BIOPHILIC DESIGN IN RESIDENTIAL ENVIRONMENTS: EXPLORING EMOTIONS, RESTORATIVENESS, AND SATISFACTION

By

Evan Cameron

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Environmental Design - Master of Arts

2025

ABSTRACT

This study explores how varying levels of biophilic implementation can influence emotional and behavioral responses within residential interiors. A total of 150 complete survey responses were collected from participants who viewed digital images of an interior living space that displayed varying amounts of indoor plants (control, moderate, and intense). Participants provided self-reported responses regarding their emotions (pleasure and arousal), perceived restorativeness, satisfaction, and willingness to stay. Results showed that perceived levels of pleasure, restorativeness, satisfaction, and willingness to stay all increased with levels of greenery. Arousal peaked at the moderate level of greenery which suggests there is a threshold that is preferred by occupants. These findings support current literature on biophilic design and related theories such as the pleasure & arousal framework and attention restoration theory, and provide the opportunity to further understand the effects of biophilic practices on users' wellbeing and spatial preferences in residential environments.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

The growing disconnect between humans and nature in residential settings has led to increased interest in biophilic design (Wilson, 1984), which seeks to connect people with nature by incorporating natural elements into built environments. Recently, there has been a growing body of research highlighting the physical, psychological, and ecological benefits of biophilic design. For example, research has shown that brief interactions with nature, lasting as little as five to twenty minutes, can offer measurable cognitive and mental health benefits, including improved focus, reduced stress, and enhanced overall well-being (Browning et al., 2014; Lencastre et al., 2022; Moslehian et al., 2023; Söderlund, & Newman, 2017). Findings from multiple studies have shown that individuals exposed to views of nature, whether direct or indirect, reported lower stress levels and improved mood (Huntsman & Bulaj, 2022; Lee & Park, 2022; Li et al. 2025; Lohr et al., 1995). These findings reinforce the growing body of evidence supporting biophilic design, suggesting that even subtle integrations of nature can have profound psychological and physiological benefits in interior spaces.

However, although the existing body of research on biophilic design in built environments has expanded significantly in recent years, there is lack of studies focusing on the emotional effects of biophilic design in residential environments. New research is being conducted in residential settings largely in response to increased environmental concerns and the general desire to lead a healthier life by the public. Much of the existing literature has focused on settings in workplaces, hospitals, and large residential complexes, examining how biophilic elements impact occupant well-being and satisfaction on a larger scale.

Currently available literature on biophilic design primarily focuses on its emotional impact in commercial spaces and large-scale residential settings, including community living

centers, apartments, and hotels. It is critical to address the gap in knowledge by examining how the amount of indoor plants can affect occupant perceptions and emotional responses in residential environments.

The Purpose of the Study

The purpose of this study is to examine how the amount of indoor plants affect occupant emotions (i.e., pleasure and arousal), restorativeness, satisfaction, and willingness to stay in a space, with a focus on the amount of indoor plants in the residential environment. The specific objective of this study is to answer the following research questions:

RQ1: How do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' emotions (i.e., pleasure and arousal)?

RQ2: How do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' perception of restorativeness?

RQ3: How do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' satisfaction?

RQ4: How do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' willingness to stay in a space?

The Significance of the Study

This study will compile a comprehensive overview of the benefits associated with biophilic design, providing valuable insights that can be shared with design professionals. The findings are expected to contribute to the broader adoption of sustainable building practices that not only enhance environmental performance but also promote emotional well-being and user satisfaction.

This study addresses the limited research on emotional responses to biophilic design in residential spaces, which is primarily focused on workplaces and public buildings. While biophilia is known to elicit emotional responses, little research explores how varying implementation levels and specific design features influence these reactions. This study is expected to provide insights into biophilic applications in personal living spaces, enhancing understanding of their impact on emotional well-being, and explore how different levels of greenery elements impact emotions in home environments, filling a gap in understanding indoor planting's role in private living spaces.

Overview of the Following Chapters

Chapter 2 is the literature review for this research paper and is composed of sections that explore the application methods and implementation rates of biophilic design features. The guiding principles of the pleasure & arousal framework and the attention restoration theory are each explored in this section due to the guided use of their questions and principles.

Chapter 3 includes the research methods and applications that were used for this study. Explanation of the stimuli creation processes, participant selection, data collection process, and survey measurement methods is included.

Chapter 4 begins with a description of participant demographics and continues with results from the reliability test and descriptive statistics that overview all measured variables, (pleasure, arousal, restorativeness, satisfaction, and willingness to stay in the space). The results of statistical methods including repeated measures ANOVA and Post hoc comparison are reported in this chapter.

Chapter 5 presents a discussion of the discovered results that examine each of the research variables, as well as a review of the known study limitations. This section also explores

the implications and interpretations that were revealed and potential research topics that can fill in gaps related to emotional impacts of indoor plants. The chapter concludes with a comprehensive conclusion of the research study and its results.

CHAPTER 2: LITERATURE REVIEW

Biophilic Design

One of the first uses of the term “Biophilia” was used by psychologist Erich Fromm to describe "the passionate love of life and of all that is alive"(Fromm, 1964). This concept was later described as 'the innate tendency in human beings to focus on life and lifelike processes” (Wilson, 1984). Existing literature findings emphasize the therapeutic potential of biophilic elements in the built environment, reinforcing their role in promoting psychological well-being and recovery.

How incorporating biophilia into architecture is more complex than placing plants and using greenery but instead is a more in-depth practice of manipulating the physical, sensory, and metaphorical types of nature (Zhong et al., 2022). By incorporating natural elements indoors, individuals can experience the comfort and connection benefits of nature without leaving their personal living space. While direct exposure to nature is believed to be ideal, research suggests that biophilic design extends beyond close physical proximity to plants, the potential benefits encompass a broader relationship including indirect experiences such as views of green spaces, natural materials, and biomorphic design patterns (Yassein & Ebrahiem, 2018).

Previous research indicates that the amount of indoor plants in an indoor environment such as the visible greenery rate, can affect occupant experiences. According to Zhaoming et al. (2022), participants exposed to vegetative walls at an 80% implementation rate experienced the highest stress reduction (Zhaoming et al., 2022). This study demonstrates a direct correlation between biophilic incorporation rates and user experiences, aligning with similar findings on vegetation density and its psychological effects. Additionally, research suggests that vegetation rates have an inflection point near 20% (Rhee et al., 2023). Rhee et al. (2023) further found that

maximum benefits for stress reduction and restoration occur at vegetation implementation rates between 13% and 24%.

Biophilia in Healthcare and Commercial Settings

Biophilic design features have been associated with significant physical and mental health benefits across diverse global settings (Kellert & Wilson 1993; Mencer, 2023). Mencer's (2023) review of studies documented the long-term advantages of these practices and the effects that indoor plants can have on patients' perceptions of hospital experiences. Additional research highlights the applicability of biophilic design in critical health interventions, including suicide prevention and the reduction of suicidal thoughts and feelings (Booth et al., 2023).

Research indicates that individuals overwhelmingly prefer direct interactions with nature, expressing dissatisfaction with the limited availability of green spaces. This is supported by results of a study that found of 138 polled cancer center staff and patients, patients placed natural lighting, views of nature, and thermal comfort at the top of 11 chosen categories, while caregivers preferred access to private and quiet spaces (Tinner et al., 2018). These findings support the argument for higher rates of biophilic practices to be adopted in medical facilities.

Studies suggest that even virtual reality environments can effectively simulate biophilic experiences, making it a valuable tool for workplaces and healthcare settings where direct access to nature may be limited. In a study comparing physical and virtual biophilic settings of an office building, Yin et al. (2018) found that participants who were exposed to natural elements had 8.6 mmHg lower systolic and 3.6 mmHg lower diastolic blood pressure. Participants demonstrated a 14% improvement in short-term memory and a reduction in negative emotions, with positive benefits being seen in participants after being exposed to both reality and virtual exposure (Yin et al., 2018).

Research has shown that incorporating natural elements into built environments can counteract the negative effects of non-places and increase enjoyment in workplaces. In a pioneering study, Lohr et al. (1995) found that the presence of indoor potted plants significantly reduced perceived stress levels while simultaneously enhancing occupants' concentration and focus. This study examined the experiences of workers in windowless offices compared to those with access to natural views.

Biophilia in Residential Spaces

Biophilic design is a widely favored approach for fostering human-nature connections, yet it remains underutilized in residential settings. While biophilic design has been extensively studied in commercial and medical settings, its application in residential architecture remains an area of growing interest (Clark-Havron, 2023). Clark-Havron (2023) reviewed biophilic design practices in residential homes, compiling case studies from previous research to explore small scale applications. Clark-Havron's (2023) review discusses how all of their selected studies collectively agreed that biophilia and biophilic design is important and should be emphasized further.

Empirical findings support the psychological benefits of biophilic integration in residential settings. Aabouelela (2023) conducted a study of university staff and students and found that there is a relationship between negative feelings and absence of natural elements. The author emphasizes "the effectiveness of integrating biophilic design into the design of residential units to improve human mental health and well-being" (Aabouelela, 2023).

The integration of greenery in residential developments has been an increasingly recognized practice that is essential for psychological well-being and sustainability. A case study examining the design of "Sinpaş Altınoran", a residential site in Ankara, Turkey, highlights how

biophilic elements contribute to stress reduction, enhanced relaxation, and improved environmental quality (Kahveci & Güneş, 2020,). The goal of this study was to determine the site requirements for urban living centers and what the criteria is that determines the classification of "Biophilic Design." Kahveci and Güneş (2020) claim that "enhanced connection can contribute to our welfare by means of minimizing stress, improving rejuvenation, thus assisting to reduce the costs and enhancing the outcomes within the built environment" (p. 127). Kahveci & Güneş determined that the large-scale development included enough environmental enhancement to meet their criteria for using structural and plant materials, with a ratio of 71% (p.150).

Research on biophilic design patterns suggests that greenery enhances mood, reduces stress, and improves cognitive clarity by replicating natural landscapes. Green spaces in residential settings are widely recognized for their mental health, cognitive, and overall well-being benefits (Ryan et al., 2014). Ryan et al. (2014) state that "good biophilic design draws from nature in a manner that is equally inspirational and restorative without disturbing the functionality of the space" (p. 63), highlighting the need to balance aesthetics and function in residential greenery integration. Ryan et al.(2014), found that the presence of vegetation, dynamic lighting, and natural textures has been shown to lower cortisol levels and improve emotional stability, making biophilic interventions valuable in urban housing projects. Further research can be conducted to quantify the effects of indirect exposure to nature, such as interior green walls or framed garden views.

Gaining insight into the decision-making factors behind willingness to pay can enable policymakers and developers to implement targeted strategies that balance affordability with environmental sustainability, ensuring that green infrastructure becomes a fundamental

component of future residential planning. The economic value of green infrastructure has become an area of growing interest. Research indicates that homebuyers are willing to pay higher prices for properties that incorporate greenery (Zalejska-Jonsson et al., 2020, p. 2). Green infrastructure provides ecological and social benefits, including improved air quality, stormwater management, and enhanced thermal insulation, contributing to both sustainability and personal comfort (Lee & Park 2021). This underscores the need for further research on consumer psychology and market preferences regarding greenery in housing developments.

Emotional Responses To Biophilia

Emotions and Restorativeness,

Emotional and psychological impacts of the built environment are significant, with natural settings being used to promote wellbeing and reduce emotional stress and fatigue. Browning et al. (2014) emphasize that experiencing natural environments positively influences emotional states by reducing tension, anger, fatigue, and overall distress when compared to the effects of urban environments.

Sayuti (2016) shows that the intersection of biophilia, emotional design, and spatial aesthetics, can extend into practices and features that are not commonly studied in the field of biophilic design. Furniture design with embedded living organisms has been studied and initial results suggest that there is a direct correlation between furniture design with living organism's (FDLO's) and positive and negative emotional responses (Sayuti, 2016). This study assessed self-reports, physiological measurements, and behavioral observations to evaluate perceptions of biophilic furniture. Interviews and survey results from participating designers suggest that biophilia may play a role in designers' motivations as well as users' emotions and experiences (Sayuti, 2016, p. 87).

A review of 45 studies examining nature connections, sensory stimuli, and spatial experiences found that natural images, plant presence, visual and non-visual connections to nature, and material connection to nature are the top patterns studied when reviewing the health effects of biophilia (Hung & Chang 2021). Hung and Chang (2021) emphasize that "practical landscape and built environments can be designed to link humans and nature and reinforce biophilia in creating healthier, more restorative residential spaces

Lee et al. (2015) demonstrated that university students who were shown a 40-second viewing of a green roof, attention rates were significantly increased when compared other students presented with views of a concrete roof and the baseline test. Participants who viewed the green roof made fewer omission errors and showed a more consistent response to the tasks presented compared to students who were presented with the concrete rooftop, thus providing evidence in support of restorative micro-breaks (Lee et al., 2015).

Amount of Indoor Plants

Research measuring emotional and neurological effects of three types of biophilic design in virtual hospital rooms using EEG and VR methods was used to make direct connections between emotions and the presented imagery. A study by Jung et al.(2023) was conducted using three different groups which were presented with hospital rooms that each had varying amounts of biophilic design elements, and found that adding plant walls can reduce negative emotions by calming the nervous system. The results from the EEG measurements provided an insight into the body's response to different stimuli, and how tension and high arousal were lowered in comparison to images with a lower biophilic presence (Jung et al., 2023).

Similar results can be found in research by Navarrete-Hernandez et al. (2024), which explored participants' emotional states by providing one of six images that ranged from 0% to

45% of greenery coverage in a street view setting. It was further found that the happiness variable that was tested showed an always positive linear relationship with an increase in presented green infrastructure, with vertical green interventions being the most impactful (Navarrete-Hernandez et al., 2024).

Effects of Occupant Characteristics

Perceptions of biophilic design have shown some variance in previous studies based on income, gender, and personal preferences, shaping interactions with natural elements in residential spaces. A study of three Nigerian Luxury Hotels found that of 415 useful responses, age and cultural background were notable moderators, with older adults and non-Nigerian guest perceiving higher levels of restoration in some aspects (Yusuf et al., 2024). These findings suggest that biophilic design interventions should be tailored to different user demographics, ensuring accessibility and maximizing benefits across diverse residential communities.

Findings indicate that higher-income participants valued natural light, stress reduction, and cognitive benefits, while lower-income participants associated biophilic features with tranquility and emotional well-being (Khanzadeh, 2024). Khanzadeh (2024) also found that males reported substantially higher mean scores than females in positive emotional responses to biophilic design elements, emphasizing gender-based differences in interior design preferences. Results also indicate that income levels may influence perceptions of biophilic design, with higher-income individuals prioritizing cognitive and productivity benefits, while lower-income participants valued emotional and sensory experiences (Khanzadeh, 2024).

Satisfaction and Willingness to Stay

Wichrowski et al. (2021) conducted a mixed-methods study examining the effects of biophilic imagery on patient satisfaction in a hospital rehabilitation unit and found a significant

increase in patient satisfaction, as well some improvement in overall quality of stay, sleep, and care. Patients assigned to rooms decorated with nature-themed curtains and wall posters rated their environments significantly higher on the chosen Environmental Assessment Scale than those in the normal rooms which were used as a control variable (Wichrowski et al., 2021).

Gong et al., (2020) investigated China's largest residential complex, where factors such as sunlight exposure and access to green spaces were critically analyzed due to the severe limitations on biophilic design implementations caused by high urban density. Findings revealed that, when compared to residents of another residential complex with greater access to greenery, individuals in settings with less greenery visible reported lower satisfaction levels and a diminished sense of well-being (Gong et al., 2020).

The integration of biophilia in Dubai's residential sector has increased recently, as noted by Skakhhshir & Sheta (2023), the UAE has focused on green building and energy efficiency, particularly across high-rise buildings, villas, and townhouses. While residents generally appreciate biophilic elements, specific biophilic elements features, such as balcony spaces and green infrastructure, received neutral to low satisfaction ratings. The study found that "occupants were highly satisfied with biophilic features in their living space (74.2%) but showed neutral to low satisfaction (42.8%) with specific features such as indoor vegetation and natural ventilation" (Shakhshir & Sheta, 2023).

In a study conducted in virtual museum environments, Dalay and Aytac (2024) found that integrated natural features in exhibitions enhanced participants' perceptions of orientation, spatial perception, and emotional responses. The researchers also found that participants generally felt more content, relaxed, and at ease, which suggests that even simulated environmental greenery can cause users to have positive spatial perceptions (Dalay & Aytac,

2024). Khozaei et al. (2022) found that when looking at the relationship of COVID-19 and mental states, the participants of their study that had higher levels of stress and mental burdens associated with COVID-19 reported significantly affected their preferences for nature and hotels that used biophilic attributes. The findings from these studies show that integrating natural features indoors can cause users to feel more comfortable and content, leading to a greater willingness to stay.

Guiding Theories

Pleasure Arousal Framework

Emotional responses can be difficult to measure and may be perceived and interpreted differently between individuals, thus multiple systems have been created to classify emotional responses. Environmental stressors such as excessive noise, crowding, and pollution can have predictable negative effects on an individual's emotional state, specifically in terms of pleasure, arousal, and dominance (Russell and Mehrabian, 1974). Mehrabian's further research into pleasure, arousal, and dominance shows that almost all emotions can be described by participants as relating to one of the branches of the proposed model (Mehrabian, 1996). Russell & Mehrabian (1977) describes and gathered evidence from 200 subjects to support the idea of dividing emotions into three dimensions. Upon further research the pleasure scale was given affective responses with six bipolar descriptors, Happy/Unhappy, Pleased/Annoyed, Satisfied/Unsatisfied, Contented/Melancholic, Hopeful/Despairing, and Relaxed/Bored, capturing the degree of positive or negative emotional engagement with the space (Mehrabian, 1976). The arousal scale measured levels of physiological and psychological activation, utilizing descriptors such as Stimulated/Relaxed, Excited/Calm, Frenzied/Sluggish, Jittery/Dull, Wide-awake/Sleepy, and Aroused/Unaroused (Mehrabian 1976). The Dominance component of

Russell & Mehrabian's (1977) framework was excluded from this study as it was determined that it was not in the scope of the research questions.

Attention Restoration Theory

Kaplan and Kaplan's (1989) *Attention Restoration Theory (ART)* provides a useful framework for understanding the connection between environments and emotional states. According to Kaplan and Kaplan (1989), *Being Away* refers to the sense of mental detachment from daily stressors, allowing individuals to experience a break from routine. *Soft Fascination* describes elements that capture attention effortlessly, such as natural textures, greenery, or flowing water, promoting cognitive restoration without demanding focused effort. *Compatibility* reflects how well an environment supports an individual's needs, ensuring that the space aligns with their preferences for relaxation and well-being (Kaplan & Kaplan, 1989).

CHAPTER 3: RESEARCH METHODS

This quantitative study employed an online survey to compare the emotional responses in individuals based on their perceptions of indoor plants in residential spaces. It examined emotional perceptions as participants view the same space with varying levels of biophilic integration. This study builds on previous studies (Fadda et al., 2023; Sayuti et al., 2015) by assessing how the amount of indoor plants impacts emotional perceptions when the visible presence of features is different.

Stimuli Creation

To measure the impact of indoor plants in residential environments, we designed three residential living areas with different levels of indoor plants being integrated. The image of the living room was selected after reviewing a range of living room images, in consultation with two experienced interior design professionals. The visual stimuli for this study were developed using Adobe Photoshop to create three variations of a single residential interior. The base image remains consistent across all conditions, ensuring uniformity in spatial layout, lighting, and non-biophilic furnishings (see Figure 1). Image A showed no indoor plants and did not include any greenery applications. Image B presented a moderate amount of visible greenery in the form of potted plants and living wall decor. Image C had an intense amount of greenery that filled the space with more plants, and larger living walls. All participants viewed the same rendered images of the interior space, the three coverage levels were determined by calculating the proportion of the image area visually occupied by plant material relative to the total visible surface area of the image using pixel-based measurements in the image editing software: 0% (control), 10% (moderate), and 25% (intense).

Image A (Control) No indoor plants	Image B (Moderate) Moderate amount of indoor plants	Image C (Intense) Intense amount of indoor plants
		

Figure 1. *Survey Images of Three Indoor Planting Conditions*

Participants

Participants were recruited through convenience sampling through Michigan State University and online survey service platform Prolific. A digital survey link was distributed to students at Michigan State University's School of Planning, Design, and Construction (SPDC), allowing them to access the study online while remaining anonymous. All SPDC participants gave their informed consent and were offered the chance to enter a raffle to receive a gift card with a $10 value in order to increase participation rates. A total of 52 responses were collected.

On the Prolific platform, participants were efficiently recruited and compensated to boost data collection. Prolific filters allowed for demographic diversity, and all participants provided informed consent before beginning the study. Participants used a Qualtrics survey that presented the same survey as other recruitment methods. A total of 112 responses were collected. After removing incomplete responses, a total of 150 complete responses were used for further analysis.

Data Collection Process

The survey was administered through the online platform Qualtrics. A pilot test was carried out with 10 respondents to identify potential issues with the survey design and data collection process. Following the pilot test and necessary adjustments to ensure smooth data collection, the main survey was conducted.

Upon beginning the survey, participants were first shown Image C (intense) of the three image variations and asked to evaluate their emotional response. This process was then repeated for Image A (control) followed by Image B (moderate). ensuring that each participant viewed and assessed all three indoor planting conditions. The order of intense → control → moderate conditions was chosen to minimize expectation bias and prevent desensitization or adaptation, which could occur if the sequence started with less intense conditions and progressed to more intense ones. This approach enables a clearer understanding of how emotional responses vary across different levels of greenery. Following the image evaluations, participants completed a demographic questionnaire to collect information on age, gender, race, and academic background.

Survey Measurement

The survey questionnaire was developed to measure (1) emotions including pleasure and arousal, (2) restorativeness, (3) satisfaction, and (4) willingness to stay (see Table 1). Participants self-reported their responses using a 7-point Likert scale. A Likert scale was chosen due to its ability to gather participants' opinions in a more efficient format than individual questions (Batterton & Hale 2017).

Emotions were measured using the pleasure and arousal scale introduced in Russell & Mehrabian's *An Approach to Environmental Psychology* (1974). The pleasure scale was given affective responses with six bipolar descriptors, happy/unhappy, satisfied/unsatisfied, contented/melancholic, hopeful/despairing, and relaxed/bored, capturing the degree of positive or negative emotional engagement with the space (Mehrabian, 1976). The arousal scale measured levels of physiological and psychological activation, utilizing descriptors such as

stimulated/relaxed, excited/calm, frenzied/sluggish, jittery/dull, wide-awake/sleepy, and aroused/unaroused (Mehrabian, 1976).

Restorativeness was measured using the perceived restorativeness scale (PRS) developed by Hartig et al. (1997), which assesses the restorative effects of natural environment. It consists of 18 items, but this study used the 6 following items: It is an escape experience; Spending time here gives me a good break from my day-to-day routine; This place has fascinating qualities; I would like to get to know this place better; I can do things I like here, and I have a sense that I belong here (Hartig et al., 1997).

Satisfaction was measured using 3 items adapted from Nanu et al.(2020), which assessed satisfaction with biophilic design in hotel lobbies. The selected questions are as follows: I would be happy with the experiences I could have in this room; I would feel satisfied with the experiences I could have in this room; I would really enjoy spending time in this room (Nanu et al., 2020).

Willingness to stay was evaluated using 2 items based on Nanu et al.(2020). The following items were selected due to their ability to gauge participant preference and comfort of the space: My willingness to stay in this room is high and The likelihood of me staying in this room is high (Nanu et al., 2020).

Table 1. *Variable Questions*

Variable	Number of Questions	Response Options	Scale
Pleasure	5	- Unhappy/ Happy - Bored/ Relaxed - Unsatisfied/ Satisfied - Melancholic/ Content - Despairing/ Hopeful	7-point bipolar scale

Table 1. (cont'd)

Arousal	5	-Relaxed/Stimulated - Calm/Excited - Sluggish/Frenzied - Dull/Jittery - Sleepy/Wide-Awake	7-point bipolar scale
Restorativeness	6	- It is an escape experience. - Spending time here gives me a good break from my day-to-day routine. - This place has fascinating qualities. - I would like to get to know this place better. - I can do things I like here. - I have a sense that I belong here.	7-point Likert (1 = Strongly disagree, 7 = Strongly agree)
Satisfaction	3	- I would be happy with the experiences I could have in this room. - I would feel satisfied with the experiences I could have in this room. - I would really enjoy spending time in this room.	7-point Likert (1 = Strongly disagree, 7 = Strongly agree)
Willingness to stay	2	- My willingness to stay in this room is high. - The likelihood of me staying in this room is high.	7-point Likert (1 = Strongly disagree, 7 = Strongly agree)

CHAPTER 4: RESULTS

Participant Profile

Participants ranged from 18 to 65+ years old, with the largest age group being 18-24 years old (n = 42, 29.4%), followed by 25-34 years old (n = 37, 25.9%). A notable portion of participants were aged 45-54 (n = 28, 19.6%), while smaller percentages were 35-44 years old (n = 19, 13.3%), 55-64 years old (n = 11, 7.7%), and 65 or older (n = 6, 4.2%). The majority of participants identified as female (n = 91, 63.6%), while n = 50 (35.0%) identified as male. The sample was predominantly Caucasian (n = 106, 70.7%), followed by African American (n = 24, 16.0%), Asian (n = 10, 6.7%), and American Indian (n = 4, 2.7%). Participants had varied levels of education, with the highest proportion having completed a four-year college degree (n = 48, 33.6%), followed by some college education (n = 39, 27.3%). Other participants had attained a graduate or professional degree (n = 19, 11.9%), an associate degree (n = 15, 10.5%) or had only completed high school (n = 20, 14.0%).

Table 2. *Participant Profile*

	Demographics	Frequency	Percent
Age	18-24	42	29.4
(N=143)	25-34	37	25.9
	35-44	19	13.3
	45-54	28	19.6
	55-64	11	7.7
	65 or older	6	4.2
Gender	Male	50	35
(N=143)	Female	91	63.6
	Others	2	1.4
Race	Caucasian	106	70.7
(N=143)	African American	24	16
	American Indian	4	2.7
	Asian	10	6.7
	Others	3	2

Table 2. (cont'd)

Education Level (N=143)	Completed high school	20	14
	Some college	39	27.3
	Associate degree	15	10.5
	Four-year college degree	48	33.6
	Graduate or professional degree	19	11.9
	Others	2	1.4

Reliability Test and Descriptive Statistics

A reliability analysis was conducted to assess the internal consistency of survey items measuring pleasure, arousal, restorativeness, satisfaction, and willingness to stay across three indoor planting conditions (Control, Moderate, and Intense). The results showed a high reliability across all variables, with Cronbach's alpha values ranging from .78 to .98, indicating strong internal consistency (see Table 3).

For pleasure, which was measured using five items, mean ratings increased as indoor plant quantity increased. Participants reported the lowest pleasure ratings in the Control condition ($M = 4.47$, $SD = 1.75$, $\alpha = .96$), with ratings increasing in the Moderate ($M = 5.23$, $SD = 1.35$, $\alpha = .95$) and Intense conditions ($M = 5.49$, $SD = 1.36$, $\alpha = .93$). This suggests that participants found environments with more greenery to be more pleasurable, with high reliability across all conditions (see Table 3 and Figure 2).

The arousal variable, also measured using five items, exhibited slightly lower but still acceptable reliability ($\alpha = .78 – .81$). Mean arousal scores were lowest in the Control condition ($M = 3.28$, $SD = 1.13$, $\alpha = .80$), increased in the Moderate condition ($M = 3.71$, $SD = 1.05$, $\alpha = .81$), but slightly declined in the Intense condition ($M = 3.65$, $SD = 1.11$, $\alpha = .78$). This pattern suggests that moderate levels of plant presence may enhance alertness more than extreme levels.

For restorativeness, measured with six items, reliability remained high across all conditions ($\alpha = .93 – .96$). The Control condition had the lowest mean restorativeness rating (M

= 4.02, SD = 1.69, α = .96), while the Moderate condition (M = 4.75, SD = 1.42, α = .96) and Intense condition (M = 5.10, SD = 1.32, α = .93) demonstrated a steady increase, reinforcing the idea that more greenery contributes to a stronger perception of restorative benefits.

The satisfaction variable, which consisted of three items, followed a similar upward trend with high internal reliability (α = .96 – .97). Satisfaction ratings were lowest in the Control condition (M = 4.33, SD = 1.70, α = .96), increased in the Moderate condition (M = 4.96, SD = 1.46, α = .97), and reached their highest in the Intense condition (M = 5.49, SD = 1.44, α = .96).

Finally, willingness to stay, measured using two items, exhibited the highest reliability coefficients (α = .96 – .98). Participants reported the lowest willingness to stay in the Control condition (M = 2.75, SD = 1.29, α = .98), with a substantial increase in the Moderate condition (M = 4.89, SD = 1.58, α = .98) and Intense condition (M = 5.49, SD = 1.59, α = .96). This suggests that plant presence significantly impacts participants' desire to remain in an environment, with more greenery leading to greater willingness to stay in the space.

Table 3. *Reliability Test and Descriptive Statistics*

Variable	Number of items	Planting Condition	Mean	S,D	Cronbach's alpha
Pleasure	5	Control	4.47	1.75	.96
		Moderate	5.23	1.35	.95
		Intense	5.49	1.36	.93
Arousal	5	Control	3.28	1.13	.80
		Moderate	3.71	1.05	.81
		Intense	3.65	1.11	.78
Restorativeness	6	Control	4.02	1.69	.96
		Moderate	4.75	1.42	.96
		Intense	5.10	1.32	.93
Satisfaction	3	Control	4.33	1.70	.96
		Moderate	4.96	1.46	.97
		Intense	5.49	1.44	.96
Willingness to stay	2	Control	2.75	1.29	.98
		Moderate	4.89	1.58	.98
		Intense	5.49	1.59	.96

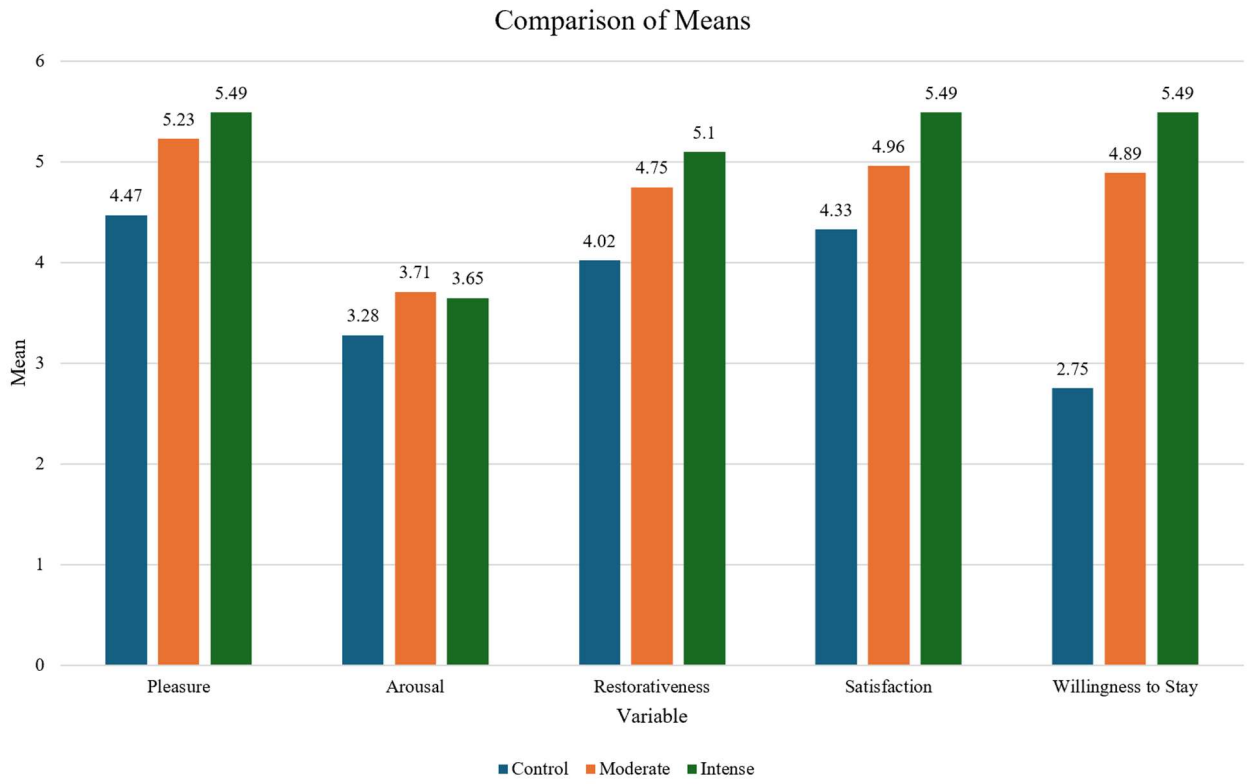


Figure 2. *Mean Emotional Responses Across Each Planting Condition*

Effects of Indoor Plants on Pleasure

A repeated measures ANOVA was conducted to assess the impact of three indoor plant quantity conditions on pleasure ratings. Given that Mauchly's Test of Sphericity was significant ($p < .05$), suggesting a violation of sphericity (see Table 4), the Greenhouse-Geisser correction was applied. The results of the repeated measures ANOVA (see Table 5) revealed significant differences in pleasure ratings across the three conditions, $F(1.92, 272.59) = 44.50$, $p < .001$, with a large effect size (partial eta squared = 0.24).

Table 4. *Result of Mauchly's Test of Sphericity for Pleasure*

					Epsilon		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Pleasure	.95	6.02	2	.049	.96	.97	.50

Table 5. *Tests of Within-Subjects Effects for Pleasure*

		Sum of Squares*	df	Mean Square	F	Sig.	Partial Eta Squared
Pleasure	Sphericity Assumed	85.43	2	42.71	45.35	<.001	.24
	Greenhouse-Geisser	85.43	1.92	44.50	45.35	<.001	.24
	Huynh-Feldt	85.43	1.94	43.91	45.35	<.001	.24
	Lower-bound	85.43	1.000	85.43	45.35	<.001	.24
Error	Sphericity Assumed	267.49	284	.94			
	Greenhouse-Geisser	267.49	272.59	.98			
	Huynh-Feldt	267.49	276.24	.96			
	Lower-bound	267.49	142.00	1.88			

Note. Greenhouse-Geisser correction was used.
Type III sum of squares

Post hoc comparisons using Bonferroni adjustments showed significant differences in pleasure ratings between conditions (see Table 6). Specifically, the Intense condition was rated significantly higher than both the Control (Mean Difference = 1.05, $p < .001$) and Moderate (Mean Difference = 0.26, $p = .045$) conditions. Additionally, the Moderate condition was rated significantly higher than the Control condition (Mean Difference = 0.78, $p < .001$).

Table 6. *Post hoc Test Results for Pleasure*

					95% Confidence Interval for Difference[b]	
(I) pleasure	(J) pleasure	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
Control	Moderate	-.78*	.11	<.001	-1.05	-.51
	Intense	-1.05*	.12	<.001	-1.35	-.74
Moderate	Control	.78*	.11	<.001	.51	1.05
	Intense	-.26*	.10	.045	-.52	-.004
Intense	Control	1.05*	.12	<.001	.74	1.35
	Moderate	.26*	.10	.045	.004	.52

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Effects of Indoor Plants on Arousal

A repeated measures ANOVA was conducted to examine the effect of three indoor plant quantity conditions on arousal ratings. Given that Mauchly's Test of Sphericity was not significant (p =.101), suggesting that the assumption of sphericity was not violated (see Table 7), no correction to the degrees of freedom was necessary. The results of the repeated measures ANOVA (see Table 8) revealed a significant effect of indoor plant quantity on arousal, $F(2, 284) = 13.98$, $p < .001$, with a small effect size (partial $\eta^2 = .09$). This indicates that arousal significantly differed across the three indoor plant quantity conditions.

Table 7. *Result of Mauchly's Test of Sphericity for Arousal*

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Arousal	.96	4.58	2	.101	.96	.98	.50

Table 8. *Tests of Within-Subjects Effects for Arousal*

Source		Sum of Squares*	df	Mean Square	F	Sig.	Partial Eta Squared
Arousal	Sphericity Assumed	15.05	2	7.52	13.98	<.001	.09
	Greenhouse-Geisser	15.05	1.93	7.76	13.98	<.001	.09
	Huynh-Feldt	15.05	1.96	7.66	13.98	<.001	.09
	Lower-bound	15.05	1.00	15.05	13.98	<.001	.09
Error	Sphericity Assumed	152.84	284	.53			
	Greenhouse-Geisser	152.84	275.20	.55			
	Huynh-Feldt	152.84	278.94	.54			
	Lower-bound	152.84	142.00	1.07			

*Type III sum of squares

Post hoc comparisons using Bonferroni adjustments showed the Control condition was rated significantly lower than both the Moderate (Mean Difference = -0.42, $p < .001$) and Intense

(Mean Difference = -0.37, p < .001) conditions (see Table 9). However, no significant difference was found between the Moderate and Intense conditions (Mean Difference = 0.04, p = 1.000).

Table 9. *Post hoc Test Results for Arousal*

					95% Confidence Interval for Difference[b]	
(I) Arousal	(J) Arousal	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
Control	Moderate	-.42*	.083	<.001	-.62	-.21
	Intense	-.37*	.09	<.001	-.59	-.14
Moderate	Control	.42*	.08	<.001	.21	.62
	Intense	.04	.08	1.000	-.15	.25
Intense	Control	.37*	.09	<.001	.14	.59
	Moderate	-.04	.08	1.000	-.25	.15

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Effects of Indoor Plants on Restorativeness

A repeated measures ANOVA was conducted to assess the impact of three indoor plant quantity conditions on restorativeness ratings. Given that Mauchly's Test of Sphericity was strongly significant (p < .01), suggesting a violation of sphericity (see Table 10), the Greenhouse-Geisser correction was applied. The results of the repeated measures ANOVA (see Table 11) revealed significant differences in restorativeness ratings across the three conditions, F(1.86, 264.38) = 50.95, p < .001, with a large effect size (partial eta squared = 0.26).

Table 10. *Result of Mauchly's Test of Sphericity on Restorativeness*

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
res	.92	10.86	2	.004	.93	.94	.50

Table 11. *Tests of Within-Subjects Effects for Restorativeness*

Source	Sum of Squares*	df	Mean Square	F	Sig.	Partial Eta Squared

Table 11. (cont'd)

Restorative	Sphericity Assumed	94.86	2	47.43	49.90	<.001	.26
	Greenhouse-Geisser	94.86	1.86	50.95	49.90	<.001	.26
	Huynh-Feldt	94.86	1.88	50.31	49.90	<.001	.26
	Lower-bound	94.86	1.00	94.86	49.90	<.001	.26
Error	Sphericity Assumed	269.94	284	.95			
	Greenhouse-Geisser	269.94	264.38	1.02			
	Huynh-Feldt	269.94	267.76	1.00			
	Lower-bound	269.94	142.00	1.90			

*Type III sum of squares

Post hoc comparisons using Bonferroni adjustments showed significant differences in restorativeness ratings between conditions (see Table 12). Specifically, the Intense condition was rated significantly higher than both the Control (Mean Difference = 1.13, $p < .001$) and Moderate (Mean Difference = 0.38, $p = .001$) conditions. Additionally, the Moderate condition was rated significantly higher than the Control condition (Mean Difference = 0.75, $p < .001$).

Table 12. *Post hoc Test Results of Restorativeness*

(I) Restorativeness	(J) Restorativeness	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Control	Moderate	-.75*	.10	<.001	-1.01	-.48
	Intense	-1.13*	.13	<.001	-1.44	-.81
Moderate	Control	.75*	.10	<.001	.48	1.01
	Intense	-.38*	.10	.001	-.63	-.12
Intense	Control	1.13*	.13	<.001	.81	1.44
	Moderate	.38*	.10	.001	.12	.63

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Effects of Indoor Plants on Satisfaction

A repeated measures ANOVA was conducted to assess the impact of three indoor plant quantity conditions on satisfaction ratings. Given that Mauchly's Test of Sphericity was strongly significant ($p < .01$), suggesting a violation of sphericity (see Table 13), the Greenhouse-Geisser correction was applied. The results of the repeated measures ANOVA (see Table 14) revealed

significant differences in satisfaction ratings across the three conditions, $F(1.83, 261.01) = 52.30$, $p < .001$, with a large effect size (partial eta squared = 0.26).

Table 13. *Result of Mauchly's Test of Sphericity for Satisfaction*

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
sat	.91	12.99	2	.002	.91	.93	.50

Table 14. *Tests of Within-Subjects Effects for Satisfaction*

Source		Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Satisf-action	Sphericity Assumed	96.14	2	48.070	51.30	<.001	.26
	Greenhouse-Geisser	96.14	1.83	52.30	51.30	<.001	.26
	Huynh-Feldt	96.14	1.86	51.65	51.30	<.001	.26
	Lower-bound	96.14	1.00	96.14	51.30	<.001	.26
Error	Sphericity Assumed	266.08	284	.937			
	Greenhouse-Geisser	266.08	261.01	1.01			
	Huynh-Feldt	266.08	264.27	1.00			
	Lower-bound	266.08	142.00	1.87			

*Type III sum of squares

Post hoc comparisons using Bonferroni adjustments showed significant differences in satisfaction ratings between conditions (see Table 15). Specifically, the Intense condition was rated significantly higher than both the Control (Mean Difference = 1.15, $p < .001$) and Moderate (Mean Difference = 0.53, $p < .001$) conditions. Additionally, the Moderate condition was rated significantly higher than the Control condition (Mean Difference = 0.62, $p < .001$).

Table 15. *Post hoc Test Results of Satisfaction*

(I) satisfaction	(J) satisfaction	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Control	Moderate	-.62*	.10	<.001	-.88	-.36
	Intense	-1.15*	.13	<.001	-1.47	-.84
Moderate	Control	.62*	.10	<.001	.36	.88
	Intense	-.53*	.10	<.001	-.78	-.28

Table 15. (cont'd)

	Control	1.15*	.13	<.001	.84	1.47
Intense	Moderate	.53*	.10	<.001	.28	.78

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Effects of Indoor Plants on Willingness to Stay in the Space

A repeated measures ANOVA was conducted to assess the impact of three indoor plant quantity conditions on willingness to stay ratings. Given that Mauchly's Test of Sphericity was strongly significant ($p < .01$), suggesting a violation of sphericity (see Table 16), the Greenhouse-Geisser correction was applied. The results of the repeated measures ANOVA (see Table 17) revealed significant differences in willingness to stay ratings across the three conditions, $F(1.87, 265.59) = 321.79$, $p < .001$, with a large effect size (partial eta squared = 0.68).

Table 16. *Result of Mauchly's Test of Sphericity on Willingness to Stay*

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Willingness to stay	.93	10.12	2	.006	.93	.94	.50

Table 17. *Tests of Within-Subjects Effects for Willingness to Stay*

Source		Sum of Squares*	df	Mean Square	F	Sig.	Partial Eta Squared
Willingness to stay	Sphericity Assumed	601.89	2	300.94	313.13	<.001	.68
	Greenhouse-Geisser	601.89	1.87	321.79	313.13	<.001	.68
	Huynh-Feldt	601.89	1.89	317.71	313.13	<.001	.68
	Lower-bound	601.89	1.00	601.89	313.13	<.001	.68
Error	Sphericity Assumed	272.94	284	.96			
	Greenhouse-Geisser	272.94	265.59	1.02			
	Huynh-Feldt	272.94	269.01	1.01			
	Lower-bound	272.94	142.00	1.92			

*Type III sum of squares

Post hoc comparisons using Bonferroni adjustments showed significant differences in willingness to stay ratings between conditions (see Table 18). Specifically, the Intense condition was rated significantly higher than both the Control (Mean Difference = 2.760, $p < .001$) and Moderate (Mean Difference = 0.605, $p < .001$) conditions. Additionally, the Moderate condition was rated significantly higher than the Control condition (Mean Difference = 2.155, $p < .001$).

Table 18. *Post hoc Test Results of Willingness to Stay*

(I) will1ingness to stay	(J) will1ingness to stay	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Control	Moderate	-2.155*	.102	<.001	-2.402	-1.908
	Intense	-2.760*	.128	<.001	-3.071	-2.449
Moderate	Control	2.155*	.102	<.001	1.908	2.402
	Intense	-.605*	.116	<.001	-.886	-.324
Intense	Control	2.760*	.128	<.001	2.449	3.071
	Moderate	.605*	.116	<.001	.324	.886

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

CHAPTER 5: DISCUSSION AND CONCLUSION

Discussion

Participants reported higher levels of pleasure as indoor plant quantities increased, with mean scores rising significantly from the Control (M = 4.47) to the Moderate (M = 5.23) and Intense (M = 5.49) conditions. The increase in pleasure reinforces previous findings by Lohr et al. (1995) and Ryan et al. (2014), which show that vegetation enhances emotional satisfaction in interior environments. These findings similarly align with Navarrete-Hernandez et al. (2024), who found that perceived happiness increased with higher levels of street greenery, and participant reports suggest an optimal effect between 35%–45% coverage. These results suggest that even small applications of plant life can positively influence emotional experiences within residential environments.

Arousal levels peaked under the Moderate greenery condition (M = 3.71), slightly higher than in the Intense setting (M = 3.65). The findings reflect Yin et al. (2018), who observed emotional benefits tapering off in highly stimulating biophilic environments. This observed pattern suggests that while some greenery is energizing, large amounts do not result in a continued upward effect on physiological or attentional responses. While consistent with previous findings, Jung et al. (2023) found that biophilic elements in hospital rooms elicited a more relaxed emotional response and reduced the amount of high-frequence band data that is found in high arousal states. These findings relate to my data, as arousal was the only variable that did not consistently increase in direct correlation with the level of greenery implemented.

Participants reported progressively higher levels of restorativeness in response to higher indoor plant quantities, with the highest scores in the Intense condition (M = 5.10). This finding supports the *Attention Restoration Theory* (Kaplan & Kaplan, 1989), which suggests that

exposure to natural elements supports cognitive recovery and stress reduction through visual and sensory engagement. The consistency of improvement across conditions further validates prior research by Huntsman & Bulaj (2022) and Rhee et al. (2023), which demonstrated that even moderate greenery can contribute to reduced stress and cognitive fatigue. A study by Lee at al. (2015), found that respondents perceived a higher restorative feeling when viewing a green roof city scene than when presented with a concrete roof scene that had no visible greenery, suggesting that even brief forty second views of nature can be beneficial.

Participants reported significantly greater satisfaction rates in the space with Intense levels of greenery (M = 5.49), suggesting that high levels of indoor plant integration brings both emotional comfort and positive feelings of the space. These reports present the idea that dense amounts of indoor plant integration contributes significantly to environmental satisfaction and suggests that residents may evaluate green-rich spaces more favorably. Similar to Wichrowski et al. (2021), participants who were located in hospital rooms that features biophilic elements rated their perceptions of the room and overall satisfaction rates higher than the selected control rooms. This aligns with Clark-Havron's (2023) findings that biophilic features enhance both emotional well-being and user preferences in residential interiors.

Participants' willingness to remain in the space showed the greatest increase across all variables, with scores rising from M = 2.75 in the Control condition to M = 5.49 in the Intense condition. These findings show that the amount of indoor plant features have a direct impact on spatial preference, with participants showing greater intent to stay in environments that display greater amounts of natural elements. Connections have also been made showing that participants viewing multiple simulated museum settings with biophilic elements felt more content, at ease, and joyful, which implies that viewers are more willing to stay in this space (Dalay & Aytac

2024). This supports previous literature that links biophilic environments to stronger spatial attachment and desirability in residential settings (Ryan et al., 2014; Zalejska-Jonsson et al., 2020).

Implications

This study fills a critical research gap by exploring the emotional effects of indoor plants in residential environments, an area that has been underexplored. It demonstrates that the quantity of indoor plant elements significantly influences emotions, restorativeness, satisfaction, and willingness to stay, thus advancing our understanding of how nature in the home impacts well-being. By testing the pleasure/arousal framework and the Perceived Restorative Survey (PRS), the study enhances theoretical knowledge in biophilic design, providing empirical evidence for the role of biophilic elements in promoting emotional and cognitive restoration. These findings offer valuable insights for future research and practical applications in residential design.

An important implication of this study relates to the broad conversation about how current environments lack support for emotional and mental connections. Gray and Birrell (2014) describe how modern society has led individuals to spend increasing amounts of time in space classified as “non-place”, a term originally coined by novelist Wendell Berry. Their research proposes that these spaces are characterized by a lack of vitality and organic connectedness, offering little in terms of sensory engagement or emotional attachment. The proposed concept highlights the distinction between environments that foster a sense of place and belonging versus those that feel lifeless or devoid of natural value.

The findings of this study suggest that the amount of indoor plants has meaningful potential to improve residential environments by positively influencing emotional responses and

behavioral intentions. For residential designers, this supports the idea of incorporating greenery as an intentional design strategy rather than a decorative feature. Design elements such as green walls, indoor planting, and views of nature can contribute to restorative environments that support mental and emotional well-being for occupants, which is further supported by Li et al. (2022), who found that green walls placed in indoor environments significantly reduced stress and improved mood among occupants.

The recent surge of interest in biophilic design principles can largely be attributed to the challenges brought forth by the COVID-19 pandemic. This growing awareness presents an opportunity for design studios to further promote sustainable building practices that incorporate biophilic principles. Using this design practice, studios can take steps that can increase awareness of sustainable design and reduce the energy consumption of build processes while implementing biophilic design (Söderlund & Newman, 2022; Totaforti, 2020; Wijesooriya et al., 2020). During this period of extended home confinement, individuals became increasingly aware of how their home environments influenced both their mental and physical well-being. Research was conducted in response to the pandemic and documented the strong connection between human-nature interaction and residential design, reinforcing the benefits of integrating biophilic elements into homes to support overall health (Nitu et al., 2022).

Study Limitations

While this study provides valuable insight into the effects of indoor plant quantities and emotional perceptions, several limitations of the study should be acknowledged. This study relied on digitally manipulated images to simulate indoor environments and may not be an exact representation of the effects of a real-world setting. This limitation was mitigated by using Photoshop editing to create the images to best resemble a real indoor space. All data was

collected through self-reporting survey questions that allowed for selection on a scale to best accommodate for individual variability. The fixed order of presented images that were presented to participants may have introduced bias, as the images were presented to all individuals in the same sequence. To reduce potential bias while viewing the images, the presentation order was arranged as Intense, Control, and then Moderate, rather than a sequential ordering. It is recommended that future studies present the images in a random order to minimize the potential bias and order effects.

Future Research Recommendations

While this study provides valuable evidence on how varying levels of greenery affect emotional and behavioral responses, several areas remain open for further investigation to expand the overall scope and generalization of these findings and the application of indoor plants in residential settings.

First, future research should explore the multisensory dimensions of biophilic design and the role of indoor plantings. While this study focused solely on visual greenery, previous studies have shown that integrating sound, scent, and tactile elements can enhance emotional and cognitive outcomes (Aristizabal et al., 2021; Joye et al., 2013). Exploring multisensory environments may offer a more contextually grounded understanding of how biophilic features influence emotional experiences within residential settings.

Additionally, future studies should incorporate physiological and behavioral measures alongside self-report scales to increase result reliability and accuracy. Biometrics such as heart rate variability, skin conductance, and cortisol levels can offer objective insight into emotional states and reduce bias in subjective reporting by participants (Yin et al., 2018; Van den Berg et al., 2015).

Previous research has shown that other variables such as age, gender, upbringing, and regional background can significantly shape perceptions of biophilic elements and preferences for spatial environments (Khanzadeh, 2024). This emphasizes that results may be influenced not only by biophilic design features, but also by demographic and cultural factors specific to a given community and should be studied further to understand the differences.

Long term research will also be needed to assess how ongoing exposure to various greenery rates impacts well-being over time. Emotional responses may shift or deepen with repeated interaction, and methods such as diary-based tracking or repeated-measures designs could help capture these changes as they unfold (Barbiero et al., 2021; Kaplan & Kaplan, 1989).

Conclusion

The primary goal of this study was to explore how Control, Moderate, and Intense amounts of indoor plant applications affect participant perceptions of pleasure, arousal, restorativeness, satisfaction, and behavior intentions.

The first research question that was looked at to be answered was how do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' emotions? Responses showed that pleasure increased as greenery rates increased, with participants rating the Intense condition highest. Arousal peaked at the Moderate condition before slightly declining under Intense greenery. This suggests that while emotional comfort continues to rise with more visible greenery, there may be an optimal range for perceived emotional benefits.

The second question to answer is how do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' perception of restorativeness? Participants reported higher levels of restorativeness in environments with a larger greenery

presence, with the intense condition receiving the highest ratings, thus supporting theories of cognitive recovery and attention restoration through exposure to natural elements.

Thirdly, this research looks at how do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' satisfaction? Similar to the other research question trends, satisfaction scores improved steadily across all three greenery levels, with the most favorable responses being seen in the Intense image. This suggests that intense applications contribute to occupants' perception of the space's quality and desirability.

The final question to be answered is how do different amounts of indoor plants (i.e., control, moderate, intense) in a residential environment affect occupants' willingness to stay in a space? Willingness to stay displayed the largest increase in participant ratings of all measured variables, with ratings more than doubling from the Control to the Intense condition. This suggests a strong behavioral correlation towards biophilic features, and that participants express a clear preference for the Moderate and Intense conditions.

As residential design practices continue to evolve in response to occupant health, sustainability, and user-centered values, the integration of indoor plants into living spaces offers users the potential to deepen their emotional connection and ease within the home environment.

BIBLIOGRAPHY

Aabouelela, A. (2023). Biophilic design as an approach towards integrating nature into the design of residential units to improve human mental health and well-being. *European Chemical Bulletin, 12*(1), 1985–2006. https://doi.org/10.48047/ecb/2023.12.1.277

Aristizabal, S., Byun, K., Porter, P., Clements, N., Campanella, C., Li, L., Mullan, A., Ly, S., Senerat, A., Nenadic, I. Z., Browning, W. D., Loftness, V., & Bauer, B. (2021). Biophilic office design: Exploring the impact of a multisensory approach on human well-being. *Journal of Environmental Psychology, 77*, 101682. https://doi.org/10.1016/j.jenvp.2021.101682

Barbiero, G., Berto, R., Venturella, A., & Maculan, N. (2021). Bracing biophilia: When biophilic design promotes pupils' attentional performance, perceived restorativeness and affiliation with nature. *Environment, Development and Sustainability*, 1-15. https://doi.org/10.1007/s10668-021-01903-1

Batterton, K. A., & Hale, K. N. (2017). The likert scale what it is and how to use it. *Phalanx*, *50*(2), 32–39. http://www.jstor.org/stable/26296382

Booth, M., Kalutara, P., & Abbasi, N. (2023). Re-thinking spatial design in homes to include means and access restriction with material impacts as passive suicide prevention methods: A systematic review of design for Australian homes. *Buildings, 13*(6), 1452. https://doi.org/10.3390/buildings13061452

Browning, W., Ryan, C., & Clancy, J. (2014). 14 patterns of biophilic design. *Terrapin Bright Green*. https://www.terrapinbrightgreen.com/reports/14-patterns/

Clark-Havron, H. (2023). Biophilic homes: Analyzing biophilic design in the residential setting (Order No. 30557067). *ProQuest Dissertations & Theses Global; ProQuest Dissertations & Theses Global Closed Collection.* (2827214134)

Dalay, L., & Aytaç, G. (2024). Evaluating biophilic design's effects on virtual museum perception and behavior. *Art & Perception*, *1*, 1-33. https://doi.org/10.1163/22134913-bja10063

Fadda, R., Congiu, S., Roeyers, H., & Skoler, T. (2023). Elements of biophilic design increase visual attention in preschoolers. *Buildings*, *13(5)*, 1160. https://doi.org/10.3 3 90/buildings13 051160

Fromm, E. (1964). *The heart of man: Its genius for good and evil.* Harper & Row.

Gray, T., & Birrell, C. (2014). Are biophilic-designed site office buildings linked to health benefits and high performing occupants? *International Journal of Environmental Research and Public Health*, *11*(12), 12204–12222. MDPI AG. http://dx.doi.org/10.3390/ijerph111212204

Gong, Y., Zoltán, E. S., & János, G. (2023). Healthy dwelling: The perspective of biophilic design in the design of the living space. *Buildings*, *13*(8), 2020. MDPI AG. http://dx.doi.org/10.3390/buildings13082020

Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997). A measure of restorative quality in environments. *Scandinavian housing and planning research*, *14*(4), 175-194.

Hung, S.-H., & Chang, C.-Y. (2021). Health benefits of evidence-based biophilic-designed environments: A review. *Journal of People, Plants, and Environment, 24*(1), 1–16. https://doi.org/10.11628/ksppe.2021.24.1.1

Huntsman, D. D., & Bulaj, G. (2022). Healthy dwelling: Design of biophilic interior environments fostering self-care practices for people living with migraines, chronic pain, and depression. *International Journal of Environmental Research and Public Health, 19*(4), 2248. https://doi.org/10.3390/ijerph19042248

Joye, Y., Pals, R., Steg, L., & Lewis-Evans, B. (2013). New methods for assessing the fascinating nature of nature experiences. *PLOS ONE, 8*(7), e65332. https://doi.org/10.1371/journal.pone.0065332

Jung, D., Kim, D., & Kim, N. (2023). Bringing nature into hospital architecture: Machine learning-based EEG analysis of the biophilia effect in virtual reality. *Journal of Environmental Psychology, 89*, 102033. https://doi.org/10.1016/j.jenvp.2023.102033

Kahveci, H., & Güneş, P. (2020). Evaluation of biophilic approach in the design of residential sites: Case of Sinpaş Altınoran, Ankara, Turkey. *Online Journal of Art and Design, 8*(3), 127–150. https://www.researchgate.net/publication/344267050

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective.* Cambridge University Press.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 15(3),* 169–182. https://doi.org/10.1016/0272-4 944(95)90001-2

Kellert, S. R., & Wilson, E. O. (Eds.). (1993). *The biophilia hypothesis.* Island Press.

Khanzadeh, M. (2024). Enhancing user experience in interior architecture through biophilic design: A case study of urban residential spaces. *New Design Ideas*, *8*(1), 137-168 https://doi.org/10.62476/ndi81137

Khozaei, F., Carbon, C., Hosseini Nia, M., & Kim, M. (2022). Preferences for hotels with biophilic design attributes in the post-COVID-19 era. *Buildings, 12*(4), 427. https://doi.org/10.3390/buildings12040427

Lee, E.-J., & Park, S.-J. (2022). Biophilic experience-based residential hybrid framework. *International Journal of Environmental Research and Public Health, 19*(14), 8512. https://doi.org/10.3390/ijerph19148512

Lee, E. J., & Park, S. J. (2021). Toward the biophilic residential regeneration for the green new deal. *International Journal of Environmental Research and Public Health*, *18*(5), 1-21– 21. https://doi-org.proxy1.cl.msu.edu/10.3390/ijerph18052523

Lee, K. , Williams, K., Sargent, L. , Williams, N., & Johnson, K. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *Journal of Environmental Psychology, 42*, 182–189. https://doi.org/10.1016/j.jenvp.2015.04.003

Lencastre, M. P. A., Guedes Vidal, D., Estrada, R., Barros, N., Leandro Maia, R., & Farinha-Marques, P. (2022). The biophilia hypothesis explored: regenerative urban green spaces and well-being in a Portuguese sample. *International Journal of Environmental Studies*, *81*(3), 1461–1475. https://doi.org/10.1080/00207233.2022.2067411

Li, K., Perrault, A., DeYoung, W. A., Cameron, E., Miller, C. T., O'Connor, A. S., Gu, M., & Braun, B. (2025). Impact of biophilic design on college student perception of mental health and environmental benefits: A dose-response study. *Building and Environment, 267*(Part C),112318. https://doi.org/10.1016/j.buildenv.2024.112318

Li, Z., Wang, Y., Liu, H., & Liu, H. (2022). Physiological and psychological effects of exposure to different types and numbers of biophilic vegetable walls in small spaces. *Building and Environment, 225*, 109645. https://doi.org/10.1016/j.buildenv.2022.109645

Lohr, V., Pearson-Mims, C., & Goodwin, G. (1995). Interior plants may improve worker productivity and reduce stress in a windowless environment. *Environmental Hort*iculture. *14*. https://doi.org/10.24266/0738-2898-14.2.97.

Mehrabian, A. (1996). Pleasure-arousal-dominance: A general framework for describing and measuring individual differences in Temperament. *Current Psychology* 14, 261–292 https://doi.org/10.1007/BF02686918.

Mehrabian, A., & Russell, J. A. (1974). *An approach to environmental psychology.* MIT Press.

Mencer, A. B. (2023). Road to recovery: Bringing the Outdoors In (Order No. 30522449). *Available from Dissertations & Theses @ Big Ten Academic Alliance; ProQuest D issertations & Theses Global; ProQuest Dissertations & Theses Global Closed Collection* . (2829377606).

Moslehian, A. S., Griffiths, R., Ristic, L., & Miller, A. M. (2023). Potential risks and beneficial impacts of using indoor plants in the biophilic design of healthcare facilities: A scoping review. *Building and Environment, 240*, 110481. https://doi.org/10.1016/j.buildenv.2023.110481

Nanu, L., Ali, F., Berezina, K., & Cobanoglu, C. (2020). The effect of hotel lobby design on booking intentions: An intergenerational examination. *International Journal of Hospitality Management*, *89*, 102530.

Navarrete-Hernandez, P., Kiarostami, N., Yang, D., & Ozcakir, A. (2024). Green enough? A dose–response curve of the impact of street greenery levels and types on perceived happiness. *Landscape and Urban Planning, 251*, 105130. https://doi.org/10.1016/j.landurbplan.2024.105130

Nitu, M. A., Gocer, O., Wijesooriya, N., Vijapur, D., & Candido, C. (2022). A biophilic design approach for improved energy performance in retrofitting residential projects. *Sustainability*, *14*(7), 3776. MDPI AG. Retrieved from http://dx.doi.org/10.3390/su14073776

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

Russell, J. A., & Mehrabian, A. (1977). Evidence for a three-factor theory of emotions. *Journal of Research in Personality, 11(3),* 273–294. https://doi.org/10.1016/0092-6566(77)90037-X

Ryan, C. O., Browning, W. D., Clancy, J. O., Andrews, S. L., & Kallianpurkar, N. B. (2014). Biophilic design patterns: Emerging nature-based parameters for health and well-being in the built environment. *International Journal of Architectural Research (Archnet-IJAR), 8*(2), 62–76.

Sayuti, A. (2016). Biophilic design? A study of emotions, influences, and perceptions of furniture design incorporating living organisms [Doctoral dissertation, University of Canberra]. *University of Canberra Repository*. https://www.researchgate.net/publication/320554599

Sayuti, N. A., Montana-Hoyos, C. A., & Bonollo, E. (2015). A study of furniture design incorporating living organisms with particular reference to biophilic and emotional design criteria. *Academic Journal of Science*, 4(1), 75–106. https://www.researchgate.net/publication/313858346

Shakhshir, K., & Sheta, W. (2023). The assessment of biophilic features in residential buildings: a case from Dubai. *Archnet-IJAR: International Journal of Architectural Research, 18*. 10.1108/ARCH-03-2023-0064.

Söderlund, J., Newman, P. (2022) How the biophilic design social movement informs planning, policy and professional practice. *Sustain Earth* 5, 4. https://doi.org/10.1186/s42055-022-00051-2

Söderlund, J., & Newman, P. (2017). Improving mental health in prisons through biophilic design. *The Prison Journal*, *97*(6), 750-772. https://doi.org/10.1177/0032885517734516

Tinner, M., Crovella, P., & Rosenbaum, P. F. (2018). Perceived Importance of Wellness Features at a Cancer Center: Patient and Staff Perspectives. *HERD*, *11*(3), 80–93. https://doi.org/10.1177/193758671875844

Totaforti, S. (2020). Emerging biophilic urbanism: The value of the human–nature relationship in the urban space. *Sustainability, 12*(13), 5487. https://doi.org/10.3390/su12135487:contentReference[oaicite:0]{index=0}

Van den Berg, A., E., Joye, Y., & Koole, S. L. (2016). Why viewing nature is more fascinating and restorative than viewing buildings: A closer look at perceived complexity. *Urban Forestry & Urban Greening, 20*, 397–401. https://doi.org/10.1016/j.ufug.2016.10.011

Wichrowski, M. J., Corcoran, J. R., Haas, F., Sweeney, G., & McGee, A. (2021). Effects of biophilic nature imagery on indexes of satisfaction in medically complex physical rehabilitation patients: An exploratory study. *Health Environments Research & Design Journal, 14*(3), 288–304. https://doi.org/10.1177/19375867211004241

Wijesooriya, N & Brambilla, A & Markauskaite, L (2020). Developing a pedagogical model for biophilic design: an integrative conjecture mapping and action research approach. *Eco-Architecture, 57-70*. 10.2495/ARC200051.

Wilson, E. O. (1984). Biophilia. *Harvard University Press.* P. 1

Yassein, G., & Ebrahiem, S. (2018). Biophilic design in the built environment to improve well-being: A systematic review of practices. *Journal of Urban Research*, *30*(1), 128-146. doi: 10.21608/jur.2018.88412

Yin, J., & Zhu, S., & Macnaughton, P., & Allen, J., & Spengler, J. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and Environment, 132*. 10.1016/j.buildenv.2018.01.006.

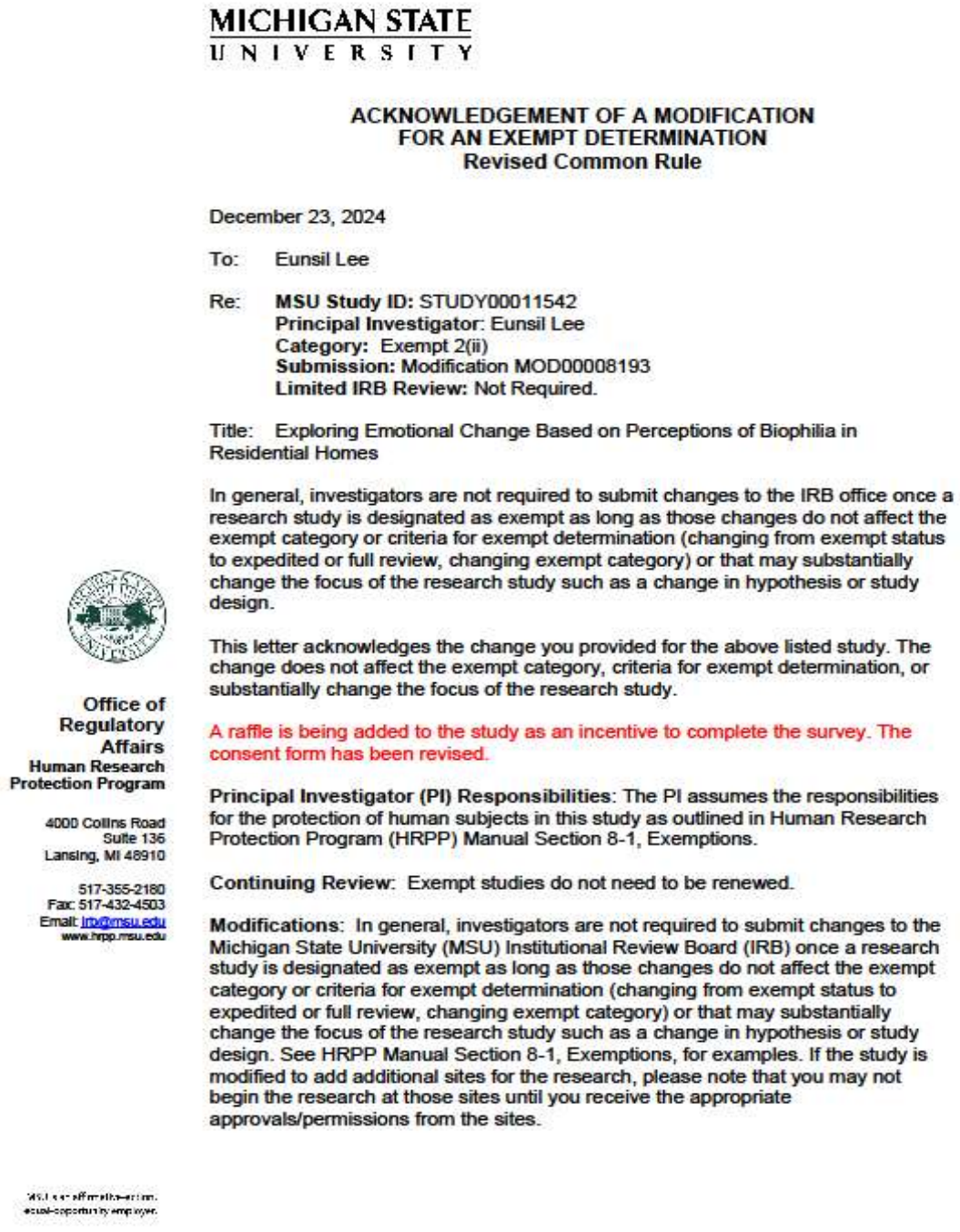
Yusuf, J. A., Isah, A. D., & Salami, S. F. (2024). Significance of demographic variables on perceived attention restoration using biophilic strategies in luxury hotels in Nigeria. *J. Umm Al-Qura University for Engineering and Architecture.* https://doi.org/10.1007/s43995-024-00091-z

Zalejska-Jonsson, A., Wilkinson, S. J., & Wahlund, R. (2020). Willingness to pay for green infrastructure in residential development—A consumer perspective. *Atmosphere, 11*(2), 152. https://doi.org/10.3390/atmos11020152

Zhaoming L., & Yujin W., & Hui L., & Hong L. (2022). Physiological and psychological effects of exposure to different types and numbers of biophilic vegetable walls in small spaces. *Building and Environment, 225*. 109645. 10.1016/j.buildenv.2022.109645.

Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. *Frontiers of Architectural Research, 11*(1), 114–141. https://doi.org/10.1016/j.foar.2021.07.006

APPENDIX A: IRB APPROVAL DOCUMENT



MICHIGAN STATE
UNIVERSITY

ACKNOWLEDGEMENT OF A MODIFICATION
FOR AN EXEMPT DETERMINATION
Revised Common Rule

December 23, 2024

To: Eunsil Lee

Re: **MSU Study ID:** STUDY00011542
Principal Investigator: Eunsil Lee
Category: Exempt 2(ii)
Submission: Modification MOD00008193
Limited IRB Review: Not Required.

Title: Exploring Emotional Change Based on Perceptions of Biophilia in Residential Homes

In general, investigators are not required to submit changes to the IRB office once a research study is designated as exempt as long as those changes do not affect the exempt category or criteria for exempt determination (changing from exempt status to expedited or full review, changing exempt category) or that may substantially change the focus of the research study such as a change in hypothesis or study design.

This letter acknowledges the change you provided for the above listed study. The change does not affect the exempt category, criteria for exempt determination, or substantially change the focus of the research study.

A raffle is being added to the study as an incentive to complete the survey. The consent form has been revised.

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

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

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

Office of Regulatory Affairs
Human Research Protection Program

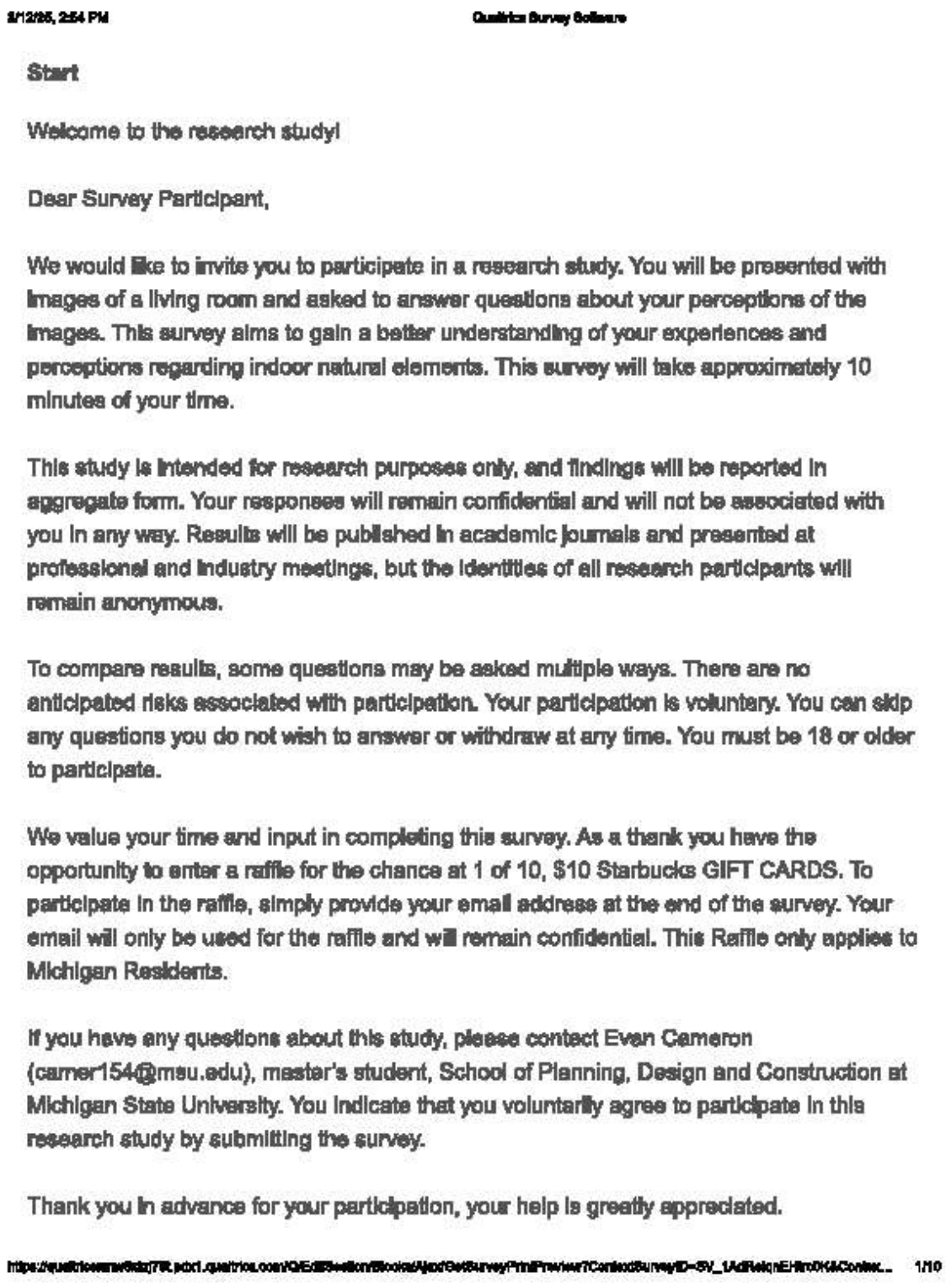
4000 Collins Road
Suite 136
Lansing, MI 48910

517-355-2180
Fax: 517-432-4503
Email: irb@msu.edu
www.hrpp.msu.edu

MSU is an affirmative-action, equal-opportunity employer.

Figure 3. *IRB Approval Document*

APPENDIX B: DISTRIBUTED SURVEY



8/12/25, 2:54 PM Qualtrics Survey Software

Start

Welcome to the research study!

Dear Survey Participant,

We would like to invite you to participate in a research study. You will be presented with images of a living room and asked to answer questions about your perceptions of the images. This survey aims to gain a better understanding of your experiences and perceptions regarding indoor natural elements. This survey will take approximately 10 minutes of your time.

This study is intended for research purposes only, and findings will be reported in aggregate form. Your responses will remain confidential and will not be associated with you in any way. Results will be published in academic journals and presented at professional and industry meetings, but the identities of all research participants will remain anonymous.

To compare results, some questions may be asked multiple ways. There are no anticipated risks associated with participation. Your participation is voluntary. You can skip any questions you do not wish to answer or withdraw at any time. You must be 18 or older to participate.

We value your time and input in completing this survey. As a thank you have the opportunity to enter a raffle for the chance at 1 of 10, $10 Starbucks GIFT CARDS. To participate in the raffle, simply provide your email address at the end of the survey. Your email will only be used for the raffle and will remain confidential. This Raffle only applies to Michigan Residents.

If you have any questions about this study, please contact Evan Cameron (camer154@msu.edu), master's student, School of Planning, Design and Construction at Michigan State University. You indicate that you voluntarily agree to participate in this research study by submitting the survey.

Thank you in advance for your participation, your help is greatly appreciated.

https://[illegible] 1/10

Figure 4. *Distributed Survey*

Figure 4. (cont'd)

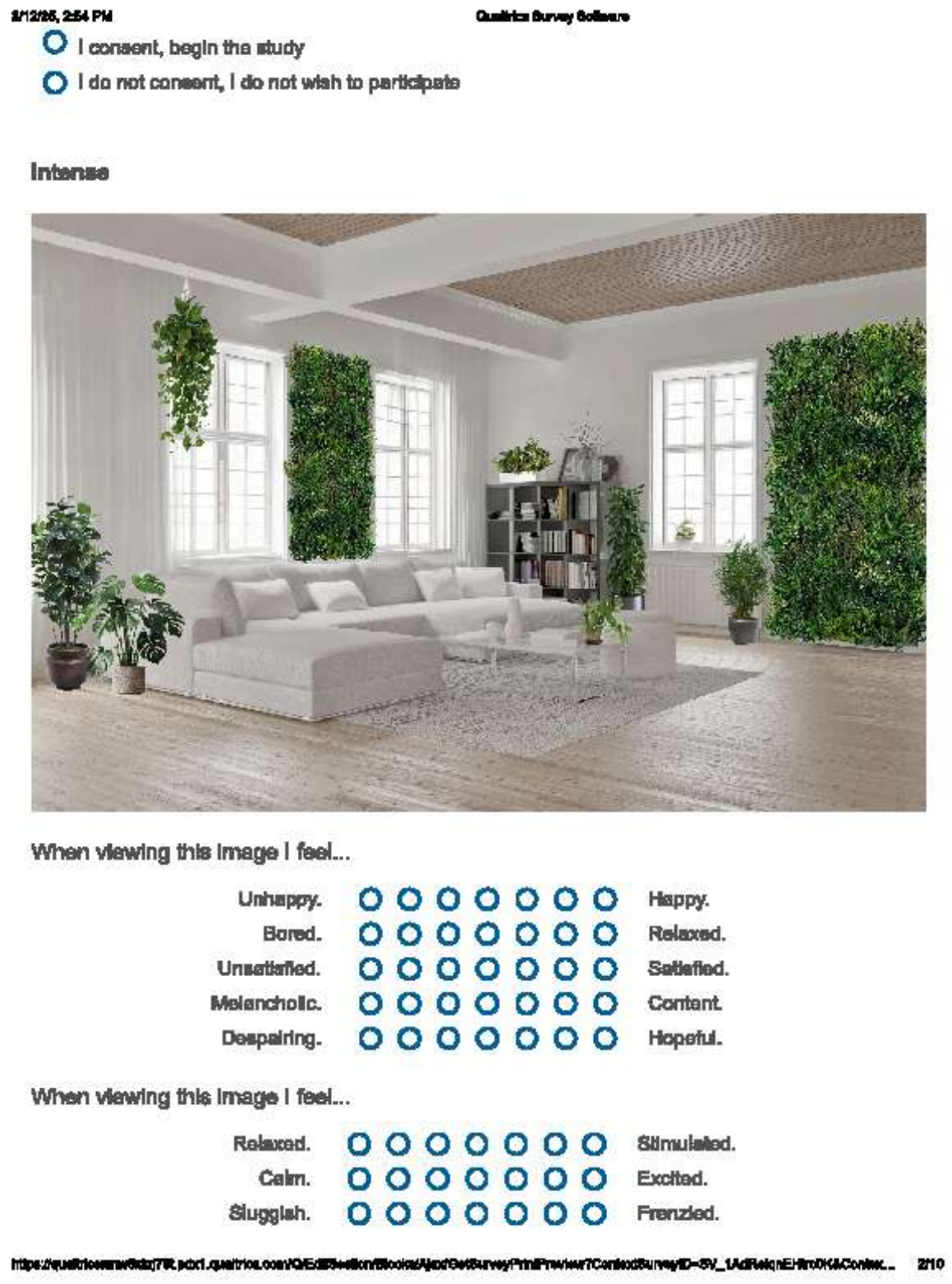


Figure 4. (cont'd)

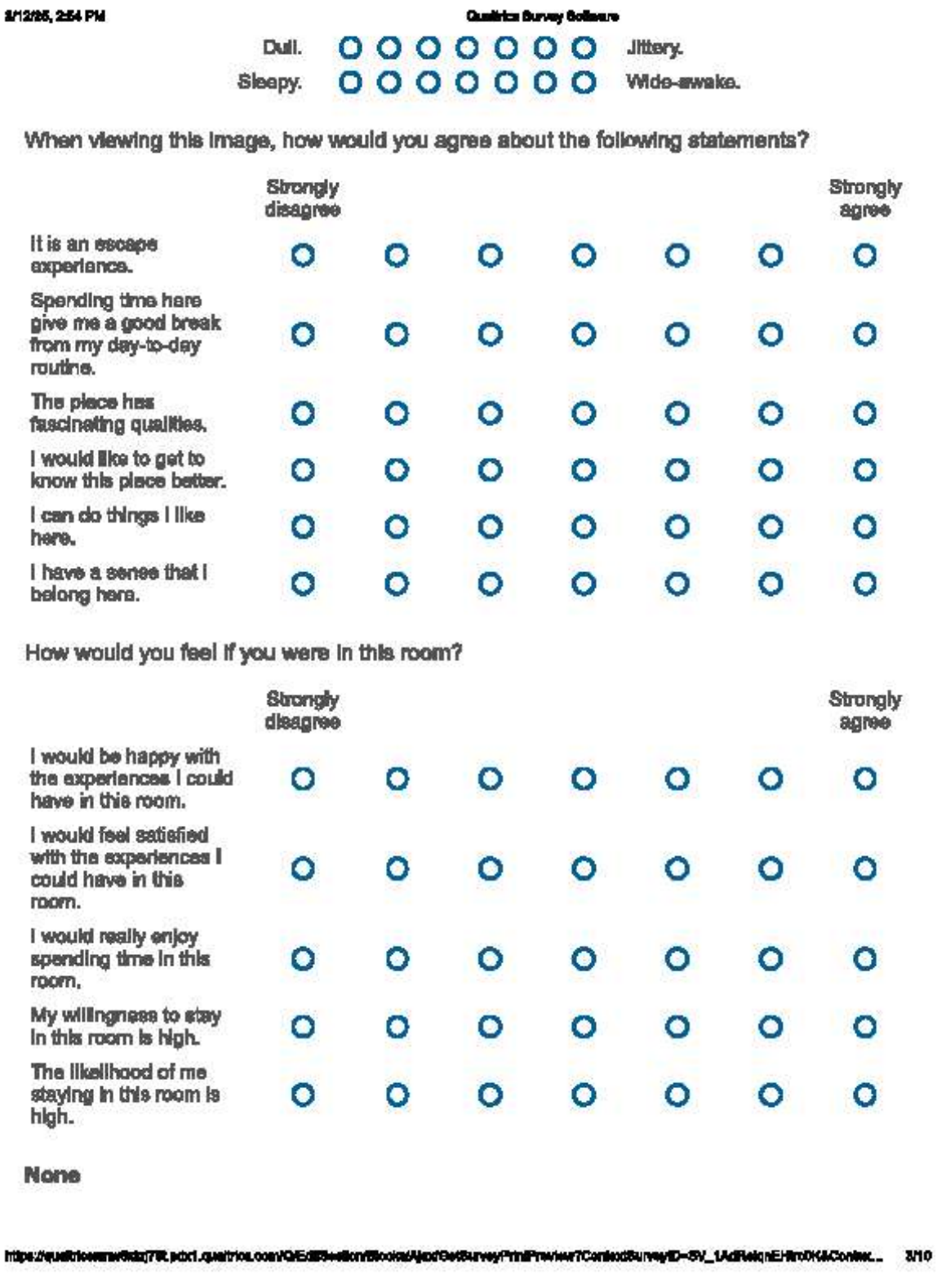


Figure 4. (cont'd)

Figure 4. (cont'd)

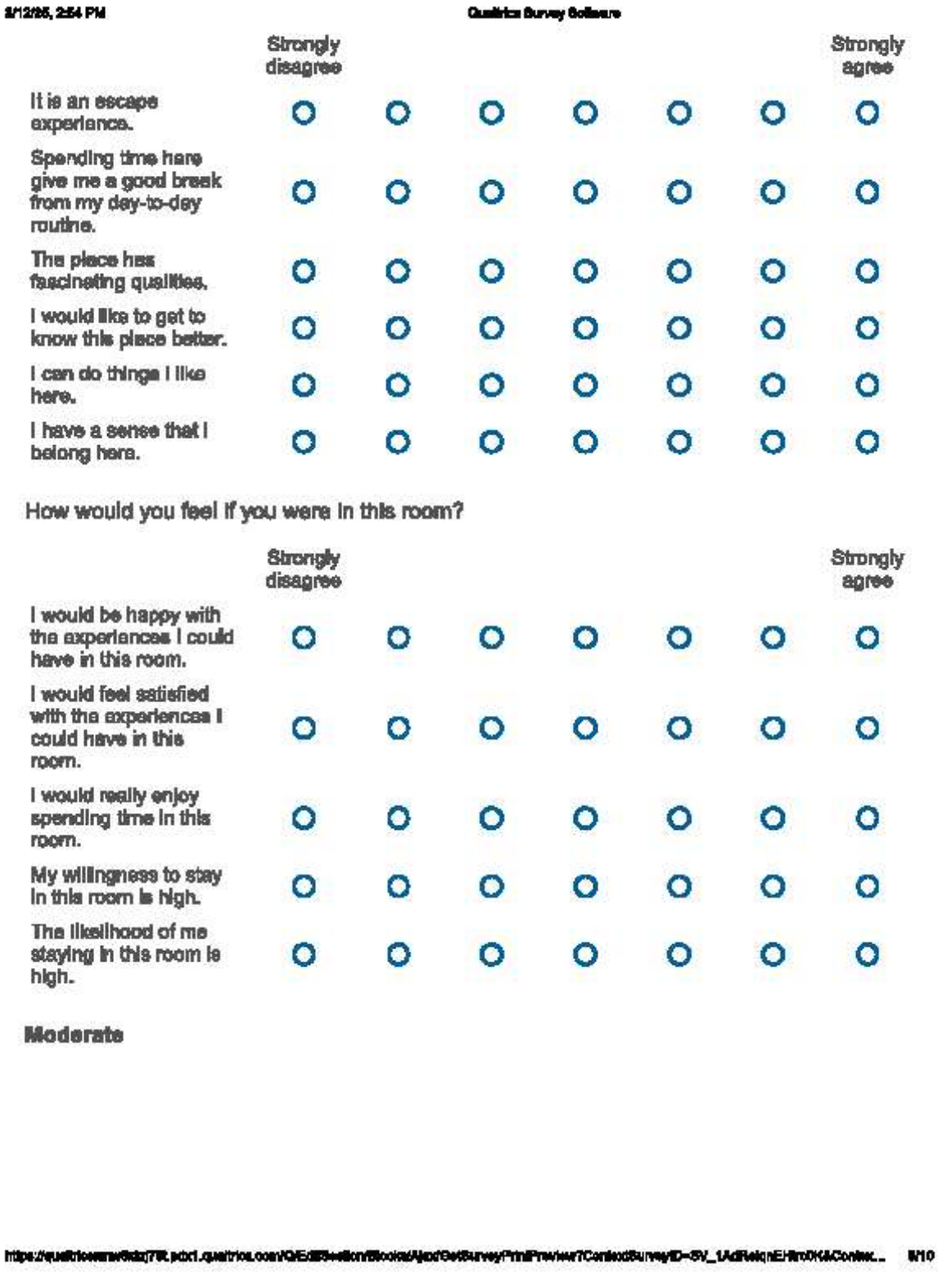


Figure 4. (cont'd)

8/12/25, 2:54 PM   Qualtrics Survey Software

Click to write the question text

When viewing this image I feel...

Unhappy.	○	○	○	○	○	○	○	Happy.
Bored.	○	○	○	○	○	○	○	Relaxed.
Unsatisfied.	○	○	○	○	○	○	○	Satisfied.
Melancholic.	○	○	○	○	○	○	○	Content.
Despairing.	○	○	○	○	○	○	○	Hopeful.

When viewing this image I feel...

Relaxed.	○	○	○	○	○	○	○	Stimulated.
Calm.	○	○	○	○	○	○	○	Excited.
Sluggish.	○	○	○	○	○	○	○	Frenzied.
Dull.	○	○	○	○	○	○	○	Jittery.
Sleepy.	○	○	○	○	○	○	○	Wide-awake.

When viewing this image, how would you agree about the following statements?

8/10

Figure 4. (cont'd)

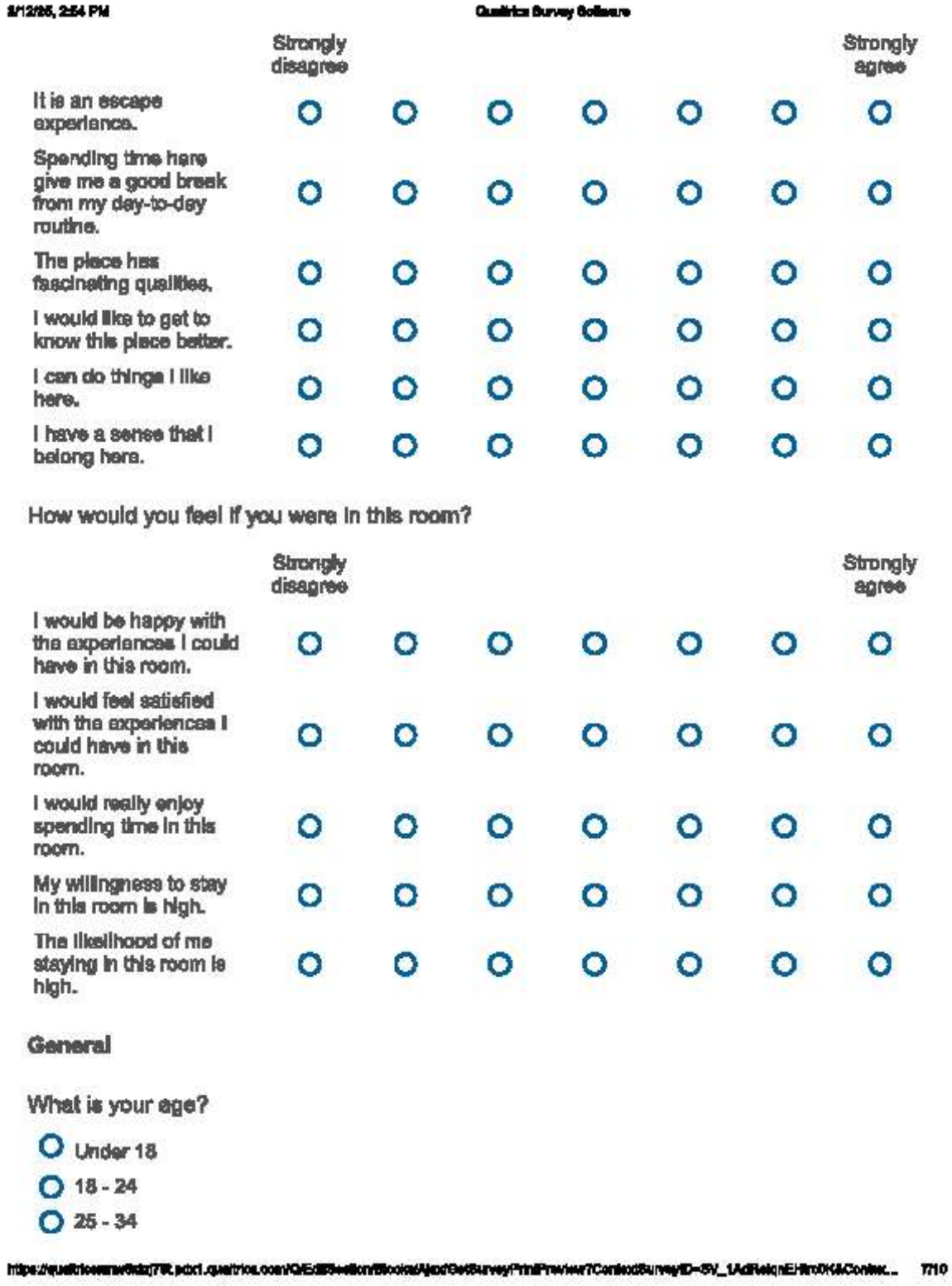


Figure 4. (cont'd)

- 35 - 44
- 45 - 54
- 55 - 64
- 65 - 74
- 75 - 84
- 85 or older

What is your gender?

- Male
- Female
- Other

How would you describe yourself? Please select all that apply.

- White
- Black or African American
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Pacific Islander
- Other

What is the highest degree or level of school you have completed?

- Less than a high school diploma
- High school degree or equivalent (e.g. GED)
- Some college, no degree
- Associate degree (e.g. AA, AS)
- Bachelor's degree (e.g. BA, BS)
- Master's degree (e.g. MA, MS, MEd)
- Doctorate or professional degree (e.g. MD, DDS, PhD)

Raffle

Figure 4. (cont'd)