-.330
Std. Error of Skewness		.333	.333	.333	.333

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging	Cool Light Comfort
N	Valid	51	51	51	51
	Missing	0	0	0	0
Mean		3.78	3.78	3.61	3.73
Median		4.00	4.00	4.00	4.00
Mode		5	5	4[a]	4
Std. Deviation		1.064	1.154	1.133	.918
Variance		1.133	1.333	1.283	.843
Skewness		-.481	-.370	-.278	-.383
Std. Error of Skewness		.333	.333	.333	.333

		Cool Light Safety	Cool Light Belonging
N	Valid	51	51
	Missing	0	0
Mean		3.65	3.47
Median		4.00	3.00
Mode		5	3
Std. Deviation		1.163	1.065
Variance		1.353	1.134
Skewness		-.451	-.127
Std. Error of Skewness		.333	.333

a. Multiple modes exist. The smallest value is shown

Table 9: Parkspace Frequency Statistics.

		Baseline Comfort	Baseline Safety	Baseline Belonging	Increased Plant Density Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.20	4.30	3.80	3.90
Median		4.00	4.50	4.00	4.00
Mode		4[a]	5	5	4
Std. Deviation		.789	.823	1.229	.994
Variance		.622	.678	1.511	.989
Skewness		-.407	-.687	-.431	-.610
Std. Error of Skewness		.687	.687	.687	.687

		Increased Plant Density Safety	Increased Plant Density Belonging	Increased Texture Comfort	Increased Texture Safety
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		3.90	3.80	4.10	4.40
Median		4.00	3.50	4.00	5.00
Mode		4	3[a]	5	5
Std. Deviation		.994	1.135	.876	.843
Variance		.989	1.289	.767	.711
Skewness		-.610	-.091	-.223	-1.001
Std. Error of Skewness		.687	.687	.687	.687

		Increased Texture Belonging	White Light Comfort	White Light Safety	White Light Belonging
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.10	3.80	3.80	3.70
Median		4.50	4.00	4.00	4.00
Mode		5	4	4	4[a]
Std. Deviation		1.101	.919	1.135	1.160
Variance		1.211	.844	1.289	1.344
Skewness		-.863	-.601	-.661	-.342
Std. Error of Skewness		.687	.687	.687	.687

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging	Cool Light Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		3.50	3.70	3.50	3.70
Median		3.50	4.00	3.50	4.00
Mode		3[a]	4[a]	3[a]	4
Std. Deviation		.850	1.160	1.080	1.059
Variance		.722	1.344	1.167	1.122
Skewness		.000	-.342	.000	-.659
Std. Error of Skewness		.687	.687	.687	.687

		Cool Light Safety	Cool Light Belonging
N	Valid	10	10
	Missing	0	0
Mean		3.40	3.20
Median		3.50	3.00
Mode		4	2[a]
Std. Deviation		.966	1.033
Variance		.933	1.067
Skewness		-.111	.272
Std. Error of Skewness		.687	.687

a. Multiple modes exist. The smallest value is shown

Table 10: Timber-Meadow Frequency Statistics.

		Baseline Comfort	Baseline Safety	Baseline Belonging	Increased Plant Density Comfort
N	Valid	11	11	11	11
	Missing	0	0	0	0
Mean		4.27	4.36	3.82	4.55
Median		4.00	5.00	4.00	5.00
Mode		4[a]	5	5	5
Std. Deviation		.905	1.206	1.401	.688
Variance		.818	1.455	1.964	.473
Skewness		-1.638	-2.536	-.943	-1.324
Std. Error of Skewness		.661	.661	.661	.661

		Increased Plant Density Safety	Increased Plant Density Belonging	Increased Texture Comfort	Increased Texture Safety
N	Valid	11	11	11	11
	Missing	0	0	0	0
Mean		4.64	4.00	4.18	4.27
Median		5.00	4.00	4.00	4.00
Mode		5	4[a]	4	4
Std. Deviation		.674	1.000	.603	.647
Variance		.455	1.000	.364	.418
Skewness		-1.800	-.733	-.028	-.291
Std. Error of Skewness		.661	.661	.661	.661

		Increased Texture Belonging	White Light Comfort	White Light Safety	White Light Belonging
N	Valid	11	11	11	11
	Missing	0	0	0	0
Mean		4.00	4.27	4.00	4.09
Median		4.00	4.00	4.00	5.00
Mode		5	4[a]	4[a]	5
Std. Deviation		1.095	.905	1.000	1.221
Variance		1.200	.818	1.000	1.491
Skewness		-.558	-1.638	-.733	-1.012
Std. Error of Skewness		.661	.661	.661	.661

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging	Cool Light Comfort
N	Valid	11	11	11	11
	Missing	0	0	0	0
Mean		4.09	3.91	3.82	3.91
Median		4.00	4.00	4.00	4.00
Mode		4[a]	3	5	4
Std. Deviation		.831	.944	1.250	.944
Variance		.691	.891	1.564	.891
Skewness		-.190	.209	-.338	-.663
Std. Error of Skewness		.661	.661	.661	.661

		Cool Light Safety	Cool Light Belonging
N	Valid	11	11
	Missing	0	0
Mean		3.82	3.45
Median		4.00	4.00
Mode		4[a]	4[a]
Std. Deviation		1.328	1.368
Variance		1.764	1.873
Skewness		-1.164	-.456
Std. Error of Skewness		.661	.661

a. Multiple modes exist. The smallest value is shown

Table 11: Streetscape Frequency Statistics.

		Baseline Comfort	Baseline Safety	Baseline Belonging	Increased Plant Density Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.40	4.30	3.90	4.10
Median		4.50	4.50	4.50	4.00
Mode		5	5	5	4
Std. Deviation		.699	.823	1.449	.738
Variance		.489	.678	2.100	.544
Skewness		-.780	-.687	-1.156	-.166
Std. Error of Skewness		.687	.687	.687	.687

		Increased Plant Density Safety	Increased Plant Density Belonging	Increased Texture Comfort	Increased Texture Safety
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.10	3.40	3.90	3.70
Median		4.50	3.00	4.00	3.50
Mode		5	3	4	3
Std. Deviation		1.101	.843	.994	1.059
Variance		1.211	.711	.989	1.122
Skewness		-.863	.389	-.610	.042
Std. Error of Skewness		.687	.687	.687	.687

		Increased Texture Belonging	White Light Comfort	White Light Safety	White Light Belonging
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		3.30	4.00	4.10	4.00

		Increased Texture Belonging	White Light Comfort	White Light Safety	White Light Belonging
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		3.30	4.00	4.10	4.00
Median		3.00	4.00	4.50	4.50
Mode		2[a]	5	5	5
Std. Deviation		1.160	1.054	1.197	1.155
Variance		1.344	1.111	1.433	1.333
Skewness		.342	-.712	-1.204	-.541
Std. Error of Skewness		.687	.687	.687	.687

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging	Cool Light Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		3.50	3.60	3.30	3.60
Median		3.00	3.00	3.00	3.50
Mode		3	3[a]	3	3
Std. Deviation		.972	1.265	1.059	.699
Variance		.944	1.600	1.122	.489
Skewness		.454	.132	.659	.780
Std. Error of Skewness		.687	.687	.687	.687

		Cool Light Safety	Cool Light Belonging
N	Valid	10	10
	Missing	0	0
Mean		3.50	3.40
Median		3.00	3.00
Mode		3	3
Std. Deviation		1.179	.966
Variance		1.389	.933
Skewness		.255	.813
Std. Error of Skewness		.687	.687

a. Multiple modes exist. The smallest value is shown

Table 12: Community Garden Frequency Statistics

		Baseline Comfort	Baseline Safety	Baseline Belonging	Increased Plant Density Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.40	4.30	3.90	4.10
Median		4.50	4.50	4.50	4.00
Mode		5	5	5	4
Std. Deviation		.699	.823	1.449	.738
Variance		.489	.678	2.100	.544
Skewness		-.780	-.687	-1.156	-.166
Std. Error of Skewness		.687	.687	.687	.687

		Increased Plant Density Safety	Increased Plant Density Belonging	Increased Texture Comfort	Increased Texture Safety
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.10	3.40	3.90	3.70
Median		4.50	3.00	4.00	3.50
Mode		5	3	4	3
Std. Deviation		1.101	.843	.994	1.059
Variance		1.211	.711	.989	1.122
Skewness		-.863	.389	-.610	.042
Std. Error of Skewness		.687	.687	.687	.687

		Increased Texture Belonging	White Light Comfort	White Light Safety	White Light Belonging
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		3.30	4.00	4.10	4.00
Median		3.00	4.00	4.50	4.50
Mode		2[a]	5	5	5
Std. Deviation		1.160	1.054	1.197	1.155
Variance		1.344	1.111	1.433	1.333
Skewness		.342	-.712	-1.204	-.541
Std. Error of Skewness		.687	.687	.687	.687

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging	Cool Light Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		3.50	3.60	3.30	3.60
Median		3.00	3.00	3.00	3.50
Mode		3	3[a]	3	3
Std. Deviation		.972	1.265	1.059	.699
Variance		.944	1.600	1.122	.489
Skewness		.454	.132	.659	.780
Std. Error of Skewness		.687	.687	.687	.687

		Cool Light Safety	Cool Light Belonging
N	Valid	10	10
	Missing	0	0
Mean		3.50	3.40
Median		3.00	3.00
Mode		3	3
Std. Deviation		1.179	.966
Variance		1.389	.933
Skewness		.255	.813
Std. Error of Skewness		.687	.687

a. Multiple modes exist. The smallest value is shown

Table 13: Greenroof Frequency Statistics.

		Baseline Comfort	Baseline Safety	Baseline Belonging	Increased Plant Density Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.40	4.60	4.10	4.30
Median		4.50	5.00	4.00	4.00
Mode		5	5	4	4
Std. Deviation		.699	.516	.738	.675
Variance		.489	.267	.544	.456
Skewness		-.780	-.484	-.166	-.434
Std. Error of Skewness		.687	.687	.687	.687

		Increased Plant Density Safety	Increased Plant Density Belonging	Increased Texture Comfort	Increased Texture Safety
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.60	4.40	4.30	4.40
Median		5.00	4.50	4.50	5.00
Mode		5	5	5	5
Std. Deviation		.516	.699	.949	1.265
Variance		.267	.489	.900	1.600
Skewness		-.484	-.780	-1.718	-2.602
Std. Error of Skewness		.687	.687	.687	.687

		Increased Texture Belonging	White Light Comfort	White Light Safety	White Light Belonging
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.10	4.10	4.10	3.80
Median		4.50	4.00	4.50	3.50
Mode		5	4[a]	5	3[a]
Std. Deviation		1.287	.994	1.197	1.135
Variance		1.656	.989	1.433	1.289
Skewness		-1.792	-1.085	-1.204	-.091
Std. Error of Skewness		.687	.687	.687	.687

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging	Cool Light Comfort
N	Valid	10	10	10	10
	Missing	0	0	0	0
Mean		4.10	4.10	4.20	4.00
Median		4.50	4.50	4.00	4.00
Mode		5	5	4	4
Std. Deviation		1.287	1.101	.919	.667
Variance		1.656	1.211	.844	.444
Skewness		-1.792	-.863	-1.546	.000
Std. Error of Skewness		.687	.687	.687	.687

		Cool Light Safety	Cool Light Belonging
N	Valid	10	10
	Missing	0	0
Mean		4.20	4.20
Median		4.00	4.00
Mode		4[a]	4
Std. Deviation		.789	.632
Variance		.622	.400
Skewness		-.407	-.132
Std. Error of Skewness		.687	.687

a. Multiple modes exist. The smallest value is shown

Table 14: Whole Sampling Pearson Correlations.

		Have you used a VR headset before?	Q2	Baseline Comfort
Have you used a VR headset before?	Pearson Correlation	1	.032	.494**
	Sig. (2-tailed)		.823	<.001
	N	51	51	51
Q2	Pearson Correlation	.032	1	.012
	Sig. (2-tailed)	.823		.932
	N	51	51	51
Baseline Comfort	Pearson Correlation	.494**	.012	1
	Sig. (2-tailed)	<.001	.932	
	N	51	51	51
Baseline Safety	Pearson Correlation	.345*	-.125	.749**
	Sig. (2-tailed)	.013	.383	<.001
	N	51	51	51
Baseline Belonging	Pearson Correlation	.330*	-.073	.636**
	Sig. (2-tailed)	.018	.612	<.001
	N	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	.048	-.192	-.132
	Sig. (2-tailed)	.738	.178	.356
	N	51	51	51
Increased Plant Density Comfort	Pearson Correlation	.229	.076	.521**
	Sig. (2-tailed)	.106	.598	<.001
	N	51	51	51
Increased Plant Density Safety	Pearson Correlation	.218	.073	.505**
	Sig. (2-tailed)	.124	.609	<.001
	N	51	51	51
Increased Plant Density Belonging	Pearson Correlation	.233	.030	.365**
	Sig. (2-tailed)	.100	.832	.008
	N	51	51	51
Increased Texture Comfort	Pearson Correlation	.367**	-.099	.603**
	Sig. (2-tailed)	.008	.488	<.001
	N	51	51	51

		Baseline Safety	Baseline Belonging	Familiarity: Do you have similar spaces near to your home?
Have you used a VR headset before?	Pearson Correlation	.345*	.330*	.048
	Sig. (2-tailed)	.013	.018	.738
	N	51	51	51
Q2	Pearson Correlation	-.125	-.073	-.192
	Sig. (2-tailed)	.383	.612	.178
	N	51	51	51
Baseline Comfort	Pearson Correlation	.749**	.636**	-.132
	Sig. (2-tailed)	<.001	<.001	.356
	N	51	51	51
Baseline Safety	Pearson Correlation	1	.635**	-.059
	Sig. (2-tailed)		<.001	.682
	N	51	51	51
Baseline Belonging	Pearson Correlation	.635**	1	-.020
	Sig. (2-tailed)	<.001		.887
	N	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	-.059	-.020	1
	Sig. (2-tailed)	.682	.887	
	N	51	51	51
Increased Plant Density Comfort	Pearson Correlation	.442**	.424**	-.092
	Sig. (2-tailed)	.001	.002	.522
	N	51	51	51
Increased Plant Density Safety	Pearson Correlation	.659**	.476**	.026
	Sig. (2-tailed)	<.001	<.001	.856
	N	51	51	51
Increased Plant Density Belonging	Pearson Correlation	.388**	.649**	.169
	Sig. (2-tailed)	.005	<.001	.237
	N	51	51	51
Increased Texture Comfort	Pearson Correlation	.473**	.537**	.132
	Sig. (2-tailed)	<.001	<.001	.358
	N	51	51	51

		Increased Plant Density Comfort	Increased Plant Density Safety	Increased Plant Density Belonging
Have you used a VR headset before?	Pearson Correlation	.229	.218	.233
	Sig. (2-tailed)	.106	.124	.100
	N	51	51	51
Q2	Pearson Correlation	.076	.073	.030
	Sig. (2-tailed)	.598	.609	.832
	N	51	51	51
Baseline Comfort	Pearson Correlation	.521**	.505**	.365**
	Sig. (2-tailed)	<.001	<.001	.008
	N	51	51	51
Baseline Safety	Pearson Correlation	.442**	.659**	.388**
	Sig. (2-tailed)	.001	<.001	.005
	N	51	51	51
Baseline Belonging	Pearson Correlation	.424**	.476**	.649**
	Sig. (2-tailed)	.002	<.001	<.001
	N	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	-.092	.026	.169
	Sig. (2-tailed)	.522	.856	.237
	N	51	51	51
Increased Plant Density Comfort	Pearson Correlation	1	.567**	.636**
	Sig. (2-tailed)		<.001	<.001
	N	51	51	51
Increased Plant Density Safety	Pearson Correlation	.567**	1	.489**
	Sig. (2-tailed)	<.001		<.001
	N	51	51	51
Increased Plant Density Belonging	Pearson Correlation	.636**	.489**	1
	Sig. (2-tailed)	<.001	<.001	
	N	51	51	51
Increased Texture Comfort	Pearson Correlation	.496**	.439**	.555**
	Sig. (2-tailed)	<.001	.001	<.001
	N	51	51	51

		Increased Texture Comfort	Increased Texture Safety	Increased Texture Belonging
Have you used a VR headset before?	Pearson Correlation	.367**	.168	.359**
	Sig. (2-tailed)	.008	.239	.010
	N	51	51	51
Q2	Pearson Correlation	-.099	-.064	-.033
	Sig. (2-tailed)	.488	.657	.819
	N	51	51	51
Baseline Comfort	Pearson Correlation	.603**	.475**	.418**
	Sig. (2-tailed)	<.001	<.001	.002
	N	51	51	51
Baseline Safety	Pearson Correlation	.473**	.567**	.304*
	Sig. (2-tailed)	<.001	<.001	.030
	N	51	51	51
Baseline Belonging	Pearson Correlation	.537**	.433**	.612**
	Sig. (2-tailed)	<.001	.002	<.001
	N	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	.132	.180	.080
	Sig. (2-tailed)	.358	.206	.575
	N	51	51	51
Increased Plant Density Comfort	Pearson Correlation	.496**	.369**	.364**
	Sig. (2-tailed)	<.001	.008	.009
	N	51	51	51
Increased Plant Density Safety	Pearson Correlation	.439**	.606**	.373**
	Sig. (2-tailed)	.001	<.001	.007
	N	51	51	51
Increased Plant Density Belonging	Pearson Correlation	.555**	.499**	.621**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Increased Texture Comfort	Pearson Correlation	1	.731**	.805**
	Sig. (2-tailed)		<.001	<.001
	N	51	51	51

		White Light Comfort	White Light Safety	White Light Belonging
Have you used a VR headset before?	Pearson Correlation	.183	.071	.177
	Sig. (2-tailed)	.197	.620	.214
	N	51	51	51
Q2	Pearson Correlation	-.021	-.063	-.116
	Sig. (2-tailed)	.884	.660	.419
	N	51	51	51
Baseline Comfort	Pearson Correlation	.486**	.147	.260
	Sig. (2-tailed)	<.001	.304	.066
	N	51	51	51
Baseline Safety	Pearson Correlation	.434**	.217	.223
	Sig. (2-tailed)	.001	.126	.116
	N	51	51	51
Baseline Belonging	Pearson Correlation	.430**	.150	.457**
	Sig. (2-tailed)	.002	.292	<.001
	N	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	.050	.261	.088
	Sig. (2-tailed)	.727	.064	.539
	N	51	51	51
Increased Plant Density Comfort	Pearson Correlation	.395**	.227	.307*
	Sig. (2-tailed)	.004	.110	.028
	N	51	51	51
Increased Plant Density Safety	Pearson Correlation	.538**	.445**	.388**
	Sig. (2-tailed)	<.001	.001	.005
	N	51	51	51
Increased Plant Density Belonging	Pearson Correlation	.427**	.339*	.518**
	Sig. (2-tailed)	.002	.015	<.001
	N	51	51	51
Increased Texture Comfort	Pearson Correlation	.562**	.370**	.409**
	Sig. (2-tailed)	<.001	.008	.003
	N	51	51	51

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging
Have you used a VR headset before?	Pearson Correlation	.126	.048	.133
	Sig. (2-tailed)	.377	.739	.352
	N	51	51	51
Q2	Pearson Correlation	.104	.035	.075
	Sig. (2-tailed)	.469	.809	.599
	N	51	51	51
Baseline Comfort	Pearson Correlation	.523**	.317*	.319*
	Sig. (2-tailed)	<.001	.023	.022
	N	51	51	51
Baseline Safety	Pearson Correlation	.416**	.405**	.253
	Sig. (2-tailed)	.002	.003	.073
	N	51	51	51
Baseline Belonging	Pearson Correlation	.373**	.271	.409**
	Sig. (2-tailed)	.007	.054	.003
	N	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	-.068	.042	.086
	Sig. (2-tailed)	.634	.770	.550
	N	51	51	51
Increased Plant Density Comfort	Pearson Correlation	.402**	.174	.324*
	Sig. (2-tailed)	.003	.223	.021
	N	51	51	51
Increased Plant Density Safety	Pearson Correlation	.416**	.496**	.412**
	Sig. (2-tailed)	.002	<.001	.003
	N	51	51	51
Increased Plant Density Belonging	Pearson Correlation	.378**	.349*	.541**
	Sig. (2-tailed)	.006	.012	<.001
	N	51	51	51
Increased Texture Comfort	Pearson Correlation	.552**	.396**	.478**
	Sig. (2-tailed)	<.001	.004	<.001
	N	51	51	51

		Cool Light Comfort	Cool Light Safety	Cool Light Belonging
Have you used a VR headset before?	Pearson Correlation	-.049	-.040	.009
	Sig. (2-tailed)	.732	.780	.951
	N	51	51	51
Q2	Pearson Correlation	.015	.003	.029
	Sig. (2-tailed)	.915	.985	.839
	N	51	51	51
Baseline Comfort	Pearson Correlation	.249	.109	.268
	Sig. (2-tailed)	.078	.447	.058
	N	51	51	51
Baseline Safety	Pearson Correlation	.224	.230	.309*
	Sig. (2-tailed)	.114	.104	.027
	N	51	51	51
Baseline Belonging	Pearson Correlation	.244	.114	.422**
	Sig. (2-tailed)	.085	.428	.002
	N	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	.185	.229	.251
	Sig. (2-tailed)	.194	.105	.076
	N	51	51	51
Increased Plant Density Comfort	Pearson Correlation	.343*	.177	.326*
	Sig. (2-tailed)	.014	.213	.020
	N	51	51	51
Increased Plant Density Safety	Pearson Correlation	.358**	.467**	.371**
	Sig. (2-tailed)	.010	<.001	.007
	N	51	51	51
Increased Plant Density Belonging	Pearson Correlation	.320*	.259	.592**
	Sig. (2-tailed)	.022	.066	<.001
	N	51	51	51
Increased Texture Comfort	Pearson Correlation	.245	.219	.380**
	Sig. (2-tailed)	.083	.122	.006
	N	51	51	51

		Race	Age	Sex	Education Level
Have you used a VR headset before?	Pearson Correlation	-.136	.368**	.411**	.137
	Sig. (2-tailed)	.342	.008	.003	.337
	N	51	51	51	51
Q2	Pearson Correlation	.070	-.229	-.043	-.147
	Sig. (2-tailed)	.625	.106	.764	.302
	N	51	51	51	51
Baseline Comfort	Pearson Correlation	-.171	.135	.295*	.126
	Sig. (2-tailed)	.229	.346	.035	.377
	N	51	51	51	51
Baseline Safety	Pearson Correlation	-.140	.094	.124	.067
	Sig. (2-tailed)	.329	.513	.385	.640
	N	51	51	51	51
Baseline Belonging	Pearson Correlation	-.070	.033	.127	-.090
	Sig. (2-tailed)	.628	.821	.374	.531
	N	51	51	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	-.122	.096	.241	.026
	Sig. (2-tailed)	.392	.503	.089	.859
	N	51	51	51	51
Increased Plant Density Comfort	Pearson Correlation	-.055	-.123	.188	-.070
	Sig. (2-tailed)	.702	.388	.185	.627
	N	51	51	51	51
Increased Plant Density Safety	Pearson Correlation	-.111	.030	.058	-.053
	Sig. (2-tailed)	.439	.834	.687	.713
	N	51	51	51	51
Increased Plant Density Belonging	Pearson Correlation	-.121	-.049	.306*	-.166
	Sig. (2-tailed)	.397	.732	.029	.243
	N	51	51	51	51
Increased Texture Comfort	Pearson Correlation	-.241	-.126	.372**	-.225
	Sig. (2-tailed)	.088	.379	.007	.112
	N	51	51	51	51

		Discomfort, Dizziness, etc	Participant
Have you used a VR headset before?	Pearson Correlation	.078	-.028
	Sig. (2-tailed)	.584	.845
	N	51	51
Q2	Pearson Correlation	.261	.057
	Sig. (2-tailed)	.064	.690
	N	51	51
Baseline Comfort	Pearson Correlation	-.007	.069
	Sig. (2-tailed)	.963	.633
	N	51	51
Baseline Safety	Pearson Correlation	-.084	.097
	Sig. (2-tailed)	.559	.498
	N	51	51
Baseline Belonging	Pearson Correlation	.116	.067
	Sig. (2-tailed)	.417	.641
	N	51	51
Familiarity: Do you have similar spaces near to your home?	Pearson Correlation	-.204	.404**
	Sig. (2-tailed)	.151	.003
	N	51	51
Increased Plant Density Comfort	Pearson Correlation	.162	-.081
	Sig. (2-tailed)	.255	.570
	N	51	51
Increased Plant Density Safety	Pearson Correlation	-.027	-.023
	Sig. (2-tailed)	.853	.874
	N	51	51
Increased Plant Density Belonging	Pearson Correlation	.211	.078
	Sig. (2-tailed)	.137	.585
	N	51	51
Increased Texture Comfort	Pearson Correlation	.027	.018
	Sig. (2-tailed)	.852	.900
	N	51	51

		Have you used a VR headset before?	Q2	Baseline Comfort
Increased Texture Safety	Pearson Correlation	.168	-.064	.475**
	Sig. (2-tailed)	.239	.657	<.001
	N	51	51	51
Increased Texture Belonging	Pearson Correlation	.359**	-.033	.418**
	Sig. (2-tailed)	.010	.819	.002
	N	51	51	51
White Light Comfort	Pearson Correlation	.183	-.021	.486**
	Sig. (2-tailed)	.197	.884	<.001
	N	51	51	51
White Light Safety	Pearson Correlation	.071	-.063	.147
	Sig. (2-tailed)	.620	.660	.304
	N	51	51	51
White Light Belonging	Pearson Correlation	.177	-.116	.260
	Sig. (2-tailed)	.214	.419	.066
	N	51	51	51
Warm Light Comfort	Pearson Correlation	.126	.104	.523**
	Sig. (2-tailed)	.377	.469	<.001
	N	51	51	51
Warm Light Safety	Pearson Correlation	.048	.035	.317*
	Sig. (2-tailed)	.739	.809	.023
	N	51	51	51
Warm Light Belonging	Pearson Correlation	.133	.075	.319*
	Sig. (2-tailed)	.352	.599	.022
	N	51	51	51
Cool Light Comfort	Pearson Correlation	-.049	.015	.249
	Sig. (2-tailed)	.732	.915	.078
	N	51	51	51
Cool Light Safety	Pearson Correlation	-.040	.003	.109
	Sig. (2-tailed)	.780	.985	.447
	N	51	51	51

		Baseline Safety	Baseline Belonging	Familiarity: Do you have similar spaces near to your home?
Increased Texture Safety	Pearson Correlation	.567**	.433**	.180
	Sig. (2-tailed)	<.001	.002	.206
	N	51	51	51
Increased Texture Belonging	Pearson Correlation	.304*	.612**	.080
	Sig. (2-tailed)	.030	<.001	.575
	N	51	51	51
White Light Comfort	Pearson Correlation	.434**	.430**	.050
	Sig. (2-tailed)	.001	.002	.727
	N	51	51	51
White Light Safety	Pearson Correlation	.217	.150	.261
	Sig. (2-tailed)	.126	.292	.064
	N	51	51	51
White Light Belonging	Pearson Correlation	.223	.457**	.088
	Sig. (2-tailed)	.116	<.001	.539
	N	51	51	51
Warm Light Comfort	Pearson Correlation	.416**	.373**	-.068
	Sig. (2-tailed)	.002	.007	.634
	N	51	51	51
Warm Light Safety	Pearson Correlation	.405**	.271	.042
	Sig. (2-tailed)	.003	.054	.770
	N	51	51	51
Warm Light Belonging	Pearson Correlation	.253	.409**	.086
	Sig. (2-tailed)	.073	.003	.550
	N	51	51	51
Cool Light Comfort	Pearson Correlation	.224	.244	.185
	Sig. (2-tailed)	.114	.085	.194
	N	51	51	51
Cool Light Safety	Pearson Correlation	.230	.114	.229
	Sig. (2-tailed)	.104	.428	.105
	N	51	51	51

		Increased Plant Density Comfort	Increased Plant Density Safety	Increased Plant Density Belonging
Increased Texture Safety	Pearson Correlation	.369**	.606**	.499**
	Sig. (2-tailed)	.008	<.001	<.001
	N	51	51	51
Increased Texture Belonging	Pearson Correlation	.364**	.373**	.621**
	Sig. (2-tailed)	.009	.007	<.001
	N	51	51	51
White Light Comfort	Pearson Correlation	.395**	.538**	.427**
	Sig. (2-tailed)	.004	<.001	.002
	N	51	51	51
White Light Safety	Pearson Correlation	.227	.445**	.339*
	Sig. (2-tailed)	.110	.001	.015
	N	51	51	51
White Light Belonging	Pearson Correlation	.307*	.388**	.518**
	Sig. (2-tailed)	.028	.005	<.001
	N	51	51	51
Warm Light Comfort	Pearson Correlation	.402**	.416**	.378**
	Sig. (2-tailed)	.003	.002	.006
	N	51	51	51
Warm Light Safety	Pearson Correlation	.174	.496**	.349*
	Sig. (2-tailed)	.223	<.001	.012
	N	51	51	51
Warm Light Belonging	Pearson Correlation	.324*	.412**	.541**
	Sig. (2-tailed)	.021	.003	<.001
	N	51	51	51
Cool Light Comfort	Pearson Correlation	.343*	.358**	.320*
	Sig. (2-tailed)	.014	.010	.022
	N	51	51	51
Cool Light Safety	Pearson Correlation	.177	.467**	.259
	Sig. (2-tailed)	.213	<.001	.066
	N	51	51	51

		Increased Texture Comfort	Increased Texture Safety	Increased Texture Belonging
Increased Texture Safety	Pearson Correlation	.731**	1	.709**
	Sig. (2-tailed)	<.001		<.001
	N	51	51	51
Increased Texture Belonging	Pearson Correlation	.805**	.709**	1
	Sig. (2-tailed)	<.001	<.001	
	N	51	51	51
White Light Comfort	Pearson Correlation	.562**	.558**	.562**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
White Light Safety	Pearson Correlation	.370**	.583**	.432**
	Sig. (2-tailed)	.008	<.001	.002
	N	51	51	51
White Light Belonging	Pearson Correlation	.409**	.372**	.598**
	Sig. (2-tailed)	.003	.007	<.001
	N	51	51	51
Warm Light Comfort	Pearson Correlation	.552**	.567**	.456**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Warm Light Safety	Pearson Correlation	.396**	.635**	.435**
	Sig. (2-tailed)	.004	<.001	.001
	N	51	51	51
Warm Light Belonging	Pearson Correlation	.478**	.537**	.627**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Cool Light Comfort	Pearson Correlation	.245	.362**	.231
	Sig. (2-tailed)	.083	.009	.103
	N	51	51	51
Cool Light Safety	Pearson Correlation	.219	.470**	.216
	Sig. (2-tailed)	.122	<.001	.127
	N	51	51	51

		White Light Comfort	White Light Safety	White Light Belonging
Increased Texture Safety	Pearson Correlation	.558**	.583**	.372**
	Sig. (2-tailed)	<.001	<.001	.007
	N	51	51	51
Increased Texture Belonging	Pearson Correlation	.562**	.432**	.598**
	Sig. (2-tailed)	<.001	.002	<.001
	N	51	51	51
White Light Comfort	Pearson Correlation	1	.667**	.802**
	Sig. (2-tailed)		<.001	<.001
	N	51	51	51
White Light Safety	Pearson Correlation	.667**	1	.684**
	Sig. (2-tailed)	<.001		<.001
	N	51	51	51
White Light Belonging	Pearson Correlation	.802**	.684**	1
	Sig. (2-tailed)	<.001	<.001	
	N	51	51	51
Warm Light Comfort	Pearson Correlation	.752**	.489**	.499**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Warm Light Safety	Pearson Correlation	.675**	.716**	.586**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Warm Light Belonging	Pearson Correlation	.740**	.587**	.767**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Cool Light Comfort	Pearson Correlation	.601**	.391**	.431**
	Sig. (2-tailed)	<.001	.005	.002
	N	51	51	51
Cool Light Safety	Pearson Correlation	.544**	.587**	.424**
	Sig. (2-tailed)	<.001	<.001	.002
	N	51	51	51

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging
Increased Texture Safety	Pearson Correlation	.567**	.635**	.537**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Increased Texture Belonging	Pearson Correlation	.456**	.435**	.627**
	Sig. (2-tailed)	<.001	.001	<.001
	N	51	51	51
White Light Comfort	Pearson Correlation	.752**	.675**	.740**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
White Light Safety	Pearson Correlation	.489**	.716**	.587**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
White Light Belonging	Pearson Correlation	.499**	.586**	.767**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Warm Light Comfort	Pearson Correlation	1	.743**	.775**
	Sig. (2-tailed)		<.001	<.001
	N	51	51	51
Warm Light Safety	Pearson Correlation	.743**	1	.791**
	Sig. (2-tailed)	<.001		<.001
	N	51	51	51
Warm Light Belonging	Pearson Correlation	.775**	.791**	1
	Sig. (2-tailed)	<.001	<.001	
	N	51	51	51
Cool Light Comfort	Pearson Correlation	.573**	.547**	.529**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Cool Light Safety	Pearson Correlation	.535**	.687**	.546**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51

		Cool Light Comfort	Cool Light Safety	Cool Light Belonging
Increased Texture Safety	Pearson Correlation	.362**	.470**	.431**
	Sig. (2-tailed)	.009	<.001	.002
	N	51	51	51
Increased Texture Belonging	Pearson Correlation	.231	.216	.417**
	Sig. (2-tailed)	.103	.127	.002
	N	51	51	51
White Light Comfort	Pearson Correlation	.601**	.544**	.590**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
White Light Safety	Pearson Correlation	.391**	.587**	.472**
	Sig. (2-tailed)	.005	<.001	<.001
	N	51	51	51
White Light Belonging	Pearson Correlation	.431**	.424**	.609**
	Sig. (2-tailed)	.002	.002	<.001
	N	51	51	51
Warm Light Comfort	Pearson Correlation	.573**	.535**	.550**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Warm Light Safety	Pearson Correlation	.547**	.687**	.589**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Warm Light Belonging	Pearson Correlation	.529**	.546**	.736**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Cool Light Comfort	Pearson Correlation	1	.806**	.687**
	Sig. (2-tailed)		<.001	<.001
	N	51	51	51
Cool Light Safety	Pearson Correlation	.806**	1	.670**
	Sig. (2-tailed)	<.001		<.001
	N	51	51	51

		Race	Age	Sex	Education Level
Increased Texture Safety	Pearson Correlation	-.389**	-.013	.284*	-.097
	Sig. (2-tailed)	.005	.925	.044	.496
	N	51	51	51	51
Increased Texture Belonging	Pearson Correlation	-.213	-.107	.288*	-.235
	Sig. (2-tailed)	.134	.456	.040	.097
	N	51	51	51	51
White Light Comfort	Pearson Correlation	-.176	.002	.183	.023
	Sig. (2-tailed)	.216	.988	.199	.871
	N	51	51	51	51
White Light Safety	Pearson Correlation	-.272	.047	.178	.114
	Sig. (2-tailed)	.054	.741	.211	.427
	N	51	51	51	51
White Light Belonging	Pearson Correlation	-.080	.015	.136	-.028
	Sig. (2-tailed)	.576	.917	.343	.847
	N	51	51	51	51
Warm Light Comfort	Pearson Correlation	-.312*	-.016	.268	.094
	Sig. (2-tailed)	.026	.912	.058	.511
	N	51	51	51	51
Warm Light Safety	Pearson Correlation	-.375**	.031	.212	.069
	Sig. (2-tailed)	.007	.828	.135	.633
	N	51	51	51	51
Warm Light Belonging	Pearson Correlation	-.254	-.045	.260	-.030
	Sig. (2-tailed)	.072	.754	.066	.833
	N	51	51	51	51
Cool Light Comfort	Pearson Correlation	-.113	.060	.069	.160
	Sig. (2-tailed)	.428	.674	.632	.263
	N	51	51	51	51
Cool Light Safety	Pearson Correlation	-.243	.157	.187	.204
	Sig. (2-tailed)	.086	.272	.190	.152
	N	51	51	51	51

		Discomfort, Dizziness, etc	Participant
Increased Texture Safety	Pearson Correlation	-.046	-.035
	Sig. (2-tailed)	.749	.807
	N	51	51
Increased Texture Belonging	Pearson Correlation	.176	-.027
	Sig. (2-tailed)	.215	.853
	N	51	51
White Light Comfort	Pearson Correlation	.082	-.072
	Sig. (2-tailed)	.569	.615
	N	51	51
White Light Safety	Pearson Correlation	.076	.050
	Sig. (2-tailed)	.598	.728
	N	51	51
White Light Belonging	Pearson Correlation	.193	-.092
	Sig. (2-tailed)	.174	.521
	N	51	51
Warm Light Comfort	Pearson Correlation	-.130	.020
	Sig. (2-tailed)	.362	.887
	N	51	51
Warm Light Safety	Pearson Correlation	-.120	.031
	Sig. (2-tailed)	.401	.830
	N	51	51
Warm Light Belonging	Pearson Correlation	-.013	.052
	Sig. (2-tailed)	.927	.719
	N	51	51
Cool Light Comfort	Pearson Correlation	-.075	-.023
	Sig. (2-tailed)	.599	.871
	N	51	51
Cool Light Safety	Pearson Correlation	-.077	.075
	Sig. (2-tailed)	.593	.601
	N	51	51

		Have you used a VR headset before?	Q2	Baseline Comfort
Cool Light Belonging	Pearson Correlation	.009	.029	.268
	Sig. (2-tailed)	.951	.839	.058
	N	51	51	51
Race	Pearson Correlation	-.136	.070	-.171
	Sig. (2-tailed)	.342	.625	.229
	N	51	51	51
Age	Pearson Correlation	.368**	-.229	.135
	Sig. (2-tailed)	.008	.106	.346
	N	51	51	51
Sex	Pearson Correlation	.411**	-.043	.295*
	Sig. (2-tailed)	.003	.764	.035
	N	51	51	51
Education Level	Pearson Correlation	.137	-.147	.126
	Sig. (2-tailed)	.337	.302	.377
	N	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	.078	.261	-.007
	Sig. (2-tailed)	.584	.064	.963
	N	51	51	51
Participant	Pearson Correlation	-.028	.057	.069
	Sig. (2-tailed)	.845	.690	.633
	N	51	51	51

		Baseline Safety	Baseline Belonging	Familiarity: Do you have similar spaces near to your home?
Cool Light Belonging	Pearson Correlation	.309*	.422**	.251
	Sig. (2-tailed)	.027	.002	.076
	N	51	51	51
Race	Pearson Correlation	-.140	-.070	-.122
	Sig. (2-tailed)	.329	.628	.392
	N	51	51	51
Age	Pearson Correlation	.094	.033	.096
	Sig. (2-tailed)	.513	.821	.503
	N	51	51	51
Sex	Pearson Correlation	.124	.127	.241
	Sig. (2-tailed)	.385	.374	.089
	N	51	51	51
Education Level	Pearson Correlation	.067	-.090	.026
	Sig. (2-tailed)	.640	.531	.859
	N	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	-.084	.116	-.204
	Sig. (2-tailed)	.559	.417	.151
	N	51	51	51
Participant	Pearson Correlation	.097	.067	.404**
	Sig. (2-tailed)	.498	.641	.003
	N	51	51	51

		Increased Plant Density Comfort	Increased Plant Density Safety	Increased Plant Density Belonging
Cool Light Belonging	Pearson Correlation	.326*	.371**	.592**
	Sig. (2-tailed)	.020	.007	<.001
	N	51	51	51
Race	Pearson Correlation	-.055	-.111	-.121
	Sig. (2-tailed)	.702	.439	.397
	N	51	51	51
Age	Pearson Correlation	-.123	.030	-.049
	Sig. (2-tailed)	.388	.834	.732
	N	51	51	51
Sex	Pearson Correlation	.188	.058	.306*
	Sig. (2-tailed)	.185	.687	.029
	N	51	51	51
Education Level	Pearson Correlation	-.070	-.053	-.166
	Sig. (2-tailed)	.627	.713	.243
	N	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	.162	-.027	.211
	Sig. (2-tailed)	.255	.853	.137
	N	51	51	51
Participant	Pearson Correlation	-.081	-.023	.078
	Sig. (2-tailed)	.570	.874	.585
	N	51	51	51

		Increased Texture Comfort	Increased Texture Safety	Increased Texture Belonging
Cool Light Belonging	Pearson Correlation	.380**	.431**	.417**
	Sig. (2-tailed)	.006	.002	.002
	N	51	51	51
Race	Pearson Correlation	-.241	-.389**	-.213
	Sig. (2-tailed)	.088	.005	.134
	N	51	51	51
Age	Pearson Correlation	-.126	-.013	-.107
	Sig. (2-tailed)	.379	.925	.456
	N	51	51	51
Sex	Pearson Correlation	.372**	.284*	.288*
	Sig. (2-tailed)	.007	.044	.040
	N	51	51	51
Education Level	Pearson Correlation	-.225	-.097	-.235
	Sig. (2-tailed)	.112	.496	.097
	N	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	.027	-.046	.176
	Sig. (2-tailed)	.852	.749	.215
	N	51	51	51
Participant	Pearson Correlation	.018	-.035	-.027
	Sig. (2-tailed)	.900	.807	.853
	N	51	51	51

		White Light Comfort	White Light Safety	White Light Belonging
Cool Light Belonging	Pearson Correlation	.590**	.472**	.609**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Race	Pearson Correlation	-.176	-.272	-.080
	Sig. (2-tailed)	.216	.054	.576
	N	51	51	51
Age	Pearson Correlation	.002	.047	.015
	Sig. (2-tailed)	.988	.741	.917
	N	51	51	51
Sex	Pearson Correlation	.183	.178	.136
	Sig. (2-tailed)	.199	.211	.343
	N	51	51	51
Education Level	Pearson Correlation	.023	.114	-.028
	Sig. (2-tailed)	.871	.427	.847
	N	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	.082	.076	.193
	Sig. (2-tailed)	.569	.598	.174
	N	51	51	51
Participant	Pearson Correlation	-.072	.050	-.092
	Sig. (2-tailed)	.615	.728	.521
	N	51	51	51

		Warm Light Comfort	Warm Light Safety	Warm Light Belonging
Cool Light Belonging	Pearson Correlation	.550**	.589**	.736**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	51	51	51
Race	Pearson Correlation	-.312*	-.375**	-.254
	Sig. (2-tailed)	.026	.007	.072
	N	51	51	51
Age	Pearson Correlation	-.016	.031	-.045
	Sig. (2-tailed)	.912	.828	.754
	N	51	51	51
Sex	Pearson Correlation	.268	.212	.260
	Sig. (2-tailed)	.058	.135	.066
	N	51	51	51
Education Level	Pearson Correlation	.094	.069	-.030
	Sig. (2-tailed)	.511	.633	.833
	N	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	-.130	-.120	-.013
	Sig. (2-tailed)	.362	.401	.927
	N	51	51	51
Participant	Pearson Correlation	.020	.031	.052
	Sig. (2-tailed)	.887	.830	.719
	N	51	51	51

		Cool Light Comfort	Cool Light Safety	Cool Light Belonging
Cool Light Belonging	Pearson Correlation	.687**	.670**	1
	Sig. (2-tailed)	<.001	<.001	
	N	51	51	51
Race	Pearson Correlation	-.113	-.243	-.193
	Sig. (2-tailed)	.428	.086	.174
	N	51	51	51
Age	Pearson Correlation	.060	.157	-.034
	Sig. (2-tailed)	.674	.272	.811
	N	51	51	51
Sex	Pearson Correlation	.069	.187	.213
	Sig. (2-tailed)	.632	.190	.134
	N	51	51	51
Education Level	Pearson Correlation	.160	.204	-.003
	Sig. (2-tailed)	.263	.152	.984
	N	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	-.075	-.077	-.046
	Sig. (2-tailed)	.599	.593	.746
	N	51	51	51
Participant	Pearson Correlation	-.023	.075	.182
	Sig. (2-tailed)	.871	.601	.202
	N	51	51	51

		Race	Age	Sex	Education Level
Cool Light Belonging	Pearson Correlation	-.193	-.034	.213	-.003
	Sig. (2-tailed)	.174	.811	.134	.984
	N	51	51	51	51
Race	Pearson Correlation	1	-.208	-.408**	-.061
	Sig. (2-tailed)		.143	.003	.670
	N	51	51	51	51
Age	Pearson Correlation	-.208	1	.216	.584**
	Sig. (2-tailed)	.143		.129	<.001
	N	51	51	51	51
Sex	Pearson Correlation	-.408**	.216	1	.203
	Sig. (2-tailed)	.003	.129		.153
	N	51	51	51	51
Education Level	Pearson Correlation	-.061	.584**	.203	1
	Sig. (2-tailed)	.670	<.001	.153	
	N	51	51	51	51
Discomfort, Dizziness, etc	Pearson Correlation	-.033	.137	.069	.063
	Sig. (2-tailed)	.817	.337	.632	.662
	N	51	51	51	51
Participant	Pearson Correlation	.136	-.162	-.029	.090
	Sig. (2-tailed)	.340	.256	.839	.531
	N	51	51	51	51

		Discomfort, Dizziness, etc	Participant
Cool Light Belonging	Pearson Correlation	-.046	.182
	Sig. (2-tailed)	.746	.202
	N	51	51
Race	Pearson Correlation	-.033	.136
	Sig. (2-tailed)	.817	.340
	N	51	51
Age	Pearson Correlation	.137	-.162
	Sig. (2-tailed)	.337	.256
	N	51	51
Sex	Pearson Correlation	.069	-.029
	Sig. (2-tailed)	.632	.839
	N	51	51
Education Level	Pearson Correlation	.063	.090
	Sig. (2-tailed)	.662	.531
	N	51	51
Discomfort, Dizziness, etc	Pearson Correlation	1	-.240
	Sig. (2-tailed)		.089
	N	51	51
Participant	Pearson Correlation	-.240	1
	Sig. (2-tailed)	.089	
	N	51	51

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

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

Table 15: Difference Between Mean of Baseline and Modified Attribute.

Mean

Participant	DIFF_PLNT_CMFT	DIFF_PLNT_SFTY	DIFF_PLNT_BLNG	DIFF_TXTR_CMFT
Timber-Meadow	-.2727	-.2727	-.1818	.0909
Parkspace	.3000	.4000	.0000	.1000
Streetscape	.3000	.2000	.5000	.5000
CommunityGarden	.3000	.5000	.2000	.3000
Greenroof	.1000	.0000	-.3000	.1000
Total	.1373	.1569	.0392	.2157

Report

Mean

Participant	DIFF_TXTR_SFTY	DIFF_TXTR_BLNG	DIFF_NEUT_CMFT	DIFF_NEUT_SFTY
Timber-Meadow	.0909	-.1818	.0000	.3636
Parkspace	-.1000	-.3000	.4000	.5000
Streetscape	.6000	.6000	.4000	.2000
CommunityGarden	.5000	.1000	.6000	.4000
Greenroof	.2000	.0000	.3000	.5000
Total	.2549	.0392	.3333	.3922

Report

Mean

Participant	DIFF_NEUT_BLNG	DIFF_WARM_CMFT	DIFF_WARM_SFTY	DIFF_WARM_BLNG
Timber-Meadow	-.2727	.1818	.4545	.0000
Parkspace	.1000	.7000	.6000	.3000
Streetscape	-.1000	.9000	.7000	.6000
CommunityGarden	.2000	.6000	.8000	.6000
Greenroof	.3000	.3000	.5000	-.1000
Total	.0392	.5294	.6078	.2745

Report

Mean

Participant	DIFF_COOL_CMFT	DIFF_COOL_SFTY	DIFF_COOL_BLNG
Timber-Meadow	.3636	.5455	.3636
Parkspace	.5000	.9000	.6000
Streetscape	.8000	.8000	.5000
CommunityGarden	.9000	1.1000	.7000
Greenroof	.4000	.4000	-.1000
Total	.5882	.7451	.4118

Table 16: Previous Use of VR.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	26	51.0	51.0	51.0
	No	25	49.0	49.0	100.0
	Total	51	100.0	100.0	

Table 9: Previous Virtual Reality Usage.

Table 17: Participant Reported Gender.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	27	52.9	52.9	52.9
	Female	24	47.1	47.1	100.0
	Total	51	100.0	100.0	

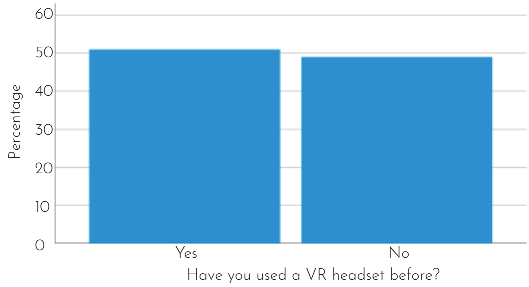

Figure 40: Percent Previous VR Usage.

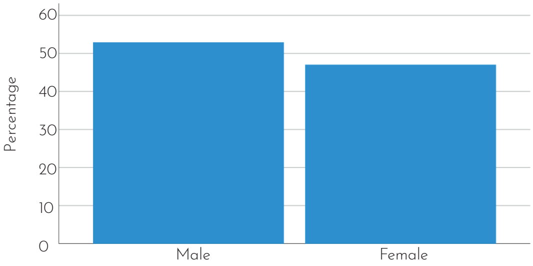

Figure 41: Percent Reported Gender.

Appendix V: Additional Information

The perception of texture on a given surface will be influenced by a variety of factors depending on the chosen material type used. The granularity of the finish on a concrete surface can be the primary factor in determining how the texture is perceived in that material. This entails that there is one variable at play in that material type. Likewise, the same principle will apply for gravel or decomposed granite surfaces, wherein the perceived texturedness of the surface is determined by the size of pebble or granule. Given the findings of this study, which suggests that the Parkspace and Timber-Meadow greenspace types may derive some benefits from an increase to their surface texture, designers should take this into account when making materials choices for these sites. Likewise, for the Streetscape and Community Garden types there was a negative association found with coarser textured surfaces. A possible design strategy for these sites is to adjust surface textures in different parts of the site—with finer texture used neared to streets and coarser textures in the interiors of the sites or in heavily treed areas.

Pavers present a much more complex series of variables when in terms of the perception of texture in a space. Similar to the concrete or decomposed granite surfaces, the size of grain will serve as one factor in the perceived degree of texture in the used pavers. However, there is the additional variable of the paver size used. Smaller pavers will be perceived as having a higher degree of texture per unit of area. This is a result of the differences in the ratio of the scale factor to the perimeter of a paver and the scale factor to the area of the paver.

More precisely:

> If the sides of paver m and of paver n have a scale factor of m/n, then the ratio of their perimeters will just be that scale factor, (m/n). However, the ratio of their areas will be $(m/n)^2$. This means that the area of a paver increases much more quickly compared to its perimeter as its size scales, resulting in smaller pavers appearing to have higher amounts of texture as their joints take up a higher proportion of the surface per unit of area.

The joint type of a paver itself will have an impact on the perceived degree of texture. The many options for paver joints may include direct abutting pavers, interlocking pavers, the use of sand or stone dust, gravel or decomposed granite, and the use of walkable groundcovers between pavers. These different paver joint options will have different texture values. This should be kept in mind when determining which type of paver joint is most suitable for a space—whether the aim is to increase or decrease the texture in a space. Likewise, the ratio of the area of the paver itself and the joint area per paver unit may influence the perception of texture. This ratio (Apaver : Ajoint) can be calculated by taking the area of a paver (Apaver = xy) and determining the area of the joint per paver unit (Ajoint = 2z(2z + x + y) where x and y are the length and width of the paver respectively and z is ½ the width of the joint.

Furthermore, the type of bond used for a given paving pattern will also influence the perceived texture of a surface. Various common bond patterns include running bond, stacked bond or jack-on-jack, herringbone, and basketweave. Each of these will change the ratio of the perceived joint area to the perceived paver area, influencing the total degree of perceived texture on the surface, when being viewed at an angle. Moreover, pavers viewed at perspective will have different distortions based on their bond type. Running bond, stacked bond, and basketweave will each have the same distortions due to their being comprised of repeating, regular, and rectangular pattern of pavers. Herringbone is distinct because its pattern is not a repeated layering of rectangles; instead, it is comprised of interlocking and diagonally oriented rectangular patterns. Below are the four aforementioned bond types oriented flat, isometrically, and in an approximated perspective view—each in turn at 0°, 45°, 90°, and 135°.

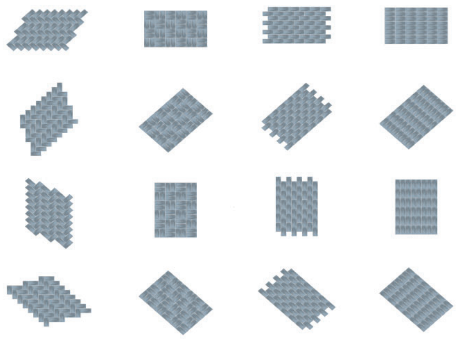

Figure 42: Bond Types Seen from Above. (Left to right: Herringbone, Basketweave, Runningbond, and Stacked Bond).

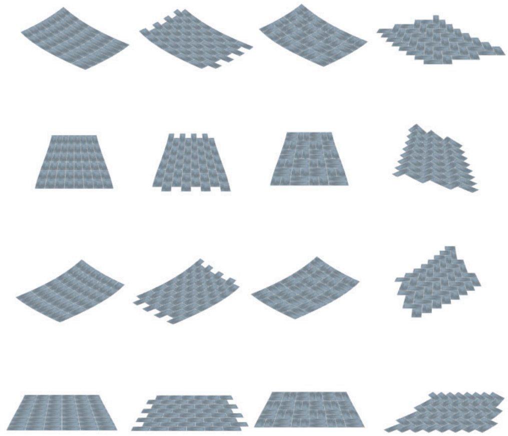

Figure 43: Bond Types at a 30° Isometric View.

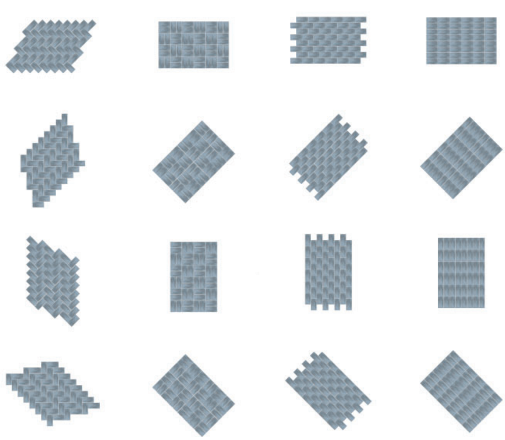

Figure 44: Bond Types Seen Through an Approximate Perspective Distortion.

The level of textures used in a greenspace should be purposeful. This data collected in this study suggests that the Parkspace and Timber-Meadow type greenspaces see benefits associated with the coarser texture while Streetscape and Community Garden types see detrimental effects. With this in mind, in a composite site with multiple uses across it, using fine-textured surfaces nearer to those spaces where they are detrimental and coarse-textured surfaces in those spaces where they are beneficial may be an effective strategy for maximizing the wellbeing of occupants.

Lastly, the individual characteristics of a greenspace type qua greenspace type will reflect the extrinsically imposed ends of the space as an artifact. Designers should keep the unique qualities of a greenspace type in mind when selecting the surface type best suited for use. While two surfaces might possess identical degrees of texture, the use of one might be more suitable and so should be favored. Likewise, the use of a surface type with a less ideal degree of texture might be better suited to a space due to factors other than its influence on the studied indicators of wellbeing, such as practicality, availability, cost, aesthetic desire, function, maintenance concerns, longevity, the nature of the thing in question, or impacts from the environment.