

**Viewing from High-rise Buildings: Effects of Surrounding
Architectural Features on Occupants' Subjective Impressions**
高層建築からの眺望：周辺建築要素が在室者の心理印象に与える影響

February 2025

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Graduate School of Science and Engineering

CHIBA UNIVERSITY

(千葉大学審査学位論文)

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Abstract

Many cities have implemented compact city regulations in response to population expansion and land scarcity, which has increased the number of high-rise buildings. In crowded cities, surrounding buildings frequently block the window views of high-rise buildings, which hurts the psychological health of the occupants. In order to address this issue, the present study analyzes the effects of window views from high-rise buildings in urban areas, concentrating on how surrounding architectural features promote positive subjective impressions. The three main aspects examined the effects of roof types, planning measures, and facade characteristics on subjective impressions. Through three experiments, this study investigates the possibility of restoration of different types of roofs, the effects of planning measures, and facade characteristics on perceived oppressiveness.

Experiment 1 investigates the impact of different roof types on restoration potential from high-rise window views. Given that visual content significantly influences restoration, this experiment explores the association between roof types and restoration as measured by the Perceived Sensory Dimensions (PSDs) and the Short Revised Restoration Scale (SRRS). Stepwise regression analysis revealed that four attributes of PSDs—Serene, Nature, Social, and Rich in Species—had significant linear relationships with subjective restoration. The study employed ANOVA and post hoc tests to assess subjective restoration changes according to site settings, viewing floor levels, and roof types. According to the findings, observation of floor levels had no apparent impact on restoration when looking at the roofs of surrounding buildings. Garden roofs surpassed flat, slope, or grass roofs regarding restorative effects when viewed from upper floors (9F and 27F). The findings indicate the effects of environmental features on subjective impressions. When changing the roof type of surrounding multi-rise buildings, garden roofs are most effective in improving the subjective restoration of high-rise residential window views compared to other roof types. This study highlights the effects of roof design on creating and restorative urban environments.

Experiment 2 examines how planning measures and visual element ratios in high-rise residential window views influence perceived oppressiveness. This study focused on three planning measures, including building layout, building spacing, and surrounding trees. This virtual reality (VR) experiment assessed the oppressiveness of various visual scenes. The results showed that staggered building layout, increased building spacing, and surrounding trees decreased the perception of oppressiveness. An ordinal logistic regression model was employed in this experiment to predict the impact of planning measures and floor levels on the probability of perceived oppressiveness. There was a nonlinear relationship between perceived oppressiveness and viewing floor level. Stepwise regression analysis showed that increasing the ratio of sky and trees reduced perceived oppressiveness. In contrast, the ratio of built elements had mixed effects: enhanced foreground buildings increased perceived oppressiveness, whereas increased background buildings alleviated it. In addition, this study showed a negative relationship between perceived oppressiveness and environmental preference. These findings indicate that perceptions of oppressiveness in high-rise environments can be improved with careful surrounding planning and balanced visual elements of window views.

Experiment 3 explores how facade characteristics and visual element ratios in high-rise window views influence perceived oppressiveness. The study examines two facade characteristics, including the window-to-wall ratio (WWR) and height-to-width ratio (HWR). The experimental scenes were evaluated using virtual reality (VR) equipment. The findings indicated that increased WWR and decreased HWR reduced the perception of oppressiveness. The relationship between oppressiveness and floor level was nonlinear. Stepwise regression analysis showed that increasing the ratio of the sky while reducing visible building ratios alleviated feelings of oppressiveness. In addition, this study revealed a negative relationship between perceived oppressiveness and environmental preference. This study shows the positive effects of facade characteristics and visual elements on improving mental well-being.

This paper explores the impact of surrounding architectural features, including roof types, planning measures, and facade characteristics, on subjective impressions. The findings offer valuable theoretical knowledge and practical suggestions to create urban environments that improve psychological well-being.

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List of Abbreviations and Acronyms

| | |
|-------|---|
| ANOVA | Analysis of Variance |
| ART | Attention Restoration Theory |
| B-BR | Background Building Ratio |
| BL | Building Layout |
| BR | Building Ratio |
| BS | Building Spacing |
| EDA | Exploratory Data Analysis |
| EP | Environmental Preference |
| F-BR | Foreground Building Ratio |
| FL | Floor Level |
| GaR | Grass Ratio |
| GR | Greenery Ratio |
| HS | Horizontal Sightline |
| HWR | Height-to-Width Ratio |
| NASA | National Aeronautics and Space Administration |
| OR | Odds Ratio |
| PO | Perceived Oppressiveness |
| PRS | Perceived Restorativeness Scale |
| PS | Panoptic Segmentation |
| PSDs | Perceived Sensory Dimensions |
| RS | Self-rating Restoration scale |
| SE | Std. Error |
| SR | Sky Ratio |
| SRRS | Short Revised Restoration Scale |
| SRT | Stress Reduction Theory |
| ST | Surrounding Trees |
| SubR | Subjective Restoration |
| TR | Tree Ratio |
| UHI | Urban Heat Island |
| VIF | Variance Inflation Factor |
| VR | Virtual Reality |
| VS | Vertical Sightline |
| WWR | Window-to-Wall Ratio |

1. Introduction

Surrounding environments with positive subjective impressions are conducive to alleviating mental health. Mental health issues are prevalent around the world, especially in compact cities. As a result, growing attention has been directed toward understanding how the built environment affects psychological well-being. Window views connect to the outside world and promote psychological healing through exposure to beautiful urban surroundings (R. Kaplan, 2001; Ulrich, 1984). However, in densely populated cities, the window views of high-rise buildings are often blocked by surrounding structures (Chung et al., 2022). This paper investigates how surrounding architectural features, including roof types, planning measures, and facade characteristics, improve the quality of views from windows in high-rise buildings. Enhancing the quality of surrounding environments benefits the mental health of residents in high-density urban areas.

1.1. Background and Significance

Psychological health issues were epidemic in urban settings (WHO, 2022). The COVID-19 pandemic intensified psychological illnesses, such as depressive disorders, anxiousness, and substance misuse (Hossain et al., 2020; Shorey et al., 2022). The widespread stress of the general population, along with the worsening mental health of vulnerable populations, places additional strain on the current healthcare system (Hossain et al., 2020).

Built environments influence the mental well-being of occupants via a connection to nature, a sense of personal agency, and indoor air quality (Beemer et al., 2021). The widespread belief is that interaction with natural settings through windows contributes positively to mental well-being (R. Kaplan, 2001; Ulrich, 1984). Today, individuals spend more than 80% of their time indoors, decreasing the opportunity in outdoor environments to contact with nature (Klepeis et al., 2001). Contacting nature elements through window views has become the most convenient and effective method.

The window view links indoor and outdoor environments, regulating occupants' subjective impressions (R. Kaplan, 2001; Ulrich, 1984). Existing literature has consistently shown the positive impact of exposure to natural or specific built environments on mental well-being (Elsadek et al., 2020). Conversely, windowless environments risk occupants' health (Finnegan & Solomon, 1981).

1.2. Problem Statement

Although high-quality window views can enhance mental well-being, they are frequently obstructed by dense urban structures in dense cities, especially living or working in high-rise buildings (Chung et al., 2022). High-rise buildings are widely used to accommodate population increases and address land constraints (Burton et al., 2003; Yeh & Yuen, 2010). Furthermore, a combination of engineering, technological, economic, and so on factors has accelerated the growth of high-rise buildings (Radushinsky et al., 2018).

The expansion of high-rise buildings increases urban density and lowers the quality of window views (Chung et al., 2022). Compared with low-rise buildings, the vertical nature of high-rise structures diminishes opportunities for contact with nature in window views (Chung et al., 2019; Jeon et al., 2021). This study investigates methods for increasing window view quality to improve subjective impressions of individuals in high-density urban environments, with a particular emphasis on changes to surrounding architectural features. The core research question is: How can we design surrounding architectural features that improve the quality of window views in high-rise buildings while positively impacting occupants' subjective impressions?

1.3. Research Outline

The primary objective of this study was to investigate the impact of surrounding architectural features observed through the window views of high-rise buildings on individual subjective

impressions, with particular emphasis on restoration and oppressiveness. This study's specific details are as follows:

1. Investigating the effect of different roof types visible from high-rise windows on subjective restoration.
2. Investigating the effect of planning measures visible from high-rise windows on perceived oppressiveness.
3. Investigating the effect of facade characteristics visible from high-rise windows on perceived oppressiveness.

2. Literature Review

2.1. Human Behavior and Surrounding Environment

People constantly interact with the built and natural environments. Environmental psychology examines how surrounding environments influence human behavior (Gifford, 2014). It also studies the behaviors that impact climate-friendly and sustainable decisions, investigates the underlying reasons for these behaviors, and creates interventions to encourage pro-environmental behavior (Stern, 2000; Uzzell & Rätzzel, 2009). Environmental psychology studies the effects of physical environments such as homes, businesses, schools, and public spaces and how interactions with nature can alleviate or exacerbate stress (S. Kaplan, 1995; Ulrich, 1984). In addition, since spending more time in virtual settings, this field pays attention to comprehending interactions that take place online (Levi & Kocher, 1999).

2.2. Psychological health Conditions

Mental health issues are widespread and often lead to severe impairment across numerous nations worldwide in contemporary society (Hossain et al., 2020; Kessler et al., 2009; Shorey et al., 2022). Psychological health concerns, including anxiety, sleep disturbances, depression, feelings of frustration, and stress-related disorders, may arise from apprehensions related to infection risks, increased work demands, lifestyle changes, and declining living conditions (Pulvirenti et al., 2020; Zhang et al., 2020). The concurrent appearance of mental illness symptoms and the associated social stigma hurt people's ability to maintain stable housing, work, interpersonal connections, self-esteem, and educational possibilities (Storrie et al., 2010). The healthcare system and society are under an enormous amount of pressure due to widespread mental health issues (Hossain et al., 2020).

People of all ages are at risk of mental health problems, including teenagers, college students, working adults, and the elderly. Significant physiological, psychological, and emotional changes, as well as increased cognitive capacity and a developing need for autonomy,

characterize the dynamic transitional age of adolescence (Gilmore & Meersand, 2013). Teenagers who grow through this phase of fast transition are more vulnerable to mental health disorders, which include eating disorders, behavioral disorders, stress disorders, and affective disorders (Shorey et al., 2022). The prevalence of severe mental illness among university students is rising noticeably, which is in line with societal trends (Storrie et al., 2010). In the meantime, university students frequently talk about how the stigma around mental illness makes them feel socially isolated, which frequently makes them reluctant to ask for help (Megivern et al., 2003).

Employees frequently struggle with mental health issues, which negatively affect their attendance and productivity at work (De Lorenzo, 2013). Employee productivity and management effectiveness may suffer if these problems are kept under wraps and work-related difficulties are attributed to other causes (De Lorenzo, 2013). Aging, as a worldwide phenomenon, also has far-reaching effects. The elderly are highly susceptible to anxiety and depressive disorders, which frequently coexist and have negative consequences like lower quality of life and higher death rates (Charney et al., 2003; De Beurs et al., 1999).

2.3. High-Rise Buildings Under Compact City Policy

Compact city policy has acquired international recognition as urban populations rise and land becomes scarce (Burton et al., 2003; Yuen & Yeh, 2011). These strategies strongly emphasize modernizing central regions, encouraging high-density development, and combining a variety of uses, including leisure, healthcare, education, and cultural venues (Jenks & Burgess, 2000). High-rise buildings are frequently used as a key strategy in both developed and developing countries. High-rise buildings have become a primary architectural form for both work and residence, effectively addressing the challenges of limited land availability and rising population density (Burton et al., 2003; Y. Wang et al., 2020; Yeh & Yuen, 2010). In addition, the high-rise concept prospers through economic riches, enlargements in construction practice, and advances in aesthetics (Radushinsky et al., 2018).

High-rise buildings are usually identified by their height above ground level, which is measured in meters or determined by the number of stories they have (Tamošaitiene & Gaudutis, 2013). However, definitions of high-rise buildings vary between countries. To standardize research, we use the definition adopted in China as a reference. In China, a high-rise building is defined as a residential structure exceeding 27 meters in height or a non-single-story public building surpassing 24 meters, with a maximum height limit of 100 meters (Ministry of Housing and Urban-Rural Development, 2019).

Although high-rise buildings address challenges related to land scarcity and population growth, they also contribute to a sense of disconnection from the external environment for occupants (Elsadek et al., 2019; Olszewska-Guizzo et al., 2018). These buildings are frequently criticized for adverse effects, which include fostering social isolation, disrupting human scales, and lowering the quality of urban life (Cappon, 1971). Furthermore, high-rise structures have a negative effect on mental health, negatively influencing variables including life satisfaction, results of restoration, physical and psychological health, quality of life, and perceived oppressiveness (Asgarzadeh et al., 2012; Gifford, 2007; J. Lee et al., 2011; Yuen & Yeh, 2011).

For many people, high-rise residential buildings are not the first choice for dwelling (Gifford, 2007). Children living in high-rise buildings have shown a twofold increase in behavioral problems, such as bedwetting and temper tantrums (Ineichen & Hooper, 1974). People living in high-rise buildings often lack interaction and helping behaviors with each other (Nadler et al., 1982). Because high-rise buildings are usually linked with higher crime rates, residents usually feel more anxious (Yancey, 1971). Moreover, research suggests that residing in high-rise buildings is linked to a greater likelihood of suicide (Lester, 1994).

2.4. Window Views and Subjective Impressions

Windows are the primary connection between indoor and outdoor spaces (Ko et al., 2020). Viewing visual elements through windows has similar effects to direct outdoor experiences (Ko et al., 2020). According to earlier research, people's impressions are influenced by experiences in both natural and built environments (Damigos & Anyfantis, 2011; R. Kaplan, 2001; Samavatekbatan et al., 2016). Considering that people today spend extended periods indoors living and working, with limited exposure to outdoor environments, the role of window views in psychological well-being receives increasing attention (R. Kaplan, 2001; Lin et al., 2022; van Esch et al., 2019).

2.4.1. Visual Connection with Natural Environments

Viewing natural settings has been repeatedly demonstrated to impact a person's psychological and physical health (Gilchrist et al., 2015; Shin, 2007; Tennessen & Cimprich, 1995). These natural environments include a variety of features, including vegetation, the sky, mountains, and water bodies.

Among the natural elements, vegetation has drawn particular attention for its substantial advantages for people's mental well-being. Ulrich (1984) found that individuals undergoing cholecystectomy surgery who had hospital rooms with windows overlooking the outside recovered much more quickly than those whose windows faced brick walls. A study further supports the beneficial effects of the natural landscape that included patients in a residential rehabilitation program. According to research, having an unhindered view of the outdoors from one's bedroom improves one's physical and emotional well-being (Raanaas et al., 2012).

Most people consider the sky as a layer of blue, and light blue tones are thought to have calming qualities to improve cognitive attention on various tasks (Lin et al., 2022; Wright, 1995). Empirical studies about the effects of color on mood and psychological processes support the idea that blue promotes increased mental activity, logical thought, and reasoning

skills (Alter, 2014; Dutton, 2009). People feel depressed when clouds cover the sky, and this perception is linked to improved cognitive function and increased focus (Harley, 2018). Different atmospheric situations, such as weather patterns or amounts of cloud cover, have been proposed to elicit different cognitive processing modes in different people (Harley, 2018).

Aside from the sky, another example of blue space is the presence of water, such as lakes, rivers, seas, and other similar bodies. Environments with water bodies are associated with higher preferences and perceived restoration than environments without water features (M. White et al., 2010). Built environments incorporating water are typically rated positively as greenery-rich (M. White et al., 2010). Residential buildings with visible blue spaces are often associated with better general well-being (Garrett et al., 2019). Water bodies offer both social and psychological benefits (de Bell et al., 2017).

Window views are associated with psychological health in a variety of settings, including offices, dormitories, and residential buildings. Residential windows with greenery enhance occupants' general well-being and neighborhood satisfaction (R. Kaplan, 2001). Students with windows overlooking natural elements in university dormitories do better than those with views of built settings on tasks requiring concentrated attention (Tennessen & Cimprich, 1995).

Employees with windows that provide natural environments report feeling happier and less frustrated at work (R. Kaplan, 1993). In the workplace, access to green window views reduces stress levels among male respondents, while for female respondents, it improves workplace attitudes without significantly reducing stress levels (Lottrup et al., 2013). Likewise, forests outside windows increase job satisfaction and lower stress levels associated with the workplace (Shin, 2007).

2.4.2. Visual Connection with Built Environments

Previous studies have demonstrated that compared to built environments, natural surroundings have more significant favorable psychological impacts (Lin et al., 2022).

However, some unique aspects of constructed environments, such as skyscrapers, historical and cultural heritage sites, and city symbols, also have beneficial psychological impressions (Damigos & Anyfantis, 2011).

The construction era of buildings, their maintenance condition, and exterior complexity—including consistency and recognizability—affect individual subjective impressions (Herzog, 1989; Herzog & Gale, 1996; Herzog & Shier, 2000; Lin et al., 2022). The perceptions are also influenced by external building features, which include size and proportion, materials, colors, and structural components (Akalin et al., 2009; Malewczyk et al., 2021; Prieto & Oldenhav, 2021; Stamps, 1999).

In addition, street environments influence mental well-being, particularly for residents on lower floors (Masoudinejad & Hartig, 2020). In contrast with static buildings, street environments introduce dynamic aspects, such as pedestrian activity, traffic, and auditory stimuli (Milgram, 1970). Widening roadways benefits psychological impressions (Ozdemir, 2010; Stamps & Smith, 2002). Furthermore, some built elements, such as parking lots and garbage storage, are associated with negative psychological perceptions (Schmid & Säumel, 2021).

2.5. Surrounding Architectural Features' Subjective Impressions

The style, design, and arrangement of surrounding buildings are included in surrounding architectural features (Nasar, 1994). Specifically, these features include roof design, such as shapes, materials, and types; planning measures, like layout and spacing; and architectural details, such as arches, pergolas, and ornamental elements; facade characteristics, including proportions, windows, doors, and decorative details.

2.5.1. Roof Types

The building roofs, the top covering of structures, are classified based on several criteria, including shape, material, function, and structural design (Allen & Iano, 2019; Ching, 2020). Roof shapes comprise flat, curved, domed, or sloped. Material classifications include tiles, metal, or green roofs featuring vegetation. Regarding function, roofs are divided into accessible spaces, such as rooftop gardens or terraces, and non-accessible spaces. From the structural perspective, roofs are supported by beams and trusses, thin shell structures, or tensile membranes.

Roof types of residential buildings typically include flat, sloped, grass, and garden roofs. Flat roofs are horizontal roofs made of concrete. Sloped roofs have an angle to drainage. Grass roofs feature low shrubs or ground cover plants. Garden roofs incorporate a variety of plantings such as trees, shrubs, vines, and other vegetation that provide atmospheric and ecological benefits.

Compared to flat and sloped roofs, green roofs offer several benefits, including improved psychological well-being, aesthetic enjoyment, and restoration (K. E. Lee et al., 2014, 2015; E. V. White & Gatersleben, 2011). Precisely designed green roofs with various vegetation shapes and colors are favored (Fernandez-Cañero et al., 2013). Viewing green roofs improve job efficiency and lessen fatigue (K. E. Lee et al., 2018). Garden roofs have beneficial psychological effects on patients in hospital settings (Reeve et al., 2017).

2.5.2. Building Planning Measures

Building design and preparation phases include layout planning, structural choices, or landscape design. Planning measures have the potential to alter people's psychological impressions by altering built environments. This study focuses on two planning measures, including building layout and building spacing.

2.5.2.1. Building Layout (BL)

Building planning and layout in urban environments are related to occupants' satisfaction and comfort. Parallel and staggered building layouts enhance airflow and wind speeds, while enclosed layouts, despite the wind shadow and direct sunlight effects, provide superior thermal comfort by more effectively reducing air temperatures (Jiang & Wu, 2020; F. Wang & Munakata, 2024b). Building layout, density, and greenery affect urban heat island (UHI) patterns differently during the day and night (Yang et al., 2010). The building layout influences the range of visible views from windows, with an appropriate design improving obstructed window views (Chung et al., 2022).

2.5.2.2. Building Spacing (BS)

Building spacing impacts several aspects of environments, such as views, privacy, and light and shade. In high-rise residential structures, altering the direction and spacing of buildings can increase internal ventilation, which benefits save energy and improve the physical and mental health of building inhabitants (F. Wang & Munakata, 2024b; Zhou et al., 2014). Raising building spacing relieves bothered by noise and visual oppression (Chung et al., 2019). Proper building spacing enhances privacy between structures and lessens the impact of surrounding activity on occupants (Carmona, 2021).

2.5.3. Building Facade Characteristics

Facade characteristics of buildings include material, color, texture, fenestration, proportions, and architectural style. This study focuses on two facade characteristics: Window-to-Wall Ratio (WWR) and Height-to-Width Ratio (HWR).

2.5.3.1. Window-to-Wall Ratio (WWR)

Building windows provide thermal insulation, vistas, natural light sources, and aesthetic enhancements (Troup et al., 2019; F. Wang & Munakata, 2024a). The window-to-wall ratio

(WWR) refers to the percentage of the building's glass area compared to its total wall area. Numerous building attributes are impacted by this ratio, such as daylighting, air leakage or ventilation, solar heat gain, occupant comfort, material selection, window size, and energy usage (Ashrae, 2013; Islam et al., 2014; F. Wang & Munakata, 2024a).

Buildings' window-to-wall ratio affects open versus enclosed, transparent versus opaque, and light versus heavy overall feelings (Ewing & Handy, 2009; Şen et al., 2011; Stamps, 1999; Taylor, 1999). Religious buildings usually have fewer windows, while office buildings frequently have more enormous glass facades (Şen et al., 2011). Residential buildings generally have a moderate amount of window area based on their function (Alkhresheh, 2012). Buildings with different window-to-wall ratios might elicit different feelings. For instance, a facade with fewer windows tends to feel heavier than one with more windows, which feels lighter (Bacow, 2013).

2.5.3.2. Height-to-Width Ratio (HWR)

The height-to-width ratio (HWR) is the ratio of buildings' vertical height compared to horizontal width. This ratio is relevant to architectural aesthetics, structural stability, and urban planning and design (Goh & Chang, 1999; Huang et al., 2021; Li & Wu, 2006).

The HWR affects the sense of enclosure in urban settings. The sense of enclosure and subjective impressions follow an inverted U-shaped relationship. Insufficient enclosure results in discomfort and loss of privacy, whereas excessive enclosure creates oppressiveness and limitation (Carmona, 2021; Jacobs, 1993). The height of buildings exceeds the street width, making people feel oppressed. The feeling of oppression can be reduced by planting trees in front of buildings (Zarghami et al., 2019).

2.6. Viewing Floor Levels (FL) and Subjective Impressions

The viewing floors affect psychological perception by changing the content of window views (Elsadek et al., 2020; Masoudinejad & Hartig, 2020; Zhang et al., 2012). People prefer higher floors for broad views, such as skies, mountains, and natural landscapes (Conroy et al., 2013; Masoudinejad & Hartig, 2020; Olszewska-Guizzo et al., 2018). Lower floors usually view crowded urban environments, such as buildings, vehicular traffic, and pedestrian activity (Masoudinejad & Hartig, 2020; Schmid & Säumel, 2021). Nevertheless, greenery around lower floors can lead to positive psychological effects (F. Wang & Munakata, 2023).

2.7. Theoretical Foundations for Psychological Effects of Window Views

Attention Restoration Theory (ART) and Stress Reduction Theory (SRT) are mutually supportive concepts explaining how natural and built environments impact people's psychological well-being (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995; Ulrich, 1984).

2.7.1. Attention Restoration Theory (ART)

According to the ART, extended durations of concentrated focus might exhaust directed attention resources. Restoring cognitive reserves through engaging in natural settings benefits concentration (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). In cognitive psychology, the capacity to concentrate on complex tasks is focused attention (R. Kaplan & Kaplan, 1989). This type of attention is limited and often leads to attentional depletion when individuals focus on a stimulus or activity that lacks inherent motivation (S. Kaplan, 1995; S. Kaplan & Berman, 2010).

The terms Being Away, Fascination, Extent, and Compatibility are used by ART to describe the distinctive qualities of restorative situations (Herzog et al., 2003; S. Kaplan, 1995).

"Being Away" describes settings that let people take a break from activities, without requiring focus. "Fascination" refers to situations that reenergize focused attention through effortless, unconscious engagement. "Extent" characterizes settings abundant in meaningful

substance and logical organization, providing lots of chances for introspection, observation, and facilitating immersion. "Compatibility" means that the surroundings promote peace between people and their surroundings while supporting personal ambitions.

2.7.2. Stress Reduction Theory (SRT)

According to the SRT, being in natural settings improves emotions of serenity and reduces psychological stress while eliciting positive feelings (Ulrich, 1983, 1984). Environments with positive psychological effects—such as bodies of water, vegetation, complex scenes, visually deep landscapes, and settings with curves—are beneficial because humans have historically lived in these types of settings for extended periods (Ulrich et al., 1991). These environments provided our ancestors with essential resources and protection from predators. Positive psychological reactions have evolved due to this evolutionary experience, and they still aid in reducing physiological stress in contemporary humans.

3. Methodology

3.1. Study Design

Three experiments in this study used visual signals as stimuli, essential for our perception of surroundings. Compared to other sensory inputs, visual signals process more information and give more complete images of the environment, substantially affecting behavioral and psychological reactions (Gibson, 1966). Timely data collection is made possible by instantaneous responses to visual signals (Ulrich, 1983).

This study explored how various surrounding architectural features of high-rise building window views—including roof types, planning measures, and facade characteristics—affect individual subjective impressions through three experiments, as outlined in the study design (Figure 3.1). All three experiments employed quantitative research methods.

Experiment 1 investigated the influence of different sites, roof types, and floor levels on perceived sensory dimensions (PSDs) and subjective restoration. Participants viewed static images through smartphones to complete the questionnaire.

Experiment 2 assessed different planning measures (building layout, building spacing, and surrounding trees) and viewing floor levels impact perceived oppressiveness and environmental preference. This experiment utilized panoramic images viewed through virtual reality (VR) headsets, followed by a questionnaire.

Experiment 3 examined the effects of various facade characteristics (window-to-wall and height-to-width ratios) and viewing floor levels on perceived oppressiveness and environmental preference. Similar to Experiment 2, this experiment used panoramic images viewed through VR headsets and included a questionnaire.

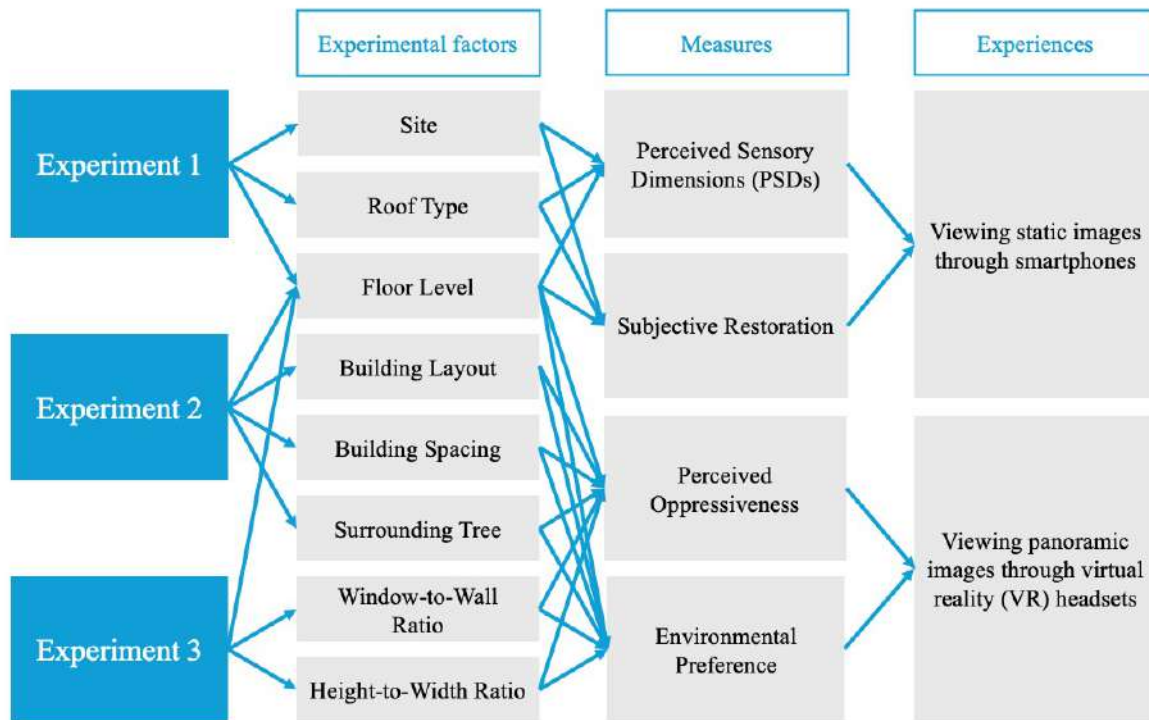


Figure 3.1: Outline of Study Design.

Source: Created by the Author.

3.2. Participants

Participants in three experiments were recruited from universities. Experiment 1 included 394 valid participants, experiment 2 involved 50, and experiment 3 involved 40. Every participant had normal vision and no psychological or cognitive health issues. Before the experiments began, participants reviewed the instructions and signed written informed consent forms. All questionnaires and experimental procedures adhered strictly to ethical academic research standards. Detailed information is provided in each experiment.

3.3. Measuring Instruments

This study primarily assessed four aspects of subjective impressions: Perceived Sensory Dimensions (PSDs), Subjective Restoration (SubR), Perceived Oppressiveness (PO), and Environmental Preference (EP). The questionnaire for Experiment 1 was developed in Mandarin to accommodate participants from China (Appendix 1). The questionnaires for

Experiments 2 and 3 were developed in Japanese and Mandarin to accommodate participants from Japan and China (Appendices 2 and 3).

3.3.1. Perceived Sensory Dimensions (PSDs)

The Perceived Sensory Dimensions (PSDs) assess landscape quality and attributes that enhance restorative experiences (Grahn & Stigsdotter, 2010). The PSDs comprised eight attributes: Serene, Nature, Rich in Species, Space, Prospect, Refuge, Social, and Culture. "Serene" describes a setting that is quiet, safe, and free from disturbance, offering a peaceful and calm atmosphere. "Nature" refers to a landscape untouched by human influence, often wild and abundant with wildlife. "Rich in Species" highlights a place filled with diverse plant and animal life. "Space" creates a sense of stepping into a different world within a natural environment. "Prospect" points to locations with captivating views that encourage lingering and appreciation. "Refuge" suggests a secluded, sheltered spot to relax and feel secure. "Social" relates to areas designed for people to gather and interact. "Culture" embodies a community's traditions, values, achievements, and heritage. These dimensions collectively illustrate how various sensory experiences enrich the restorative nature of landscapes (Memari et al., 2017).

Some PSDs are theoretically related to the evolutionary origins of the preference (Adevi & Grahn, 2012). The "Prospect and Refuge" concept captures the very survival-related need for vistas, allowing viewing and concealing in habitats (Appleton, 1975). The "Rich in Species" dimension falls squarely under the biophilia hypothesis (Wilson, 2017). The "Nature" dimension denotes environments that provide restoration and are marked by the absence of people and spectacular sights (Herzog et al., 1997). The "Space" implies an inherent preference for expansive and scenic natural environments, a sense of entering another world (R. Kaplan & Kaplan, 1989). The foundational structure of PSDs concerns the supply of favorable natural features, diversion, and privacy while promoting active exercise and reinforcing social bonding at the same time (Memari et al., 2017).

This experiment developed tailored items for assessing window views, building on the original Perceived Sensory Dimensions (PSDs) evaluation items. Each of the eight dimensions from the original PSDs—Serene, Nature, Rich in Species, Space, Prospect, Refuge, Social, and Culture—was evaluated through several sub-items (Table 3.1). Following a process of selection and refinement, 22 sub-items were created to assess perceptions of window scenes (Table 3.2).

Table 3.1: Evaluation Items of PSDs.

| PSDs | Factors |
|-------------|---------------------------------|
| Nature | Nature quality |
| | Wild and untouched |
| | Free growing lawns |
| | Possible to light a fire |
| | Not crowded |
| Culture | Feels safe |
| | Hilly |
| | Fountains |
| | Statues |
| | Foreign plants |
| Prospect | City park characteristic |
| | Pond, canal |
| | Flowers |
| | Wooded pasture quality |
| | Plane, well-cut grass |
| Social | Prospect |
| | Cut lawns |
| | Football fields on grass |
| | Football fields on gravel |
| | Football fields are lit up |
| Social | Small ball grounds |
| | Showers, changing rooms |
| | Entertainment |
| | Exhibitions |
| Social | Restaurant |
| | Market stalls |

| | |
|-----------------|--|
| | <p>Paths made of gravel</p> <p>Special park animals</p> <p>General good lighting</p> <p>Roads well lit up</p> <p>Access to restrooms</p> <p>Places sheltered from the wind</p> <p>Sunny places</p> <p>Shady places</p> <p>Several seats and benches</p> <p>Tables and benches</p> <p>Plenty of people</p> <p>Feels safe</p> <p>Paths with hard surfaces</p> |
| Space | <p>Spacious</p> <p>Areas not crossed by paths</p> <p>Lots of trees</p> <p>Places sheltered from the wind</p> <p>Sunny places</p> <p>Shady places</p> <p>Places where people can gather</p> |
| Rich in Species | <p>One can detect several species of animals</p> <p>Natural plant and animal populations</p> <p>Many native plants to study</p> |
| Refuge | <p>Many bushes</p> <p>Animals that people can feed and pet</p> <p>Sandpits</p> <p>Tables and benches</p> <p>Watching people being active</p> <p>Play equipment</p> <p>Feels safe</p> |
| Serene | <p>Silent and calm</p> <p>No bikes</p> <p>Not crowded</p> <p>No mopeds</p> <p>Clean and well maintained</p> <p>No traffic noise</p> <p>Feels safe</p> |

*Factors highlighted in bold are instrumental in assessing this study's perception of window views.

Source: F. Wang & Munakata (2023).

Table 3.2: Key Factors of PSDs in Window Views Dominate by Roofs (22 Items).

| PSDs | Factors |
|-----------------|---|
| Nature | An environment with natural qualities. |
| | An environment with wild and untouched qualities. |
| | Free growing vegetation. |
| Culture | An environment with cultural features, such as fountains and statues. |
| | An environment has the characteristics of a city park. |
| | Decorated with ornamental plants or flowers. |
| Prospect | An environment with open views. |
| | Vistas over the surroundings. |
| | Plane and well-cut grassy surfaces. |
| Social | Possible to watch entertainment or exhibitions. |
| | An abundance of people and movements in the environment. |
| | There are several seats and benches. |
| Space | The environment is experienced as spacious and free. |
| | The environment has lots of trees. |
| | Places where people can gather. |
| Rich in Species | Various species of plants. |
| | Feeling exist various animals, such as birds, insects, etc. |
| Refuge | An environment with many bushes. |
| | It feels safe in this environment. |
| Serene | The environment is silent and calm. |
| | The density of buildings and plants is moderate, uncrowded. |
| | Not disturbed by traffic noise. |

Source: F. Wang & Munakata (2023).

3.3.2. Subjective Restoration (SubR)

The Short Revised Restoration Scale (SRRS) addressed the practical limitations of earlier restoration scales. The SRRS, with fewer variables, was a condensed version of the original Self-rating Restoration scale (RS), which comprised 17 items and was derived from the longer Perceived Restorativeness Scale (PRS) created by Hartig and colleagues (Han, 2003; Hartig, 1996). This revision simplified the assessment of the restorative quality of environments for more practical application (Han, 2003).

The PRS and SRRS evaluated the restorative qualities of environments. The PRS concentrated on directed attention fatigue, while the SRRS described various restoration attributes. According to the SRRS, in addition to attentional recovery, restoration includes behavioral, emotional, physiological, and cognitive aspects (Han, 2003; R. Kaplan & Kaplan, 1989; Ulrich, 1983).

This experiment assessed the subjective restoration using the SRRS. The SRRS incorporated Attention Restoration Theory (ART) and Stress Reduction Theory (SRT) principles (Han, 2003). This scale consisted of four dimensions: Emotion, Cognition, Physiology, and Behavior. Specifically, the dimension of Emotion included two sub-items: "I feel grouchy – good-natured" and "I feel anxious – relaxed." The dimension of Cognition encompassed two sub-items: "I am interested in the present scene" and "I feel attentive to the present scene." The dimension of Physiology included two sub-items: "My breathing is getting faster" and "My hands are sweating." The dimension of Behavior included two sub-items: "I would like to visit here more often" and "I would like to stay here longer."

3.3.3. Perceived Oppressiveness (PO)

In urban environments, perceived oppressiveness links to personal space and control issues (Schmidt & Keating, 1979). When personal space is invaded, it generates a feeling of tension (Asgarzadeh et al., 2012). In high-density urban environments, the oppressiveness caused by buildings restricts the recovery from stress (Asgarzadeh et al., 2012).

Asgarzadeh et al. (2012) developed a scale to measure perceived oppressiveness. This scale encompassed five dimensions: perception of oppressiveness, oppressiveness dissatisfaction, openness, openness dissatisfaction, and pleasantness (Asgarzadeh et al., 2012). Perception of oppressiveness evaluated whether an observer feels a sense of oppression, while oppressiveness dissatisfaction measured the degree of disturbance caused by this feeling. Openness examined whether an individual perceives the scene as restrictive or visually free,

whereas openness dissatisfaction assessed satisfaction with the perceived openness.

Pleasantness gauged how enjoyable and attractive a scene appears.

3.3.4. Environmental Preference (EP)

Environmental preference, a method employed in environmental assessment, explores how individuals perceive and choose their surroundings. It focuses on identifying the types of environments that individuals find most appealing. The visual environments are crucial to daily life experiences (Bulut & Yilmaz, 2009). Four informational variables were considered to predict environmental preferences: coherence, complexity, legibility, and mystery (Kaplan R., Kaplan S., 1998).

Coherence refers to scenes where various landscape components harmonize, creating a sense of order and directing attention. Complexity pertains to the richness of information within a scene, characterized by a variety of distinct elements. Legibility describes landscapes with clear and easily recognizable elements. Mystery suggests the potential for viewers to be intrigued and motivated to explore further into the scene (R. Kaplan & Kaplan, 1989).

Natural and built elements are the fundamental differences in environmental characteristics (R. Kaplan & Kaplan, 1989). This study used a concise item to gauge environmental preferences (Luo et al., 2022).

3.4. Statistical Analysis

Statistical analysis and graph production were performed in this study using RStudio Desktop and Python. RStudio is an integrated development environment for R that includes scripting, data visualization, and analysis tools. Python is a versatile programming language with readability and broad application across multiple domains.

4. Experiment One: Effects of Roof Types on Subjective Impressions

4.1. Materials and Methods

4.1.1. Research Hypothesis

This experiment investigated the relationship between roof types of perceptions, as assessed by the Perceived Sensory Dimensions (PSDs), and subjective restoration, measured by the Short Revised Restoration Scale (SRRS). Based on existing literature, this study offers the subsequent hypothesis.

Hypothesis 1-1: The attributes of "Nature" and "Rich in Species" within the Perceived Sensory Dimensions (PSDs) positively correlate with subjective restoration.

Hypothesis 1-2: Among various roof types, the garden roof offers the highest potential for subjective restoration.

4.1.2. Participants

The questionnaires were administered to university students from 12 different cities in China through an online platform. These cities included Chengdu, Nanjing, Hangzhou, Wuhan, Chongqing, Beijing, Zhengzhou, Changsha, Guangzhou, Tianjin, Xian, and Shanghai. The total number of participants was 555, distributed as 180 at Site 1, 177 at Site 2, and 198 at Site 3. The 394 participants—129 from Site 1, 131 from Site 2, and 134 from Site 3—provided valid answers. The main reason for removing respondents who were judged ineffective was their noticeably short than average response times. The questionnaire effectiveness ratings for each site were 71.7% at Site 1, 74.0% at Site 2, and 67.7% at Site 3. All sites together had an average questionnaire effectiveness of 71.0%.

Table 4.1 presents participants' demographic characteristics across three sites. The gender distribution showed 66 males at Site 1, 61 at Site 2, and 58 at Site 3, totaling 185 males (47.0%). Female participants numbered 63 at Site 1, 70 at Site 2, and 76 at Site 3, totaling 209 females (53.0%). The average age of participants was 22.5 years at Site 1, 22.1 years at

Site 2, and 22.2 years at Site 3, with an overall average age of 22.3 years. Regarding education level, 107 participants at Site 1, 122 at Site 2, and 121 at Site 3 were undergraduates, totaling 350 (88.8%). Postgraduates included 22 at Site 1, 9 at Site 2, and 13 at Site 3, totaling 44 (11.2%).

Table 4.1: Demographic Information of Experiment 1 (N=394).

| | | Site 1 | Site 2 | Site 3 | Total | Percentage |
|-----------------|---------------|--------|--------|--------|-------|------------|
| Gender | Male | 66 | 61 | 58 | 185 | 47.0% |
| | Female | 63 | 70 | 76 | 209 | 53.0% |
| Education level | Undergraduate | 107 | 122 | 121 | 350 | 88.8% |
| | Postgraduate | 22 | 9 | 13 | 44 | 11.2% |
| Age | Average age | 22.5 | 22.1 | 22.2 | 22.3 | |

Source: F. Wang & Munakata (2023).

4.1.3. Experimental Stimuli

The efficacy of the experimental stimuli used in this investigation has been confirmed. Because static images have been shown to depict natural scenes accurately, they were chosen to simulate actual window views (Stamps, 1990). Furthermore, previous studies recreated environments using static images to assess the restorative characteristics and perceived sensory dimensions (PSDs) (Memari et al., 2017).

4.1.3.1. Factor Settings

There were three primary factors in this experiment: the site (Site 1, 2, and 3), the floor level (3F, 9F, and 27F), and the roof type (Flat, Slope, Grass, and Garden roofs) (Table 4.2).

Table 4.2: Factor Settings for Experiment 1.

| Factors | Level | | | |
|-------------|-----------|------------|------------|-------------|
| | 1 | 2 | 3 | 4 |
| Site | Site 1 | Site 2 | Site 3 | |
| Floor level | 3F | 9F | 27F | |
| Roof type | Flat roof | Slope roof | Grass roof | Garden roof |

Source: Created by the Author.

This experiment selected three distinct sites to offer a variety of environments (Figure 4.1). The images were shot in Wuhan, where city environments combine mid-rises and residential high-rises. Over the past 20 years, Wuhan has improved the energy efficiency of older multi-rise residential buildings by changing roof types and exterior wall insulation, among other things.

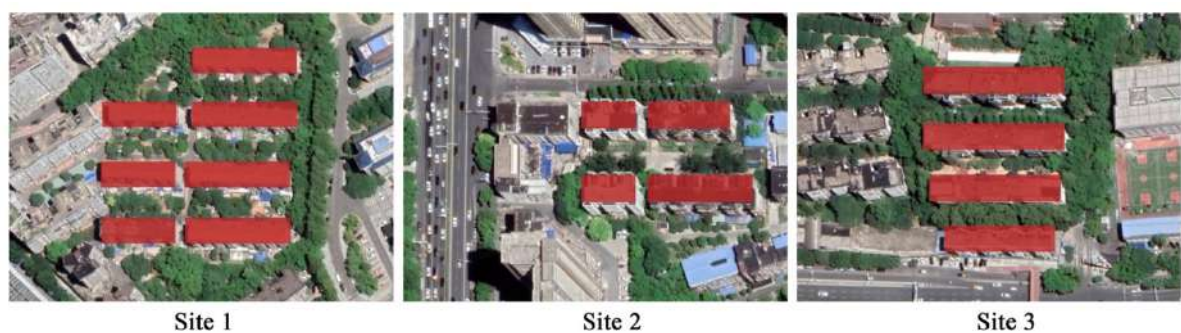


Figure 4.1: Spatial Layouts of Each Site in Experiment 1.

Source: F. Wang & Munakata (2023).

Site 1, Site 2, and Site 3 had distinct building features and environmental contexts. Site 1 comprised seven foreground buildings, each with six floors and painted light warm grey, situated among multi-rise residential structures in a lush, green area with minimal traffic on interior roads. Site 2 featured four foreground buildings, each with seven floors and painted white, surrounded by high-rise residential buildings with little greenery. The roads included both heavily trafficked city roads and quieter interior roads. Site 3 consisted of four foreground buildings, each with six floors and painted light warm grey, similar to Site 1. It was surrounded by multi-rise residential buildings and abundant greenery, with the addition of a distant hill in the natural landscape. The roads around Site 3 included heavily trafficked city roads and quieter interior roads.

In China, high-rise residential buildings typically have 30 floors, while multi-rise residential buildings generally range from 5 to 7 floors. This experiment categorized the observation floors into three distinct zones to analyze the effects of viewing height. The low-floor zone ranges from the 1st to the 7th floors; the low-middle floor zone ranges from the 8th to the 15th floors; and the high-floor zone ranges from the 16th floor and above. The 3rd floor (3F) was selected to depict the low-floor zone, where observers had a restricted view of the roof due to the lower viewpoint. The 9th floor (9F) was selected to depict the low-middle floor zone, where observers had a comprehensive view of the entire roof. The 27th floor (27F) was selected to depict the high-floor zone, where observers viewed the roof from a greater distance.

Four different roof types were defined: flat, sloped, grass, and garden roofs. In this experiment, different roof types were defined by the following descriptions. The horizontal roofing of grey concrete represented the flat roof. The sloped roof was three meters high and made of red bricks. The grass roof was primarily covered with ground-cover plants. The garden roof included a variety of elements, such as lawns, trees, and paved paths.

4.1.3.2. Photography Implementation

The experiment employed the DJI Air 2s drone with a 22 mm focal length lens (equivalent to a 35 mm format) to capture photographs. This method was chosen to address privacy concerns from photographing within residents' homes. During the photo sessions, the drone was positioned approximately 50 meters from the front of the target building. The building's roof was the primary visual reference point in each image. Due to the photography angle, sky visibility varied: it was most visible from the 3rd floor, somewhat visible from the 9th floor, and not visible from the 27th floor. The photo shoot was conducted in April 2022.

4.1.3.3. Image Processing

The processing of experimental images was divided into two steps. In the first step, a drone was used to shoot photos of building roofs at three sites from three different heights: the 3rd floor (11 meters), the 9th floor (29 meters), and the 27th floor (83 meters). This step resulted in nine pictures. In the second step, Adobe Photoshop (2020) was used to modify the roof types of pictures to create four variations: flat roof, sloped roof, grass roof, and garden roof. This process produced 36 pictures for the experiment (Figure 4.2, Figure 4.3, Figure 4.4).

4.1.4. Procedures

4.1.4.1. Pilot Testing

A preliminary questionnaire was filled out by 22 respondents from Wuhan University in China for this investigation. Their feedback ensured the effectiveness of the final questionnaire. The main study's analysis excluded data from the pilot test.

4.1.4.2. Main Experiment Implementation

The main experiment was carried out via the Tencent Questionnaire platform online between June and July of 2022. The target population for this experiment was Chinese university students. Participants were recruited through Tencent Questionnaire's public WeChat account. They completed the questionnaire on their smartphones. In order to reduce stress caused by the experiment's extended duration, this experiment designed the survey to last about 20 minutes. Each participant was assigned to one of three groups and assessed 12 photos from various experimental sites.













| Roof type | Floor level | Image | Roof type | Floor level | Image |
|------------|-------------|---|-------------|-------------|--|
| Flat roof | 3F |  | Slope roof | 3F |  |
| Flat roof | 9F |  | Slope roof | 9F |  |
| Flat roof | 27F |  | Slope roof | 27F |  |
| Grass roof | 3F |  | Garden roof | 3F |  |
| Grass roof | 9F |  | Garden roof | 9F |  |
| Grass roof | 27F |  | Garden roof | 27F |  |

Figure 4.2: Experimental Images of Site 1.

Source: F. Wang & Munakata (2023).













| Roof type | Floor level | Image | Roof type | Floor level | Image |
|------------|-------------|---|-------------|-------------|---|
| Flat roof | 3F |  | Slope roof | 3F |  |
| Flat roof | 9F |  | Slope roof | 9F |  |
| Flat roof | 27F |  | Slope roof | 27F |  |
| Grass roof | 3F |  | Garden roof | 3F |  |
| Grass roof | 9F |  | Garden roof | 9F |  |
| Grass roof | 27F |  | Garden roof | 27F |  |

Figure 4.3: Experimental Images of Site 2.

Source: F. Wang & Munakata (2023).













| Roof type | Floor level | Image | Roof type | Floor level | Image |
|------------|-------------|---|-------------|-------------|--|
| Flat roof | 3F |  | Slope roof | 3F |  |
| Flat roof | 9F |  | Slope roof | 9F |  |
| Flat roof | 27F |  | Slope roof | 27F |  |
| Grass roof | 3F |  | Garden roof | 3F |  |
| Grass roof | 9F |  | Garden roof | 9F |  |
| Grass roof | 27F |  | Garden roof | 27F |  |

Figure 4.4: Experimental Images of Site 3.

Source: F. Wang & Munakata (2023).

4.1.5. Statistical Analysis Process of Experiment 1

The statistical analysis process of Experiment 1 included four aspects (Figure 4.5):

1. Descriptive statistics was used to calculate each scene's mean value for PSDs.
2. Stepwise multiple linear regression was utilized to investigate the relationship between Perceived Sensory Dimensions (PSDs) and subjective restoration.
3. Analysis of variance (ANOVA) was performed to examine the association between roof types and Perceived Sensory Dimensions (PSDs).
4. Analysis of variance (ANOVA) was conducted to investigate the main effects of site, floor level, and roof type, along with their interaction effects, on subjective restoration.

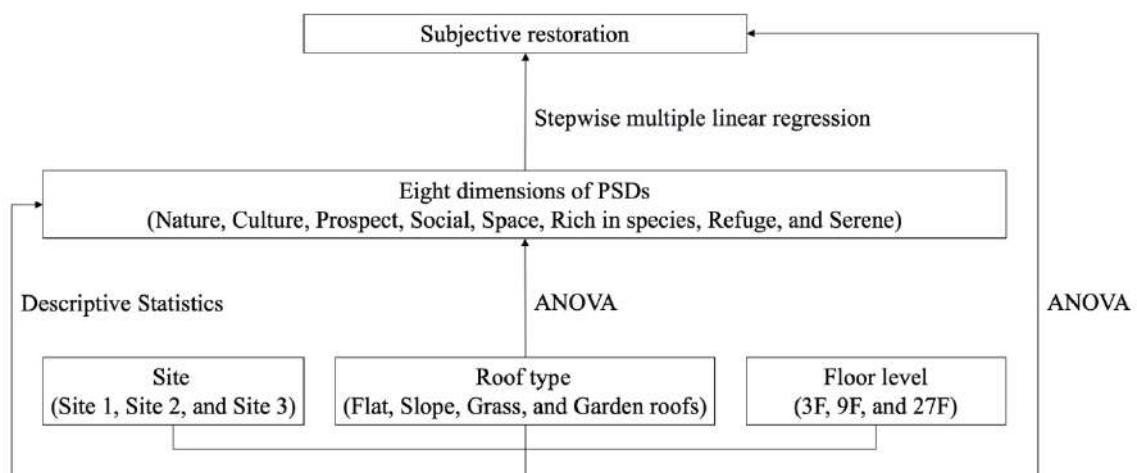


Figure 4.5: Main Analysis Processes in Experiment 1.

Source: F. Wang & Munakata (2023).

4.2. Results

4.2.1. Perceived Sensory Dimensions (PSDs) Values in Different Scenes

The mean value for each attribute of PSDs was computed to describe the characteristics of different scenes (Table 4.3). Different attributes of PSDs—Nature, Culture, Prospect, Social, Space, Rich in Species, Refuge, and Serene—provide a comprehensive framework for evaluating the sensory qualities of each scene.

In the "Nature" dimension, values ranged from 2.25 to 3.80. The highest value of 3.80 was at Site 1, 3F, with flat, grass, and garden roof types, while the lowest value of 2.25 was at Site 1, 27F, with a flat roof. In the "Culture" dimension, values varied between 2.62 and 3.66. The highest value of 3.66 was at Site 1, 27F, with a garden roof, while the lowest value of 2.62 was at Site 1, 27F, with a flat roof.

In the "Prospect" dimension, values ranged from 2.61 to 3.90. The highest value of 3.90 was at Site 1, 27F, with a garden roof, while the lowest value of 2.61 was at Site 1, 3F, with flat and grass roofs. In the "Social" dimension, values ranged from 2.74 to 3.59. The highest value of 3.59 was at Site 1, 27F, with a garden roof, while the lowest value of 2.74 was at Site 1, 3F, with a sloped roof.

In the "Space" dimension, values varied between 2.81 and 3.75. The highest value of 3.75 was at Site 1, 27F, with a garden roof, while the lowest value of 2.81 was at Site 2, 3F, with a sloped roof. In the "Rich in Species" dimension, values ranged from 2.60 to 3.64. The highest value of 3.64 was at Site 3, 27F, with a garden roof, while the lowest value of 2.60 was at Site 1, 27F, with a flat roof.

In the "Refuge" dimension, values ranged from 2.73 to 3.55. The highest value of 3.55 was at Site 1, 27F, with a garden roof, while the lowest value of 2.73 was at Site 2, 27F, with a flat roof. In the "Serene" dimension, values ranged from 2.79 to 3.64. The highest value of 3.64 was at Site 1, 27F, with a garden roof, while the lowest value of 2.79 was at Site 2, 27F, with a flat roof.

Table 4.3: Mean Value of PSDs in Different Scenes.

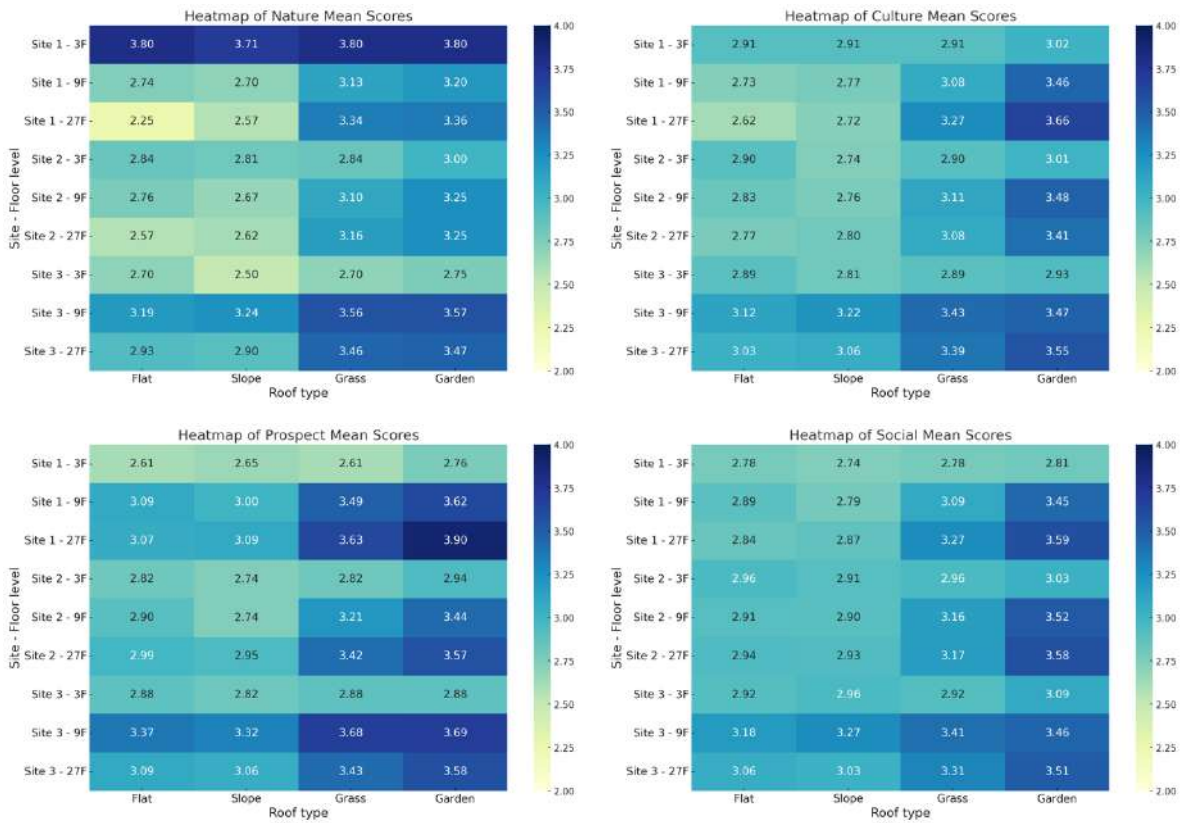
| No. | Site | Floor level | Roof type | | Nature | Culture | Prospect | Social | Space | Rich in Species | Refuge | Serene |
|-----|--------|-------------|-----------|----------------|--------|---------|----------|--------|-------|-----------------|--------|--------|
| 1 | Site 1 | 3F | Flat | Mean | 3.80 | 2.91 | 2.61 | 2.78 | 3.20 | 3.55 | 3.28 | 3.46 |
| | | | | Std. Deviation | 0.89 | 0.94 | 0.91 | 1.00 | 0.86 | 0.95 | 0.96 | 0.82 |
| 2 | Site 1 | 3F | Slope | Mean | 3.71 | 2.91 | 2.65 | 2.74 | 3.12 | 3.44 | 3.14 | 3.46 |
| | | | | Std. Deviation | 0.88 | 1.03 | 1.03 | 1.06 | 0.92 | 0.98 | 1.04 | 0.82 |

| | | | | | | | | | | | | |
|----|--------|-----|--------|----------------|------|------|------|------|------|------|------|------|
| 3 | Site 1 | 3F | Grass | Mean | 3.80 | 2.91 | 2.61 | 2.78 | 3.20 | 3.55 | 3.28 | 3.46 |
| | | | | Std. Deviation | 0.89 | 0.94 | 0.91 | 1.00 | 0.86 | 0.95 | 0.96 | 0.82 |
| 4 | Site 1 | 3F | Garden | Mean | 3.80 | 3.02 | 2.76 | 2.81 | 3.18 | 3.58 | 3.33 | 3.56 |
| | | | | Std. Deviation | 0.88 | 1.02 | 1.04 | 0.98 | 0.87 | 0.93 | 1.01 | 0.81 |
| 5 | Site 1 | 9F | Flat | Mean | 2.74 | 2.73 | 3.09 | 2.89 | 3.04 | 2.97 | 2.97 | 3.14 |
| | | | | Std. Deviation | 0.98 | 0.87 | 0.75 | 0.90 | 0.81 | 0.99 | 1.00 | 0.85 |
| 6 | Site 1 | 9F | Slope | Mean | 2.70 | 2.77 | 3.00 | 2.79 | 2.97 | 2.93 | 2.85 | 3.11 |
| | | | | Std. Deviation | 0.94 | 0.92 | 0.84 | 0.88 | 0.84 | 0.99 | 1.03 | 0.89 |
| 7 | Site 1 | 9F | Grass | Mean | 3.13 | 3.08 | 3.49 | 3.09 | 3.27 | 3.22 | 2.98 | 3.36 |
| | | | | Std. Deviation | 0.90 | 0.92 | 0.89 | 0.88 | 0.85 | 0.97 | 0.99 | 0.81 |
| 8 | Site 1 | 9F | Garden | Mean | 3.20 | 3.46 | 3.62 | 3.45 | 3.58 | 3.45 | 3.33 | 3.56 |
| | | | | Std. Deviation | 0.96 | 0.96 | 0.87 | 0.93 | 0.86 | 0.91 | 1.01 | 0.86 |
| 9 | Site 1 | 27F | Flat | Mean | 2.25 | 2.62 | 3.07 | 2.84 | 2.85 | 2.60 | 2.76 | 2.83 |
| | | | | Std. Deviation | 0.96 | 0.94 | 0.91 | 0.95 | 0.86 | 1.07 | 1.04 | 0.90 |
| 10 | Site 1 | 27F | Slope | Mean | 2.57 | 2.72 | 3.09 | 2.87 | 2.96 | 2.83 | 2.92 | 2.94 |
| | | | | Std. Deviation | 0.89 | 0.89 | 0.94 | 0.95 | 0.89 | 0.97 | 1.00 | 0.87 |
| 11 | Site 1 | 27F | Grass | Mean | 3.34 | 3.27 | 3.63 | 3.27 | 3.50 | 3.44 | 3.20 | 3.41 |
| | | | | Std. Deviation | 0.95 | 0.99 | 0.92 | 1.00 | 0.85 | 0.97 | 1.05 | 0.83 |
| 12 | Site 1 | 27F | Garden | Mean | 3.36 | 3.66 | 3.90 | 3.59 | 3.75 | 3.59 | 3.55 | 3.64 |
| | | | | Std. Deviation | 1.00 | 0.91 | 0.83 | 0.88 | 0.80 | 0.92 | 0.99 | 0.84 |
| 13 | Site2 | 3F | Flat | Mean | 2.84 | 2.90 | 2.82 | 2.96 | 2.92 | 2.85 | 2.94 | 3.03 |
| | | | | Std. Deviation | 1.02 | 1.04 | 1.02 | 0.96 | 0.96 | 1.08 | 1.14 | 0.97 |
| 14 | Site 2 | 3F | Slope | Mean | 2.81 | 2.74 | 2.74 | 2.91 | 2.81 | 2.79 | 2.96 | 3.03 |
| | | | | Std. Deviation | 1.05 | 0.98 | 0.91 | 0.99 | 0.97 | 1.08 | 1.08 | 0.92 |
| 15 | Site 2 | 3F | Grass | Mean | 2.84 | 2.90 | 2.82 | 2.96 | 2.92 | 2.85 | 2.94 | 3.03 |
| | | | | Std. Deviation | 1.02 | 1.04 | 1.02 | 0.96 | 0.96 | 1.08 | 1.14 | 0.97 |
| 16 | Site 2 | 3F | Garden | Mean | 3.00 | 3.01 | 2.94 | 3.03 | 3.12 | 3.08 | 3.00 | 3.24 |
| | | | | Std. Deviation | 0.95 | 0.96 | 0.94 | 0.92 | 0.88 | 0.99 | 1.04 | 0.90 |
| 17 | Site 2 | 9F | Flat | Mean | 2.76 | 2.83 | 2.90 | 2.91 | 2.99 | 2.82 | 3.01 | 3.09 |
| | | | | Std. Deviation | 1.04 | 0.92 | 0.95 | 0.93 | 0.88 | 1.08 | 1.01 | 0.86 |
| 18 | Site 2 | 9F | Slope | Mean | 2.67 | 2.76 | 2.74 | 2.90 | 2.92 | 2.80 | 2.96 | 3.13 |
| | | | | Std. Deviation | 1.04 | 0.98 | 0.96 | 0.97 | 0.99 | 1.04 | 1.08 | 0.98 |
| 19 | Site 2 | 9F | Grass | Mean | 3.10 | 3.11 | 3.21 | 3.16 | 3.24 | 3.08 | 2.97 | 3.36 |
| | | | | Std. Deviation | 0.95 | 0.85 | 0.89 | 0.86 | 0.82 | 0.97 | 1.04 | 0.87 |
| 20 | Site 2 | 9F | Garden | Mean | 3.25 | 3.48 | 3.44 | 3.52 | 3.47 | 3.26 | 3.28 | 3.42 |
| | | | | Std. Deviation | 0.87 | 0.89 | 0.84 | 0.85 | 0.86 | 0.99 | 1.07 | 0.86 |
| 21 | Site 2 | 27F | Flat | Mean | 2.57 | 2.77 | 2.99 | 2.94 | 2.95 | 2.69 | 2.73 | 2.79 |
| | | | | Std. Deviation | 1.08 | 1.02 | 0.97 | 0.92 | 0.91 | 1.04 | 1.03 | 0.93 |
| 22 | Site 2 | 27F | Slope | Mean | 2.62 | 2.80 | 2.95 | 2.93 | 2.89 | 2.77 | 2.90 | 2.84 |
| | | | | Std. Deviation | 1.03 | 0.97 | 0.98 | 1.00 | 0.92 | 0.99 | 1.04 | 0.95 |
| 23 | Site 2 | 27F | Grass | Mean | 3.16 | 3.08 | 3.42 | 3.17 | 3.28 | 3.12 | 3.08 | 3.04 |
| | | | | Std. Deviation | 0.89 | 0.85 | 0.86 | 0.77 | 0.81 | 0.92 | 1.08 | 0.92 |
| 24 | Site 2 | 27F | Garden | Mean | 3.25 | 3.41 | 3.57 | 3.58 | 3.57 | 3.32 | 3.37 | 3.31 |
| | | | | Std. Deviation | 0.92 | 0.87 | 0.89 | 0.87 | 0.86 | 0.97 | 0.99 | 0.92 |
| 25 | Site 3 | 3F | Flat | Mean | 2.70 | 2.89 | 2.88 | 2.92 | 2.97 | 2.86 | 2.80 | 2.89 |
| | | | | Std. Deviation | 1.04 | 0.96 | 1.06 | 0.93 | 0.89 | 1.07 | 1.09 | 0.90 |
| 26 | Site 3 | 3F | Slope | Mean | 2.50 | 2.81 | 2.82 | 2.96 | 2.82 | 2.69 | 2.73 | 2.96 |
| | | | | Std. Deviation | 1.08 | 1.01 | 1.04 | 0.96 | 0.96 | 1.13 | 1.10 | 0.99 |
| 27 | Site 3 | 3F | Grass | Mean | 2.70 | 2.89 | 2.88 | 2.92 | 2.97 | 2.86 | 2.80 | 2.89 |
| | | | | Std. Deviation | 1.04 | 0.96 | 1.06 | 0.93 | 0.89 | 1.07 | 1.09 | 0.90 |
| 28 | Site 3 | 3F | Garden | Mean | 2.75 | 2.93 | 2.88 | 3.09 | 3.04 | 2.92 | 2.93 | 3.04 |
| | | | | Std. Deviation | 1.00 | 0.93 | 1.03 | 0.95 | 0.93 | 0.99 | 1.08 | 0.87 |
| 29 | Site 3 | 9F | Flat | Mean | 3.19 | 3.12 | 3.37 | 3.18 | 3.32 | 3.29 | 3.12 | 3.29 |
| | | | | Std. Deviation | 0.95 | 0.92 | 0.85 | 0.80 | 0.87 | 1.05 | 1.06 | 0.86 |
| 30 | Site 3 | 9F | Slope | Mean | 3.24 | 3.22 | 3.32 | 3.27 | 3.38 | 3.42 | 3.24 | 3.36 |
| | | | | Std. Deviation | 0.87 | 0.88 | 0.82 | 0.80 | 0.79 | 0.85 | 0.97 | 0.89 |
| 31 | Site 3 | 9F | Grass | Mean | 3.56 | 3.43 | 3.68 | 3.41 | 3.69 | 3.64 | 3.43 | 3.50 |
| | | | | Std. Deviation | 0.78 | 0.82 | 0.86 | 0.81 | 0.74 | 0.78 | 0.99 | 0.75 |
| 32 | Site 3 | 9F | Garden | Mean | 3.57 | 3.47 | 3.69 | 3.46 | 3.69 | 3.57 | 3.24 | 3.51 |
| | | | | Std. Deviation | 0.91 | 0.86 | 0.86 | 0.88 | 0.76 | 0.86 | 1.04 | 0.85 |

| | | | | | | | | | | | | |
|-------|--------|-----|--------|----------------|------|------|------|------|------|------|------|------|
| 33 | Site 3 | 27F | Flat | Mean | 2.93 | 3.03 | 3.09 | 3.06 | 3.15 | 3.18 | 3.02 | 3.08 |
| | | | | Std. Deviation | 0.92 | 0.92 | 0.88 | 0.85 | 0.77 | 0.96 | 0.98 | 0.86 |
| 34 | Site 3 | 27F | Slope | Mean | 2.90 | 3.06 | 3.06 | 3.03 | 3.10 | 3.16 | 3.05 | 3.10 |
| | | | | Std. Deviation | 1.04 | 0.99 | 1.00 | 0.89 | 0.84 | 1.00 | 1.11 | 0.93 |
| 35 | Site 3 | 27F | Grass | Mean | 3.46 | 3.39 | 3.43 | 3.31 | 3.44 | 3.48 | 3.27 | 3.40 |
| | | | | Std. Deviation | 0.93 | 0.88 | 0.93 | 0.86 | 0.81 | 0.93 | 0.97 | 0.81 |
| 36 | Site 3 | 27F | Garden | Mean | 3.47 | 3.55 | 3.58 | 3.51 | 3.62 | 3.64 | 3.43 | 3.42 |
| | | | | Std. Deviation | 0.86 | 0.83 | 0.89 | 0.88 | 0.79 | 0.78 | 0.95 | 0.90 |
| Total | | | | Mean | 3.06 | 3.05 | 3.13 | 3.08 | 3.19 | 3.15 | 3.08 | 3.21 |
| | | | | Std. Deviation | 1.04 | 0.97 | 0.99 | 0.95 | 0.91 | 1.03 | 1.05 | 0.91 |

Source: F. Wang & Munakata (2023).

The heatmaps depicted the mean values for eight attributes of PSDs across various sites, floor levels, and roof types (Figure 4.6).



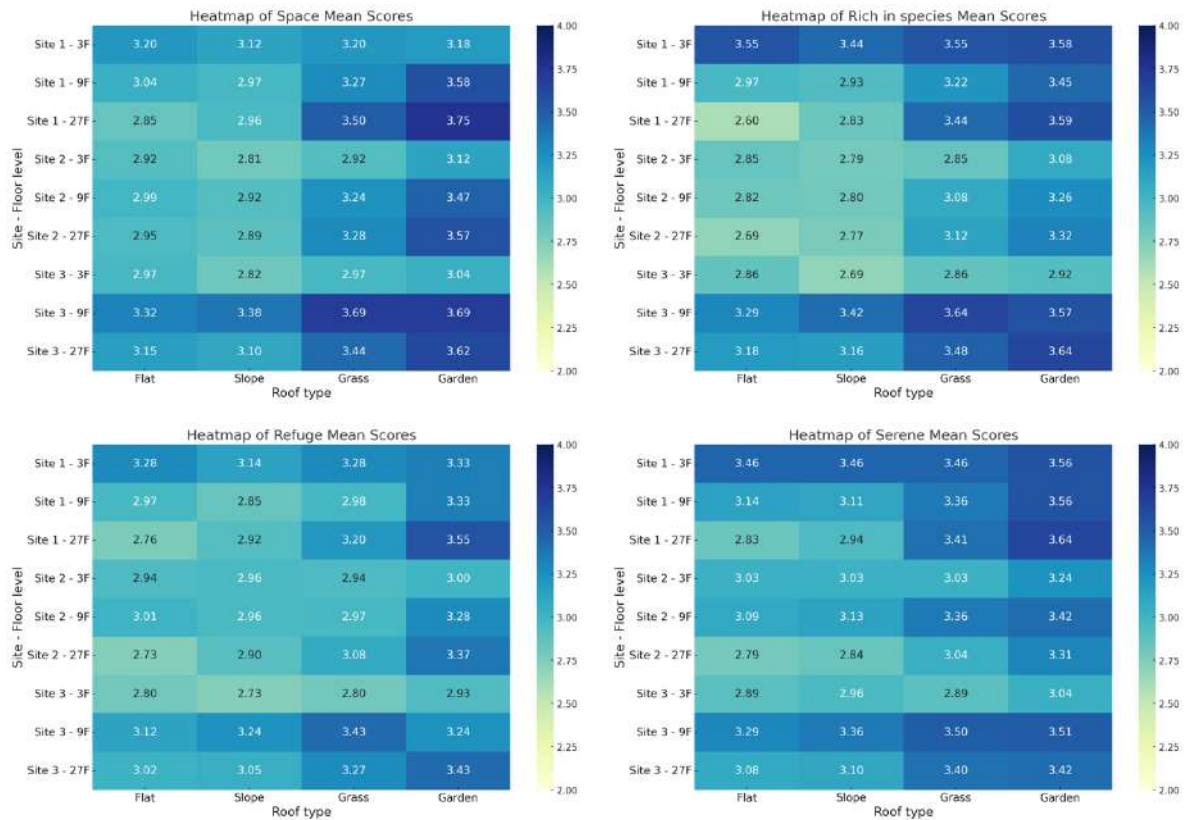


Figure 4.6: Heatmap of PSDs Mean Values.

Source: Created by the Author.

4.2.2. Relationship Between PSDs and Subjective Restoration

The stepwise multivariate linear regression analysis treated Subjective Restoration as the dependent variable. The independent variables included the eight attributes of Perceived Sensory Dimensions (PSDs), namely "Nature," "Culture," "Prospect," "Social," "Space," "Rich in Species," "Refuge," and "Serene." Furthermore, the sequence of image presentation was considered a candidate variable, accounting for the 12 different orders of images used in the questionnaire.

Variables were excluded if their significance level exceeded 0.05. Collinearity tests were performed for each model, and any variable with a variance inflation factor (VIF) above 3.0 was removed to mitigate multicollinearity (Zuur et al., 2009). The final stepwise regression analysis model identified significant predictors of subjective restoration, achieving an

adjusted R-squared value of 0.621 (Table 4.4). This result indicated that approximately 62.1% of the variance in restoration was explained by the model. The analysis revealed that four variables—Serene, Nature, Rich in Species, and Social—were significant predictors of Subjective Restoration ($p < 0.001$ for all). Conversely, Culture, Prospect, Space, and Refuge were excluded from the model as they were deemed non-significant contributors, lacking statistically significant linear relationships with the dependent variable.

The intercept, estimated at 0.921 ($p < 0.001$), represented the baseline Subjective Restoration value when all predictors were zero. The predictor "Serene" showed a significant positive relationship with Subjective Restoration (Estimate = 0.358, $p < 0.001$), indicating that each unit increase in "Serene" led to an average increase of 0.358 units in Subjective Restoration. The predictor "Nature" showed a significant positive impact on Subjective Restoration (Estimate = 0.164, $p < 0.001$), indicating that each unit increase in "Nature" led to an average increase of 0.164 units in Subjective Restoration. The predictor "Social" showed a significant positive relationship with Subjective Restoration (Estimate = 0.151, $p < 0.001$), indicating that each unit increase in "Social" led to an average increase of 0.151 units in Subjective Restoration. Furthermore, the predictor "Rich in Species" showed a significant positive impact on Subjective Restoration (Estimate = 0.091, $p < 0.001$), indicating that each unit increase in "Rich in Species" led to an average increase of 0.091 units in Subjective Restoration. The variance inflation factor (VIF) values for all predictors ranged from 1.790 to 2.434, indicating that multicollinearity was not a significant concern in this model.

Table 4.4: Stepwise Regression Analysis of PSDs for Predicting Subjective Restoration (N = 4728).

| | Estimate | Std. Error | t value | p | | VIF |
|-----------------|----------|------------|---------|---------|-----|-------|
| (Constant) | 0.921 | 0.028 | 32.380 | < 0.001 | *** | |
| Serene | 0.358 | 0.011 | 32.459 | < 0.001 | *** | 2.016 |
| Nature | 0.164 | 0.010 | 16.799 | < 0.001 | *** | 2.039 |
| Social | 0.151 | 0.010 | 15.098 | < 0.001 | *** | 1.790 |
| Rich in Species | 0.091 | 0.011 | 8.480 | < 0.001 | *** | 2.434 |

Dependent Variable: Subjective Restoration

Adjusted R-squared: 0.621

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2023).

The bar chart presented the coefficient estimates from the stepwise regression analysis predicting the "Subjective Restoration" variable based on significant predictor variables (Figure 4.7). The estimates provided a quantifiable measure of how much each predictor variable influences the dependent variable. "Serene" had the most significant contribution to subjective restoration, followed by "Nature" and "Social," with "Rich in Species" having the most minor contribution.

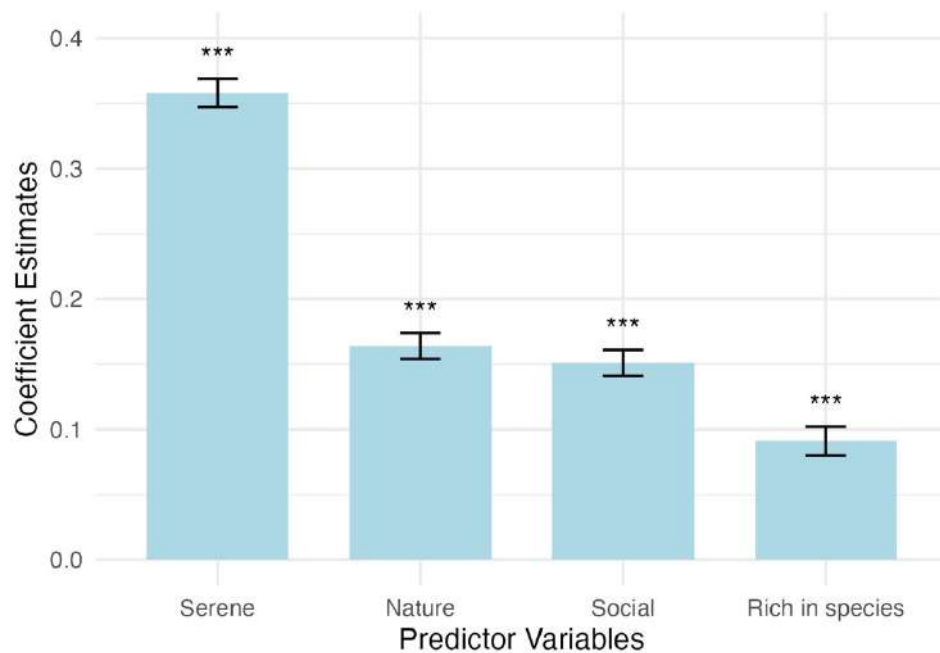


Figure 4.7: Bar Chart of Coefficient Estimates from PSDs for Predicting Subjective Restoration

Source: Created by the Author.

4.2.3. Effects of Roof Type on PSDs

4.2.3.1. ANOVA of Roof Type on PSDs

The analysis of variance (ANOVA) results in Table 4.5 examined the effects of Roof Type on the eight attributes of PSDs: Nature, Culture, Prospect, Social, Space, Rich in Species, Refuge, and Serene.

The effect of Roof Type was statistically significant across all eight attributes of PSDs: Nature ($F(3, 4724) = 62.674, p < 0.001, \eta^2p = 0.038$), Culture ($F(3, 4724) = 65.217, p < 0.001, \eta^2p = 0.040$), Prospect ($F(3, 4724) = 56.205, p < 0.001, \eta^2p = 0.034$), Social ($F(3, 4724) = 49.016, p < 0.001, \eta^2p = 0.030$), Space ($F(3, 4724) = 65.796, p < 0.001, \eta^2p = 0.040$), Rich in Species ($F(3, 4724) = 45.130, p < 0.001, \eta^2p = 0.028$), Refuge ($F(3, 4724) = 34.403, p < 0.001, \eta^2p = 0.021$), and Serene ($F(3, 4724) = 36.628, p < 0.001, \eta^2p = 0.023$).

Table 4.5: Effects of Roof Type on PSDs (N = 4728).

Dependent variable(s): Nature, Culture, Prospect, Social, Space, Rich in Species, Refuge, and Serene

Independent variable (s): Roof Type

| Dependent variable | Independent variable | MS | MSE | df1 | df2 | F | p | η^2p [90% CI of η^2p] | η^2G |
|--------------------|----------------------|--------|-------|-----|------|--------|---------|----------------------------------|-----------|
| Nature | Roof Type | 64.892 | 1.035 | 3 | 4724 | 62.674 | < 0.001 | *** 0.038 [.029,.047] | 0.038 |
| Culture | Roof Type | 59.201 | 0.908 | 3 | 4724 | 65.217 | < 0.001 | *** 0.040 [.031, .049] | 0.040 |
| Prospect | Roof Type | 53.234 | 0.947 | 3 | 4724 | 56.205 | < 0.001 | *** 0.034 [.026,.043] | 0.034 |
| Social | Roof Type | 42.752 | 0.872 | 3 | 4724 | 49.016 | < 0.001 | *** 0.030 [.022, .038] | 0.030 |
| Space | Roof Type | 51.764 | 0.787 | 3 | 4724 | 65.796 | < 0.001 | *** 0.040 [.031, .049] | 0.040 |
| Rich in Species | Roof Type | 46.658 | 1.034 | 3 | 4724 | 45.130 | < 0.001 | *** 0.028 [.020, .036] | 0.028 |
| Refuge | Roof Type | 30.341 | 0.882 | 3 | 4724 | 34.403 | < 0.001 | *** 0.021 [.015, .028] | 0.021 |
| Serene | Roof Type | 29.742 | 0.812 | 3 | 4724 | 36.628 | < 0.001 | *** 0.023 [.016, .030] | 0.023 |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2023).

4.2.3.2. Pairwise Comparisons of Roof Types on PSDs

The post hoc test (Tukey HSD) of ANOVA further elucidated pairwise comparisons of different roof types—Flat Roof, Slope Roof, Grass Roof, and Garden Roof—across the eight attributes of Perceived Sensory Dimensions (PSDs): Nature, Culture, Prospect, Social, Space, Rich in Species, Refuge, and Serene (Table 4.6).

Table 4.6: Pairwise Comparisons of Roof Types Across Each Attributes of PSDs (N = 4728).

| Dependent variable | Contrast | Estimate | S.E. | df | t | p | Cohen's d [95% CI of d] |
|--------------------|--------------------------|----------|-------|------|--------|---------|--------------------------|
| Nature | Slope Roof - Flat Roof | -0.009 | 0.042 | 4724 | -0.216 | 0.996 | -0.009 [-0.115, 0.097] |
| | Grass Roof - Flat Roof | 0.367 | 0.042 | 4724 | 8.766 | < 0.001 | *** 0.361 [0.255, 0.466] |
| | Grass Roof - Slope Roof | 0.376 | 0.042 | 4724 | 8.981 | < 0.001 | *** 0.369 [0.264, 0.475] |
| | Garden Roof - Flat Roof | 0.431 | 0.042 | 4724 | 10.288 | < 0.001 | *** 0.423 [0.317, 0.529] |
| | Garden Roof - Slope Roof | 0.440 | 0.042 | 4724 | 10.504 | < 0.001 | *** 0.432 [0.326, 0.538] |
| | Garden Roof - Grass Roof | 0.064 | 0.042 | 4724 | 1.523 | 0.424 | 0.063 [-0.043, 0.168] |
| Culture | Slope Roof - Flat Roof | -0.002 | 0.039 | 4724 | -0.05 | 1.000 | -0.002 [-0.108, 0.104] |
| | Grass Roof - Flat Roof | 0.250 | 0.039 | 4724 | 6.39 | < 0.001 | *** 0.263 [0.157, 0.369] |
| | Grass Roof - Slope Roof | 0.252 | 0.039 | 4724 | 6.44 | < 0.001 | *** 0.265 [0.159, 0.371] |
| | Garden Roof - Flat Roof | 0.462 | 0.039 | 4724 | 11.801 | < 0.001 | *** 0.485 [0.380, 0.591] |
| | Garden Roof - Slope Roof | 0.464 | 0.039 | 4724 | 11.851 | < 0.001 | *** 0.487 [0.382, 0.593] |
| | Garden Roof - Grass Roof | 0.212 | 0.039 | 4724 | 5.411 | < 0.001 | *** 0.223 [0.117, 0.328] |
| Prospect | Slope Roof - Flat Roof | -0.051 | 0.040 | 4724 | -1.268 | 0.583 | -0.052 [-0.158, 0.054] |
| | Grass Roof - Flat Roof | 0.260 | 0.040 | 4724 | 6.495 | < 0.001 | *** 0.267 [0.161, 0.373] |
| | Grass Roof - Slope Roof | 0.311 | 0.040 | 4724 | 7.763 | < 0.001 | *** 0.319 [0.214, 0.425] |
| | Garden Roof - Flat Roof | 0.395 | 0.040 | 4724 | 9.876 | < 0.001 | *** 0.406 [0.301, 0.512] |
| | Garden Roof - Slope Roof | 0.446 | 0.040 | 4724 | 11.144 | < 0.001 | *** 0.458 [0.353, 0.564] |
| | Garden Roof - Grass Roof | 0.135 | 0.040 | 4724 | 3.381 | 0.004 | ** 0.139 [0.033, 0.245] |
| Social | Slope Roof - Flat Roof | -0.007 | 0.038 | 4724 | -0.176 | 0.998 | -0.007 [-0.113, 0.098] |
| | Grass Roof - Flat Roof | 0.176 | 0.038 | 4724 | 4.581 | < 0.001 | *** 0.188 [0.083, 0.294] |
| | Grass Roof - Slope Roof | 0.183 | 0.038 | 4724 | 4.757 | < 0.001 | *** 0.196 [0.090, 0.301] |
| | Garden Roof - Flat Roof | 0.397 | 0.038 | 4724 | 10.336 | < 0.001 | *** 0.425 [0.319, 0.531] |
| | Garden Roof - Slope Roof | 0.404 | 0.038 | 4724 | 10.512 | < 0.001 | *** 0.432 [0.327, 0.538] |
| | Garden Roof - Grass Roof | 0.221 | 0.038 | 4724 | 5.755 | < 0.001 | *** 0.237 [0.131, 0.342] |
| Space | Slope Roof - Flat Roof | -0.045 | 0.036 | 4724 | -1.229 | 0.608 | -0.051 [-0.156, 0.055] |
| | Grass Roof - Flat Roof | 0.236 | 0.036 | 4724 | 6.462 | < 0.001 | *** 0.266 [0.160, 0.372] |
| | Grass Roof - Slope Roof | 0.281 | 0.036 | 4724 | 7.691 | < 0.001 | *** 0.316 [0.211, 0.422] |
| | Garden Roof - Flat Roof | 0.402 | 0.036 | 4724 | 11.022 | < 0.001 | *** 0.453 [0.348, 0.559] |
| | Garden Roof - Slope Roof | 0.447 | 0.036 | 4724 | 12.251 | < 0.001 | *** 0.504 [0.398, 0.610] |
| | Garden Roof - Grass Roof | 0.166 | 0.036 | 4724 | 4.560 | < 0.001 | *** 0.188 [0.082, 0.293] |
| Rich in Species | Slope Roof - Flat Roof | 0.002 | 0.042 | 4724 | 0.051 | 1.000 | 0.002 [-0.104, 0.108] |
| | Grass Roof - Flat Roof | 0.268 | 0.042 | 4724 | 6.402 | < 0.001 | *** 0.263 [0.158, 0.369] |
| | Grass Roof - Slope Roof | 0.266 | 0.042 | 4724 | 6.352 | < 0.001 | *** 0.261 [0.156, 0.367] |
| | Garden Roof - Flat Roof | 0.398 | 0.042 | 4724 | 9.507 | < 0.001 | *** 0.391 [0.285, 0.497] |
| | Garden Roof - Slope Roof | 0.396 | 0.042 | 4724 | 9.457 | < 0.001 | *** 0.389 [0.283, 0.495] |
| | Garden Roof - Grass Roof | 0.130 | 0.042 | 4724 | 3.105 | 0.010 | * 0.128 [0.022, 0.233] |
| Refuge | Slope roof - Flat roof | -0.003 | 0.039 | 4724 | -0.066 | 1.000 | -0.003 [-0.108, 0.103] |
| | Grass roof - Flat roof | 0.162 | 0.039 | 4724 | 4.194 | < 0.001 | *** 0.173 [0.067, 0.278] |
| | Grass roof - Slope roof | 0.165 | 0.039 | 4724 | 4.26 | < 0.001 | *** 0.175 [0.070, 0.281] |
| | Garden roof - Flat roof | 0.334 | 0.039 | 4724 | 8.651 | < 0.001 | *** 0.356 [0.250, 0.462] |
| | Garden roof - Slope roof | 0.337 | 0.039 | 4724 | 8.717 | < 0.001 | *** 0.359 [0.253, 0.464] |
| | Garden roof - Grass roof | 0.172 | 0.039 | 4724 | 4.457 | < 0.001 | *** 0.183 [0.078, 0.289] |
| Serene | Slope Roof - Flat Roof | 0.035 | 0.037 | 4724 | 0.951 | 0.777 | 0.039 [-0.067, 0.145] |
| | Grass Roof - Flat Roof | 0.204 | 0.037 | 4724 | 5.501 | < 0.001 | *** 0.226 [0.121, 0.332] |
| | Grass Roof - Slope Roof | 0.169 | 0.037 | 4724 | 4.550 | < 0.001 | *** 0.187 [0.081, 0.293] |

| | | | | | | | |
|--------------------------|-------|-------|------|-------|---------|-----|----------------------|
| Garden Roof - Flat Roof | 0.342 | 0.037 | 4724 | 9.236 | < 0.001 | *** | 0.380 [0.274, 0.486] |
| Garden Roof - Slope Roof | 0.307 | 0.037 | 4724 | 8.285 | < 0.001 | *** | 0.341 [0.235, 0.447] |
| Garden Roof - Grass Roof | 0.138 | 0.037 | 4724 | 3.736 | 0.001 | ** | 0.154 [0.048, 0.259] |

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2023).

The figures presented pairwise comparisons of different roof types on the eight attributes of PSDs, focusing on the Estimate and Cohen's d values (Figure 4.8). The "Estimate" represented the mean difference between the compared groups, where a negative estimate indicated a lower mean for the second group, and a positive estimate suggested a higher mean. Cohen's d provided a standardized measure of effect size, revealing the magnitude of these differences irrespective of sample size (Cohen, 1977). The values were generally interpreted as follows: a small effect ($0.20 \leq d < 0.50$), a medium effect ($0.50 \leq d < 0.80$), and a large effect ($d \geq 0.80$). When Cohen's d fell below 0.20, the effect size was considered negligible.

In the Nature dimension, the Garden Roof significantly outperformed Flat and Slope Roofs. Compared to the Flat Roof, the estimate was 0.431 with a Cohen's d of 0.423, indicating a small effect size. Compared to the Slope Roof, the estimate was 0.440 with a Cohen's d of 0.432, indicating a small effect size. However, the Garden Roof revealed a negligible effect compared to the Grass Roof, with an estimate of 0.064 and a Cohen's d of 0.063.

In the Culture dimension, the Garden Roof significantly outperformed Flat, Slope, and Grass Roofs. Compared to the Flat Roof, the estimate was 0.462 with a Cohen's d of 0.485, reflecting a small effect size. Compared to the Slope Roof, the estimate was 0.464 with a Cohen's d of 0.487, reflecting a small effect size. Compared to the Grass Roof, the estimate was 0.212 with a Cohen's d of 0.223, indicating a small effect size.

In the Prospect dimension, the Garden Roof significantly outperformed Flat, Slope, and Grass Roofs. Compared to the Flat Roof, the estimate was 0.395 with a Cohen's d of 0.406, indicating a small effect size. Compared to the Slope Roof, the estimate was 0.446 with a Cohen's d of 0.458, reflecting a small effect size. However, the Garden Roof revealed a negligible effect compared to the Grass Roof, with an estimate of 0.135 and a Cohen's d of 0.139.

In the Social dimension, the Garden Roof significantly outperformed Flat, Slope, and Grass Roofs. Compared to the Flat Roof, the estimate was 0.397 with a Cohen's d of 0.425, indicating a small effect size. Compared to the Slope Roof, the estimate was 0.404 with a Cohen's d of 0.432, reflecting a small effect size. Compared to the Grass Roof, the estimate was 0.221 with a Cohen's d of 0.237, indicating a small effect size.

In the Space dimension, the Garden Roof significantly outperformed Flat, Slope, and Grass Roofs. Compared to the Flat Roof, the estimate was 0.402 with a Cohen's d of 0.453, indicating a small effect size. Compared to the Slope Roof, the estimate was 0.447 with a Cohen's d of 0.504, indicating a medium effect size. However, the Garden Roof revealed a negligible effect compared to the Grass Roof, with an estimate of 0.166 and a Cohen's d of 0.188.

In the Rich in Species dimension, the Garden Roof significantly outperformed Flat, Slope, and Grass Roofs. Compared to the Flat Roof, the estimate was 0.398 with a Cohen's d of 0.391, indicating a small effect size. Compared to the Slope Roof, the estimate was 0.396 with a Cohen's d of 0.389, indicating a small effect size. However, the Garden Roof revealed a negligible effect compared to the Grass Roof, with an estimate of 0.130 and a Cohen's d of 0.128.

In the Refuge dimension, the Garden Roof significantly outperformed Flat, Slope, and Grass Roofs. Compared to the Flat Roof, the estimate was 0.334 with a Cohen's d of 0.356, indicating a small effect size. Compared to the Slope Roof, the estimate was 0.337 with a Cohen's d of 0.359, indicating a small effect size. However, the Garden Roof revealed a negligible effect compared to the Grass Roof, with an estimate of 0.172 and a Cohen's d of 0.183.

In the Serene dimension, the Garden Roof significantly outperformed Flat, Slope, and Grass Roofs. Compared to the Flat Roof, the estimate was 0.342 with a Cohen's d of 0.380, indicating a small effect size. Compared to the Slope Roof, the estimate was 0.307 with a Cohen's d of 0.341, indicating a small effect size. However, the Garden Roof revealed a negligible effect compared to the Grass Roof, with an estimate of 0.138 and a Cohen's d of 0.154.

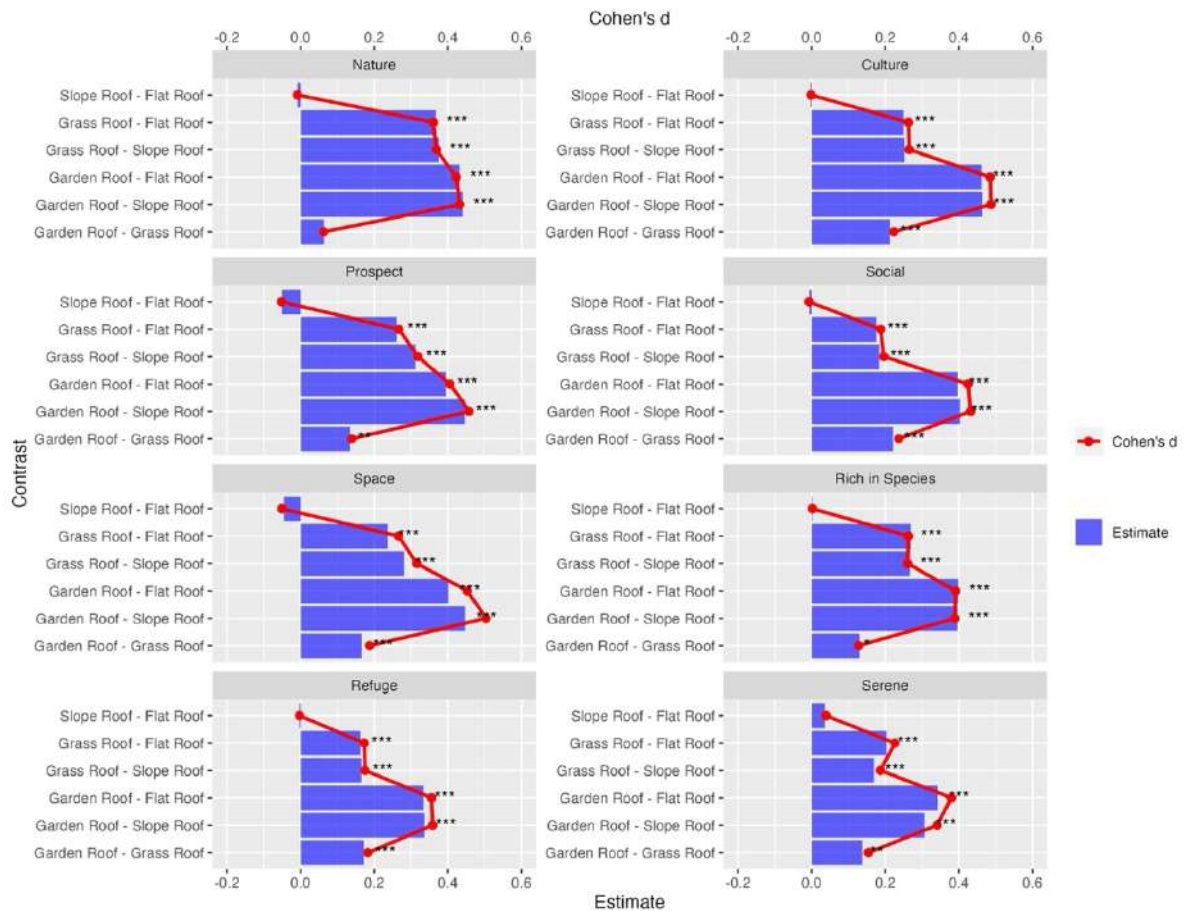


Figure 4.8: Estimates and Effect Sizes for Roof Type Comparisons across PSDs.

Source: Created by the Author.

4.2.4. Effects of Site, Floor Level, and Roof Type on Subjective Restoration

4.2.4.1. ANOVA of Main and Interaction Effects on Subjective Restoration

The ANOVA results in Table 4.7 indicated significant main effects and interaction effects on Subjective Restoration, across the factors of Site, Floor Level, and Roof Type. The main effect of Site significantly affected Subjective Restoration ($F(2, 4692) = 11.947, p < 0.001, \eta^2p = 0.005$). Floor Level significantly influenced Subjective Restoration ($F(2, 4692) = 3.276, p = 0.038, \eta^2p = 0.001$). Additionally, Roof Type significantly affected Subjective Restoration ($F(3, 4692) = 73.022, p < 0.001, \eta^2p = 0.045$).

The interaction effects further revealed relationships among the factors. Specifically, the interaction between Site and Floor Level was statistically significant ($F(4, 4692) = 33.967, p$

< 0.001, $\eta^2p = 0.028$). The interaction between Site and Roof Type was not significant. In contrast, the interaction between Floor Level and Roof Type was significant ($F(6, 4692) = 10.228, p < 0.001, \eta^2p = 0.013$). Furthermore, the three-way interaction between Site, Floor Level, and Roof Type did not significantly affect Subjective Restoration.

Table 4.7: ANOVA Results for Main Effects and Interaction Effects on Subjective Restoration (N = 4728).

Dependent variable(s): Subjective Restoration
 Between-subjects factor(s): Site, Floor Level, Roof Type

| | MS | MSE | df1 | df2 | F | p | η^2p [90% CI of η^2p] | η^2G |
|-------------------------------|--------|-------|-----|------|--------|---------|----------------------------------|-----------|
| Site | 6.842 | 0.573 | 2 | 4692 | 11.947 | < 0.001 | *** 0.005 [.002, .009] | 0.005 |
| Floor Level | 1.876 | 0.573 | 2 | 4692 | 3.276 | 0.038 | * 0.001 [.000, .003] | 0.001 |
| Roof Type | 41.819 | 0.573 | 3 | 4692 | 73.022 | < 0.001 | *** 0.045 [.035, .054] | 0.045 |
| Site * Floor Level | 19.453 | 0.573 | 4 | 4692 | 33.967 | < 0.001 | *** 0.028 [.020, .036] | 0.028 |
| Site * Roof Type | 0.738 | 0.573 | 6 | 4692 | 1.289 | 0.259 | 0.002 [.000, .003] | 0.002 |
| Floor Level * Roof Type | 5.858 | 0.573 | 6 | 4692 | 10.228 | < 0.001 | *** 0.013 [.007, .018] | 0.013 |
| Site * Floor Level* Roof Type | 0.572 | 0.573 | 12 | 4692 | 0.999 | 0.447 | 0.003 [.000, .003] | 0.003 |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2023).

4.2.4.2. Pairwise Comparisons of Main Effects on Subjective Restoration

The post hoc test (Tukey HSD) for pairwise comparisons of Site, Floor Level, and Roof Type on Subjective Restoration revealed the following findings (Table 4.8, Figure 4.9).

Comparisons between Sites showed that Site 2 had significantly lower Subjective Restoration than Site 1 (Estimate = -0.127, $p < 0.001$, Cohen's $d = -0.168$), and Site 3 also had significantly lower outcomes compared to Site 1 (Estimate = -0.096, $p = 0.001$, Cohen's $d = -0.127$). However, there was no significant difference between Site 3 and Site 2 (Estimate = 0.031, $p = 0.477$, Cohen's $d = 0.041$).

Regarding Floor Levels, none of the comparisons showed significant differences in Subjective Restoration. The comparison between the 9F and 3F (Estimate = 0.059, $p = 0.074$,

Cohen's $d = 0.078$), 27F and 3F (Estimate = -0.002 , $p = 0.998$, Cohen's $d = -0.002$), 27F and 9F (Estimate = -0.061 , $p = 0.064$, Cohen's $d = -0.08$) were not significant.

Comparisons between Roof Types showed that the Grass Roof significantly enhanced Subjective Restoration compared to the Flat Roof (Estimate = 0.230 , $p < .001$, Cohen's $d = 0.304$) and Slope Roof (Estimate = 0.195 , $p < .001$, Cohen's $d = 0.258$). The Garden Roof significantly enhanced Subjective Restoration compared to the Flat Roof (Estimate = 0.405 , $p < .001$, Cohen's $d = 0.536$), Slope Roof (Estimate = 0.371 , $p < .001$, Cohen's $d = 0.490$), and Grass Roof (Estimate = 0.175 , $p < .001$, Cohen's $d = 0.231$).

Table 4.8: Pairwise Comparisons of Main Effects of Site, Floor Level, and Roof Type on Subjective Restoration (N = 4728).

| Contrast | Estimate | S.E. | df | t | p | | Cohen's d [95% CI of d] |
|--------------------------|----------|-------|------|--------|---------|-----|-------------------------|
| Site 2 - Site 1 | -0.127 | 0.027 | 4692 | -4.691 | < 0.001 | *** | -0.168 [-0.252, -0.084] |
| Site 3 - Site 1 | -0.096 | 0.027 | 4692 | -3.561 | 0.001 | ** | -0.127 [-0.210, -0.043] |
| Site 3 - Site 2 | 0.031 | 0.027 | 4692 | 1.16 | 0.477 | | 0.041 [-0.042, 0.124] |
| 9F - 3F | 0.059 | 0.027 | 4692 | 2.187 | 0.074 | . | 0.078 [-0.006, 0.161] |
| 27F - 3F | -0.002 | 0.027 | 4692 | -0.059 | 0.998 | | -0.002 [-0.086, 0.081] |
| 27F - 9F | -0.061 | 0.027 | 4692 | -2.246 | 0.064 | . | -0.08 [-0.164, 0.004] |
| Slope Roof - Flat Roof | 0.035 | 0.031 | 4692 | 1.114 | 0.681 | | 0.046 [-0.060, 0.152] |
| Grass Roof - Flat Roof | 0.230 | 0.031 | 4692 | 7.392 | < 0.001 | *** | 0.304 [0.198, 0.410] |
| Grass Roof - Slope Roof | 0.195 | 0.031 | 4692 | 6.279 | < 0.001 | *** | 0.258 [0.153, 0.364] |
| Garden Roof - Flat Roof | 0.405 | 0.031 | 4692 | 13.018 | < 0.001 | *** | 0.536 [0.430, 0.641] |
| Garden Roof - Slope Roof | 0.371 | 0.031 | 4692 | 11.904 | < 0.001 | *** | 0.490 [0.384, 0.595] |
| Garden Roof - Grass Roof | 0.175 | 0.031 | 4692 | 5.625 | < 0.001 | *** | 0.231 [0.126, 0.337] |

Pooled SD for computing Cohen's d: 0.757

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2023).

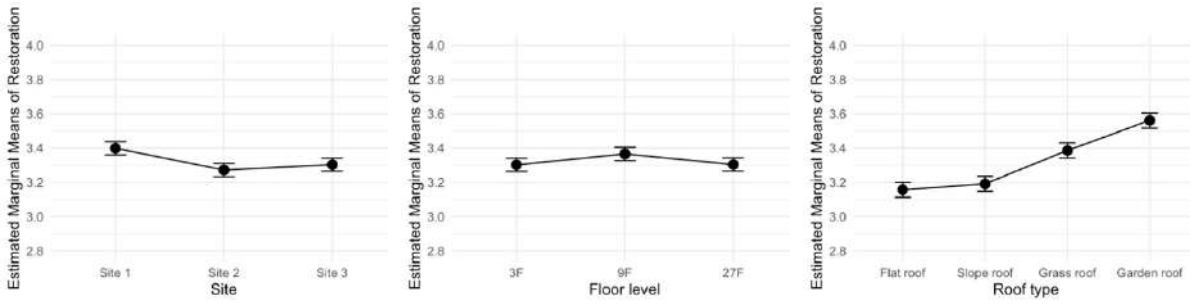


Figure 4.9: Main Effects of Site, Floor Level, and Roof Type on Subjective Restoration.

Source: F. Wang & Munakata (2023).

The bar chart depicted pairwise comparisons of Estimates and Cohen's d for the main effects of Site, Floor Level, and Roof Type on Subjective Restoration (Figure 4.10).

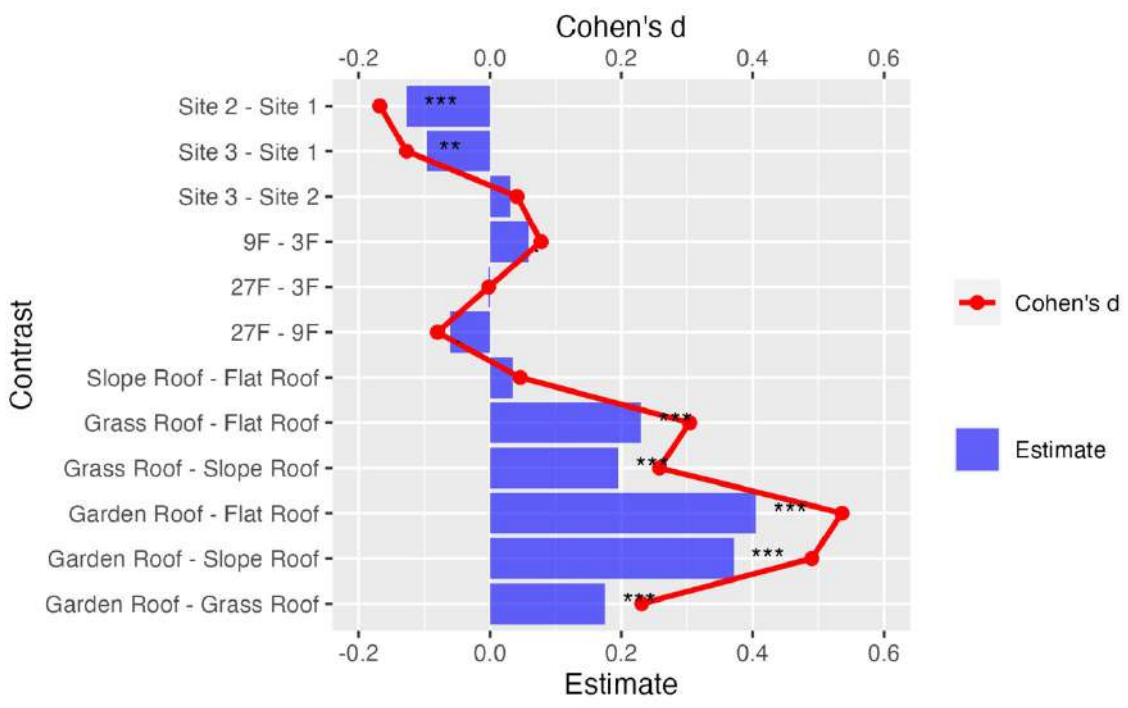


Figure 4.10: Bar Chart of Pairwise Comparisons: Estimates and Cohen's d for Site, Floor Level, and Roof Type on Subjective Restoration.

Source: Created by the Author.

4.2.4.3. Pairwise Comparisons of Interaction Effects Between Site and Floor Level on Subjective Restoration

The post hoc test (Tukey HSD) for pairwise comparisons indicated significant interaction effects between Site and Floor Level on Subjective Restoration (Table 4.9, Figure 4.11).

Regarding Site comparisons within each Floor level, significant differences were observed for the 3F, significant differences were observed between Site 2 and Site 1 (Estimate = -0.360 , $p < 0.001$, Cohen's $d = -0.475$), Site 3 and Site 1 (Estimate = -0.523 , $p < 0.001$, Cohen's $d = -0.691$), and Site 3 and Site 2 (Estimate = -0.163 , $p = 0.001$, Cohen's $d = -0.215$). For the 9F, significant differences were found between Site 3 and Site 1 (Estimate = 0.219 , $p < 0.001$, Cohen's $d = 0.289$) and Site 3 and Site 2 (Estimate = 0.150 , $p = 0.004$, Cohen's $d = 0.199$). However, comparisons between Site 2 and Site 1 were not significant (Estimate = 0.068 , $p = 0.314$, Cohen's $d = 0.090$). For the 27F, the differences were not significant between comparisons.

Regarding Floor Level comparisons within each Site, significant differences were observed for Site 1 between 9F and 3F (Estimate = -0.331 , $p < 0.001$, Cohen's $d = -0.437$) and between 27F and 3F (Estimate = -0.271 , $p < 0.001$, Cohen's $d = -0.358$). For Site 2, there were no significant differences. For Site 3, significant differences were found between 9F and 3F (Estimate = 0.410 , $p < 0.001$, Cohen's $d = 0.542$), between 27F and 3F (Estimate = 0.268 , $p < 0.001$, Cohen's $d = 0.354$), and between 27F and 9F (Estimate = -0.143 , $p = 0.006$, Cohen's $d = -0.189$).

Table 4.9: Pairwise Comparison of Interaction Effects Between Site and Floor Level on Subjective Restoration (N = 4728).

Dependent Variable: Subjective Restoration

| Contrast | | | Estimate | S.E. | df | t | p | | Cohen's d [95% CI of d] | |
|----------|-----------------|-------------|----------|--------|-------|------|---------|---------|-------------------------|-------------------------|
| Site | Site 2 - Site 1 | Floor Level | 3F | -0.360 | 0.047 | 4692 | -7.661 | < 0.001 | *** | -0.475 [-0.621, -0.330] |
| | Site 3 - Site 1 | | 3F | -0.523 | 0.047 | 4692 | -11.197 | < 0.001 | *** | -0.691 [-0.835, -0.546] |
| | Site 3 - Site 2 | | 3F | -0.163 | 0.046 | 4692 | -3.507 | 0.001 | ** | -0.215 [-0.359, -0.071] |
| | Site 2 - Site 1 | | 9F | 0.068 | 0.047 | 4692 | 1.453 | 0.314 | | 0.090 [-0.055, 0.235] |
| | Site 3 - Site 1 | | 9F | 0.219 | 0.047 | 4692 | 4.682 | < 0.001 | *** | 0.289 [0.144, 0.433] |
| | Site 3 - Site 2 | | 9F | 0.150 | 0.046 | 4692 | 3.234 | 0.004 | ** | 0.199 [0.055, 0.343] |
| | Site 2 - Site 1 | | 27F | -0.090 | 0.047 | 4692 | -1.916 | 0.134 | | -0.119 [-0.264, 0.027] |

| | | | | | | | | | | |
|-------------|-----------------|--------|--------|--------|-------|------|--------|---------|-----|-------------------------|
| | Site 3 - Site 1 | | 27F | 0.016 | 0.047 | 4692 | 0.347 | 0.936 | | 0.021 [-0.123, 0.166] |
| | Site 3 - Site 2 | | 27F | 0.106 | 0.046 | 4692 | 2.283 | 0.058 | . | 0.140 [-0.004, 0.284] |
| Floor level | 9F - 3F | Site 1 | Site 1 | -0.331 | 0.047 | 4692 | -7.018 | < 0.001 | *** | -0.437 [-0.583, -0.291] |
| | 27F - 3F | | Site 1 | -0.271 | 0.047 | 4692 | -5.754 | < 0.001 | *** | -0.358 [-0.504, -0.212] |
| | 27F - 9F | | Site 1 | 0.060 | 0.047 | 4692 | 1.265 | 0.415 | | 0.079 [-0.067, 0.225] |
| | 9F - 3F | Site 2 | Site 2 | 0.097 | 0.047 | 4692 | 2.077 | 0.095 | . | 0.128 [-0.017, 0.273] |
| | 27F - 3F | | Site 2 | -0.001 | 0.047 | 4692 | -0.031 | 0.999 | | -0.002 [-0.147, 0.143] |
| | 27F - 9F | | Site 2 | -0.099 | 0.047 | 4692 | -2.107 | 0.088 | . | -0.130 [-0.275, 0.015] |
| | 9F - 3F | Site 3 | Site 3 | 0.410 | 0.046 | 4692 | 8.879 | < 0.001 | *** | 0.542 [0.399, 0.686] |
| | 27F - 3F | | Site 3 | 0.268 | 0.046 | 4692 | 5.792 | < 0.001 | *** | 0.354 [0.211, 0.497] |
| | 27F - 9F | | Site 3 | -0.143 | 0.046 | 4692 | -3.087 | 0.006 | ** | -0.189 [-0.332, -0.045] |

Pooled SD for computing Cohen's d: 0.757

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2023).

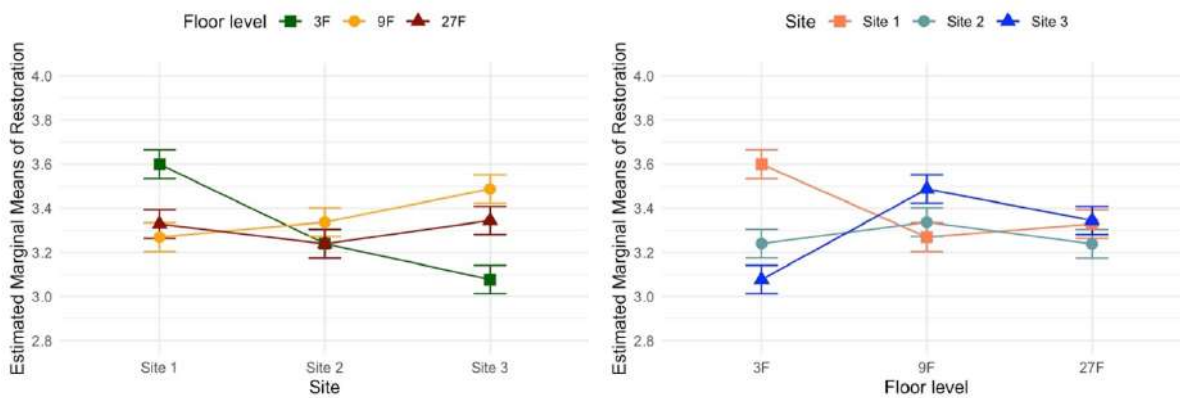


Figure 4.11: Interaction Effect of Site and Floor Level on Subjective Restoration.

Source: F. Wang & Munakata (2023).

The bar chart depicted pairwise comparisons of Estimates and Cohen's d for interaction effects between Site and Floor Level on Subjective Restoration (Figure 4.12).

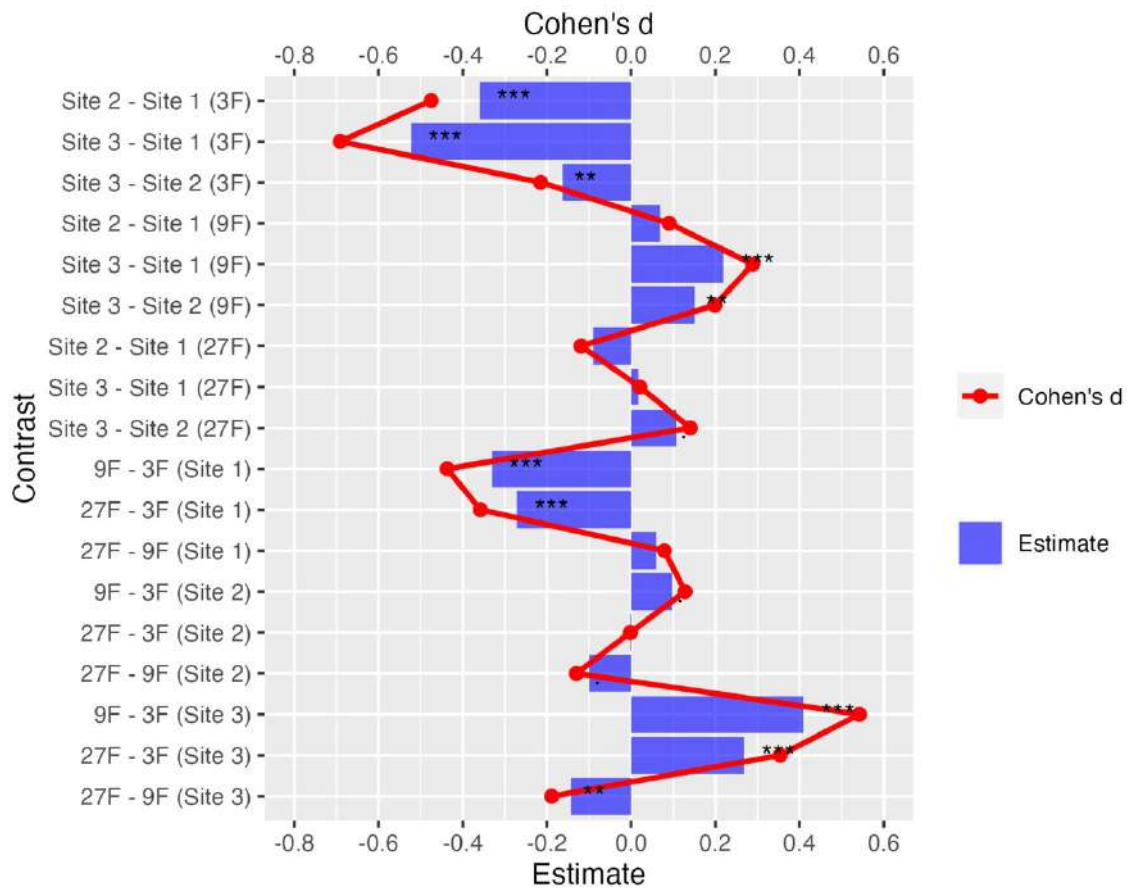


Figure 4.12: Bar Chart of Estimates and Cohen's d for Interaction Effects between Site and Floor Level on Subjective Restoration.

Source: Created by the Author.

4.2.4.4. Pairwise Comparisons of Interaction Effects Between Floor Level and Roof Type on Subjective Restoration

The post hoc test (Tukey HSD) for pairwise comparisons indicated significant interaction effects between Floor Level and Roof Type on Subjective Restoration (Table 4.10, Figure 4.13). For the Flat Roof, significant differences were observed between 9F and 3F (Estimate = -0.128 , $p = 0.046$, Cohen's $d = -0.170$), between 27F and 3F (Estimate = -0.279 , $p < 0.001$, Cohen's $d = -0.369$), and between 27F and 9F (Estimate = -0.151 , $p = 0.014$, Cohen's $d = -0.200$). For the Slope Roof, no significant differences were found between 9F and 3F (Estimate = -0.032 , $p = 0.825$, Cohen's $d = -0.042$), between 27F and 3F (Estimate = -0.105 ,

$p = 0.125$, Cohen's $d = -0.139$), or between 27F and 9F (Estimate = -0.073 , $p = 0.362$, Cohen's $d = -0.097$). For the Grass Roof, significant differences were found between 9F and 3F (Estimate = 0.151 , $p = 0.014$, Cohen's $d = 0.199$) and between 27F and 3F (Estimate = 0.132 , $p = 0.039$, Cohen's $d = 0.174$), but not between 27F and 9F (Estimate = -0.019 , $p = 0.932$, Cohen's $d = -0.025$). For the Garden Roof, significant differences were found between 9F and 3F (Estimate = 0.245 , $p < 0.001$, Cohen's $d = 0.324$) and between 27F and 3F (Estimate = 0.247 , $p < 0.001$, Cohen's $d = 0.326$), but not between 27F and 9F (Estimate = 0.002 , $p = 1.000$, Cohen's $d = 0.002$).

Regarding Roof Type comparisons within each Floor Level, for 3F, no significant differences were observed between Slope Roof and Flat Roof (Estimate = -0.056 , $p = 0.731$, Cohen's $d = -0.073$), Grass Roof and Flat Roof (Estimate = -0.000 , $p = 1.000$, Cohen's $d = -0.000$), Grass Roof and Slope Roof (Estimate = 0.056 , $p = 0.731$, Cohen's $d = 0.073$), Garden Roof and Flat Roof (Estimate = 0.105 , $p = 0.205$, Cohen's $d = 0.139$), or Garden Roof and Grass Roof (Estimate = 0.105 , $p = 0.205$, Cohen's $d = 0.139$). However, a significant difference was found between Garden Roof and Slope Roof (Estimate = 0.161 , $p = 0.015$, Cohen's $d = 0.213$). For 9F, significant differences were observed between Grass Roof and Flat Roof (Estimate = 0.279 , $p < 0.001$, Cohen's $d = 0.369$), Grass Roof and Slope Roof (Estimate = 0.238 , $p < 0.001$, Cohen's $d = 0.315$), Garden Roof and Flat Roof (Estimate = 0.479 , $p < 0.001$, Cohen's $d = 0.633$), Garden Roof and Slope Roof (Estimate = 0.438 , $p < 0.001$, Cohen's $d = 0.579$), and Garden Roof and Grass Roof (Estimate = 0.200 , $p = 0.001$, Cohen's $d = 0.264$). Comparisons between Slope Roof and Flat Roof (Estimate = 0.041 , $p = 0.872$, Cohen's $d = 0.054$) were not significant. For 27F, significant differences were observed between Grass Roof and Flat Roof (Estimate = 0.411 , $p < 0.001$, Cohen's $d = 0.543$), Grass Roof and Slope Roof (Estimate = 0.292 , $p < 0.001$, Cohen's $d = 0.386$), Garden Roof and Flat Roof (Estimate = 0.631 , $p < 0.001$, Cohen's $d = 0.834$), Garden Roof and Slope Roof (Estimate = 0.513 , $p < 0.001$, Cohen's $d = 0.678$), and Garden Roof and Grass Roof (Estimate

= 0.220, $p < 0.001$, Cohen's $d = 0.291$). Comparisons between Slope Roof and Flat Roof (Estimate = 0.119, $p = 0.123$, Cohen's $d = 0.157$) were not significant.

Table 4.10: Pairwise Comparison of Interaction Effects Between Floor Level and Roof Type on Subjective Restoration (N = 4728).

Dependent Variable: Subjective Restoration

| Contrast | | Estimate | S.E. | df | t | p | Cohen's d [95% CI of d] |
|------------------------------|---------------------------------|----------|-------|-------|---------|--------------------------|-----------------------------|
| Floor Level | 9F - 3F Roof Flat Roof | -0.128 | 0.054 | 4692 | -2.381 | 0.046 | * -0.170 [-0.337, -0.003] |
| | 27F - 3F Type Flat Roof | -0.279 | 0.054 | 4692 | -5.182 | < 0.001 | *** -0.369 [-0.536, -0.202] |
| | 27F - 9F Flat Roof | -0.151 | 0.054 | 4692 | -2.801 | 0.014 | * -0.200 [-0.367, -0.033] |
| | 9F - 3F Slope Roof | -0.032 | 0.054 | 4692 | -0.590 | 0.825 | -0.042 [-0.209, 0.125] |
| | 27F - 3F Slope Roof | -0.105 | 0.054 | 4692 | -1.951 | 0.125 | -0.139 [-0.306, 0.028] |
| | 27F - 9F Slope Roof | -0.073 | 0.054 | 4692 | -1.361 | 0.362 | -0.097 [-0.264, 0.070] |
| | 9F - 3F Grass Roof | 0.151 | 0.054 | 4692 | 2.799 | 0.014 | * 0.199 [0.032, 0.367] |
| | 27F - 3F Grass Roof | 0.132 | 0.054 | 4692 | 2.441 | 0.039 | * 0.174 [0.007, 0.341] |
| | 27F - 9F Grass Roof | -0.019 | 0.054 | 4692 | -0.358 | 0.932 | -0.025 [-0.193, 0.142] |
| | 9F - 3F Garden Roof | 0.245 | 0.054 | 4692 | 4.546 | < 0.001 | *** 0.324 [0.157, 0.491] |
| | 27F - 3F Garden Roof | 0.247 | 0.054 | 4692 | 4.574 | < 0.001 | *** 0.326 [0.159, 0.493] |
| | 27F - 9F Garden Roof | 0.002 | 0.054 | 4692 | 0.028 | 1.000 | 0.002 [-0.165, 0.169] |
| Roof type | Slope Roof - Flat Roof Floor 3F | -0.056 | 0.054 | 4692 | -1.031 | 0.731 | -0.073 [-0.257, 0.110] |
| | Grass Roof - Flat Roof level 3F | -0.000 | 0.054 | 4692 | -0.000 | 1.000 | -0.000 [-0.183, 0.183] |
| | Grass Roof - Slope Roof 3F | 0.056 | 0.054 | 4692 | 1.031 | 0.731 | 0.073 [-0.110, 0.257] |
| | Garden Roof - Flat Roof 3F | 0.105 | 0.054 | 4692 | 1.955 | 0.205 | 0.139 [-0.044, 0.322] |
| | Garden Roof - Slope Roof 3F | 0.161 | 0.054 | 4692 | 2.986 | 0.015 | * 0.213 [0.030, 0.396] |
| | Garden Roof - Grass Roof 3F | 0.105 | 0.054 | 4692 | 1.955 | 0.205 | 0.139 [-0.044, 0.322] |
| | Slope Roof - Flat Roof 9F | 0.041 | 0.054 | 4692 | 0.76 | 0.872 | 0.054 [-0.129, 0.237] |
| | Grass Roof - Flat Roof 9F | 0.279 | 0.054 | 4692 | 5.18 | < 0.001 | *** 0.369 [0.186, 0.552] |
| | Grass Roof - Slope Roof 9F | 0.238 | 0.054 | 4692 | 4.42 | < 0.001 | *** 0.315 [0.132, 0.498] |
| | Garden Roof - Flat Roof 9F | 0.479 | 0.054 | 4692 | 8.882 | < 0.001 | *** 0.633 [0.450, 0.816] |
| | Garden Roof - Slope Roof 9F | 0.438 | 0.054 | 4692 | 8.122 | < 0.001 | *** 0.579 [0.396, 0.762] |
| | Garden Roof - Grass Roof 9F | 0.200 | 0.054 | 4692 | 3.702 | 0.001 | ** 0.264 [0.081, 0.447] |
| | Slope Roof - Flat Roof 27F | 0.119 | 0.054 | 4692 | 2.200 | 0.123 | 0.157 [-0.026, 0.340] |
| | Grass Roof - Flat Roof 27F | 0.411 | 0.054 | 4692 | 7.624 | < 0.001 | *** 0.543 [0.360, 0.726] |
| | Grass Roof - Slope Roof 27F | 0.292 | 0.054 | 4692 | 5.423 | < 0.001 | *** 0.386 [0.203, 0.570] |
| | Garden Roof - Flat Roof 27F | 0.631 | 0.054 | 4692 | 11.711 | < 0.001 | *** 0.834 [0.651, 1.018] |
| Garden Roof - Slope Roof 27F | 0.513 | 0.054 | 4692 | 9.510 | < 0.001 | *** 0.678 [0.495, 0.861] | |
| Garden Roof - Grass Roof 27F | 0.220 | 0.054 | 4692 | 4.087 | < 0.001 | *** 0.291 [0.108, 0.474] | |

Pooled SD for computing Cohen's d: 0.757

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2023).

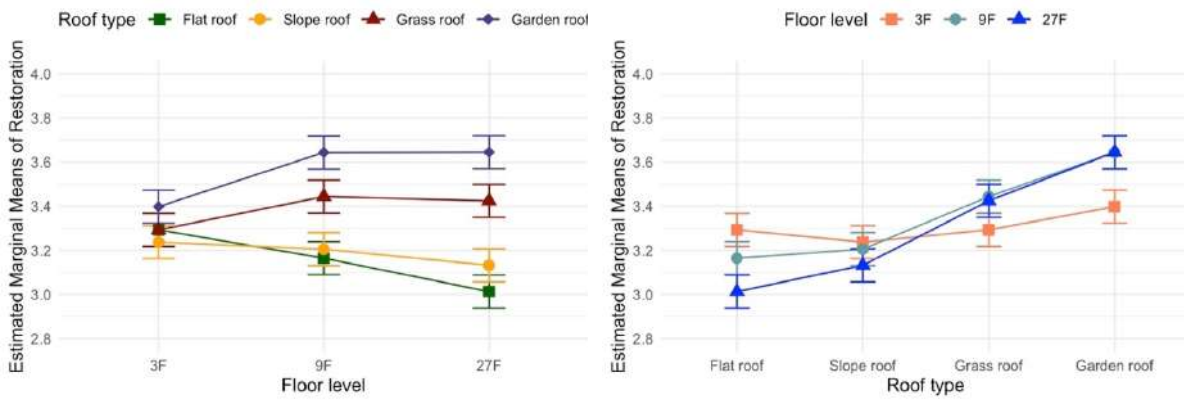


Figure 4.13: Interaction Effect of Floor Level and Roof Type on Subjective Restoration.

Source: F. Wang & Munakata (2023).

The bar chart depicted pairwise comparisons of Estimates and Cohen's d for interaction effects between Floor Level and Roof Type on Subjective Restoration (Figure 4.14).

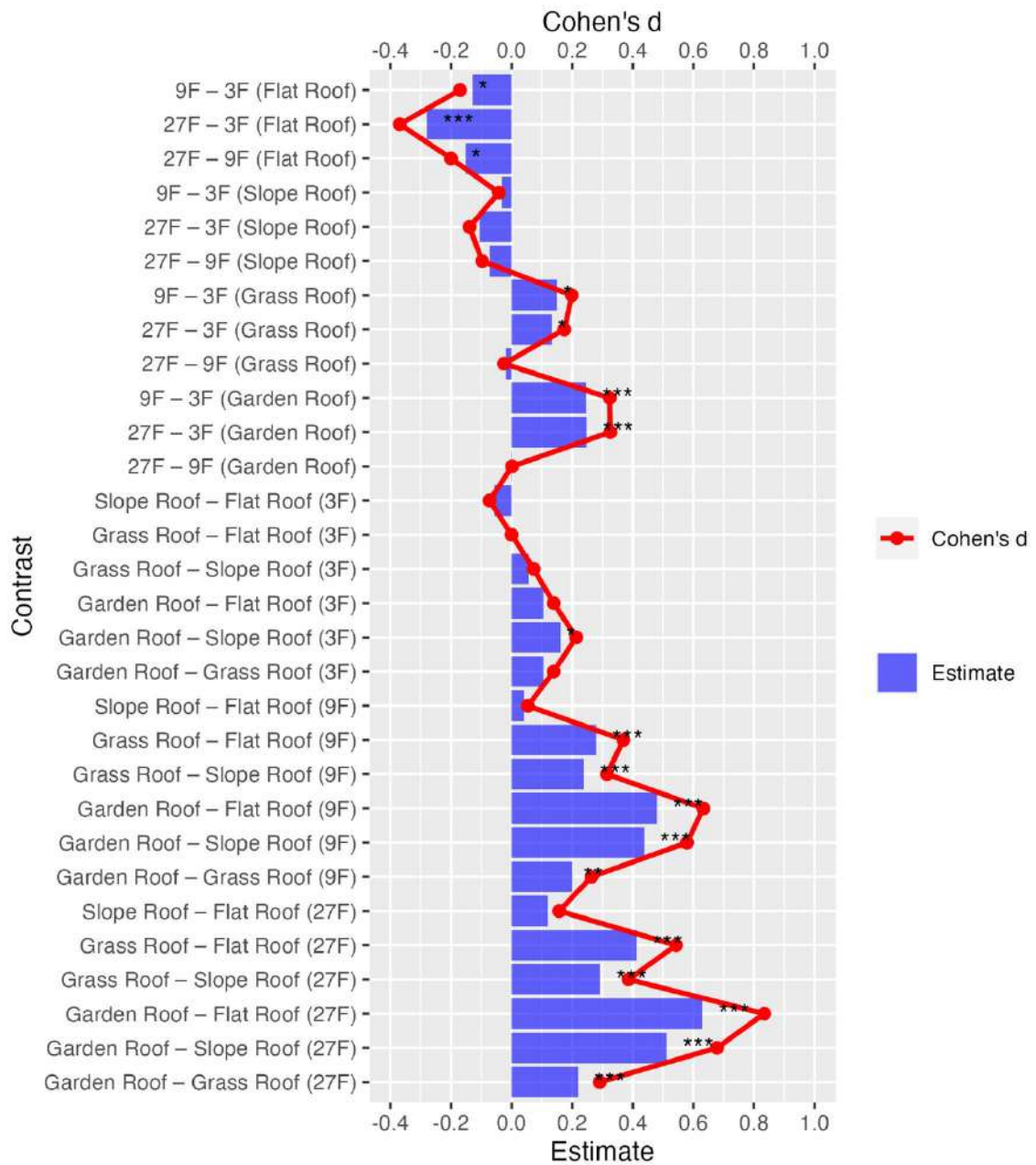


Figure 4.14: Bar Chart of Estimates and Cohen's d for Interaction Effects between Floor Level and Roof Type on Subjective Restoration.

Source: Created by the Author.

4.3. Discussion

This experiment investigated how different roof types affect subjective restoration. The following sections provide observations and conclusions based on the results.

4.3.1. Evaluating Urban Environments Using PSDs

The garden roof viewed from higher floors, such as the 9th and 27th floors, received the highest ratings in most dimensions, according to the mean values for each attribution of PSDs. This result implies that garden roofs enhance visual quality when viewed from the upper floors. Garden roofs receive higher ratings because of their aesthetic and natural features, promoting relaxation and well-being (K. E. Lee et al., 2015). Garden roofs, as a type of green roof, offer more biodiversity and visual appeal than flat or sloped roofs (Williams et al., 2019).

4.3.2. Predicting Subjective Restoration Based on PSDs

Four attributes of the Perceived Sensory Dimensions (PSDs)—Serene, Nature, Rich in Species, and Social—significantly affected subjective restoration by stepwise multivariate linear regression. The model explained 62.1% of the variance (Adjusted R-squared = 0.621). This result supported Hypothesis 1-1.

Among the significant predictors, "Serene" showed the most positive relationship with restoration (Estimate = 0.358, $p < 0.001$). Prior research demonstrated the health benefits of serene places, which are quiet and peaceful (Grahn & Stigsdotter, 2010). Urban noise negatively impacts health by affecting hearing, sleep, cognitive performance, and stressful restoration (Annerstedt et al., 2013; Basner et al., 2014). Evolution theory holds that natural sounds are more beneficial to human health than urban noise (Grahn & van den Bosch, 2014; Pálsdóttir et al., 2014).

"Nature" showed a positive relationship with restoration (Estimate = 0.164, $p < 0.001$).

Attention Restoration Theory (ART) and Stress Reduction Theory (SRT) indicate that natural settings improve attention and lower stress (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995; Ulrich, 1983, 1984). ART suggests that natural settings aid in recovering from mental fatigue by engaging individuals in ways that restore cognitive capacities (R. Kaplan & Kaplan, 1989;

S. Kaplan, 1995). Nature facilitates restorative experiences through fascination, extent, compatibility, and a sense of being away, collectively contributing to the renewal of attention (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). Similarly, SRT argues that exposure to natural environments diminishes stress and improves overall well-being by inducing a calming effect that alleviates physiological and psychological stress, promoting better mental well-being (Ulrich, 1983, 1984).

The analysis found a positive relationship between "Social" and restoration (Estimate = 0.151, $p < 0.001$). This result emphasizes the role of social interactions and public areas in increasing environmental well-being and satisfaction (Cattell et al., 2008). Fostering social engagement settings can provide emotional support, reduce feelings of isolation, lower loneliness, and boost perceived social support (Peschardt & Stigsdotter, 2013; Thompson, 2002). These surroundings help to provide more effective restorative experiences.

"Rich in Species" showed a positive relationship with restoration (Estimate = 0.091, $p < 0.001$). This dimension indicates the effects of biodiversity in restoration (Nghiem et al., 2021). Diverse species promote ecological balance and provide a rich sensory experience (Schebella et al., 2019). Diverse plants and animals make an environment more appealing and help reduce attention fatigue (S. Kaplan, 1990). Rich in species considers environmental complexity, which predicts subjective restoration (Han, 2003).

4.3.3. Impact of Roof Type on PSDs

The ANOVA analysis showed that roof type significantly affects all eight attributes of Perceived Sensory Dimensions (PSDs). Pairwise comparison results revealed a consistent pattern in which the garden roof outperforms flat and slope roofs across all dimensions. The results indicated that the garden roof enhances perceptions of Nature, Culture, Prospect, Social, Space, Rich in Species, Refuge, and Serene compared to non-vegetated or less complex roof types. However, most effects are negligible when comparing the garden roof to

the grass roof. While the garden roof has significant advantages over slope and flat roofs, it has slight advantages over the grass roof. The findings suggest that incorporating green roofs, especially the garden roof, into urban planning improves psychological well-being.

4.3.4. Effects of Environmental Features on Subjective Restoration

4.3.4.1. Influence of Site, Floor Level, and Roof Type on Subjective Restoration

The main effect of the site on subjective restoration was significant ($F(2, 4692) = 11.947, p < 0.001, \eta^2p = 0.005$), indicating that the location of buildings significantly affects restoration. Pairwise comparisons using the Tukey HSD test showed that Sites 2 and 3 had notably lower restoration outcomes than Site 1, with Cohen's d values of -0.168 and -0.127 , respectively. These differences are statistically significant, but the effect sizes are negligible. This result suggests that, although the environmental context plays a role in restoration, its impact is relatively small. Other factors, such as roof type, surrounding greenery, noise levels, and urban density, may substantially influence restoration outcomes.

The floor level significantly influenced subjective restoration ($F(2, 4692) = 3.276, p = 0.038, \eta^2p = 0.001$), although pairwise comparisons did not reveal any significant differences. This finding differs from previous research, which found that higher floors positively correlate with a preference for window views. For instance, elevating viewing floors and increasing the visible proportion of greenery has enhanced the restoration effect (Olszewska-Guizzo et al., 2018). Similarly, occupants are often willing to pay a premium to live on higher floors of high-rise apartments (Conroy et al., 2013; Xiao et al., 2019).

The discrepancy in this study may be attributed to the specific content that was viewed, which focused on the building roof, due to the chosen shooting angles. Research indicated that the typical line of sight angle, when seated with the trunk and head upright, is a steep downward view, averaging around -29° (Kroemer & Hill, 1986). In contrast, the focus on the building roof diverges from customary viewing practices. Therefore, when the view was

limited to the building roof, the results did not find statistically significant differences in restorative effects between floor levels.

Roof type exhibited significant effects on restoration ($F(3, 4692) = 73.022, p < 0.001, \eta^2p = 0.045$). Pairwise comparisons showed that the grass and garden roofs significantly enhanced restoration, with the garden roof having the highest positive impact. Compared to the flat roof, the effect size for the garden roof was medium (Cohen's $d = 0.536$), underscoring the restorative benefits of incorporating green roofs into urban design. This result supported Hypothesis 1-2.

Previous studies have found the restorative potential of garden roofs, particularly those that possess a varied vegetational structure and color (Fernandez-Cañero et al., 2013). Compared to flat and sloped roofs, green roofs integrating plants and flowers are beneficial and therapeutic (K. E. Lee et al., 2015). In contrast, flat and sloped roofs are designed more simplistically in general. Environmental complexity is a key factor affecting environmental preference and restoration (R. Kaplan & Kaplan, 1989). These findings add to prior evidence that incorporating natural components into the built environment effectively enhances restoration (R. Kaplan, 2001; Ulrich, 1984).

4.3.4.2. Influence of Interaction Effects on Subjective Restoration

The interaction between site and floor level on restoration was significant ($F(4, 4692) = 33.967, p < 0.001, \eta^2p = 0.028$). The higher restoration values were recorded at 3F of Site 1 and 9F of Site 3. Analysis of the experimental images revealed that these views shared notable characteristics, such as extensive green spaces, expansive vistas, and rich environmental diversity, which promote restoration (Grahn & Stigsdotter, 2010; R. Kaplan, 2001; Masoudinejad & Hartig, 2020).

The interaction between floor level and roof type ($F(6, 4692) = 10.228, p < 0.001, \eta^2p = 0.013$) was significant, indicating that restorative effects of roof types vary with floor levels. Pairwise comparisons show that, on the 3rd floor, only the comparison between the sloped roof and garden roof demonstrated a significant difference in restoration. This finding might be due to the difficulty distinguishing roof types from lower floors. Conversely, on the 9th and 27th floors, most comparisons between roof types significantly influenced restoration, except between the flat and sloped roofs. The visual distinction between flat and sloped roofs is not noticeable when viewing from higher floors. Therefore, roof type had minimal impact on restoration for viewers on lower floors, and it became significant for viewers on higher floors.

These findings offer practical insights for designers considering the roof design of multi-rise buildings. In areas with numerous multi-rise buildings, the choice of roof type may have a limited effect on the restorative experiences of nearby residents. However, green roofs provide more significant restorative benefits for occupants on higher floors in areas with many high-rise buildings.

5. Experiment Two: Effects of Planning Measures on Subjective Impressions

5.1. Materials and Methods

5.1.1. Research Hypothesis

In urban high-rise residential areas, window views are often obstructed by surrounding natural and built environments. This experiment explored the impact of planning measures (building layout, building spacing, and surrounding trees), viewing floor levels, and the visual elements ratio (sky, grass, trees, foreground buildings, and background buildings) on the perceived oppressiveness of window views in high-rise residential buildings. Based on existing literature, this study proposes the following hypothesis.

Hypothesis 2-1: Staggered building layouts and increased building spacing reduce perceived oppressiveness.

Hypothesis 2-2: Natural elements visible from windows mitigate perceived oppressiveness.

Hypothesis 2-3: Increasing the viewing floors enhances the sky ratio in window views.

Hypothesis 2-4: A negative correlation exists between perceived oppressiveness and environmental preference.

5.1.2. Participants

Participants were recruited from the Architecture and Design Department of the Faculty of Engineering at Chiba University. Experiment 2 included 50 participants (Table 5.1). Among the participants, 28 were men (56.0%), and 22 were women (44.0%). Regarding educational background, 11 (22.0%) were undergraduates, while 39 (78.0%) were postgraduates. The participants ranged in age from 20 to 34, having an average age of 24.5 years. After the experiment was finished, each participant was given a 2000-yen book card as an appreciation.

Table 5.1: Demographic Information of Experiment 2 (N = 50).

| | Description | | Percentage |
|--------|-------------|----|------------|
| Gender | Man | 28 | 56.0% |
| | Women | 22 | 44.0% |

| | | | |
|-----------------|---------------|------|-------|
| Education level | Undergraduate | 11 | 22.0% |
| | Postgraduate | 39 | 78.0% |
| Age | Minimum age | 20 | |
| | Maximum age | 34 | |
| | Average age | 24.5 | |

Source: F. Wang & Munakata (2024b).

5.1.3. Experimental Stimuli

This experiment selected panoramic photographs displayed in virtual reality (VR) headsets to simulate window views of high-rise buildings. Prior studies have demonstrated the effectiveness of VR panoramic imagery in simulating and evaluating urban environments (Brivio et al., 2021; Luo et al., 2022; Shi et al., 2020). VR headsets provide an immersive experience where interactive head and eye movements simulate real-world environments. Precise control over environmental variables by the computer-generated model removed distractions like traffic noise, lighting, and observation time.

5.1.3.1. Factor Settings

There were four variable factors in the experiment. One observed variable, Floor Level (FL), and three planning measures, Building Layout (BL), Building Spacing (BS), and Surrounding Trees (ST), were shown in Table 5.2. In addition, the experiment had several fixed factors.

Table 5.2: Factor Settings for Experiment 2.

| | | Level | | |
|-------------------|------------------------------------|---|-----------|-----|
| | | 1 | 2 | 3 |
| Planning measures | Building Layout (BL) | Parallel | Staggered | |
| | Building Spacing (BS) | 15 m | 30 m | |
| | Surrounding Trees (ST) | Nonexistent | Existent | |
| Observed variable | Floor Level (FL) | 3F | 9F | 30F |
| Fixed factors | Building distance | 50 m | | |
| | Building width | 45 m | | |
| | Building height | 90 m (30F, Height of each floor = 3 m) | | |
| | Room size | 5.4 m (length) × 3.6 m (width) × 3.0 m (height) | | |
| | Window size | 2.6 m (width) × 1.8 m (height) | | |
| | Eye height | 1.5 m | | |
| | Distance between window and viewer | 0.5 m | | |

| | |
|---|------------------------|
| Sky type | Clear sky |
| Glass type | Clear glass |
| Window-to-wall ratio (Foreground building) | 42.7 % |
| Window-to-wall ratio (High-rise background building) | 33.6 % |
| Window-to-wall ratio (Multi-rise background building) | 47.7 % |
| External wall materials of surrounding buildings | Low-reflectivity paint |

Source: F. Wang & Munakata (2024b).

There were two layouts in Building Layout (BL): Parallel and Staggered. There were six buildings in the staggered layout and five in the parallel layout. The two distances covered in Building Spacing (BS) were 15 and 30 meters. The 15 meters complied with China's fire safety laws for high-rise building spacing, a minimum of 13 meters. The 30 meters was an upgraded building spacing (Figure 5.1).

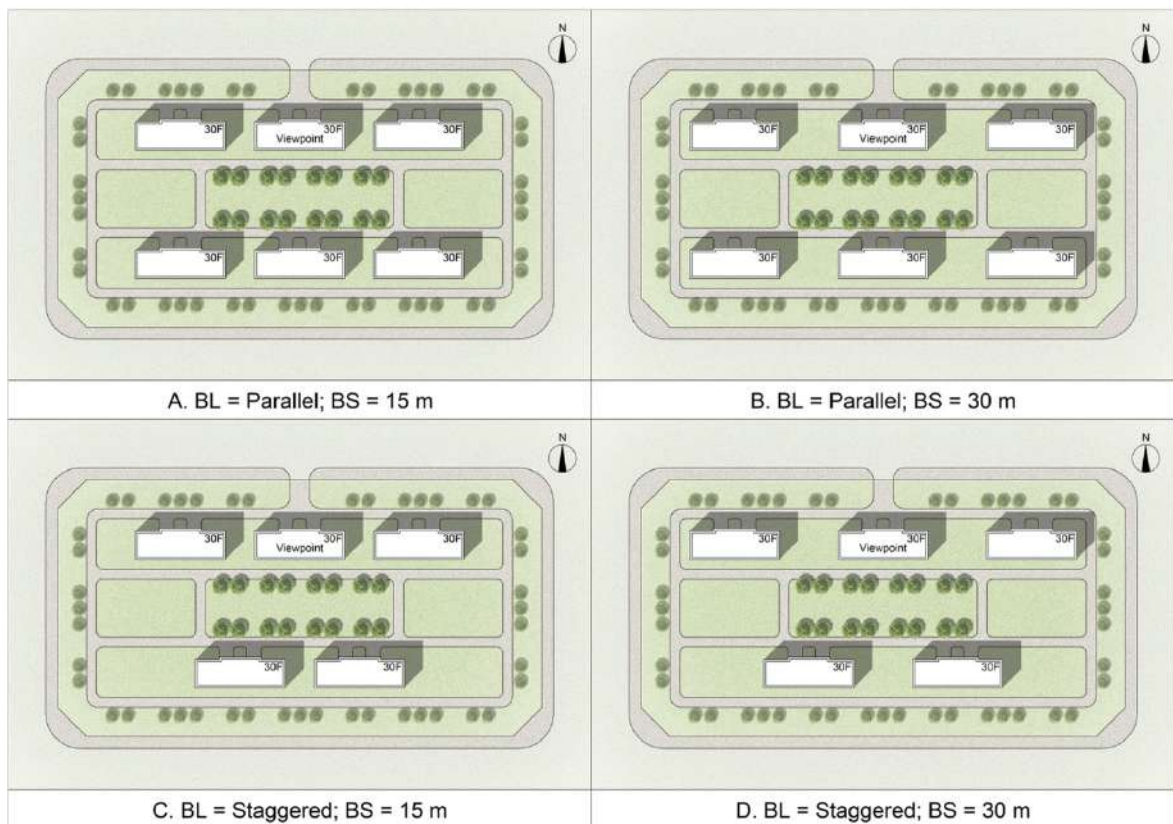


Figure 5.1: Building Layout (BL) and Building Spacing (BS) Configurations.

Source: F. Wang & Munakata (2024b).

Surrounding Trees (ST) included two conditions: Nonexistent and Existent. In China, high-rise residential buildings generally have around 30 floors. The viewing Floor Level (FL) was divided into three zones based on the height from the ground level: low-floor zone (1F - 6F), low-middle floor zone (7F - 12F), and high-floor zone (above 13F). Specifically, the 3rd floor (3F) was selected to depict the low-floor zone, the 9th floor (9F) the low-middle floor zone, and the 30th floor (30F) the high-floor zone.

The chosen observation spot was in the middle building of the northern side, and this building's south-facing central room. The observer stood 0.5 meters away from the window, with their line of sight at a height of 1.5 meters, to simulate the perspective of standing and looking out of the window.

5.1.3.2. Image Processing

This study created 3D digital models using SketchUp (version 2022) and rendered them using Enscape (version 1.1.21 for Mac). This model replicated an area located in Hangzhou, China. The area features six 30-floor high-rise residential buildings arranged in parallel, with each building spaced 30 meters apart. Each building has a width of 45 meters, and the distance between the structures is 50 meters. These specifications are typical of high-rise residential complexes in China. This experiment employed a full factorial design to generate 24 panoramic images representing distinct combinations of the experimental factors (Figure 5.2).

| No. | Variable factors | Panoramic images | VR screenshot (Horizontal sightline = 0°; Vertical sightline = 0°) |
|-----|--|---|--|
| 01 | BL = Staggered BS = 15 m ST = Nonexistent FL = 3F |  |  |

02
BL =
Staggered
BS = 15 m
ST=
Nonexistent
FL = 9F



03
BL =
Staggered
BS = 15 m
ST=
Nonexistent
FL = 27F



04
BL =
Staggered
BS = 15 m
ST=
Existing
FL = 3F



05
BL =
Staggered
BS = 15 m
ST=
Existing
FL = 9F



06
BL =
Staggered
BS = 15 m
ST=
Existing
FL = 27F



07
BL =
Parallel
BS = 15 m
ST=
Nonexistent
FL = 3F



08
 BL =
 Parallel
 BS = 15 m
 ST =
 Nonexistent
 FL = 9F



09
 BL =
 Parallel
 BS = 15 m
 ST =
 Nonexistent
 FL = 27F



10
 BL =
 Parallel
 BS = 15 m
 ST =
 Existent
 FL = 3F



11
 BL =
 Parallel
 BS = 15 m
 ST =
 Existent
 FL = 9F



12
 BL =
 Parallel
 BS = 15 m
 ST =
 Existent
 FL = 27F



13
 BL =
 Staggered
 BS = 30 m
 ST =
 Nonexistent
 FL = 3F



14
 BL =
 Staggered
 BS = 30 m
 ST=
 Nonexistent
 FL = 9F



15
 BL =
 Staggered
 BS = 30 m
 ST=
 Nonexistent
 FL = 27F



16
 BL =
 Staggered
 BS = 30 m
 ST=
 Existent
 FL = 3F



17
 BL =
 Staggered
 BS = 30 m
 ST=
 Existent
 FL = 9F



18
 BL =
 Staggered
 BS = 30 m
 ST=
 Existent
 FL = 27F



19
 BL =
 Parallel
 BS = 30 m
 ST=
 Nonexistent
 FL = 3F



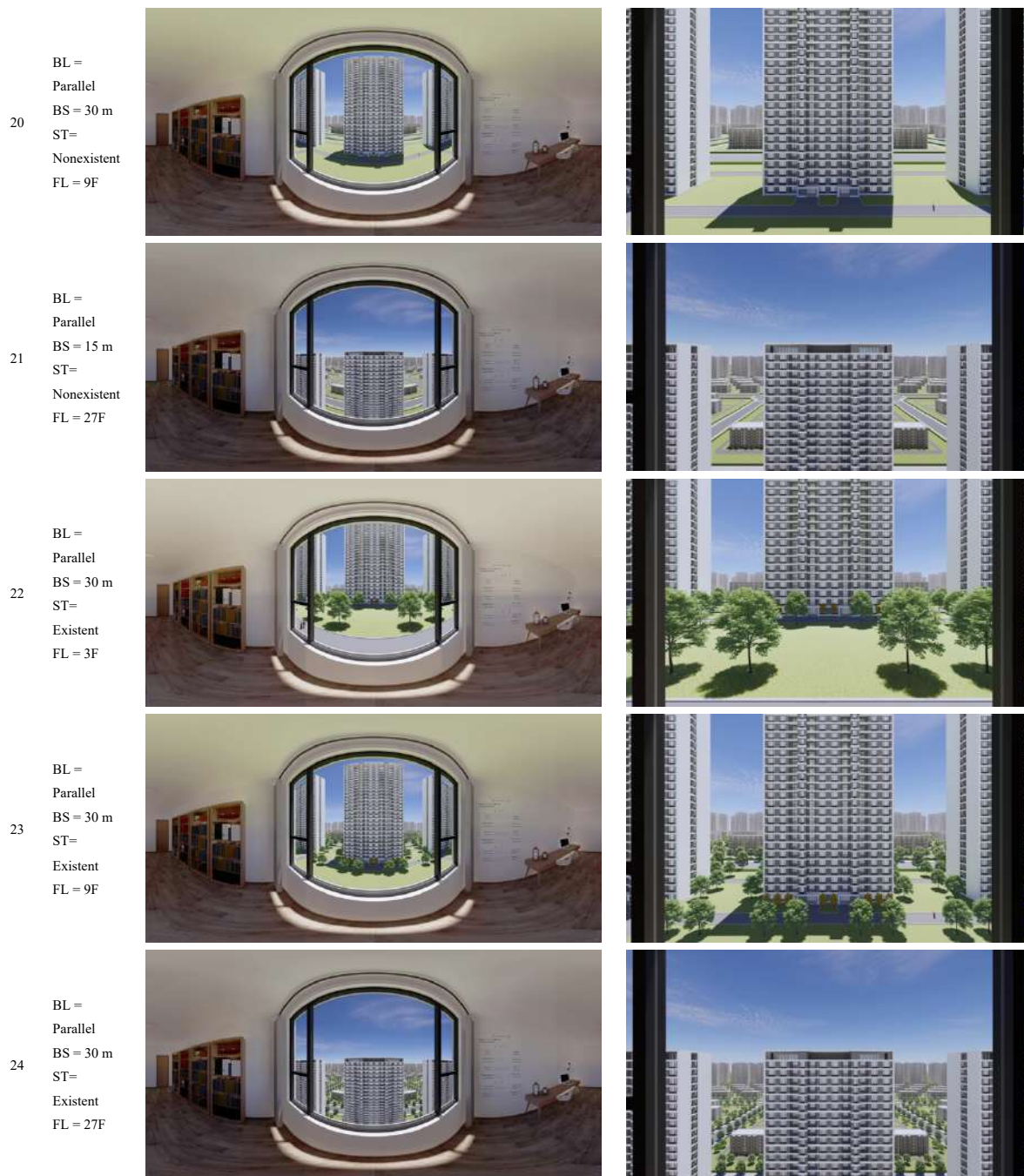


Figure 5.2: Experimental Images of Experiment 2.

Source: F. Wang & Munakata (2024b).

5.1.4. Procedures

Experiments 2 was conducted in the experimental room of the Faculty of Engineering at Chiba University, Japan. Participants were seated in a freely rotatable chair, which facilitated easy and safe viewing of the scenes while wearing virtual reality (VR) headsets. Before

starting the experiment, participants fine-tuned their virtual reality headsets to guarantee a comfortable and unobstructed view of both outdoor and indoor virtual environments.

Participants wearing virtual reality headsets in the experiment completed the questionnaire verbally while concentrating on the virtual window views. The questionnaire was displayed on the wall within the VR environment to ensure participants answered questions while wearing the headset. The experimenter recorded their verbal responses on an answer sheet. Following the completion of one scene's questions, participants took off their VR headsets, took a minute to relax, and resumed the experiment. Participants took off the VR headsets after completing all experimental scenes and wrote out their demographic information on an additional questionnaire.

Experiment 2 was conducted from May 22 to June 22, 2023, using Meta Quest 2 VR headsets (Figure 5.3). There were no time limits for each questionnaire within the experiment, so subjects could observe the scenes and respond to the questions in a virtual environment freely (Figure 5.4, Figure 5.5).



Figure 5.3: Participant Using VR Headsets (Meta Quest 2) for Experiment 2.

Source: F. Wang & Munakata (2024b).

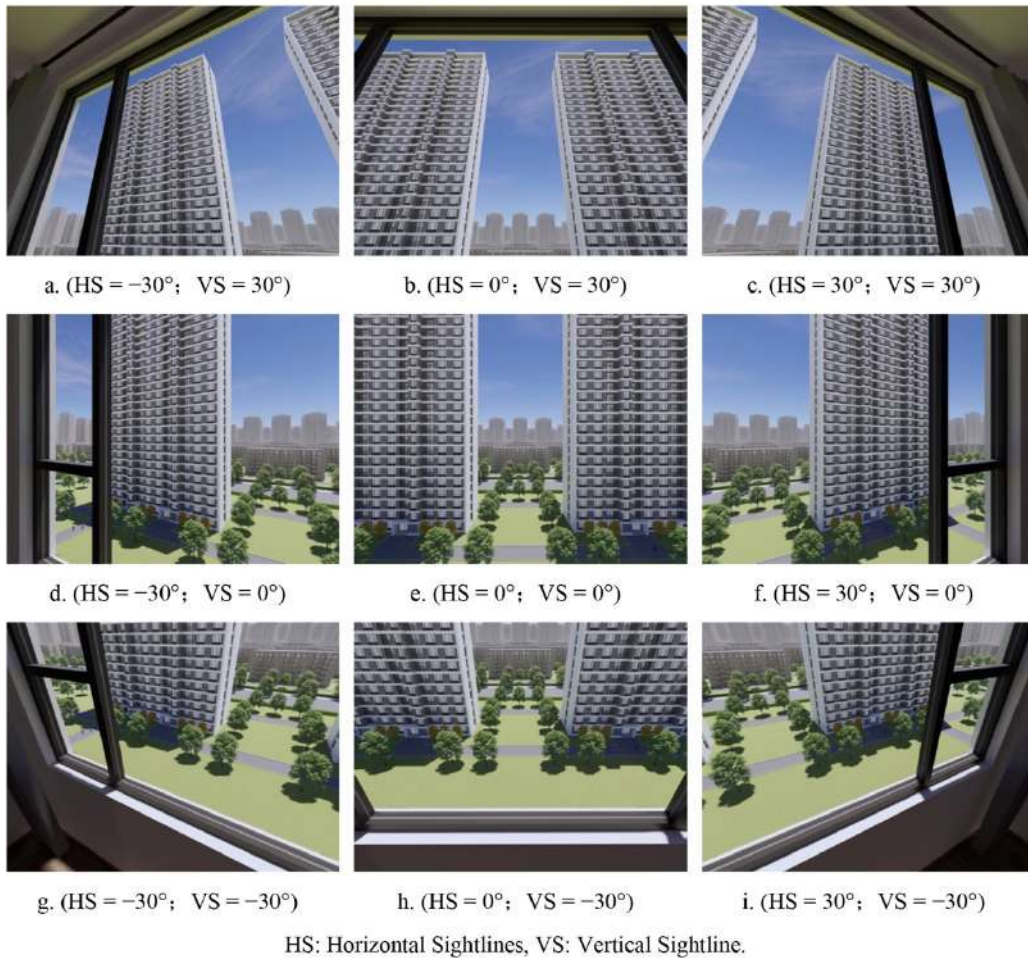


Figure 5.4: Scenes of Experiment 2 (BL = Staggered, BS = 30 m, ST = Existent, FL = 9F).

Source: F. Wang & Munakata (2024b).

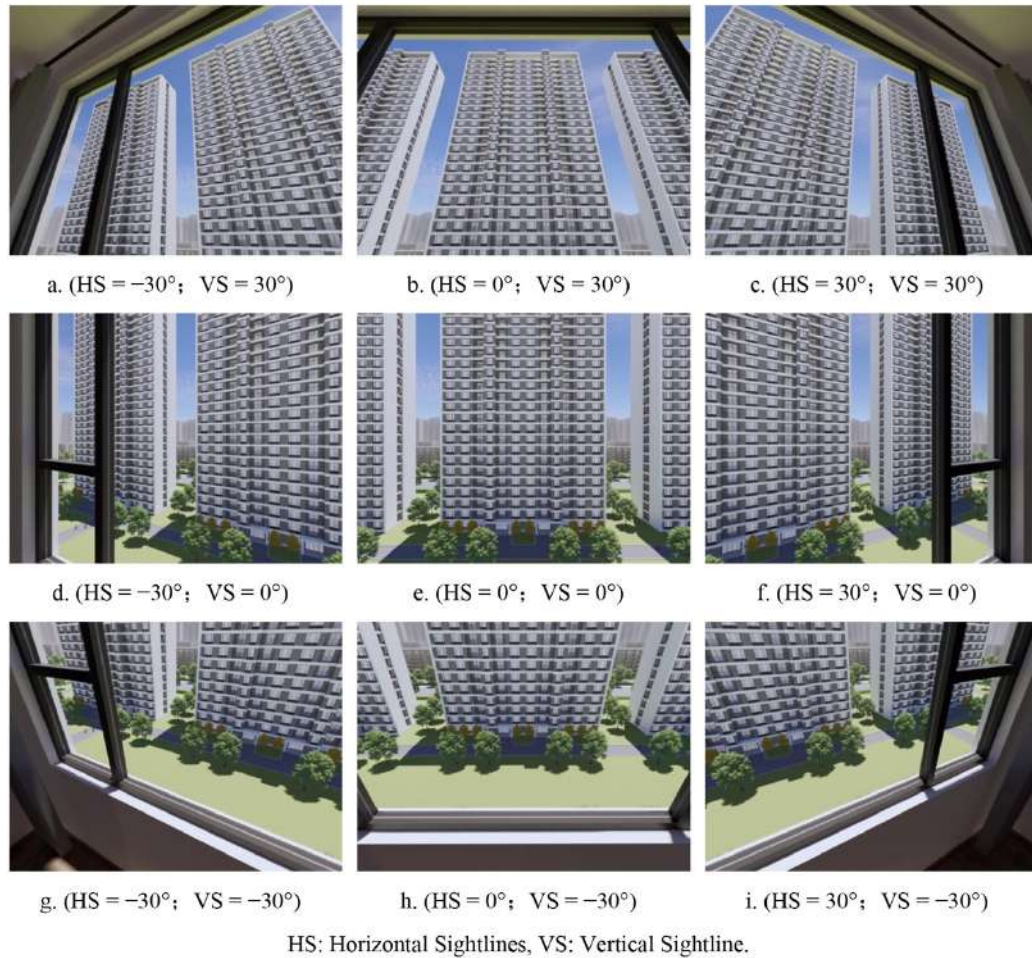


Figure 5.5: Scenes of Experiment 2 (BL = Parallel, BS = 15 m, ST = Existent, FL = 9F).

Source: F. Wang & Munakata (2024b).

5.1.5. Extracting Visual Elements from Window Views and Calculating Ratios

The main visual elements of window views were extracted in Experiment 2. In Experiment 2, the extracted visual elements included Sky Ratio (SR), Grass Ratio (GaR), Tree Ratio (TR), Foreground Building Ratio (F-BR), and Background Building Ratio (B-BR) (Figure 5.6). The extracting steps were as follows.

Step 1: Extracting Visual Elements Using Deep Learning Model

A deep learning model using Panoptic Segmentation (PS) classified panoramic images based on color distinctions. The PS was implemented through a Python script with the DeepLab2

library from TensorFlow. It was an approach to help identify and extract respective visual elements from the panoramic images.

Step 2: Classifying Foreground and Background Buildings

Visual elements of buildings in Experiment 2 were divided into two categories: foreground and background buildings. Foreground buildings were defined as those within 50 m from the observer ($D \leq 50$ m), while background buildings were those located beyond 50 m from the observer ($D > 50$ m).

Step 3: Transforming Panoramic Images to Fisheye Projections

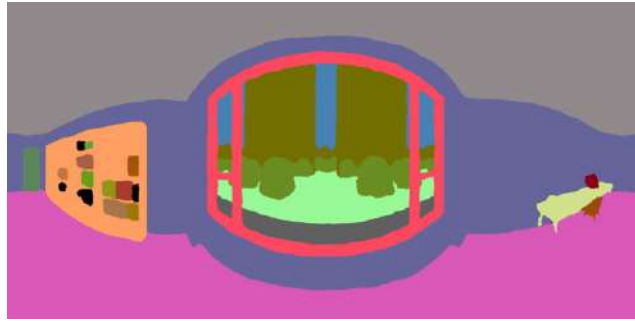
Panoramic images were converted into fisheye projections to achieve precise quantitative analysis. This conversion entailed shifting from the equirectangular projection format to the orthographic projection characteristic of the fisheye image. The transformation was performed using G.Projector software developed by NASA.

Step 4: Calculating the Ratio of Visual Elements

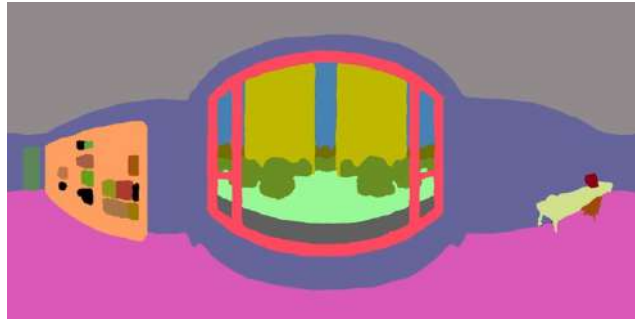
The fisheye images were used to calculate the ratio of visual elements within the window views using a Python script.



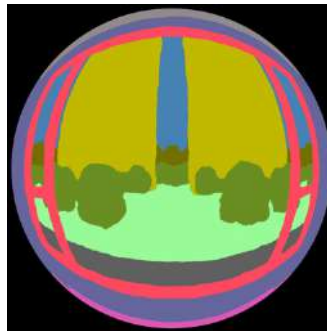
Step 1: Classifying Visual Elements Using Deep Learning Model



Step 2: Classifying Foreground and Background Buildings



Step 3: Transforming Panoramic Images to Fisheye Projections



Step 4: Calculating the Ratio of Visual Elements

Figure 5.6: Calculation Procedure for Visual Elements in Experiment 2.

Source: F. Wang & Munakata (2024b).

In Experiment 2, the results for SR, GaR, TR, F-BR, and B-BR were presented in Table 5.3.

The distribution of ratios for visual elements was as follows: SR (15.496 ± 11.973), GaR (8.458 ± 5.793), TR (2.825 ± 4.218), F-BR (31.338 ± 6.722), and B-BR (2.858 ± 1.440).

Table 5.3: Ratios of Visual Elements in Window Views for Experiment 2 (N = 24).

| | N | Minimum (%) | Maximum (%) | Mean (%) | Std. Deviation (%) |
|-----|----|-------------|-------------|----------|--------------------|
| SR | 24 | 3.200 | 32.200 | 15.496 | 11.973 |
| GaR | 24 | 0.700 | 17.400 | 8.458 | 5.793 |
| TR | 24 | 0.000 | 11.800 | 2.825 | 4.218 |

| | | | | | |
|------|----|--------|--------|--------|-------|
| F-BR | 24 | 22.300 | 45.900 | 31.338 | 6.722 |
| B-BR | 24 | 1.000 | 6.600 | 2.858 | 1.440 |

Source: F. Wang & Munakata (2024b).

5.1.6. Statistical Analysis Process of Experiment 2

The statistical analysis process of Experiment 2 included six aspects (Figure 5.7):

1. Analysis of variance (ANOVA) was conducted to investigate the main and interaction effects of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) on Perceived Oppressiveness (PO).
2. Ordinal logistic regression was used to determine how Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) predicted the likelihood of Perceived Oppressiveness (PO).
3. Multiple nonlinear regression was conducted to explore how Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) predicted Perceived Oppressiveness (PO).
4. Stepwise multiple linear regression analysis was conducted to explore the influence of various visual elements—Sky Ratio (SR), Grass Ratio (GaR), Tree Ratio (TR), Foreground Building Ratio (F-BR), and Background Building Ratio (B-BR)—on Perceived Oppressiveness (PO).
5. Multiple linear regression analysis was performed to evaluate the impact of planning measures—Building Layout (BL), Building Spacing (BS), and Surrounding Trees (ST)—and Floor Level (FL) on the visual elements.
6. Bivariate correlation analysis was used to investigate the relationship between Perceived Oppressiveness (PO) and Environmental Preference (EP).

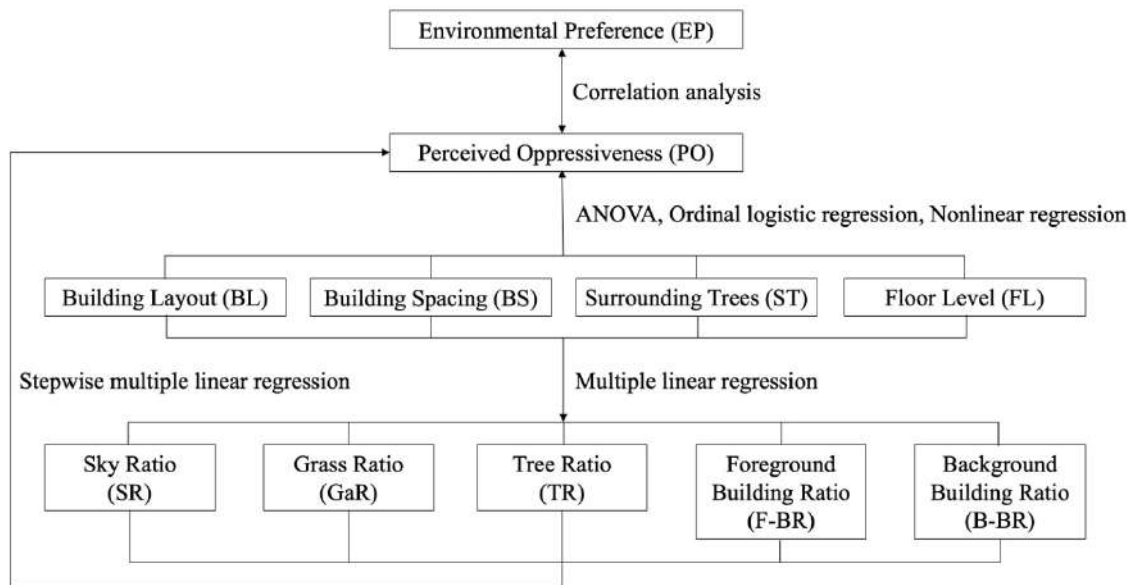


Figure 5.7: Main Analysis Processes in Experiment 2.

Source: F. Wang & Munakata (2024b).

5.2. Results

5.2.1. Effects of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) on Perceived Oppressiveness (PO)

5.2.1.1. ANOVA of Main and Interaction Effects on PO

The ANOVA results in Table 5.4 indicated significant main and interaction effects on Perceived Oppressiveness (PO) across the factors of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL). The main effect of BL on PO was significant ($F(1, 1176) = 290.349, p < 0.001, \eta^2_p = 0.198$). BS significantly influenced PO ($F(1, 1176) = 135.683, p < 0.001, \eta^2_p = 0.103$). ST significantly influenced PO ($F(1, 1176) = 91.602, p < 0.001, \eta^2_p = 0.072$). Additionally, FL showed a significant effect on PO ($F(2, 1176) = 201.472, p < 0.001, \eta^2_p = 0.255$).

The interaction effects further revealed relationships among the factors. Specifically, the interaction between BL and BS was significant ($F(1, 1176) = 20.933, p < .001, \eta^2_p = 0.017$). However, the interactions between BL and ST, BL and FL, BS and ST, as well as BS and FL,

were not significant. In contrast, the interaction between ST and FL was significant ($F(2, 1176) = 10.494, p < .001, \eta^2p = 0.018$). Additionally, higher-order interactions were examined, including the three-way interactions—BL, BS, and ST; BL, BS, and FL; BL, ST, and FL; and BS, ST, and FL—all of which were not significant. Similarly, the four-way interaction among BL, BS, ST, and FL was not significant.

Table 5.4: ANOVA Results for Main Effects and Interaction Effects on Perceived

Oppressiveness (PO) (N = 1200).

Dependent variable(s): PO

Between-subjects factor(s): BL, BS, ST, FL

| | MS | MSE | df1 | df2 | F | p | η^2p [90% CI of η^2p] | η^2G |
|-------------------|---------|-------|-----|------|---------|---------|----------------------------------|-----------|
| BL | 395.601 | 1.363 | 1 | 1176 | 290.349 | < 0.001 | *** 0.198 [.166, .231] | 0.198 |
| BS | 184.867 | 1.363 | 1 | 1176 | 135.683 | < 0.001 | *** 0.103 [.078, .131] | 0.103 |
| ST | 124.807 | 1.363 | 1 | 1176 | 91.602 | < 0.001 | *** 0.072 [.050, .097] | 0.072 |
| FL | 274.506 | 1.363 | 2 | 1176 | 201.472 | < 0.001 | *** 0.255 [.221, .288] | 0.255 |
| BL * BS | 28.521 | 1.363 | 1 | 1176 | 20.933 | < 0.001 | *** 0.017 [.007, .032] | 0.017 |
| BL * ST | 1.267 | 1.363 | 1 | 1176 | 0.93 | 0.335 | 0.001 [.000, .006] | 0.001 |
| BL * FL | 1.881 | 1.363 | 2 | 1176 | 1.38 | 0.252 | 0.002 [.000, .008] | 0.002 |
| BS * ST | 0.141 | 1.363 | 1 | 1176 | 0.103 | 0.748 | 0.000 [.000, .003] | 0.000 |
| BS * FL | 0.683 | 1.363 | 2 | 1176 | 0.501 | 0.606 | 0.001 [.000, .004] | 0.001 |
| ST * FL | 14.297 | 1.363 | 2 | 1176 | 10.494 | < 0.001 | *** 0.018 [.007, .031] | 0.018 |
| BL * BS * ST | 0.001 | 1.363 | 1 | 1176 | 0.001 | 0.98 | 0.000 [.000, .000] | 0.000 |
| BL * BS * FL | 0.021 | 1.363 | 2 | 1176 | 0.015 | 0.985 | 0.000 [.000, .000] | 0.000 |
| BL * ST * FL | 0.543 | 1.363 | 2 | 1176 | 0.398 | 0.672 | 0.001 [.000, .004] | 0.001 |
| BS * ST * FL | 0.601 | 1.363 | 2 | 1176 | 0.441 | 0.644 | 0.001 [.000, .002] | 0.001 |
| BL * BS * ST * FL | 0.016 | 1.363 | 2 | 1176 | 0.012 | 0.988 | 0.000 [.000, .000] | 0.000 |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024b).

5.2.1.2. Pairwise Comparisons of Main Effects on PO

The post hoc test (Tukey HSD) for pairwise comparisons of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) on Perceived Oppressiveness (PO) revealed the following findings (Table 5.5, Figure 5.8).

Comparisons between BL revealed that the Staggered had significantly lower PO compared to the Parallel (Estimate = -1.148 , $p < 0.001$, Cohen's $d = -0.984$). Comparisons between BS revealed that the 30 m resulted in significantly lower PO compared to the 15 m (Estimate = -0.785 , $p < 0.001$, Cohen's $d = -0.673$). Comparisons between ST revealed that the Existent resulted in significantly lower PO compared to the Nonexistent (Estimate = -0.645 , $p < 0.001$, Cohen's $d = -0.553$). Comparisons between FL revealed that the 9F resulted in significantly higher PO compared to 3F (Estimate = 0.248 , $p = 0.008$, Cohen's $d = 0.212$). The 30F resulted in significantly lower PO compared to the 3F (Estimate = -1.295 , $p < 0.001$, Cohen's $d = -1.109$) and the 9F (Estimate = -1.542 , $p < 0.001$, Cohen's $d = -1.321$).

Table 5.5: Pairwise Comparisons of Main Effects of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) on Perceived Oppressiveness (PO) (N = 1200).

| | Contrast | Estimate | S.E. | df | t | p | Cohen's d [95% CI of d] |
|----|------------------------|----------|-------|------|---------|---------|-----------------------------|
| BL | Staggered - Parallel | -1.148 | 0.067 | 1176 | 17.040 | < 0.001 | *** -0.984 [-1.097, -0.871] |
| BS | 30 m -15 m | -0.785 | 0.067 | 1176 | -11.648 | < 0.001 | *** -0.673 [-0.786, -0.559] |
| ST | Existent - Nonexistent | -0.645 | 0.067 | 1176 | -9.571 | < 0.001 | *** -0.553 [-0.666, -0.439] |
| FL | 9F - 3F | 0.248 | 0.083 | 1176 | 2.999 | 0.008 | ** 0.212 [0.046, 0.378] |
| | 30F - 3F | -1.295 | 0.083 | 1176 | -15.69 | < 0.001 | *** -1.109 [-1.275, -0.943] |
| | 30F - 9F | -1.542 | 0.083 | 1176 | -18.688 | < 0.001 | *** -1.321 [-1.487, -1.156] |

Pooled SD for computing Cohen's d: 1.167

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024b).

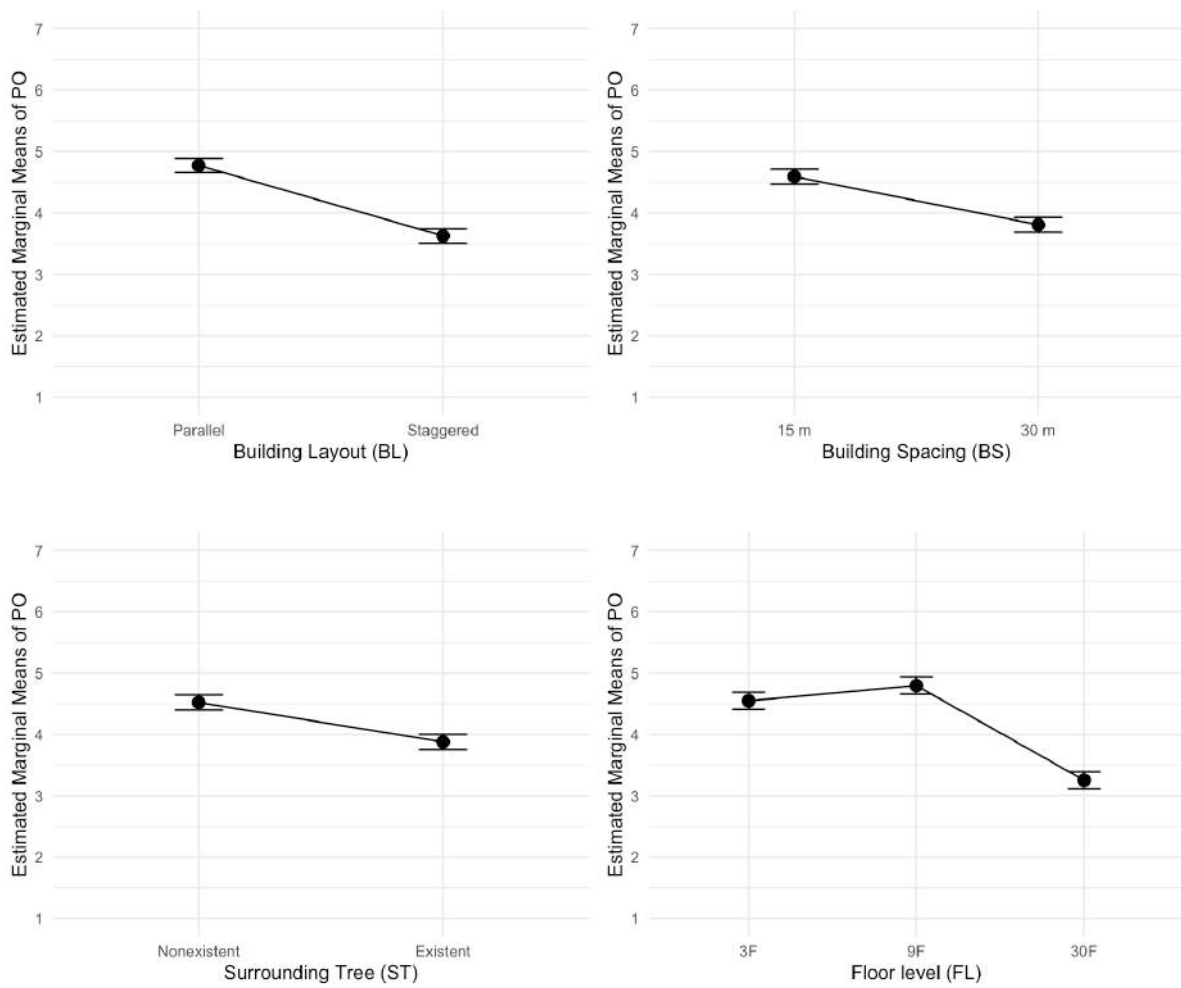


Figure 5.8: Main Effects of BL, BS, ST, and FL on Perceived Oppressiveness (PO).

Source: F. Wang & Munakata (2024b).

The bar chart depicted pairwise comparisons of Estimates and Cohen's d for the main effects of BL, BS, ST, and FL on PO (Figure 5.9).

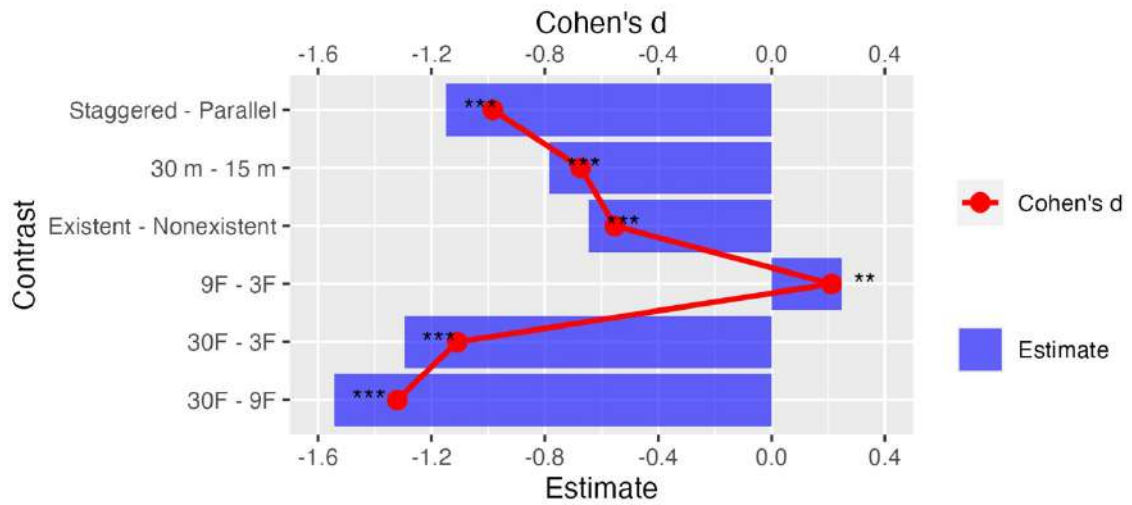


Figure 5.9: Bar Chart of Pairwise Comparisons: Estimates and Cohen's d for BL, BS, ST, and FL on Perceived Oppressiveness (PO).

Source: Created by the Author.

5.2.1.3. Pairwise Comparisons of Interaction Effects between BL and BS on PO

The post hoc test (Tukey HSD) for pairwise comparisons indicated significant interaction effects between Building Layout (BL) and Building Spacing (BS) on Perceived Oppressiveness (PO) (Table 5.6, Figure 5.10).

For BS at 30 meters compared to 15 meters, significant differences were observed when BL was Staggered (Estimate = -1.093 , $p < 0.001$, Cohen's $d = -0.937$) and Parallel (Estimate = -0.477 , $p < 0.001$, Cohen's $d = -0.408$). For BL at Staggered compared to Parallel, significant differences were observed when BS was 30 meters (Estimate = -1.457 , $p < 0.001$, Cohen's $d = -1.248$) and 15 meters (Estimate = -0.840 , $p < 0.001$, Cohen's $d = -0.720$).

Table 5.6: Pairwise Comparison of Interaction Effects Between Building Layout (BL) and Building Spacing (BS) on Perceived Oppressiveness (PO) (N = 1200).

Dependent Variable: PO

| Contrast | Estimate | S.E. | df | t | p | Cohen's d [95% CI of d] |
|----------------|----------|-------|------|---------|---------|-----------------------------|
| BS 30 m - 15 m | -1.093 | 0.095 | 1176 | -11.472 | < 0.001 | *** -0.937 [-1.097, -0.776] |

| | | | | | | | | | |
|----|----------------------|----------|--------|-------|------|---------|---------|-----|-------------------------|
| | 30 m - 15 m | Parallel | -0.477 | 0.095 | 1176 | -5.001 | < 0.001 | *** | -0.408 [-0.569, -0.248] |
| BL | Staggered - Parallel | BS 30 m | -1.457 | 0.095 | 1176 | -15.284 | < 0.001 | *** | -1.248 [-1.408, -1.088] |
| | Staggered - Parallel | 15 m | -0.840 | 0.095 | 1176 | -8.814 | < 0.001 | *** | -0.720 [-0.880, -0.559] |

Pooled SD for computing Cohen's d: 1.167

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024b).

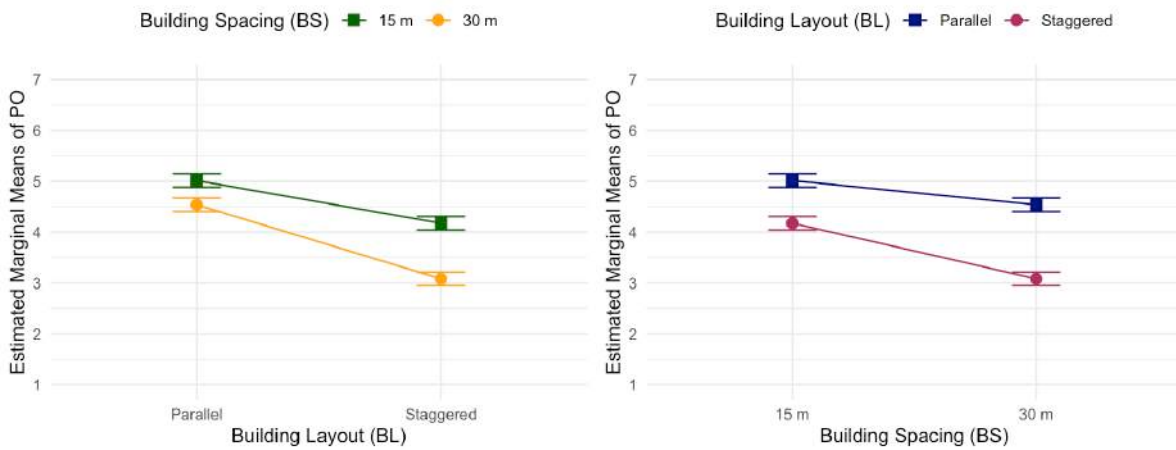


Figure 5.10: Interaction Effect of BL and BS on Perceived Oppressiveness (PO).

Source: F. Wang & Munakata (2024b).

The bar chart presented pairwise comparisons of Estimates and Cohen's d for interaction effects between BL and BS on PO (Figure 5.11).

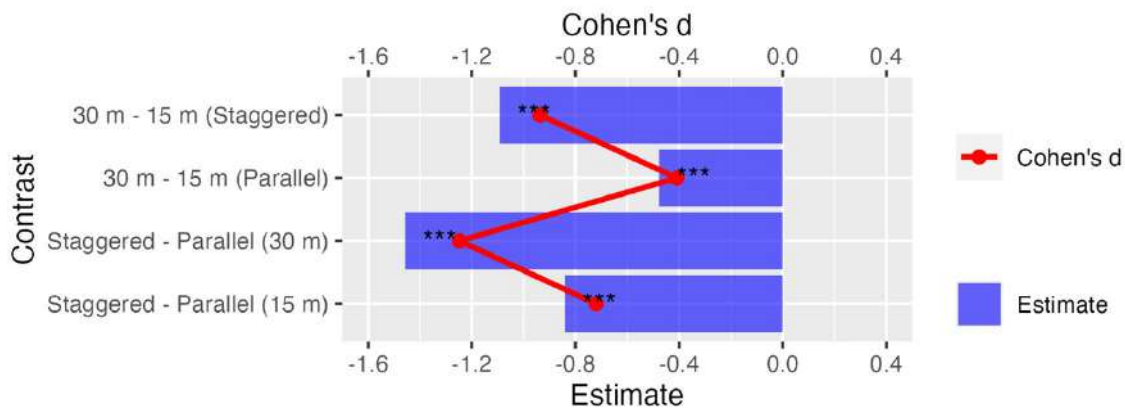


Figure 5.11: Bar Chart of Estimates and Cohen's d for Interaction Effects of Building Layout (BL) and Building Spacing (BS) on Perceived Oppressiveness (PO).

Source: Created by the Author.

5.2.1.4. Pairwise Comparisons of Interaction Effects between ST and FL on PO

The post hoc test (Tukey HSD) for pairwise comparisons indicated a significant interaction effect between FL and ST on PO (Table 5.7, Figure 5.12). For ST at Nonexistent, significant differences were observed between 30F and 3F (Estimate = -1.665, $p < 0.001$, Cohen's $d = -1.426$), and between 30F and 9F (Estimate = -1.660, $p < 0.001$, Cohen's $d = -1.422$). However, the comparison between 9F and 3F was not significant (Estimate = -0.005, $p = 0.999$, Cohen's $d = -0.004$). For ST at Existent, significant differences were observed between 9F and 3F (Estimate = 0.500, $p < 0.001$, Cohen's $d = 0.428$), between 30F and 3F (Estimate = -0.925, $p < 0.001$, Cohen's $d = -0.792$), and between 30F and 9F (Estimate = -1.425, $p < 0.001$, Cohen's $d = -1.221$).

For FL at 3F, a significant difference was observed between Existent and Nonexistent (Estimate = -1.060, $p < 0.001$, Cohen's $d = -0.908$). For FL at 9F, a significant difference was observed between Existent and Nonexistent (Estimate = -0.555, $p < 0.001$, Cohen's $d = -0.475$). For FL at 30F, a significant difference was observed between Existent and Nonexistent (Estimate = -0.320, $p = 0.006$, Cohen's $d = -0.274$).

Table 7

Table 5.7: Pairwise Comparison of Interaction Effects Between Floor Level (FL) and Surrounding Trees (ST) on Perceived Oppressiveness (PO) (N = 1200).

| Contrast | | | Estimate | S.E. | df | t | p | Cohen's d [95% CI of d] |
|----------|----------|----------------|----------|-------|------|---------|---------|-----------------------------|
| FL | 9F - 3F | ST Nonexistent | -0.005 | 0.117 | 1176 | -0.043 | 0.999 | -0.004 [-0.239, 0.230] |
| | 30F - 3F | Nonexistent | -1.665 | 0.117 | 1176 | -14.264 | < 0.001 | *** -1.426 [-1.661, -1.192] |
| | 30F - 9F | Nonexistent | -1.660 | 0.117 | 1176 | -14.221 | < 0.001 | *** -1.422 [-1.657, -1.187] |
| | 9F - 3F | Existent | 0.500 | 0.117 | 1176 | 4.284 | < 0.001 | *** 0.428 [0.194, 0.663] |
| | 30F - 3F | Existent | -0.925 | 0.117 | 1176 | -7.925 | < 0.001 | *** -0.792 [-1.027, -0.558] |
| | 30F - 9F | Existent | -1.425 | 0.117 | 1176 | -12.208 | < 0.001 | *** -1.221 [-1.455, -0.986] |

| | | | | | | | | | | |
|----|------------------------|----|-----|--------|-------|------|--------|---------|-----|-------------------------|
| ST | Existent - Nonexistent | FL | 3F | -1.060 | 0.117 | 1176 | -9.081 | < 0.001 | *** | -0.908 [-1.104, -0.712] |
| | Existent - Nonexistent | | 9F | -0.555 | 0.117 | 1176 | -4.755 | < 0.001 | *** | -0.475 [-0.672, -0.279] |
| | Existent - Nonexistent | | 30F | -0.320 | 0.117 | 1176 | -2.741 | 0.006 | ** | -0.274 [-0.470, -0.078] |

Pooled SD for computing Cohen's d: 1.167

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024b).

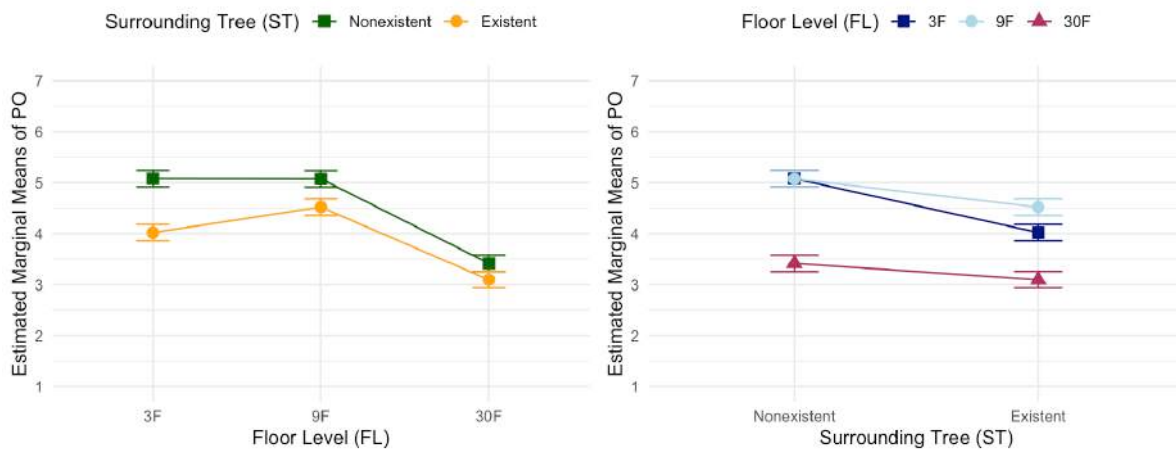


Figure 5.12: Interaction Effect of ST and FL on Perceived Oppressiveness (PO).

Source: F. Wang & Munakata (2024b).

The bar chart presented pairwise comparisons of Estimates and Cohen's d for interaction effects between FL and ST on PO (Figure 5.13).

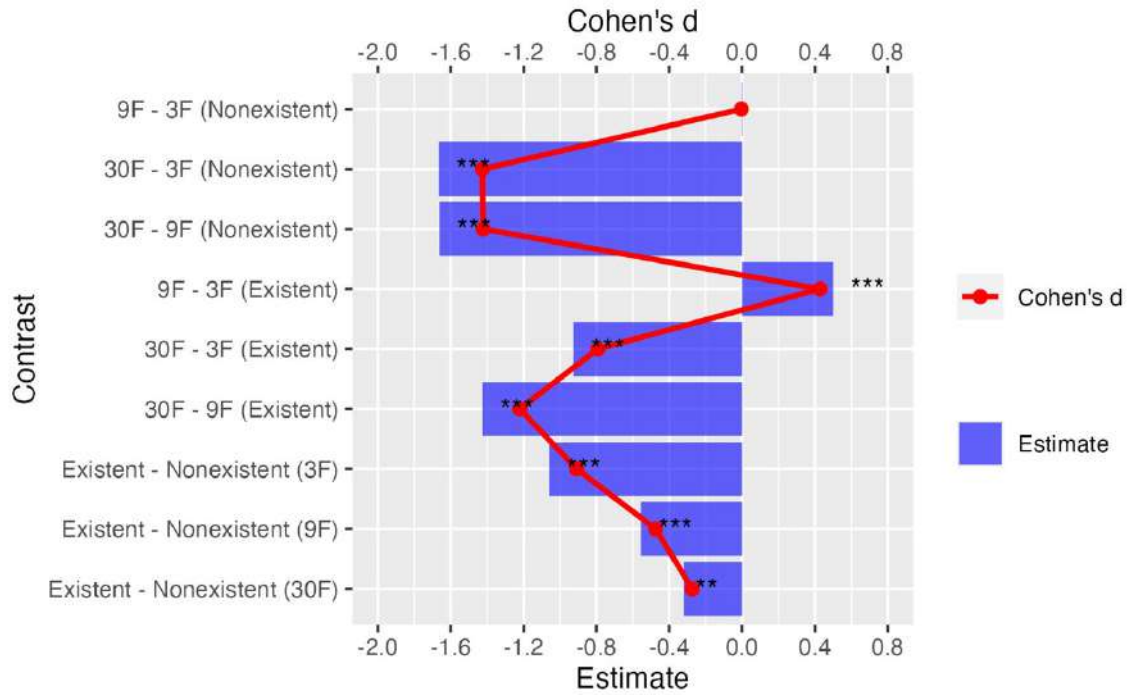


Figure 5.13: Bar Chart of Estimates and Cohen's d for Interaction Effects of Surrounding Trees (ST) and Floor Level (FL) on Perceived Oppressiveness (PO).

Source: Created by the Author.

5.2.2. Ordinal Logistic Regression Model for PO

The dependent variable, Perceived Oppressiveness (PO), was grouped into three categories: low, medium, and high (Table 5.8). This adjustment improved the model's interpretability and statistical power. The ordinal logistic regression model was expressed as follows:

$$\text{logit}(Y) = \sum b_i x_i + \varepsilon$$

In this equation, x_i represented the independent variables, b_i represented the coefficients of the independent variables, and ε was a logistically distributed error term.

Table 5.8: Ordinal Classification of Perceived Oppressiveness (PO).

| Dependent Variables | Ordinal Groups | | |
|-------------------------------|----------------|------------|----------|
| | 1 (Low) | 2 (Medium) | 3 (High) |
| Perceived oppressiveness (PO) | PO < 4 | 4 ≤ PO ≤ 5 | PO > 5 |

Source: F. Wang & Munakata (2024b).

In the ordinal logistic regression model, Perceived Oppressiveness (PO) was the dependent variable, while Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) were the independent variables. Before conducting the ordinal logistic regression analysis, a test for parallelism was administered to validate the proportional odds assumption. The non-significant result of the parallel lines test ($p = 0.225$) confirmed the assumption of parallelism. Consequently, the model was formulated as follows:

$$\text{logit}(Y_{PO}) = \alpha + b_{BL}BL + b_{BS}BS + b_{ST}ST + b_{FL}FL + \varepsilon$$

In the model, BL and ST were treated as nominal variables. BL was divided into Parallel and Staggered, while ST was divided into Nonexistent and Existent. BS and FL were considered interval variables.

The ordinal logistic regression analysis results provided a comprehensive understanding of the influence of various independent variables on the PO, along with their statistical significance (Table 5.9). The intercepts were highly significant, with intercept 1 having a regression coefficient of -5.060 ($SE = 0.269$, $t = -18.800$, $OR = 0.006$, $p < 0.001$) and intercept 2 having a regression coefficient of -2.410 ($SE = 0.229$, $t = -10.529$, $OR = 0.090$, $p < 0.001$).

For the BL, the Staggered compared to the reference Parallel showed a significant negative effect with a regression coefficient of -1.708 ($SE = 0.126$, $t = -13.527$, $OR = 0.181$, $p < 0.001$). The variable BS also had a significant negative impact, with a regression coefficient of -0.077 ($SE = 0.008$, $t = -9.511$, $OR = 0.926$, $p < 0.001$).

Regarding the ST, the Existent compared to the reference Nonexistent exhibited a significant negative effect with a regression coefficient of -0.976 ($SE = 0.120$, $t = -8.122$, $OR = 0.377$, $p < 0.001$). Lastly, the variable FL showed a significant negative impact with a regression coefficient of -0.080 ($SE = 0.006$, $t = -14.263$, $OR = 0.923$, $p < 0.001$).

Table 5.9: Parameter Estimates for Variables in the Ordinal Logistic Regression Model (N = 1200).

| | Co-variable | Regression coefficient | Std. Error | t-value | Odds ratio (OR) | p-value | |
|----|-------------|------------------------|------------|---------|-----------------|---------|-----|
| | Intercept 1 | -5.060 | 0.269 | -18.800 | 0.006 | < 0.001 | *** |
| | Intercept 2 | -2.410 | 0.229 | -10.529 | 0.090 | < 0.001 | *** |
| BL | Parallel | Ref | | | | | |
| | Staggered | -1.708 | 0.126 | -13.527 | 0.181 | < 0.001 | *** |
| BS | | -0.077 | 0.008 | -9.511 | 0.926 | < 0.001 | *** |
| ST | Nonexistent | Ref | | | | | |
| | Existent | -0.976 | 0.120 | -8.122 | 0.377 | < 0.001 | *** |
| FL | | -0.080 | 0.006 | -14.263 | 0.923 | < 0.001 | *** |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024b).

The OR value illustrated the effects of these independent variables on the likelihood of experiencing higher perceived oppressiveness (Figure 5.14). For Building Layout (BL), the "Parallel" layout was the reference category with an OR of 1. In contrast, the "Staggered" layout exhibited an OR of 0.181, indicating that the Staggered layout significantly reduced the odds of higher PO compared to the Parallel layout. An OR less than 1 signified a positive effect, suggesting that staggered layouts were associated with lower PO. Building Spacing (BS) had an OR of 0.926, implying that each unit increase in building spacing resulted in a 7.4% decrease in the odds of higher PO (calculated as $1 - 0.926 = 0.074$). This indicated that greater spacing between buildings reduced the likelihood of higher PO.

Regarding Surrounding Trees (ST), the "Nonexistent" category was the reference with an OR of 1, while the "Existent" category had an OR of 0.377. This substantial reduction suggested that the presence of surrounding trees significantly lowered the odds of experiencing higher PO. Floor Level (FL) had an OR of 0.923, indicating that each unit increase in floor level led to a 7.7% decrease in the odds of higher PO (calculated as $1 - 0.923 = 0.077$). Higher floor levels were thus associated with lower PO.

The OR values for all independent variables were less than 1, demonstrating that staggered building layouts, increased building spacing, the presence of surrounding trees, and higher floor levels were all associated with lower odds of higher perceived oppressiveness.

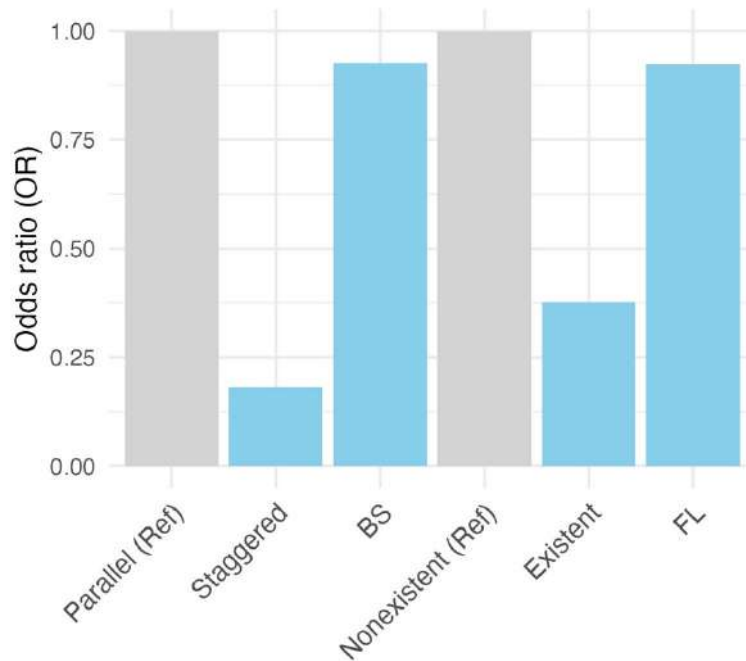


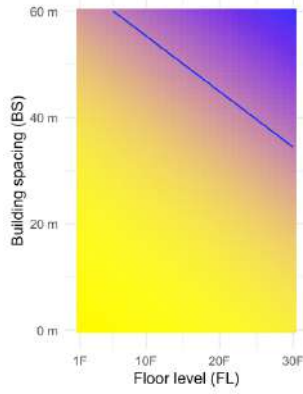
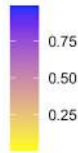
Figure 5.14: Bar Chart of Odds Ratios (OR) from Ordinal Logistic Regression.

Source: Created by the Author.

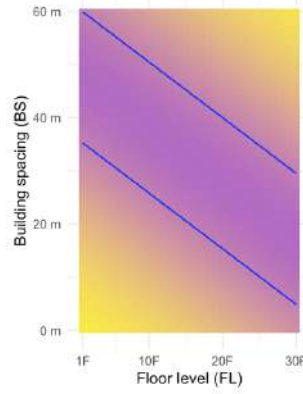
The predicted probability charts of Perceived Oppressiveness (PO) illustrated the impact of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Levels (FL) (Figure 5.15). Each graph represented the probability distributions of low, medium, and high PO across specific conditions. Staggered BL, increased BS, existing ST, and higher FL were considered practical measures to decrease PO.

Building layout (BL) =
Parallel
Surrounding trees (ST) =
Nonexistent

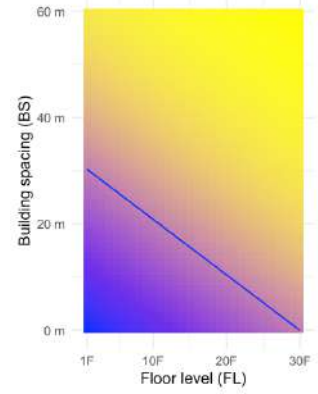
Probability of Perceived
oppressiveness (PO)



Probability Map for PO (Low)



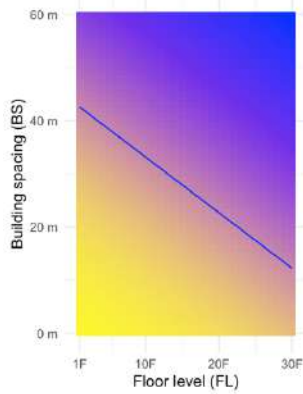
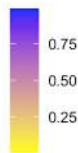
Probability Map for PO (Medium)



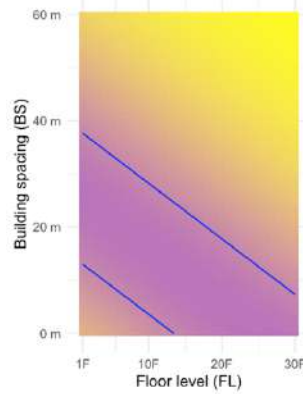
Probability Map for PO (High)

Building layout (BL) =
Staggered
Surrounding trees (ST) =
Nonexistent

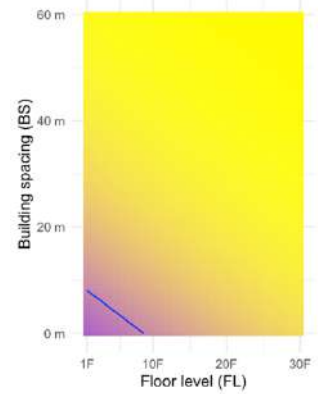
Probability of Perceived
oppressiveness (PO)



Probability Map for PO (Low)



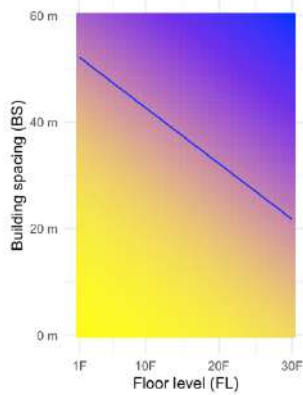
Probability Map for PO (Medium)



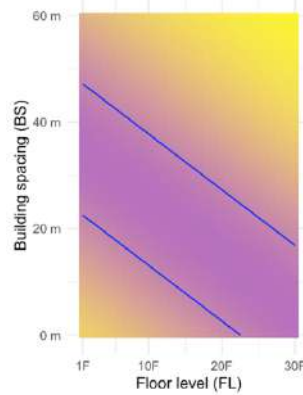
Probability Map for PO (High)

Building layout (BL) =
Parallel
Surrounding trees (ST) =
Existent

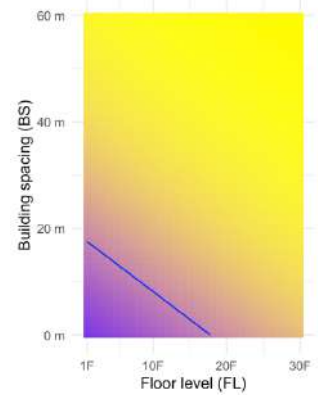
Probability of Perceived
oppressiveness (PO)



Probability Map for PO (Low)



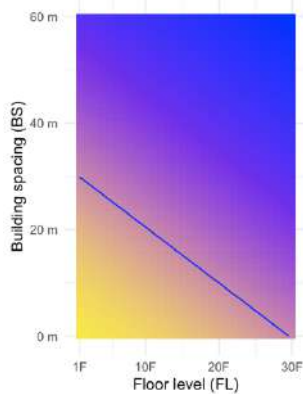
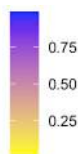
Probability Map for PO (Medium)



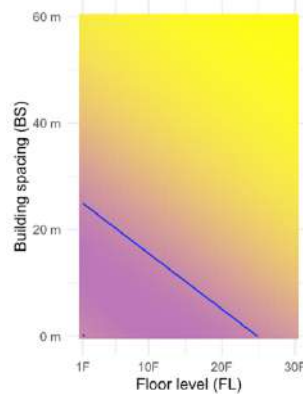
Probability Map for PO (High)

Building layout (BL) =
Staggered
Surrounding trees (ST) =
Existent

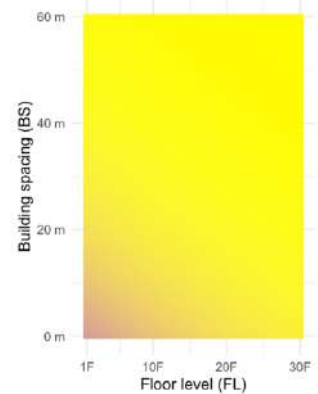
Probability of Perceived
oppressiveness (PO)



Probability Map for PO (Low)



Probability Map for PO (Medium)



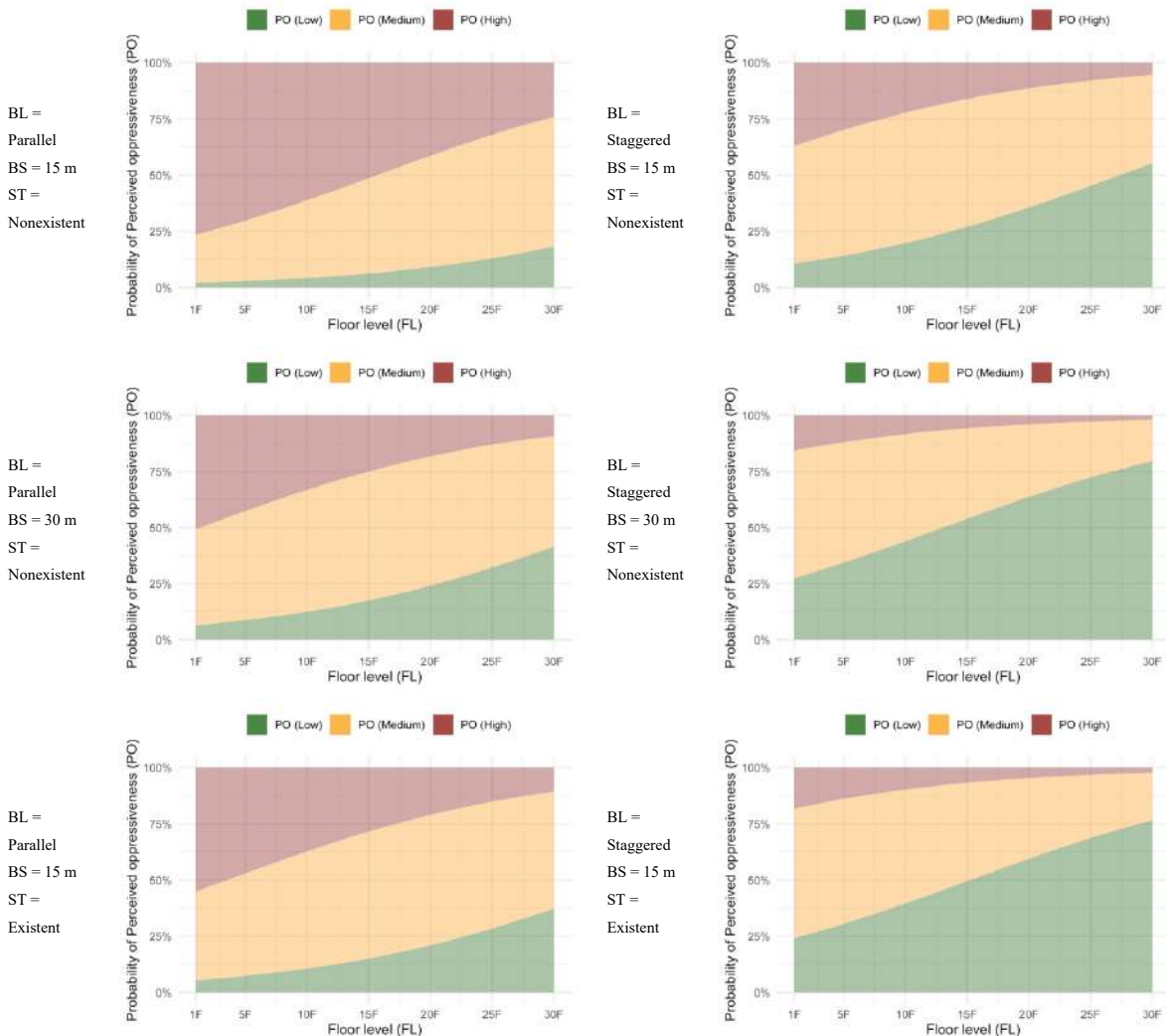
Probability Map for PO (High)

*Blue line represents a probability contour of 0.5.

Figure 5.15: Predicted Probabilities of Perceived Oppressiveness (PO) Across Different Planning Measures and Viewing Floor Levels.

Source: F. Wang & Munakata (2024b).

Furthermore, this study examined the probability of perceived oppressiveness (PO) at various Floor Levels (FL) based on specific combinations of Building Layouts (BL) (Parallel and Staggered), Building Spacings (BS) (15m and 30m), and Surrounding Trees (ST) (Nonexistent and Existent). These variables resulted in eight different scenarios, illustrated in Figure 5.16. Each graph represented the probability distributions of low, medium, and high PO across different floor levels under specific combinations. Staggered BL, increased BS, existent ST, and higher FL were effective measures to reduce PO.



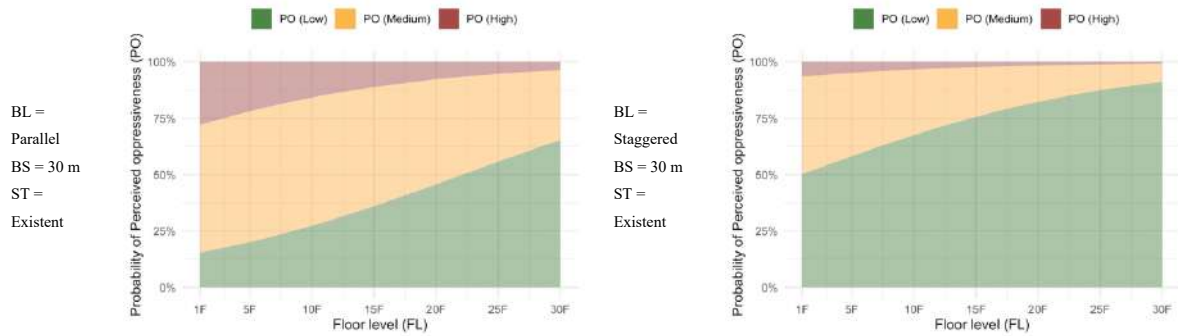


Figure 5.16: Predicted Probability of Perceived Oppressiveness (PO) Based on Specific Combinations of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL).

Source: Created by the Author.

5.2.3. Planning Measures and Observed Factors as Predictors of PO

In the nonlinear regression analysis, Perceived Oppressiveness (PO) was treated as the dependent variable. The independent variables included Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor level (FL). Scatter plots were created for each pair to understand the relationships between these variables (Figure 5.17). The Exploratory Data Analysis (EDA) revealed that BL, BS, and ST exhibited linear relationships with PO, whereas FL exhibited a nonlinear relationship with PO. Various model fittings indicated that a second-degree polynomial model best predicted PO ($p < 0.001$) when using FL as the predictor. Consequently, the specific multiple nonlinear regression model for PO was expressed as follows:

$$Y_{PO} = \beta_0 + \beta_1 \times BL + \beta_2 \times BS + \beta_3 \times ST + \beta_4 \times FL + \beta_5 \times FL^2 + \epsilon$$

In this equation, Y_{PO} was the response variable. BL and ST were dummy variables that represented the two levels of the categorical variables BL and ST, respectively. BS and FL were continuous independent variables, where FL^2 represented the quadratic term. The intercept was denoted by β_0 , and the coefficients for the respective variables were β_1 , β_2 , β_3 , β_4 , and β_5 . The error term was represented by ϵ .

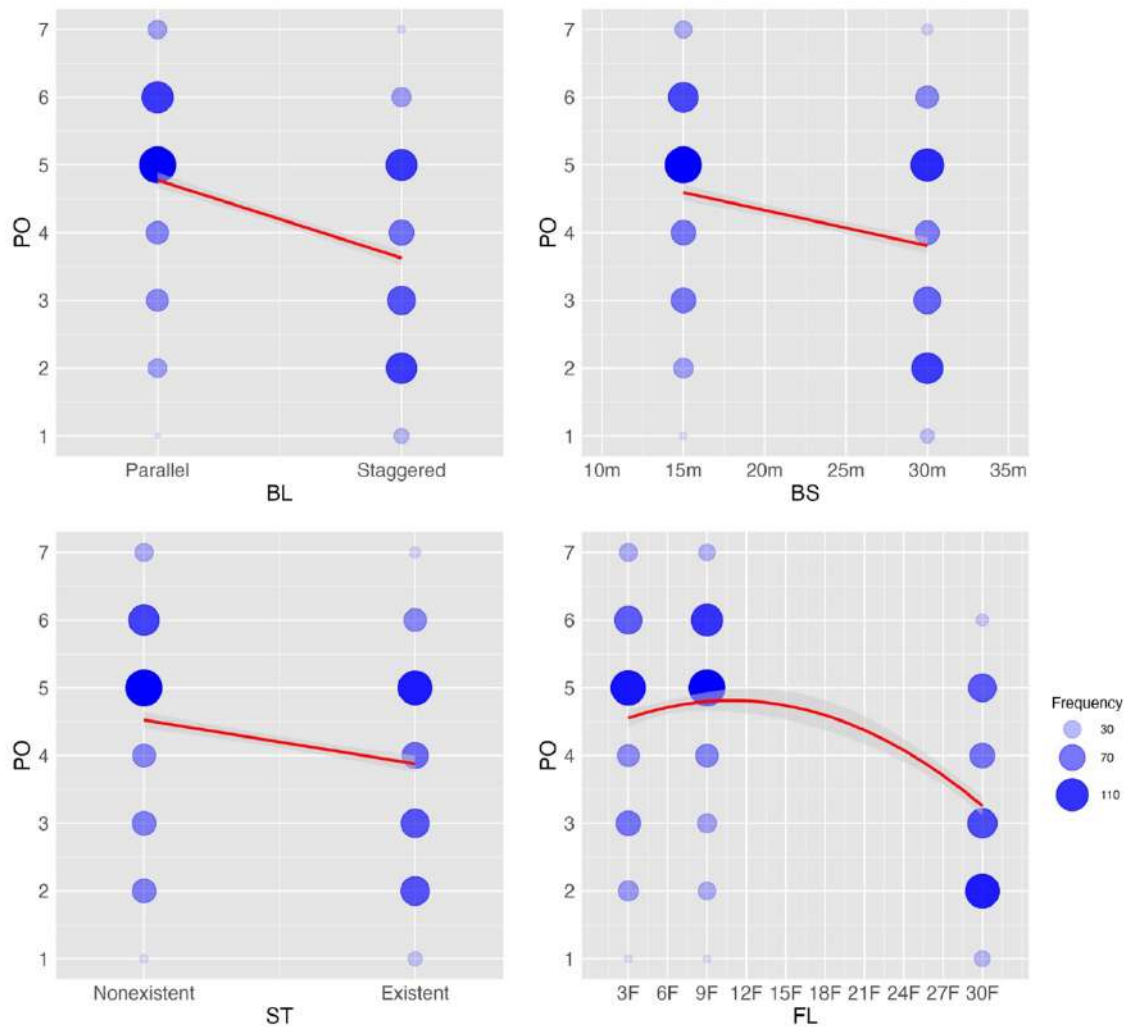


Figure 5.17: Scatter Plots with Regression Lines and 95% Confidence Intervals for PO.

Source: Created by the Author.

For the PO model, the adjusted R-squared value was 0.427 (Table 5.10), indicating that approximately 42.7% of the variance in PO was explained. The intercept, with an estimate of 6.275 (SE = 0.118, $t = 53.086$, $p < 0.001$), represented the baseline PO value when all predictors were zero.

The BS exhibited a significant negative relationship with PO (Estimate = -0.052 , $p < 0.001$), indicating that an increase of one unit in BS was associated with a decrease in PO by 0.052 units. The BL showed significant negative effects on PO, with BL at Staggered (Estimate = $-$

1.148, $p < 0.001$). Compared to the reference category (Parallel), BL at Staggered was associated with a decrease in PO by 1.148 units.

The ST showed significant negative effects on PO, with ST at Existent (Estimate = -0.645 , $p < 0.001$). Compared to the reference category (Nonexistent), ST at Existent was associated with a decrease in PO by 0.645 units. The polynomial terms of FL significantly impacted PO, with the first term (Estimate = -21.903 , $p < 0.001$) and the second term (Estimate = -8.323 , $p = 0.001$).

Table 5.10: Effects of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) on Predicting Perceived Oppressiveness (PO) (N = 1200).

| | Estimate | Std. Error | t value | p | |
|-------------------------|----------|------------|---------|---------|-----|
| (Intercept) | 6.275 | 0.118 | 53.086 | < 0.001 | *** |
| BS | -0.052 | 0.005 | -11.503 | < 0.001 | *** |
| factor (BL) Parallel | Ref | | | | |
| factor (BL) Staggered | -1.148 | 0.068 | -16.826 | < 0.001 | *** |
| factor (ST) Nonexistent | Ref | | | | |
| factor (ST) Existent | -0.645 | 0.068 | -9.451 | < 0.001 | *** |
| poly (FL, 2) 1 | -21.903 | 1.182 | -18.529 | < 0.001 | *** |
| poly (FL, 2) 2 | -8.323 | 1.182 | -7.041 | 0.001 | *** |

Adjusted R-squared: 0.427

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: Created by the Author.

Graphical analysis was employed to visually illustrate the predictions of PO based on the characteristics of planning measures and observation floors (Figure 5.18). The model categorized BL and ST as nominal variables while treating BS and FL as continuous variables. BL was classified into two categories: Parallel and Staggered. ST was classified into two categories: Nonexistent and Existent. The graphs depicted BS values ranging from 0 m to 60 m and FL ranging from 1F to 30F, with each floor having a height of 3.0 meters.

In the PO model, the contour lines of the predicted PO value presented an inverted U shape. When FL, BS, and ST were constant, the predicted PO value decreased as BL changed from Parallel to Staggered. When FL, BS, and BL were constant, the predicted PO value decreased as ST changed from Nonexistent to Existent. When BL, ST, and FL were constant, the predicted PO value decreased as BS increased. When BL, BS, and ST were constant, the predicted value of PO initially increased with rising FL before declining after reaching a certain threshold.

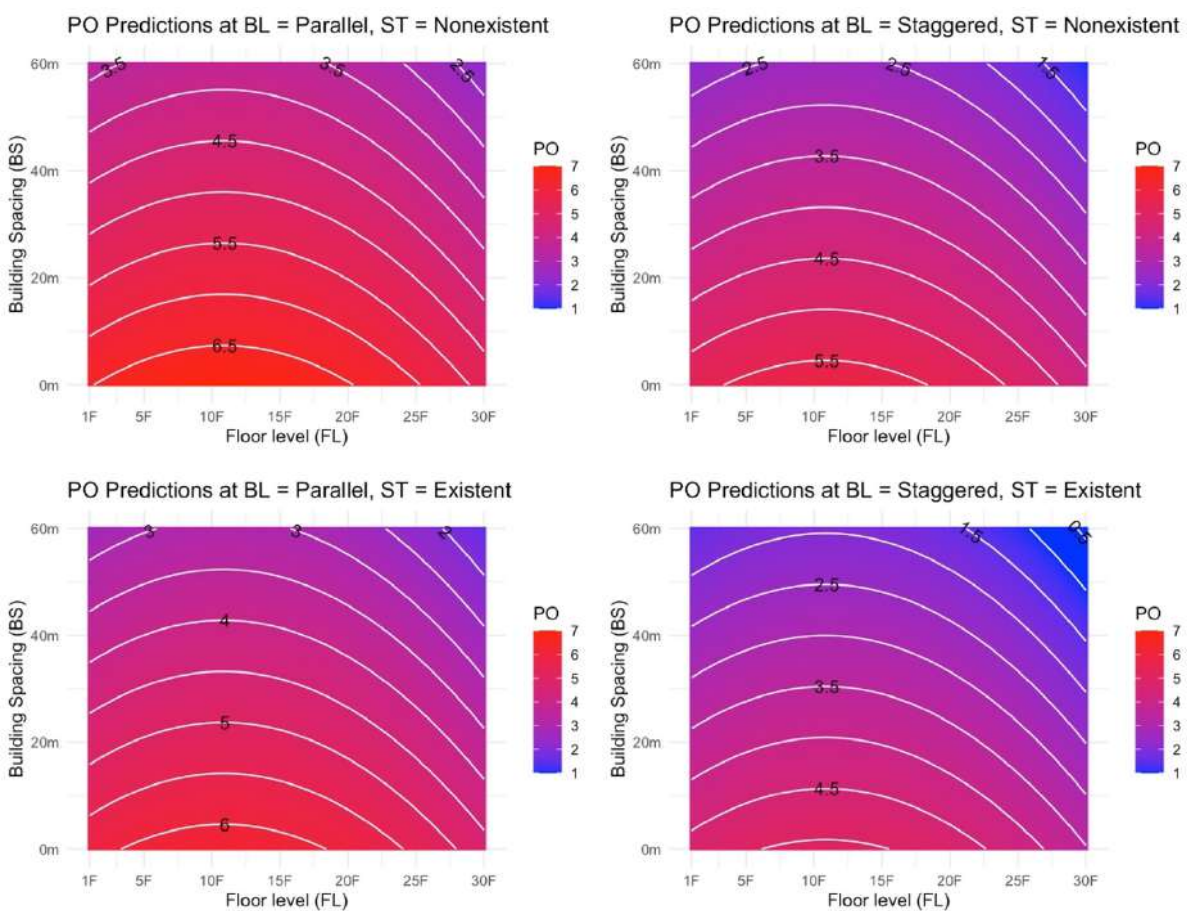


Figure 5.18: Effects of BL, BS, ST, and FL on Perceived Oppressiveness (PO).

Source: Created by the Author.

5.2.4. Prediction of PO by Visual Elements (SR, GaR, TR, F-BR, and B-BR)

In the stepwise multiple linear regression analysis, Perceived Oppressiveness (PO) was the dependent variable. The independent variables included five visual elements: Sky Ratio (SR),

Grass Ratio (GaR), Tree Ratio (TR), Foreground Building Ratio (F-BR), and Background Building Ratio (B-BR). The mean value of each scene's PO was used to represent the overall oppressiveness.

The final stepwise regression analysis model identified significant predictors of PO, achieving an adjusted R-squared value of 0.895 (Table 5.11). This indicated that approximately 89.5% of the variance in PO was explained by the model. The analysis revealed that four variables—SR, TR, F-BR, and B-BR—are significant predictors of PO. Conversely, GaR was excluded from the model as it was deemed a non-significant contributor, lacking statistically significant linear relationships with PO.

The intercept, with an estimate of 4.690 ($p < 0.001$), represented the baseline PO value when all predictors are zero. The predictor SR exhibited a significant negative relationship with PO (Estimate = -0.033 , $p = 0.004$), indicating that each unit increase in SR leads to an average decrease of 0.033 units in PO. The predictor TR also exhibited a significant negative relationship with PO (Estimate = -0.105 , $p < 0.001$), indicating that each unit increase in TR leads to an average decrease of 0.105 units in PO. Conversely, F-BR had a positive effect on PO (Estimate = 0.047 , $p = 0.009$), suggesting an average increase of 0.047 units in PO per unit increase in F-BR. The B-BR had a negative effect on PO (Estimate = -0.407 , $p < 0.001$), suggesting an average decrease of 0.407 units in PO per unit increase in B-BR. All predictors had variance inflation factor (VIF) values ranging from 1.933 to 2.813, showing that multicollinearity was not of significant concern in this model.

Table 5.11: Significant Visual Elements for Predicting Perceived Oppressiveness (PO) (N = 24).

| | | Estimate | Std. Error | t value | p | | VIF |
|----|-------------|----------|------------|---------|---------|-----|-------|
| PO | (Intercept) | 4.690 | 0.720 | 6.513 | < 0.001 | *** | |
| | SR | -0.033 | 0.010 | -3.235 | 0.004 | ** | 2.813 |
| | TR | -0.105 | 0.024 | -4.386 | < 0.001 | *** | 1.952 |

| | | | | | | |
|------|--------|-------|--------|---------|-----|-------|
| F-BR | 0.047 | 0.016 | 2.898 | 0.009 | ** | 2.281 |
| B-BR | -0.407 | 0.070 | -5.806 | < 0.001 | *** | 1.933 |

Adjusted R-squared (PO): 0.895

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024b).

The bar chart presented the coefficient estimates from the regression analysis predicting PO based on significant predictor variables (Figure 5.19). The estimates provided a quantifiable measure of how much each predictor variable influences the dependent variable. The magnitude of the estimates showed that B-BR has the largest negative effect, followed by TR with a significant negative effect, SR also with a negative impact, and F-BR with a positive effect.

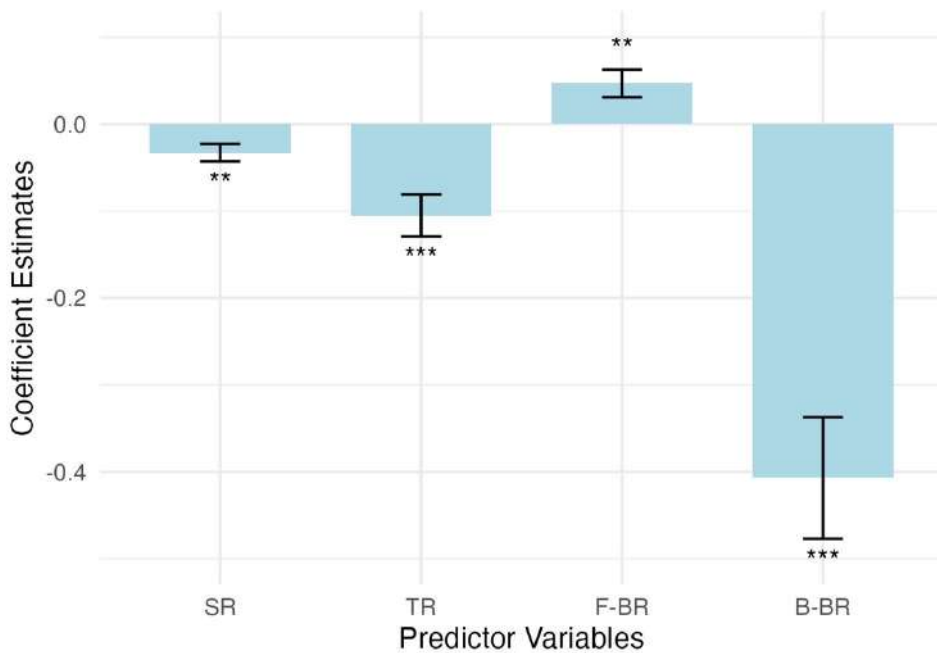


Figure 5.19: Bar Chart of Coefficient Estimates for Visual Elements Predicting Perceived Oppressiveness (PO).

Source: Created by the Author.

5.2.5. Planning Measures and Viewing Floor Levels Predicting Visual Elements

In the multiple linear regression analysis, several planning measures and viewing Floor Level (FL) were used as independent variables to predict visual elements (Table 5.12). These planning measures included Building Layout (BL), Building Spacing (BS), and Surrounding Trees (ST). The visual elements being predicted were Sky Ratio (SR), Tree Ratio (TR), Foreground Building Ratio (F-BR), and Background Building Ratio (B-BR).

In the Sky Ratio (SR) model (Adjusted R-squared = 0.990), the intercept was significant (Estimate = 4.154, $p < 0.001$). The BL at Staggered exhibited a significant positive relationship with SR (Estimate = 2.108, $p < 0.001$), indicating that the Staggered layout leads to an average increase of 2.108 units in SR compared to the Parallel layout. Increasing BS from 15 to 30 meters also showed a significant positive effect (Estimate = 2.808, $p < 0.001$), suggesting that each unit increase in building spacing leads to an average increase of 2.808 units in SR. The ST at Existent did not significantly impact SR (Estimate = 0.125, $p = 0.803$). The FL at 9F (Estimates = 1.338, $p = 0.040$) and 30F (Estimates = 25.125, $p < 0.001$) showed significant positive effects on SR. Specifically, the 9F leads to an average increase of 1.338 units in SR, and the 30F leads to an average increase of 25.125 units in SR compared to the reference of 3F.

In the Tree Ratio (TR) model (Adjusted R-squared = 0.658), the intercept was significant (Estimate = 2.704, $p = 0.042$). However, the BL (Estimate = 0.200, $p = 0.845$) and BS (Estimate = -0.083, $p = 0.935$) did not show significant effects. This indicates that these factors did not contribute meaningfully to the visual elements in this model. The ST at Existent exhibited a significant positive relationship with TR (Estimate = 5.650, $p < 0.001$), indicating that the Existent of ST leads to an average increase of 5.650 units in TR compared to Nonexistent of ST. The FL at 9F (Estimates = -3.138, $p = 0.020$) and 30F (Estimates = -5.150, $p < 0.001$) exhibited significant negative effects on TR, implying that floor levels of

9F and 30F lead to average decreases of 3.138 and 5.150 units in TR, compared to the reference of 3F.

In the Foreground Building Ratio (F-BR) model (Adjusted R-squared = 0.952), the intercept was significant (Estimate = 34.300, $p < 0.001$). The BL at Staggered exhibited a significant negative relationship with F-BR (Estimate = -4.292 , $p < 0.001$), indicating that the Staggered layout leads to an average decrease of 4.292 units in F-BR compared to the Parallel layout. Increasing BS from 15 to 30 meters showed a significant negative effect (Estimate = -4.742 , $p < 0.001$), suggesting that each unit increase in BS leads to an average decrease of 4.742 units in F-BR. The ST at Existent significantly reduced F-BR (Estimate = -2.042 , $p = 0.003$), indicating that the Existent of ST leads to an average decrease of 2.042 units in F-BR compared to Nonexistent. The FL at 9F (Estimates = 10.238, $p < 0.001$) and 30F (Estimates = -2.513 , $p = 0.003$) showed significant effects on F-BR. Specifically, the 9F leads to an average increase of 10.238 units in F-BR, while the 30F leads to an average decrease of 2.513 units in F-BR compared to the reference of 3F.

In the Background Building Ratio (B-BR) model (Adjusted R-squared = 0.819), the intercept was significant (Estimate = 0.692, $p = 0.037$). The BL at Staggered exhibited a significant positive relationship with B-BR (Estimate = 1.417, $p < 0.001$), indicating that the Staggered layout leads to an average increase of 1.417 units in B-BR compared to the Parallel layout. Increasing BS from 15 to 30 meters showed a significant positive effect (Estimate = 1.183, $p < 0.001$), suggesting that each unit increase in BS leads to an average increase of 1.183 units in B-BR. The ST did not show a significant effect (Estimate = -0.433 , $p = 0.101$). The FL at 9F (Estimates = 1.050, $p = 0.003$) and 30F (Estimates = 2.200, $p < 0.001$) showed significant effects on B-BR. Specifically, floor levels of 9F and 30F lead to average increases of 1.050 and 2.200 units in B-BR, respectively, compared to the reference of 3F.

Table 5.12: Predictive Analysis of Visual Elements Based on Planning Measures and Viewing Floor Levels (N = 24).

| | | | Estimate | Std. Error | t value | p | VIF |
|------|----|-------------|----------|------------|---------|---------|-----------|
| SR | | (Intercept) | 4.154 | 0.603 | 6.887 | < 0.001 | *** |
| | BL | Parallel | Ref | | | | |
| | | Staggered | 2.108 | 0.493 | 4.281 | < 0.001 | *** 1.000 |
| | BS | 15 m | Ref | | | | |
| | | 30 m | 2.808 | 0.493 | 5.702 | < 0.001 | *** 1.000 |
| | ST | Nonexistent | Ref | | | | |
| | | Existent | 0.125 | 0.493 | 0.254 | 0.803 | 1.000 |
| | FL | 3F | Ref | | | | |
| | | 9F | 1.338 | 0.603 | 2.217 | 0.040 | * 1.000 |
| | | 30F | 25.125 | 0.603 | 41.651 | < 0.001 | *** 1.000 |
| TR | | (Intercept) | 2.704 | 1.233 | 2.192 | 0.042 | * |
| | BL | Parallel | Ref | | | | |
| | | Staggered | 0.200 | 1.007 | 0.199 | 0.845 | 1.000 |
| | BS | 15 m | Ref | | | | |
| | | 30 m | -0.083 | 1.007 | -0.083 | 0.935 | 1.000 |
| | ST | Nonexistent | Ref | | | | |
| | | Existent | 5.650 | 1.007 | 5.610 | < 0.001 | *** 1.000 |
| | FL | 3F | Ref | | | | |
| | | 9F | -3.138 | 1.233 | -2.544 | 0.020 | * 1.000 |
| | | 30F | -5.150 | 1.233 | -4.175 | < 0.001 | *** 1.000 |
| F-BR | | (Intercept) | 34.300 | 0.736 | 46.630 | < 0.001 | *** |
| | BL | Parallel | Ref | | | | |
| | | Staggered | -4.292 | 0.601 | -7.146 | < 0.001 | *** 1.000 |
| | BS | 15 m | Ref | | | | |
| | | 30 m | -4.742 | 0.601 | -7.895 | < 0.001 | *** 1.000 |
| | ST | Nonexistent | Ref | | | | |
| | | Existent | -2.042 | 0.601 | -3.399 | 0.003 | ** 1.000 |
| | FL | 3F | Ref | | | | |
| | | 9F | 10.238 | 0.736 | 13.918 | < 0.001 | *** 1.000 |
| | | 30F | -2.513 | 0.736 | -3.416 | 0.003 | ** 1.000 |
| B-BR | | (Intercept) | 0.692 | 0.307 | 2.255 | 0.037 | * |
| | BL | Parallel | Ref | | | | |
| | | Staggered | 1.417 | 0.251 | 5.656 | < 0.001 | *** 1.000 |
| | BS | 15 m | Ref | | | | |
| | | 30 m | 1.183 | 0.251 | 4.725 | < 0.001 | *** 1.000 |
| | ST | Nonexistent | Ref | | | | |

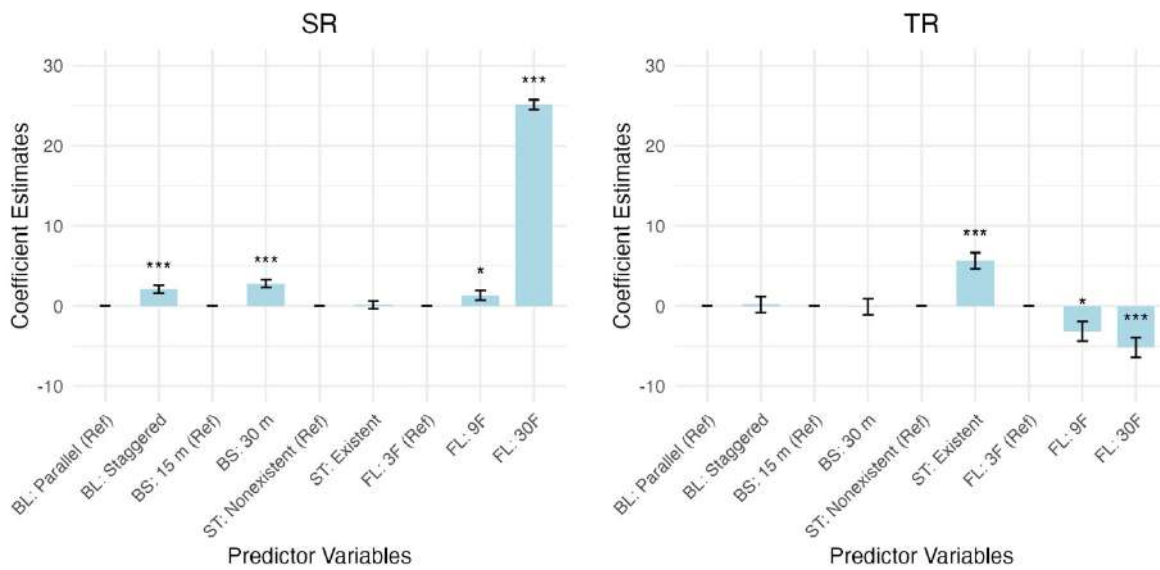
| | | | | | | | |
|----|----------|--------|-------|--------|---------|-----|-------|
| | Existent | -0.433 | 0.251 | -1.730 | 0.101 | | 1.000 |
| FL | 3F | Ref | | | | | |
| | 9F | 1.050 | 0.307 | 3.423 | 0.003 | ** | 1.000 |
| | 30F | 2.200 | 0.307 | 7.172 | < 0.001 | *** | 1.000 |

Adjusted R-squared: 0.990 (SR), 0.658 (TR), 0.952 (F-BR), 0.819 (B-BR)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024b).

The bar chart presented coefficient estimates derived from regression analyses predicting variables such as the Sky Ratio (SR), Tree Ratio (TR), Foreground Building Ratio (F-BR), and Background Building Ratio (B-BR) (Figure 5.20). These predictions were based on several predictor variables, including Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor level (FL). These estimates quantified the impact of each predictor variable on its corresponding dependent variable.



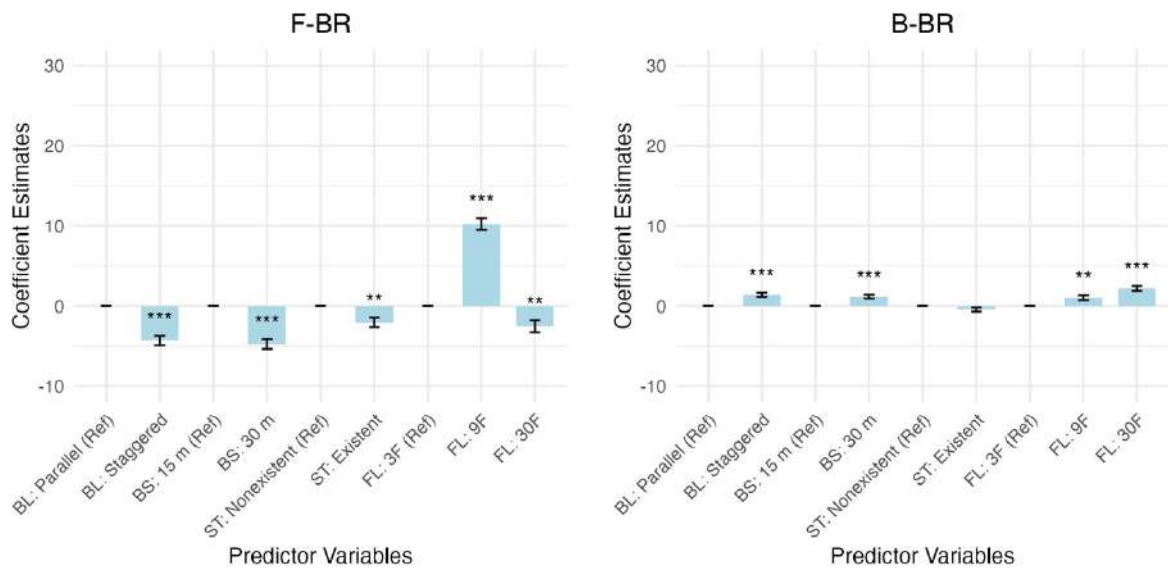


Figure 5.20: Bar Chart of Coefficient Estimates for Planning Measures and Viewing Floor Levels Predicting Visual Elements.

Source: Created by the Author.

5.2.6. Relationship between PO and EP

The relationship between Perceived Oppressiveness (PO) and Environmental Preference (EP) was examined using Pearson's correlation coefficient. The analysis showed a significant negative correlation (Pearson's $r = -0.620$, 95% CI $[-0.654, -0.584]$, $p < 0.001$, $N = 1200$) between PO and EP (Figure 5.21). This strong inverse relationship indicated that as perceived oppressiveness increases, environmental preference decreases.

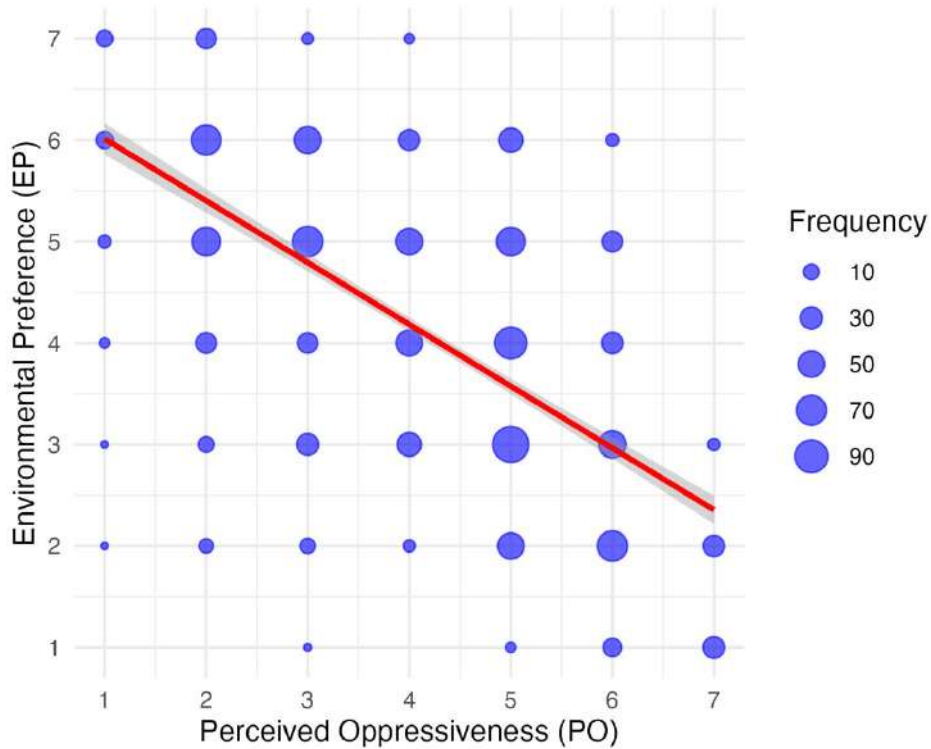


Figure 5.21: Scatter Plot with Prediction Line for Correlation Analysis.

Source: Created by the Author.

5.3. Discussion

This study examined how planning measures, floor levels, and visual elements affect perceived oppressiveness. The following sections provide observations and conclusions based on the results.

5.3.1. Effects of Planning Measures and Floor Levels on Perceived Oppressiveness (PO)

5.3.1.1. Influence of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) on PO

The main effects of Building Layout (BL) ($F(1, 1176) = 290.349, p < 0.001, \eta^2p = 0.198$) and Building Spacing (BS) ($F(1, 1176) = 135.683, p < 0.001, \eta^2p = 0.103$) on Perceived Oppressiveness (PO) were significant. The results showed that planning measures have a significant effect on PO.

Broader window views are achieved by staggered building layout and wider building spacing, which decrease the feeling of oppression. This finding is consistent with Hypothesis 2-1. Experiencing open public spaces improves mental health and a sense of spaciousness by reducing psychological stress (Asgarzadeh et al., 2014; Francis et al., 2012). Increased window view depth, viewing more sky or distant objects, contributes to a sense of openness and supports psychological restoration (Masoudinejad & Hartig, 2020). Obscured views could lead to anxiety and mental strain (Gatersleben & Andrews, 2013). The prospect and refuge theory explains preferences for wide spaces over congested areas and busy streets (Chung et al., 2022; R. Kaplan, 2001). Permeability theory states that increasing the depth of space can enhance spaciousness and reduce confinement (Stamps, 2010).

The main effect of Surrounding Trees (ST) on Perceived Oppressiveness (PO) was significant ($F(1, 1176) = 91.602, p < 0.001, \eta^2p = 0.072$), indicating that the visibility of trees through windows reduces PO. Urban vegetation, particularly trees in front of tall buildings, reduces uncomfortable sensations (Asgarzadeh et al., 2012, 2014). Cities, parks, and other green spaces with trees greatly lower stress levels and improve mental health (Nilsson et al., 2011). Frequent exposure to nature, especially in places with many trees, elevates mood and promotes calmness (Nilsson et al., 2011; Wolf et al., 2020).

The main effect of Floor Level (FL) on Perceived Oppressiveness (PO) was significant ($F(2, 1176) = 201.472, p < 0.001, \eta^2p = 0.255$). The relationship between PO and FL was not linear. Participants reported the highest perceived oppressiveness from the 9th floor, which offered obstructed views without natural elements (Chung et al., 2022). Moderate perceived oppressiveness was reported from the 3rd floor, where ground space with grass and trees was visible (Asgarzadeh et al., 2009). The lowest perceived oppressiveness was reported from the 30th floor, where broad skies and distant objects were visible (Masoudinejad & Hartig, 2020).

5.3.1.2. Influence of Interaction Effects on PO

The interaction between Building Layout (BL) and Building Spacing (BS) on Perceived Oppressiveness (PO) was significant ($F(1, 1176) = 20.933, p < 0.001, \eta^2p = 0.017$).

Enhancing visual openness and reducing crowding can mitigate perceived oppressiveness (Chung et al., 2019, 2022). Appropriate spatial planning in urban design enhances psychological comfort (Dillon, 2005). Furthermore, the interaction between Surrounding Trees (ST) and Floor Level (FL) on Perceived Oppressiveness (PO) was significant ($F(2, 1176) = 10.494, p < .001, \eta^2p = 0.018$). Integrating natural elements, particularly trees, into urban environments benefits the mental well-being of occupants at various floor levels (F. Wang & Munakata, 2023).

5.3.2. Predicting PO through Ordinal Logistic Regression Model

The ordinal logistic regression model shows the effects of Building Layout (BL), Building Spacing (BS), Surrounding Trees (ST), and Floor Level (FL) on Perceived Oppressiveness (PO). The probability maps of PO quantify the impact of different planning measures and viewing levels on the sense of oppression. These maps show the probability of low, medium, and high PO across different scenarios. Staggered building layouts with surrounding trees produce a lower probability of high PO at different floor levels. Increased building spacing and higher viewing floor levels also result in a lower probability of high PO. Careful consideration of staggered building layout, increased building spacing, adding surrounding trees, and higher viewing floor levels in urban planning is conducive to urban residents gaining positive psychological impressions (F. Wang & Munakata, 2024b).

5.3.3. Predicting PO through Multiple Nonlinear Regression Model

The multiple nonlinear regression analysis examined the effects of various planning measures and viewing floors on Perceived Oppressiveness (PO). The Exploratory Data Analysis (EDA) indicated linear relationships between Building Layout (BL), Building Spacing (BS), and

Surrounding Trees (ST) with PO, while Floor Level (FL) exhibited a nonlinear relationship with PO.

The graphical analysis predicted PO values for various BL, BS, ST, and FL combinations. The value of PO varies with FL in an inverted U-shape, showing that PO increases with the floor level up to a certain point before decreasing. This finding further clarifies the impact of viewing floors on the sense of oppression based on the ordered logistic regression. The obstructed window views give the middle floors a higher sense of oppression. The lower floors have plants outside the windows, and the higher floors have broader views, which relieves their oppressiveness (Masoudinejad & Hartig, 2020). Staggered building layouts, increased building spacing, and surrounding trees led to lower perceived oppressiveness across all floor levels. Thoughtfully designed natural elements and well-planned building layouts contribute to improved psychological well-being (Dillon, 2005; F. Wang & Munakata, 2024b).

5.3.4. Quantitative Analysis of Visual Elements in Window Views

The linear regression analysis indicated that four visual elements—Sky Ratio (SR), Tree Ratio (TR), Foreground Building Ratio (F-BR), and Background Building Ratio (B-BR)—significantly affect Perceived Oppressiveness (PO). This finding showed that raising the ratio of natural elements like skies and trees reduces oppressiveness, consistent with Hypothesis 2-2. Window views incorporating natural elements promote mental health and reduce feelings of oppression (Asgarzadeh et al., 2012, 2014; R. Kaplan, 2001; Masoudinejad & Hartig, 2020).

Built elements influence oppressiveness in both positive and negative ways. Increasing foreground buildings enhances oppressiveness, while increasing background buildings reduces oppressiveness. Previous research suggested that built elements harm occupants' psychological health or preferences (R. Kaplan, 2001). This study extends the existing

literature by indicating that architectural elements have a dual role. Foreground buildings enhance enclosure and crowding. In contrast, background buildings create an organized and orderly vision to reduce the sense of oppression (F. Wang & Munakata, 2024b).

5.3.5. Identifying Favorable Visual Elements in Urban Environments

According to multiple linear regression, viewing from higher floors, staggered building layouts, and wider building spacing increased the viewable sky area. This finding supports Hypothesis 2-3. The visibility of trees through windows was enhanced by planting trees around buildings. Staggered layouts and increased building spacing decreased the foreground building ratio. Higher floors had different effects on visible foreground buildings. The foreground building ratio was higher on the 9th floor and lower on the 30th floor as compared to the 3rd floor. In addition, higher floors, improved building spacing, and staggered layout increased the visibility of background buildings.

5.3.6. Negative Bivariate Correlation between PO and EP

This study supported Hypothesis 2-4 by finding a significant negative relationship between perceived oppressiveness (PO) and environmental preference (EP). The strong inverse relationship between PO and EP supports the notion that environmental characteristics impact human psychological responses (Gifford, 2007). When individuals perceive surrounding environments as oppressiveness, it reduces their preference. This finding aligns with prior research indicating that people prefer open, green, and visually appealing environments over dense, built-up, and visually restrictive environments (Gifford, 2007; Ulrich, 1984). Furthermore, it should also be noted that oppressiveness is not the only factor determining environmental preference.

6. Experiment Three: Effect of Facade Characteristics on Subjective Impressions

6.1. Materials and Methods

6.1.1. Research Hypothesis

This experiment explored the perceived oppressiveness of window views in various built environments to address the negative impacts of high-rise buildings. Specifically, this experiment investigated the impact of facade characteristics (window-to-wall ratio and height-to-width ratio), viewing floor level, and the visual elements ratio (sky, greenery, and buildings) on perceived oppressiveness. Based on existing literature, this study posits the subsequent hypothesis.

Hypothesis 3-1: Increasing the window area of the facade reduces perceived oppressiveness.

Hypothesis 3-2: A positive correlation exists between the proportion of sky visible through windows and perceived oppressiveness.

Hypothesis 3-3: There is an inverse relationship between perceived oppressiveness and environmental preference.

6.1.2. Participants

Participants were recruited from the Architecture and Design Department in the Faculty of Engineering at Chiba University. The 40 participants were in Experiment 3 (Table 6.1). There were 17 women (42.5%) and 23 males (57.5%) in the gender distribution. Regarding educational level, 31 (77.5%) were postgraduates and 9 (22.5%) were undergraduates. The participants ranged from 20 to 34 years, with an average age of 25.1 years. A 2000-yen book card was provided to each participant as an appreciation for their participation.

Table 6.1: Demographic Information of Experiment 3 (N = 40).

| | | | Percentage |
|-----------------|---------------|----|------------|
| Gender | Man | 23 | 57.5% |
| | Women | 17 | 42.5% |
| Education level | Undergraduate | 9 | 22.5% |

| | | | |
|-----|--------------|------|-------|
| | Postgraduate | 31 | 77.5% |
| Age | Minimum age | 20 | |
| | Maximum age | 34 | |
| | Average age | 25.1 | |

Source: F. Wang & Munakata (2024a).

6.1.3. Experimental Stimuli

Like Experiment 2, this experiment used VR headsets to display panoramic images that simulated views from high-rise office building windows.

6.1.3.1. Factor Settings

This experiment included three variable factors: two facade characteristics—Window-to-Wall Ratio (WWR) and Height-to-Width Ratio (HWR)—and an observed factor, Floor Level (FL) (Table 6.2). Additionally, this study included several fixed factors in this experiment.

Table 6.2: Factor Settings for Experiment 3.

| Factors | | Level | | |
|------------------------|------------------------------------|---|-------------------|-------------------|
| | | 1 | 2 | 3 |
| Facade characteristics | Window-to-Wall Ratio (WWR) | 25 % | 50 % | 75% |
| | Height-to-Width Ratio (HWR) | 1:2 (45 m / 90 m) | 1:1 (63 m / 63 m) | 2:1 (90 m / 45 m) |
| Observed factor | Floor Level (FL) | 2F | 10F | 18F |
| Fix factors | Floor height | 4.5 m | | |
| | Facade area | 4000 m ² (±5%) | | |
| | Building distance | 50 m | | |
| | Room size | 7.5 m (length) × 4.5 m (width) × 4.5 m (height) | | |
| | Window size | 3.9 m (width) × 3.9 m (height) | | |
| | Eye height | 1.5 m | | |
| | Distance between window and viewer | 0.5 m | | |

Source: F. Wang & Munakata (2024a).

The window-to-wall ratio (WWR) included three levels: 25%, 50%, and 75% (Figure 6.1). The height-to-width ratio (HWR) covered three settings: 1:2, 1:1, and 2:1. The observation building in this experiment had a total of 20 floors with a height of 90 meters. To consider the viewer's elevation relative to ground level, viewing Floor Level (FL) was divided into three

categories: low-floor zone (1F - 6F), middle-floor zone (7F - 13F), and high-floor zone (14F - 20F). Specifically, the 2nd floor (2F) was selected to depict the low-floor zone, the 10th floor (10F) the middle-floor zone, and the 18th floor (18F) the high-floor zone.

The selected viewpoint was in the central room of the building's north side. Like Experiment 2, the observer stood 0.5 meters away from the window with their line of sight at a height of 1.5 meters to simulate the perspective of someone standing and looking out the window.

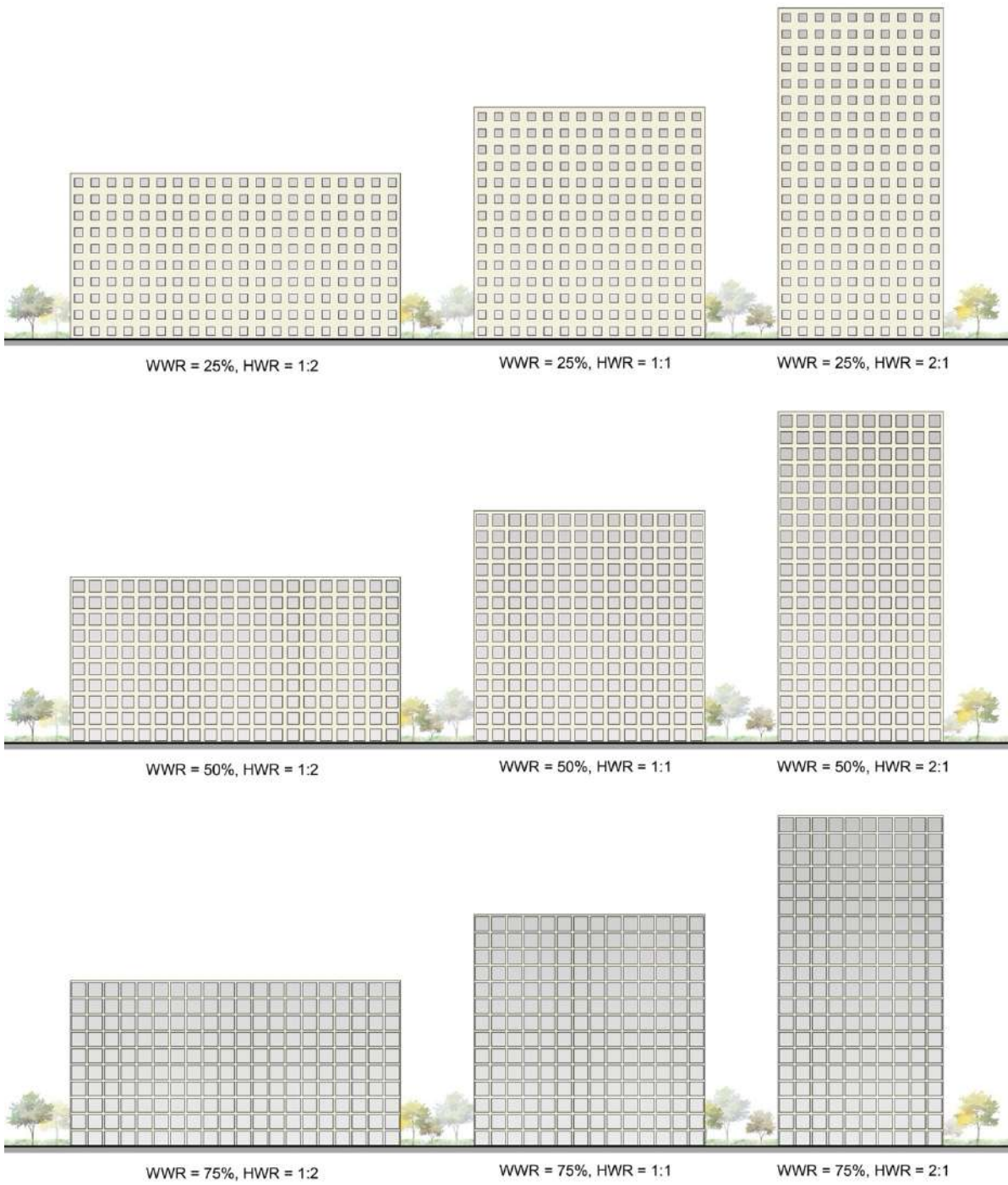












Figure 6.1: Height-to-Width Ratio (HWR) and Window-to-Wall Ratio (WWR) Configurations.

Source: F. Wang & Munakata (2024a).

6.1.3.2. Image Processing

This study created 3D digital models using SketchUp (version 2022) and rendered them using Enscape (version 2.0.1 for Mac). Experimental models depicted typical high-rise office buildings in urban settings. This experiment employed a full factorial design to generate 27 panoramic images representing distinct combinations of the experimental factors (Figure 6.2).

| No. | Variable factors | Panoramic images | VR screenshot (Horizontal sightline = 0°; Vertical sightline = 0°) |
|-----|------------------------------------|---|--|
| 01 | WWR = 25% HWR = 1:2 FL = 2F |  |  |
| 02 | WWR = 25% HWR = 1:2 FL = 10F |  |  |
| 03 | WWR = 25% HWR = 1:2 FL = 18F |  |  |
| 04 | WWR = 25% HWR = 1:1 FL = 2F |  |  |
| 05 | WWR = 25% HWR = 1:1 FL = 10F |  |  |

06
WWR =
25%
HWR = 1:1
FL = 18F



07
WWR =
25%
HWR = 2:1
FL = 2F



08
WWR =
25%
HWR = 2:1
FL = 10F



09
WWR =
25%
HWR = 2:1
FL = 18F



10
WWR =
50%
HWR = 1:2
FL = 2F



11
WWR =
50%
HWR = 1:2
FL = 10F



12
WWR =
50%
HWR = 1:2
FL = 18F



13
WWR =
50%
HWR = 1:1
FL = 2F



14
WWR =
50%
HWR = 1:1
FL = 10F



15
WWR =
50%
HWR = 1:1
FL = 18F



16
WWR =
50%
HWR = 2:1
FL = 2F



17
WWR =
50%
HWR = 2:1
FL = 10F



18
WWR =
50%
HWR = 2:1
FL = 18F



19
WWR =
75%
HWR = 1:2
FL = 2F



20
WWR =
75%
HWR = 1:2
FL = 10F



21
WWR =
75%
HWR = 1:2
FL = 18F



22
WWR =
75%
HWR = 1:1
FL = 2F



23
WWR =
75%
HWR = 1:1
FL = 10F



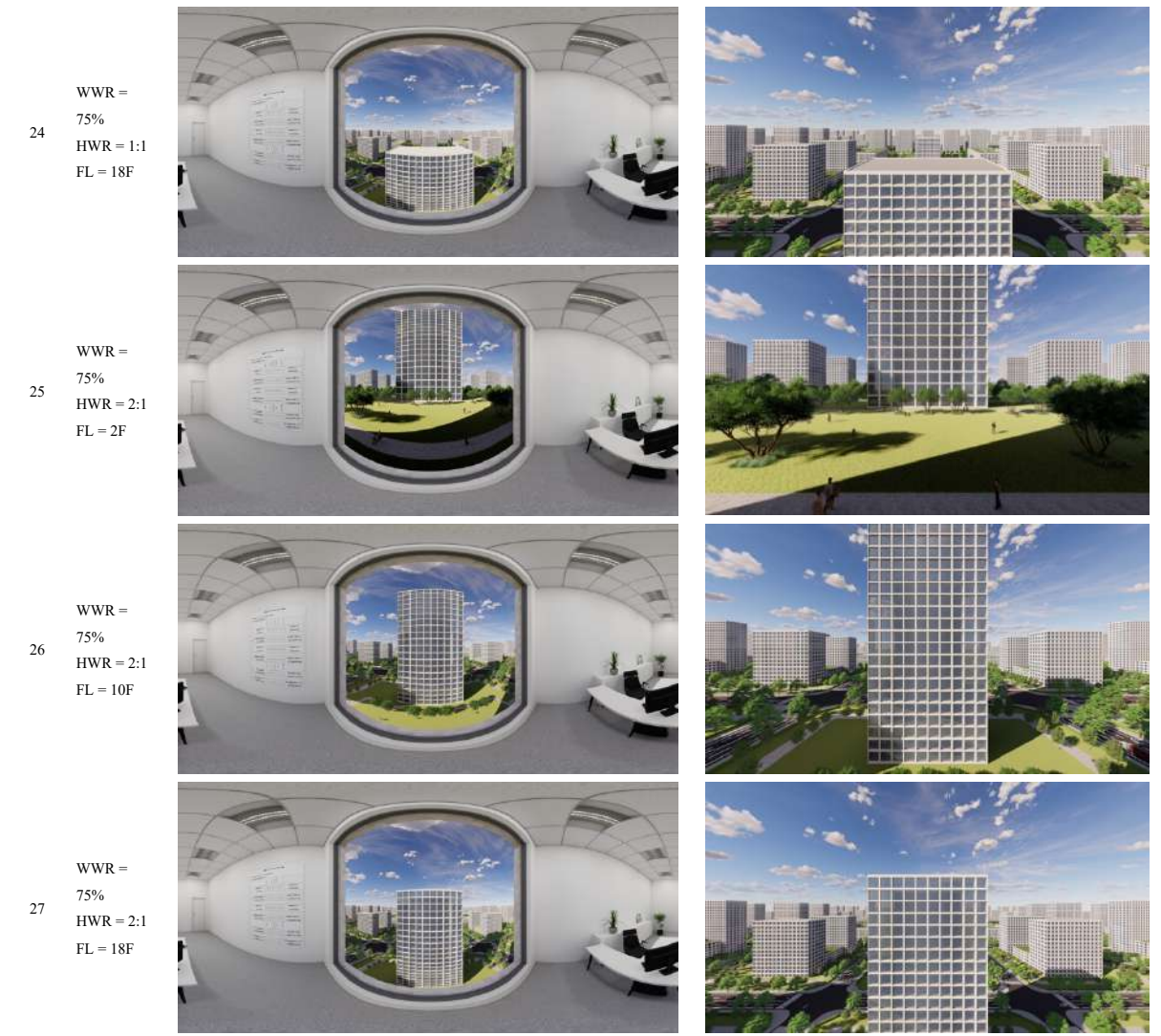


Figure 6.2: Experimental Images of Experiment 3.

Source: F. Wang & Munakata (2024a).

6.1.4. Procedures

Experiment 3 was conducted in the experimental room of the Faculty of Engineering at Chiba University, Japan. Participants were seated in a freely rotatable chair, which facilitated easy and safe viewing of the scenes while wearing virtual reality (VR) headsets. Before starting the experiment, participants fine-tuned their virtual reality headsets to guarantee a comfortable and unobstructed view of both outdoor and indoor virtual environments.

Participants wearing virtual reality headsets in the experiment completed the questionnaire verbally while concentrating on the virtual window views. The questionnaire was displayed

on the wall within the VR environment to ensure participants answered questions while wearing the headset. The experimenter recorded their verbal responses on an answer sheet. Following the completion of one scene's questions, participants took off their VR headsets, took a minute to relax, and resumed the experiment. Participants took off the VR headsets after completing all experimental scenes and wrote out their demographic information on an additional questionnaire.

Experiment 3 was conducted from November 20 to December 15, 2023, using Meta Quest 3 VR headsets (Figure 6.3, Figure 6.4). The approach for this experiment was slightly different from that of Experiment 2. Each scene was viewed for a minute before participants responded to the relevant questions to manage the overall duration of the experiment.



Figure 6.3: Participant Using VR Headsets (Meta Quest 3) for Experiment 3.

Source: F. Wang & Munakata (2024a).

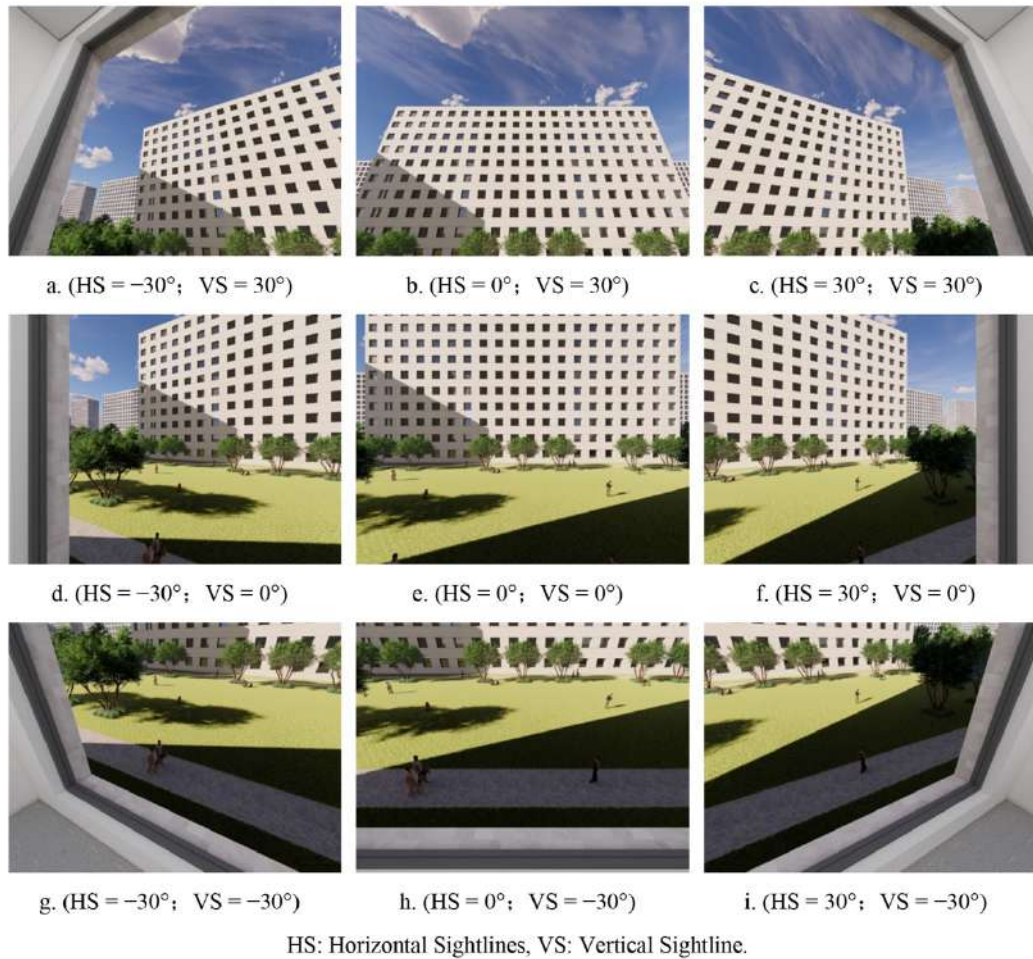


Figure 6.4: Scenes of Experiment 3 (WWR = 25%, HWR = 1:2, FL = 2F).

Source: F. Wang & Munakata (2024a).

6.1.5. Extracting Visual Elements from Window Views and Calculating Ratios

The main visual elements of window views were extracted in Experiment 3. In Experiment 3, the extracted visual elements included Sky Ratio (SR), Building Ratio (BR), and Greenery Ratio (GR) (Figure 6.5). The extracting steps were as follows.

Step 1: Extracting Visual Elements Using Deep Learning Model

A deep learning model using Panoptic Segmentation (PS) classified panoramic images based on color distinctions. The PS was implemented through a Python script with the DeepLab2 library from TensorFlow. It was an approach to help identify and extract respective visual elements from the panoramic images.

Step 2: Transforming Panoramic Images to Fisheye Projections

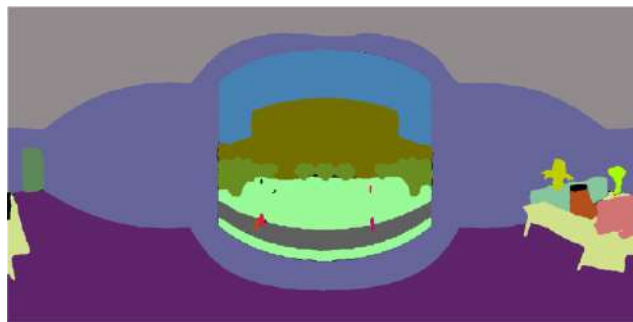
Panoramic images were converted into fisheye projections to achieve precise quantitative analysis. This conversion entailed shifting from the equirectangular projection format to the orthographic projection characteristic of the fisheye image. The transformation was performed using G.Projector software developed by NASA.

Step 3: Calculating the Ratio of Visual Elements

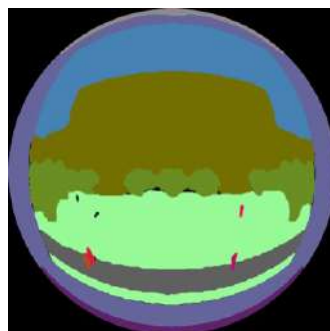
The fisheye images were used to calculate the ratio of visual elements within the window views using a Python script.



Step 1: Classifying Visual Elements Using Deep Learning Model



Step 2: Transforming Panoramic Images to Fisheye Projections



Step 3: Calculating the Ratio of Visual Elements

Figure 6.5: Calculation Procedure for Visual Elements in Experiment 3.

Source: F. Wang & Munakata (2024a).

In Experiment 3, the results for SR, BR, and GR were presented in Table 6.3. The distribution of ratios for visual elements was as follows: SR (29.143 ± 11.624), BR (30.862 ± 4.885), and GR (13.043 ± 10.581).

Table 6.3: Ratios of Visual Elements in Window Views for Experiment 3 (N = 27).

| | N | Minimum (%) | Maximum (%) | Mean (%) | Std. Deviation (%) |
|----|----|-------------|-------------|----------|--------------------|
| SR | 27 | 14.380 | 44.440 | 29.143 | 11.624 |
| BR | 27 | 25.610 | 39.800 | 30.862 | 4.885 |
| GR | 27 | 2.530 | 27.350 | 13.043 | 10.581 |

Source: F. Wang & Munakata (2024a).

6.1.6. Statistical Analysis Process of Experiment 3

The statistical analysis process of Experiment 3 included four aspects (Figure 6.6):

1. Analysis of variance (ANOVA) was conducted to investigate the main and interaction effects of Window-to-Wall Ratio (WWR), Height-to-Width Ratio (HWR), and Floor Level (FL) on Perceived Oppressiveness (PO).
2. Multiple nonlinear regression analysis was performed to evaluate the impact of facade characteristics—Window-to-Wall Ratio (WWR) and Height-to-Width Ratio (HWR)—as well as Floor Level (FL) on Perceived Oppressiveness (PO).
3. Stepwise multiple linear regression analysis was conducted to assess the influence of visual elements—Sky Ratio (SR), Building Ratio (BR), and Greenery Ratio (GR)—on Perceived Oppressiveness (PO).
4. Bivariate correlation analysis was used to investigate the relationship between Perceived Oppressiveness (PO) and Environmental Preference (EP).

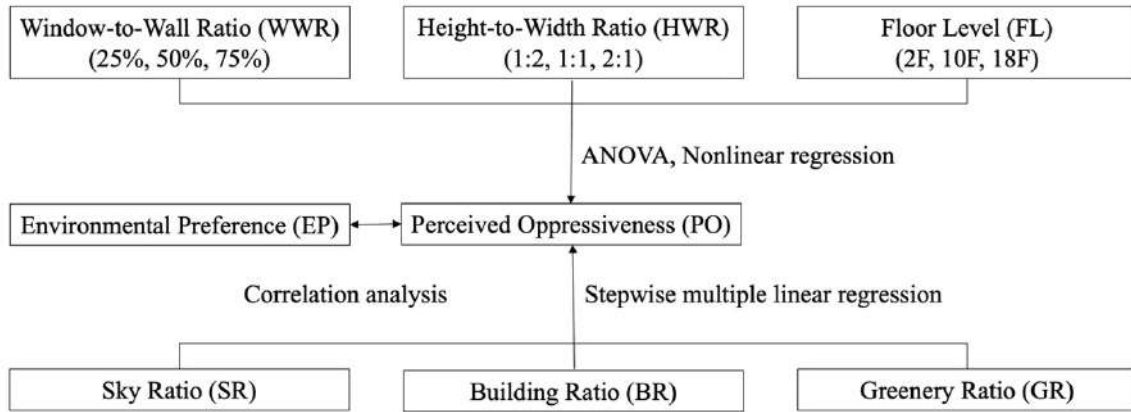


Figure 6.6: Main Analysis Processes in Experiment 3.

Source: F. Wang & Munakata (2024a).

6.2. Results

6.2.1. Effects of Window-to-wall ratio (WWR), Height-to-Width Ratio (HWR), and Floor Level (FL) on Perceived Oppressiveness (PO)

6.2.1.1. ANOVA of main and interaction effects on PO

The ANOVA results in Table 6.4 indicated significant main effects and interaction effects on Perceived Oppressiveness (PO) across the factors of Window-to-wall ratio (WWR), Height-to-Width Ratio (HWR), and Floor Level (FL) (Table 6.4). The main effect of WWR on PO was significant ($F(2, 1053) = 8.239, p < 0.001, \eta^2_p = 0.015$). HWR significantly influenced PO ($F(2, 1053) = 84.890, p < 0.001, \eta^2_p = 0.139$). Additionally, FL significantly influenced PO ($F(2, 1053) = 309.988, p < 0.001, \eta^2_p = 0.371$).

The interaction effects further revealed relationships among the factors. Specifically, the interaction between HWR and FL was statistically significant ($F(4, 1053) = 39.873, p < .001, \eta^2_p = 0.132$). However, the interaction between WWR and HWR and the interaction between WWR and FL were not significant. The three-way interaction among WWR, HWR, and FL was also not significant.

Table 6.4: ANOVA Results for Main Effects and Interaction Effects on Perceived Oppressiveness (PO) (N = 1080).

Dependent variable(s): PO

Between-subjects factor(s): WWR, HWR, FL

| | MS | MSE | df1 | df2 | F | p | η^2 p[90% CI of η^2 p] | η^2 G |
|----------------|---------|-------|-----|------|---------|---------|----------------------------------|------------|
| WWR | 11.518 | 1.398 | 2 | 1053 | 8.239 | < 0.001 | *** 0.015 [.005, .029] | 0.015 |
| HWR | 118.673 | 1.398 | 2 | 1053 | 84.890 | < 0.001 | *** 0.139 [.108, .170] | 0.139 |
| FL | 433.351 | 1.398 | 2 | 1053 | 309.988 | < 0.001 | *** 0.371 [.334, .405] | 0.371 |
| WWR * HWR | 0.908 | 1.398 | 4 | 1053 | 0.649 | 0.627 | 0.002 [.000, .006] | 0.002 |
| WWR * FL | 0.598 | 1.398 | 4 | 1053 | 0.428 | 0.789 | 0.002 [.000, .004] | 0.002 |
| HWR * FL | 55.741 | 1.398 | 4 | 1053 | 39.873 | < 0.001 | *** 0.132 [.100, .161] | 0.132 |
| WWR * HWR * FL | 1.684 | 1.398 | 8 | 1053 | 1.205 | 0.293 | 0.009 [.000, .013] | 0.009 |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024a).

6.2.1.2. Pairwise Comparisons of Main Effects on PO

The post hoc test (Tukey HSD) for pairwise comparisons of WWR, HWR, and FL on PO revealed the following findings (Table 6.5, Figure 6.7).

Comparisons between WWR showed that the 50% condition had significantly lower PO compared to the 25% condition (Estimate = -0.228, $p = 0.027$, Cohen's $d = -0.193$). The 75% condition had significantly lower PO compared to the 25% condition (Estimate = -0.353, $p < 0.001$, Cohen's $d = -0.298$). However, there was no significant difference between the 75% and 50% conditions (Estimate = -0.125, $p = 0.332$, Cohen's $d = -0.106$).

Comparisons between HWR revealed that the 1:1 condition had significantly higher PO compared to the 1:2 condition (Estimate = 0.531, $p < 0.001$, Cohen's $d = 0.449$). The 2:1 condition had significantly higher PO compared to the 1:2 condition (Estimate = 1.147, $p < 0.001$, Cohen's $d = 0.970$). Similarly, the 2:1 condition had significantly higher PO compared to the 1:1 condition (Estimate = 0.617, $p < 0.001$, Cohen's $d = 0.522$).

Comparisons between FL showed that the 10F had significantly higher PO compared to the 2F (Estimate = 0.347, $p < 0.001$, Cohen's $d = 0.294$). The 18F had significantly lower PO compared to the 2F (Estimate = -1.703 , $p < 0.001$, Cohen's $d = -1.440$). Additionally, the 18F showed significantly lower PO compared to the 10F (Estimate = -2.050 , $p < 0.001$, Cohen's $d = -1.734$).

Table 6.5: Pairwise Comparisons of Main Effects of Window-to-Wall Ratio (WWR), Height-to-Width Ratio (HWR), and Floor Level (FL) on Perceived Oppressiveness (PO) (N = 1080).

| | Contrast | Estimate | S.E. | df | t | p | | Cohen's d [95% CI of d] |
|-----|-----------|----------|-------|------|---------|---------|-----|-------------------------|
| WWR | 50% - 25% | -0.228 | 0.088 | 1053 | -2.585 | 0.027 | * | -0.193 [-0.368, -0.018] |
| | 75% - 25% | -0.353 | 0.088 | 1053 | -4.003 | < 0.001 | *** | -0.298 [-0.473, -0.123] |
| | 75% - 50% | -0.125 | 0.088 | 1053 | -1.418 | 0.332 | | -0.106 [-0.281, 0.069] |
| HWR | 1:1 - 1:2 | 0.531 | 0.088 | 1053 | 6.020 | < 0.001 | *** | 0.449 [0.274, 0.624] |
| | 2:1 - 1:2 | 1.147 | 0.088 | 1053 | 13.018 | < 0.001 | *** | 0.970 [0.795, 1.145] |
| | 2:1 - 1:1 | 0.617 | 0.088 | 1053 | 6.997 | < 0.001 | *** | 0.522 [0.347, 0.696] |
| FL | 10F - 2F | 0.347 | 0.088 | 1053 | 3.940 | < 0.001 | *** | 0.294 [0.119, 0.469] |
| | 18F - 2F | -1.703 | 0.088 | 1053 | -19.322 | < 0.001 | *** | -1.440 [-1.615, -1.265] |
| | 18F - 10F | -2.050 | 0.088 | 1053 | -23.262 | < 0.001 | *** | -1.734 [-1.909, -1.559] |

Pooled SD for computing Cohen's d: 1.182

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024a).

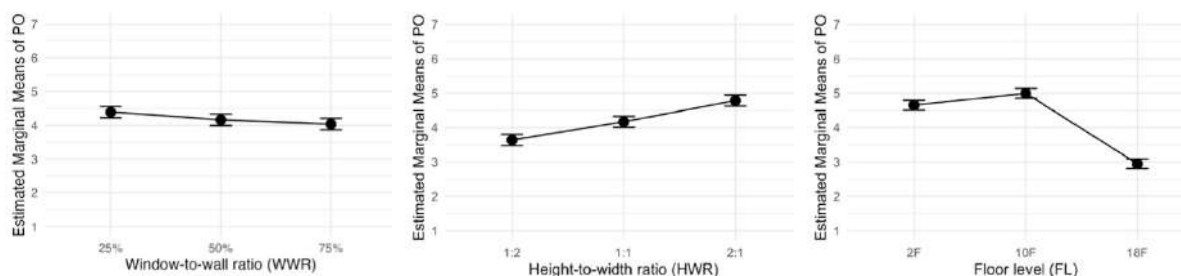


Figure 6.7: Main Effects of WWR, HWR, and FL on Perceived Oppressiveness (PO).

Source: F. Wang & Munakata (2024a).

The bar chart depicted pairwise comparisons of Estimates and Cohen's d for the main effects of WWR, HWR, and FL on PO (Figure 6.8).

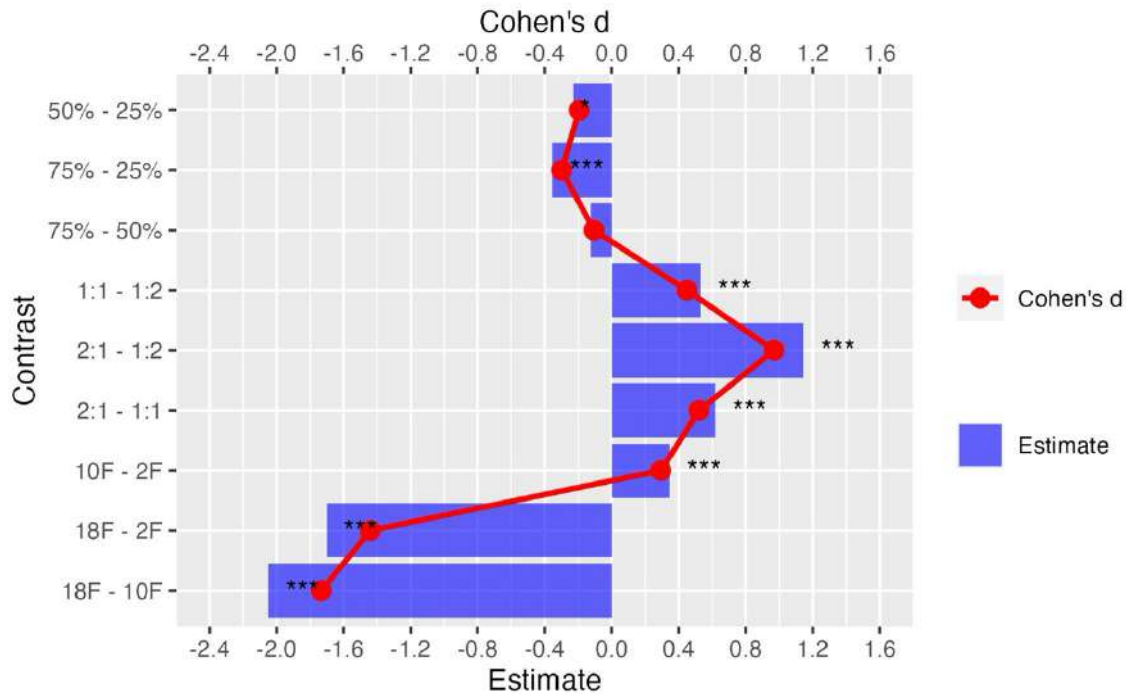


Figure 6.8: Bar Chart of Pairwise Comparisons: Estimates and Cohen's d for WWR, HWR, FL on Perceived Oppressiveness (PO).

Source: Created by the Author.

6.2.1.3. Pairwise Comparisons of Interaction Effects between HWR and FL on PO

The post hoc test (Tukey HSD) for pairwise comparisons indicated significant interaction effects between HWR and Floor Level on PO (Table 6.6, Figure 6.9).

For FL at 2F, comparison between the 1:1 and 1:2 condition (Estimate = 0.325, $p = 0.084$, Cohen's $d = 0.275$), 2:1 and 1:2 condition (Estimate = 0.300, $p = 0.121$, Cohen's $d = 0.254$), and 2:1 and 1:1 condition (Estimate = -0.025 , $p = 0.985$, Cohen's $d = -0.021$) were not significant. For FL at 10F, a significant difference was found between the 2:1 and 1:2 condition (Estimate = 0.475, $p = 0.005$, Cohen's $d = 0.402$), while the comparison between

the 1:1 and 1:2 condition (Estimate = 0.317, $p = 0.096$, Cohen's $d = 0.268$), and between the 2:1 and 1:1 condition (Estimate = 0.158, $p = 0.553$, Cohen's $d = 0.134$) were not significant. For FL at 18F, significant differences were observed for all comparisons: 1:1 and 1:2 condition (Estimate = 0.950, $p < 0.001$, Cohen's $d = 0.803$), 2:1 and 1:2 condition (Estimate = 2.667, $p < 0.001$, Cohen's $d = 2.255$), and 2:1 and 1:1 condition (Estimate = 1.717, $p < 0.001$, Cohen's $d = 1.452$).

For HWR at 1:2 condition, significant differences were observed between 18F and 2F (Estimate = -2.700, $p < 0.001$, Cohen's $d = -2.284$), and 18F and 10F (Estimate = -2.992, $p < 0.001$, Cohen's $d = -2.530$). The comparison between 10F and 2F was not significant (Estimate = 0.292, $p = 0.136$, Cohen's $d = 0.247$). For HWR at 1:1 condition, comparisons between 10F and 2F (Estimate = 0.283, $p = 0.152$, Cohen's $d = 0.240$) were not significant, while significant differences were found between 18F and 2F (Estimate = -2.075, $p < 0.001$, Cohen's $d = -1.755$) and 18F and 10F (Estimate = -2.358, $p < 0.001$, Cohen's $d = -1.995$). For HWR at 2:1 condition, significant differences were observed between 10F and 2F (Estimate = 0.467, $p = 0.006$, Cohen's $d = 0.395$) and 18F and 10F (Estimate = -0.800, $p < 0.001$, Cohen's $d = -0.677$). The comparison between 18F and 2F was not significant (Estimate = -0.333, $p = 0.074$, Cohen's $d = -0.282$).

Table 6.6: Pairwise Comparison of Interaction Effects between Height-to-Width Ratio (HWR) and Floor Level (FL) on Perceived Oppressiveness (PO) (N = 1080).

Dependent Variable: PO

| | Contrast | | | Estimate | S.E. | df | t | p | | Cohen's d [95% CI of d] |
|-----|-----------|----|-----|----------|-------|------|--------|---------|-----|-------------------------|
| HWR | 1:1 - 1:2 | FL | 2F | 0.325 | 0.153 | 1053 | 2.129 | 0.084 | . | 0.275 [-0.028, 0.578] |
| | | | 2F | 0.300 | 0.153 | 1053 | 1.965 | 0.121 | | 0.254 [-0.049, 0.557] |
| | | | 2F | -0.025 | 0.153 | 1053 | -0.164 | 0.985 | | -0.021 [-0.324, 0.282] |
| | 1:1 - 1:2 | | 10F | 0.317 | 0.153 | 1053 | 2.075 | 0.096 | . | 0.268 [-0.035, 0.571] |
| | | | 10F | 0.475 | 0.153 | 1053 | 3.112 | 0.005 | ** | 0.402 [0.099, 0.705] |
| | | | 10F | 0.158 | 0.153 | 1053 | 1.037 | 0.553 | | 0.134 [-0.169, 0.437] |
| | 1:1 - 1:2 | | 18F | 0.950 | 0.153 | 1053 | 6.224 | < 0.001 | *** | 0.803 [0.500, 1.106] |
| | | | 18F | 2.667 | 0.153 | 1053 | 17.47 | < 0.001 | *** | 2.255 [1.952, 2.558] |
| | | | 18F | 1.717 | 0.153 | 1053 | 11.246 | < 0.001 | *** | 1.452 [1.149, 1.755] |

| | | | | | | | | | | |
|----|-----------|-----|-----|--------|-------|------|---------|---------|-----|-------------------------|
| FL | 10F - 2F | HWR | 1:2 | 0.292 | 0.153 | 1053 | 1.911 | 0.136 | | 0.247 [-0.056, 0.550] |
| | 18F - 2F | | 1:2 | -2.700 | 0.153 | 1053 | -17.689 | < 0.001 | *** | -2.284 [-2.587, -1.981] |
| | 18F - 10F | | 1:2 | -2.992 | 0.153 | 1053 | -19.599 | < 0.001 | *** | -2.530 [-2.833, -2.227] |
| | 10F - 2F | | 1:1 | 0.283 | 0.153 | 1053 | 1.856 | 0.152 | | 0.24 [-0.063, 0.543] |
| | 18F - 2F | | 1:1 | -2.075 | 0.153 | 1053 | -13.594 | < 0.001 | *** | -1.755 [-2.058, -1.452] |
| | 18F - 10F | | 1:1 | -2.358 | 0.153 | 1053 | -15.450 | < 0.001 | *** | -1.995 [-2.298, -1.692] |
| | 10F - 2F | | 2:1 | 0.467 | 0.153 | 1053 | 3.057 | 0.006 | ** | 0.395 [0.092, 0.698] |
| | 18F - 2F | | 2:1 | -0.333 | 0.153 | 1053 | -2.184 | 0.074 | . | -0.282 [-0.585, 0.021] |
| | 18F - 10F | | 2:1 | -0.800 | 0.153 | 1053 | -5.241 | < 0.001 | *** | -0.677 [-0.980, -0.374] |

Pooled SD for computing Cohen's d: 1.182

P-value adjustment: Tukey HSD

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024a).

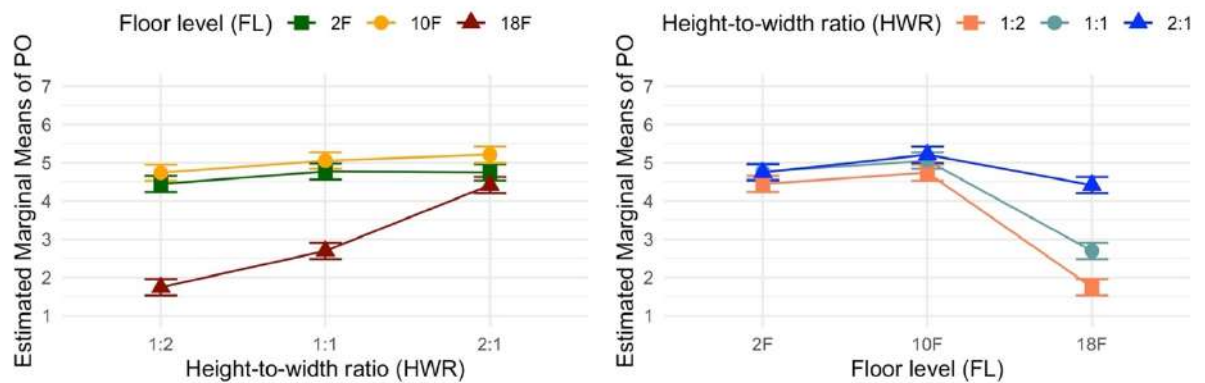


Figure 6.9: Interaction Effect of HWR and FL on Perceived Oppressiveness (PO).

Source: F. Wang & Munakata (2024a).

The bar chart depicted pairwise comparisons of Estimates and Cohen's d for interaction effects between HWR and FL on PO (Figure 6.10).

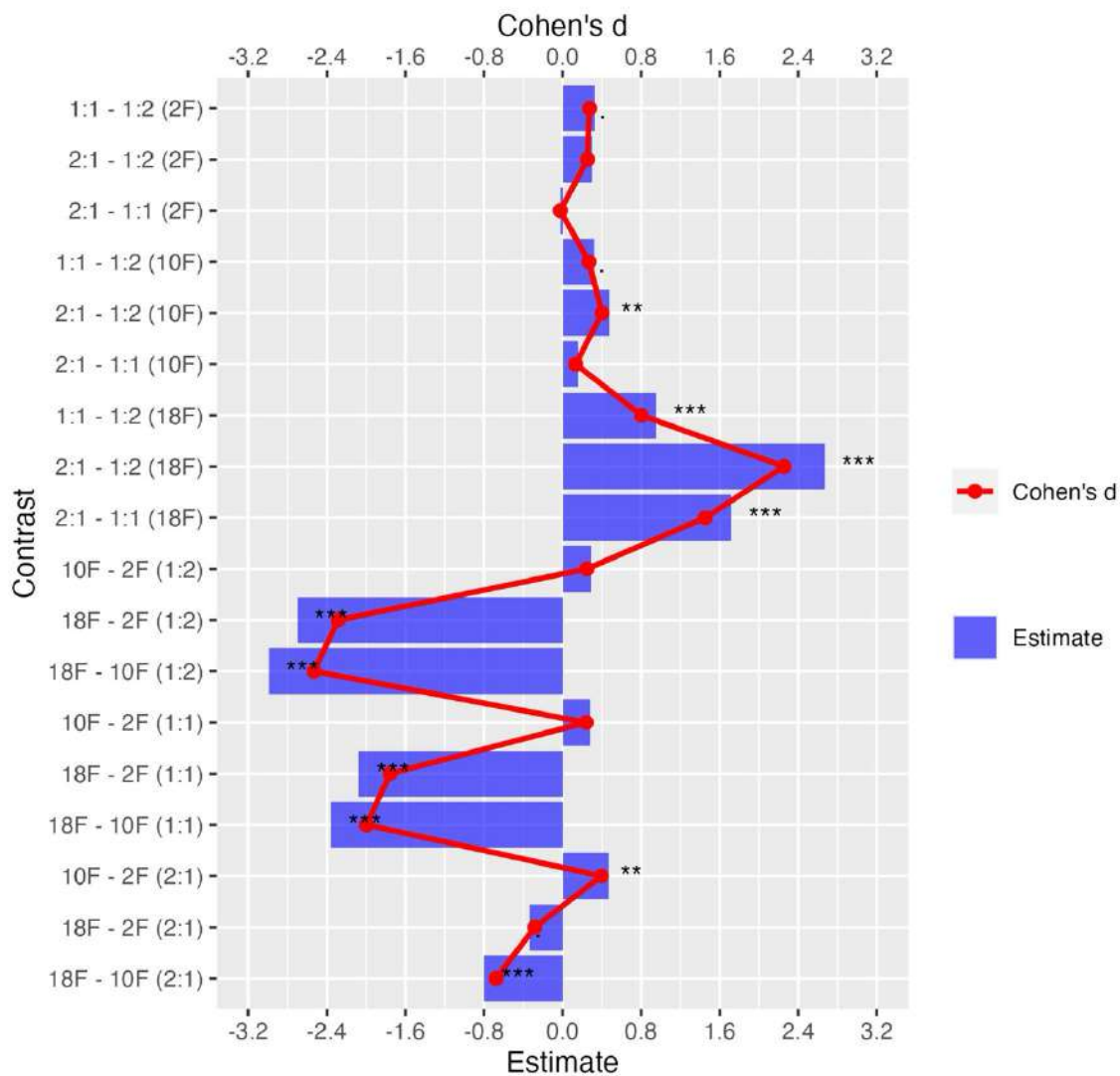


Figure 6.10: Bar Chart of Estimates and Cohen's d for Interaction Effects of Building Layout (BL) and Building Spacing (BS) on Perceived Oppressiveness (PO).

Source: Created by the Author.

6.2.2. Facade Characteristics and Observed Factors as Predictors of PO

In the nonlinear regression analysis, Perceived Oppressiveness (PO) was treated as a dependent variable. The independent variables included the Window-to-Wall ratio (WWR), Height-to-Width Ratio (HWR), and Floor Level (FL). Scatter plots were created for each pair to understand the relationships between these variables (Figure 6.11). The Exploratory Data Analysis (EDA) revealed that WWR and HWR have linear relationships with PO, whereas

FL exhibited a nonlinear relationship with PO. Various model fittings indicated that a second-degree polynomial model best predicted PO ($p < 0.001$). Consequently, the specific multiple nonlinear regression model for PO was expressed as follows:

$$Y_{PO} = \beta_0 + \beta_1 \times WWR + \beta_2 \times HWR + \beta_3 \times FL + \beta_4 \times FL^2 + \epsilon,$$

In this equation, Y_{PO} was the response variable. WWR, HWR, and FL were continuous independent variables, where FL^2 represented the quadratic term. The intercept was denoted by β_0 , and the coefficients for the respective variables were β_1 , β_2 , β_3 , β_4 , and β_5 . The error term was represented by ϵ .

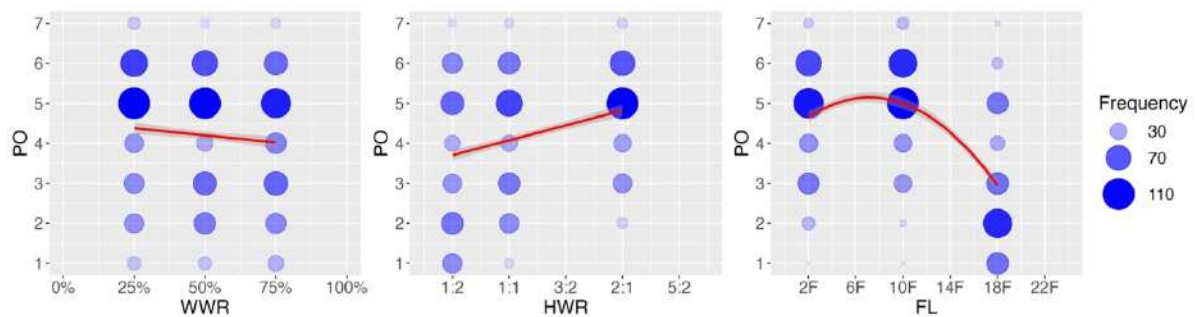


Figure 6.11: Scatter Plots with Regression Lines and 95% Confidence Intervals for PO.

Source: F. Wang & Munakata (2024a).

For the PO model, the adjusted R-squared value was 0.392 (Table 6.7), indicating that approximately 39.2% of the variance in PO was explained by the model. The intercept, with an estimate of 3.683 (SE = 0.125, $t = 29.530$, $p < 0.001$), represented the baseline PO value when all predictors were zero. The WWR exhibited a significant negative relationship with PO (Estimate = -0.007 , $p < 0.001$), indicating that an increase of one unit in WWR was associated with a decrease in PO by 0.007 units. The HWR exhibited a significant positive relationship with PO (Estimate = 0.007 , $p < 0.001$), indicating that an increase of one unit in HWR was associated with an increase in PO by 0.007 units. The polynomial terms of FL significantly impacted PO, with the first term (Estimate = -22.850 , $p < 0.001$) and the second term (Estimate = -18.570 , $p < 0.001$).

Table 6.7: Effects of Window-to-Wall Ratio (WWR), Height-to-Width Ratio (HWR), and Floor Level (FL) on Predicting Perceived Oppressiveness (PO) (N = 1080).

| | Estimate | Std. Error | t value | p | | VIF |
|----------------|----------|------------|---------|---------|-----|-------|
| (Intercept) | 3.683 | 0.125 | 29.530 | < 0.001 | *** | |
| WWR | -0.007 | 0.002 | -3.742 | < 0.001 | *** | 1.000 |
| HWR | 0.007 | 0.001 | 12.048 | < 0.001 | *** | 1.000 |
| poly (FL, 2) 1 | -22.850 | 1.265 | -18.059 | < 0.001 | *** | 1.000 |
| poly (FL, 2) 2 | -18.570 | 1.265 | -14.679 | < 0.001 | *** | 1.000 |

Adjusted R-squared: 0.392

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024a).

Graphical analysis illustrated the predictions of PO based on facade characteristics and viewing floor levels (Figure 6.12). The model treated WWR, HWR, and FL as interval variables. In order to visualize the impact of three continuous independent variables on the dependent variable, this study plotted the predictions of WWR and FL on PO for various HWR ratios. Specifically, this study examined HWR ratios of 1:2, 1:1, 3:2, 2:1, 5:2, and 3:1 in 2D graphs. The graphs depicted WWR ranging from 0% to 100% and FL ranging from 1F to 20F, with each floor having a height of 4.5 meters.

In the PO model, the contour lines of the predicted PO value presented an inverted U shape. When FL and WWR were constant, the predicted value of PO increased as HWR changed from 1:2 to 1:1, 3:2, 2:1, 5:2, and 3:1. When HWR and FL were constant, the predicted value of PO decreased as increasing WWR. When WWR and HWR were constant, the predicted value of PO initially increased with rising FL before declining after reaching a certain threshold.

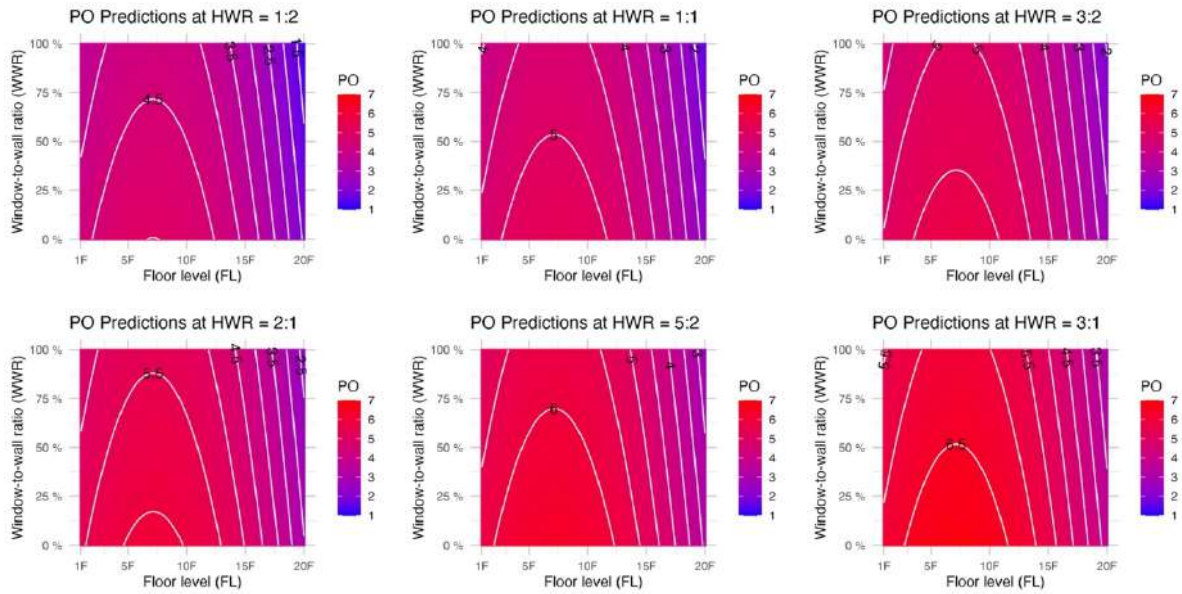


Figure 6.12: Effects of WWR, HWR, and FL on Perceived Oppressiveness (PO).

Source: F. Wang & Munakata (2024a).

6.2.3. Prediction of PO by Visual Elements (SR, BR, and GR) on PO

In the stepwise multiple linear regression analysis, Perceived Oppressiveness (PO) was dependent variables. The independent variables included three visual elements: Sky Ratio (SR), Building Ratio (BR), and Greenery Ratio (GR). The mean value of each scene's PO was used to represent the overall oppressiveness.

The final stepwise regression analysis model identified significant predictors of PO, achieving an adjusted R-squared value of 0.709 (Table 6.8). This indicated that approximately 70.9% of the variance in PO was explained by the model. The analysis revealed that two variables—SR and BR—are significant predictors of PO. Conversely, GR was excluded from the model as it was deemed a non-significant contributor, lacking statistically significant linear relationships with PO.

The intercept, with an estimate of 2.314 ($p = 0.009$), represented the baseline PO value when all predictors are zero. The predictor SR exhibited a significant negative relationship with PO (Estimate = -0.070 , $p < 0.001$), indicating that each unit increase in SR leads to an average

decrease of 0.070 units in PO. Conversely, BR had a positive effect on PO (Estimate = 0.127, $p < 0.001$), suggesting an average increase of 0.127 units in PO per unit increase in BR. The variance inflation factor (VIF) values for all predictors were 1.006, indicating that multicollinearity was not a significant concern in this model.

Table 6.8: Significant Visual Elements for Predicting Perceived Oppressiveness (PO) (N = 27).

| | | Estimate | Std. Error | t value | p | | VIF |
|----|-------------|----------|------------|---------|---------|-----|-------|
| PO | (Intercept) | 2.314 | 0.815 | 2.839 | 0.009 | ** | |
| | SR | -0.070 | 0.010 | -6.642 | < 0.001 | *** | 1.006 |
| | BR | 0.127 | 0.025 | 5.085 | < 0.001 | *** | 1.006 |

Adjusted R-squared (PO): 0.709

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: F. Wang & Munakata (2024a).

The bar chart provided illustrates the coefficient estimates from the regression analysis predicting PO based on significant predictor variables (Figure 6.13). The estimates provided a quantifiable measure of how much each predictor variable influences the dependent variable. The magnitude of the estimates showed that BR has a significant positive effect on PO, followed by SR with a significant negative effect on PO.

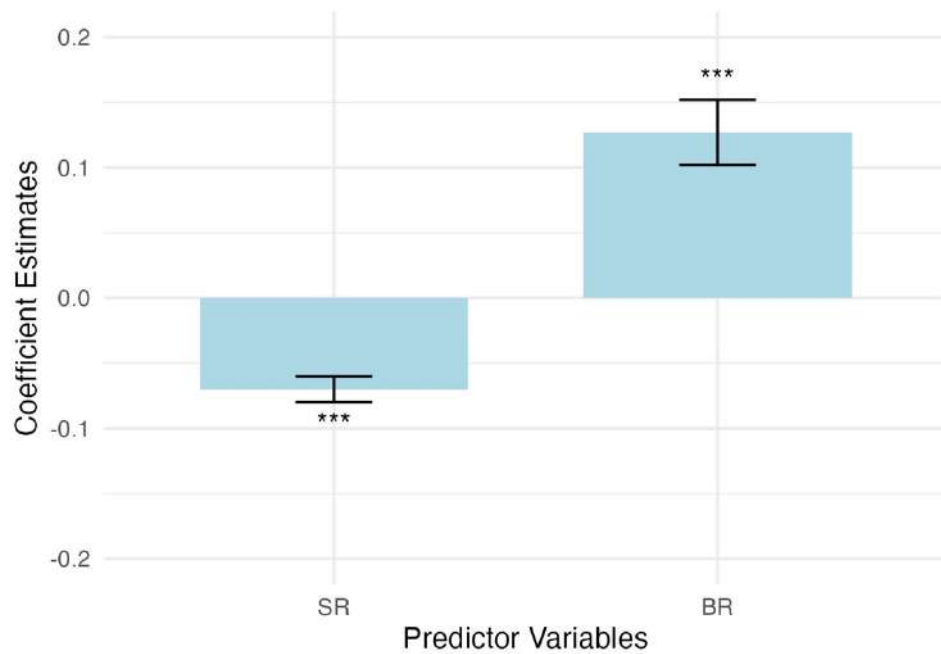


Figure 6.13: Bar Chart of Coefficient Estimates for Visual Elements Predicting PO.

Source: Created by the Author.

6.2.4. Relationship between PO and EP

The relationship between Perceived Oppressiveness (PO) and Environmental Preference (EP) was examined using Pearson's correlation coefficient. The analysis showed a significant negative correlation (Pearson's $r = -0.627$, 95% CI $[-0.662, -0.589]$, $p < 0.001$, $N = 1080$) between PO and EP (Figure 6.14). This strong inverse relationship indicated that as perceived oppressiveness increases, environmental preference decreases.

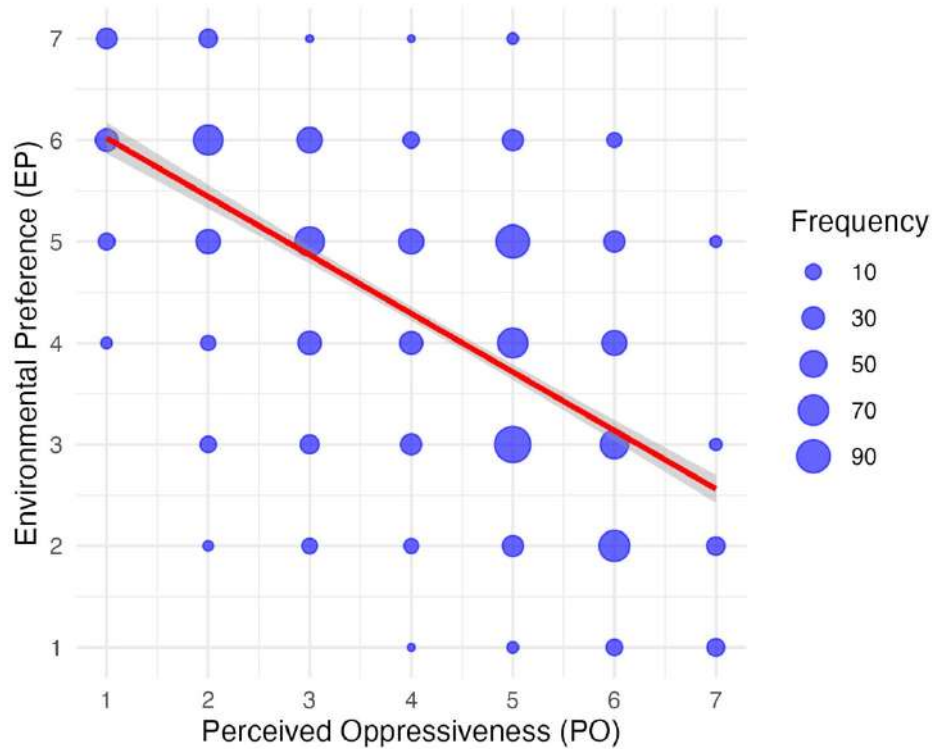


Figure 6.14: Scatter Plot with Prediction Line for Correlation Analysis.

Source: Created by the Author.

6.3. Discussion

This study examined how facade characteristics, floor levels, and visual elements affect perceived oppressiveness. The following sections provide observations and conclusions based on the results.

6.3.1. Effects of Facade Characteristics and Floor Levels on Perceived Oppressiveness (PO)

6.3.1.1. Influence of Window-to-wall ratio (WWR), Height-to-Width Ratio (HWR), and Floor Level (FL) on PO

The main effects of Window-to-Wall Ratio (WWR) on Perceived Oppressiveness (PO) were significant ($F(2, 1053) = 8.239, p < 0.001, \eta^2p = 0.015$). In line with Hypothesis 3-1, raising the WWR decreased oppressiveness. Buildings with a higher window-to-wall ratio are generally office or commercial complexes, while those with a lower WWR are often religious or residential structures (Şen et al., 2011). Perceptions are influenced by variations in this

ratio: a higher window-to-wall ratio elicits feelings of lightness, whereas a lower window-to-wall ratio produces feelings of heaviness (Bacow, 2013). High-rise office buildings often have a higher window-to-wall ratio due to their larger volume. In contrast, residential buildings typically have a lower window-to-wall ratio, offering stability and security.

The main effects of the Height-to-Width Ratio (HWR) on Perceived Oppressiveness (PO) were significant ($F(2, 1053) = 84.890, p < 0.001, \eta^2p = 0.139$). A higher HWR heightened the sense of oppressiveness. Previous literature indicated that building height impacts perceived oppression more than width (Zarghami et al., 2019). When the height was fixed, the width of 20 m was a critical threshold beyond which the oppressive effect increased significantly (Zarghami et al., 2019). When the height is constant and the width is varied, a lower height-to-width ratio is associated with increased feelings of oppression. In contrast, when the width is constant and the height is varied, a higher height-to-width ratio is associated with increased oppression (Zarghami et al., 2019). Compared to earlier studies, this study used an experimental setup that changed the width and height simultaneously while keeping the facade area constant. Under this condition, increasing the height-to-width ratio resulted in increased perceived oppressiveness (F. Wang & Munakata, 2024a).

The main effects of Floor Level (FL) on Perceived Oppressiveness (PO) were significant ($F(2, 1053) = 309.988, p < 0.001, \eta^2p = 0.371$). The relationship between perceived oppressiveness and floor level was not linear, consistent with the findings of Experiment 2. Perceived oppressiveness varied across floor levels: PO was highest on the 10th floor, followed by the 2nd floor, and lowest on the 18th floor.

6.3.1.2. Influence of Interaction Effects on PO

The interaction between the Height-to-Width Ratio (HWR) and Floor Level (FL) on Perceived Oppressiveness (PO) was significant ($F(4, 1053) = 39.873, p < 0.001, \eta^2p = 0.132$). Specifically, on the 18th floor, the HWR of 2:1 resulted in significantly higher PO

than the HWR of 1:2 and 1:1. On the 10th floor, the HWR of 2:1 resulted in significantly higher PO than the HWR of 1:2. This result suggests that the effect of height-to-width ratio on perceived oppressiveness is significant at higher viewing floors, but not significant at lower viewing floors (F. Wang & Munakata, 2024a).

For occupants on lower floors, the sense of oppression caused by the height-to-width ratio is not significant due to the limited viewing range of window views or greenery outside the window. However, for occupants on higher floors, the main contents of the window views change to buildings or skies, leading to the height-to-width ratio significantly impacting perceived oppressiveness.

6.3.2. Predicting PO through Multiple Nonlinear Regression Model

The multiple nonlinear regression analysis examined the impact of facade characteristics and viewing Floor Level (FL) on Perceived Oppressiveness (PO). The Exploratory Data Analysis (EDA) indicated that the Window-to-Wall Ratio (WWR) and Height-to-Width Ratio (HWR) exhibited a linear relationship with PO. In contrast, FL exhibited a nonlinear relationship with PO.

The Graphical analysis predicted PO values for various WWR, HWR, and FL combinations. The value of PO varies with FL in an inverted U-shape, showing that PO increases with the floor level up to a certain point before decreasing. As the window-to-wall ratio increases, the sense of oppression decreases, while as the height-to-width ratio increases, the sense of oppression increases. This finding provides a reference for high-rise buildings planning that promote positive psychological impressions.

6.3.3. Quantitative Analysis of Visual Elements in Window Views

The linear regression analysis identified two significant predictors of perceived oppressiveness (PO): the Sky Ratio (SR) and Building Ratio (BR). Partial results are similar

to Experiment 2, which demonstrated that an increased sky ratio in window views reduces perceived oppressiveness, confirming Hypothesis 3-2. Viewing the sky promotes mental well-being by reducing unpleasant psychological experiences (R. Kaplan, 2001; Masoudinejad & Hartig, 2020). Broadly visible skies improve a variety of physical and perceptual qualities, including spaciousness and visual complexity (Masoudinejad & Hartig, 2020). The visibility of the skies also provides a broader view with more depth of field.

This research revealed a positive correlation between the ratio of buildings in window views and perceived oppressiveness. Different from the findings in Experiment 2, this experiment did not differentiate between foreground and background buildings because the area occupied by foreground buildings remained constant. Built elements, such as buildings and parking lots, are not conducive to improving preferences and psychological well-being (Lin et al., 2022). People generally believed that natural settings were more beautiful than built environments. Compared to viewing built surroundings, experiencing natural settings improves emotions and concentration (van den Berg et al., 2003).

The high levels of multicollinearity between the Greenery Ratio (GR), Sky Ratio (SR), and Building Ratio (BR) in this study excluded the GR from being a predictor of PO. By eliminating predictors with little contributions to explanatory power, the stepwise regression method used in the analysis tends to favor predictors that best explain the variance in the dependent variable. Different from findings in existing literature, greenery did not significantly affect oppressiveness. Previous studies demonstrated that vegetation improves psychological health and perceptions of the surroundings by reducing oppressive feelings and enhancing aesthetic quality, among other benefits (Asgarzadeh et al., 2009; Lin et al., 2022). The effects of greenery on perceived oppressiveness are affected by surrounding environments (F. Wang & Munakata, 2024a). When other environmental elements dominate, such as the sky or buildings, the perception of greenery might be diminished.

6.3.4. Negative Bivariate Correlation between PO and EP

Consistent with the findings of Experiment 2, this study found a significant negative relationship between perceived oppressiveness (PO) and environmental preference (EP). This result supports Hypothesis 3-3, indicating that as perceived oppressiveness increases, environmental preference decreases. Previous studies have shown that people avoid events that generate psychological stress that hurt their satisfactions and well-being (Zimring, 1982). Furthermore, it is discussed further in the general discussion that environmental preference is not just determined by oppressiveness.

7. General Discussion

7.1. Theoretical Contributions

7.1.1. Theoretical Expansion of ART and SRT in Urban Environments

This study expands the application of Attention Restoration Theory (ART) and Stress Reduction Theory (SRT) theories to urban environments. In previous literature, ART and SRT emphasize the positive impact of nature on psychological well-being. ART proposes that natural environments restore cognitive resources by allowing the brain to engage in involuntary attention, which recovers the directed attention system (R. Kaplan & Kaplan, 1989). SRT emphasizes that natural environments relieve physiological and psychological stress and promote emotional well-being (Ulrich, 1983, 1984).

The results of this study showed that partial exposure to natural elements within urban environments—such as green roofs and visible trees—has restorative effects (F. Wang & Munakata, 2023). Building planning measures, including staggered building layouts and greater building spacing, enhance positive psychological experiences (F. Wang & Munakata, 2024b). These planning measures are conducive to increasing green areas and broader views within the window views. In addition, building facade characteristics also have positive psychological experiences by enhancing the window-to-wall ratio and reducing the height-to-width ratio (F. Wang & Munakata, 2024a). Increasing the window-to-wall ratio creates a more transparent and lighter visual experience. In contrast, reducing the height-to-width ratio provides a more complex and richer visual composition, such as the sky, vistas, and vegetation. These findings expand the application of ART and SRT in urban environments. In urban settings, especially high-rise buildings, residents may not have total immersion in natural landscapes but can still experience psychological benefits from the presence of natural or built elements.

7.1.2. Relationship Between Perceived Oppressiveness and Environmental Preference

This study investigates the relationship between perceived oppressiveness and environmental preference in urban and high-rise building environments. The results showed negative relations between perceived oppressiveness and environmental preference. Under different experimental conditions, oppressive environments receive lower preference ratings and vice versa. This finding expands the existing literature on the relationship between subjective impressions.

Furthermore, perceived oppressiveness is not the only determinant of environmental preference. People may dislike a specific environment because it feels threatening, unsafe, noisy, or unattractive. Although perceived oppressiveness and environmental preference have an inverse relationship, both are influenced by diverse and different environmental and psychological factors.

7.2. Practical Implications

7.2.1. Integrating Green Roofs and Biodiversity in Urban Design

Urbanization transforms cities into densely built environments, lacking natural elements or greenery. This study suggests that incorporating green roofs into urban environments improves the psychological well-being of urban dwellers. Green roofs, particularly garden roofs, provide diversified plant species, meeting aesthetic needs while promoting ecological sustainability.

Integrating green roofs into building design requires structural, functional, and aesthetic considerations to ensure compatibility with architectural and environmental objectives. Architects first examine the building's structural capabilities to sustain the additional loads associated with green roofs, which include vegetation, substrate, and water retention. For retrofitting projects, lightweight green roof systems or structural reinforcements may be required, whereas new construction allows for optimum designs that seamlessly include green

roofs. Drainage systems, waterproofing layers, and roof slopes should all be considered early in the design process to avoid long-term problems like water infiltration and structural instability. Green roofs have multiple functions to meet environmental and social needs. As recreational or public gardens, green roofs promote social interaction and improve user well-being. In addition, incorporating green roofs into building designs enhances visual appeal while achieving sustainability goals.

Designing a green roof requires understanding the environment and climate to ensure ecological performance. Plant selection should be based on local climate conditions, with drought-tolerant species preferred in arid regions and various vegetation combinations in temperate regions. Roof microclimates, such as wind and solar exposure, must also be considered to maintain plant growth. Architects are essential in facilitating collaboration between engineers, landscape architects, and ecologists to ensure that green roof designs are technically feasible and meet larger ecological goals.

These findings provide a direction for architects and urban planners to use green roofs as optional design features contributing to ecological and psychological health. Green roofs incorporate various plant species to enhance the visual appeal and bring ecological benefits such as purifying the air and regulating the temperature of the microclimate.

7.2.2. Urban Planning Measures to Reduce Oppressiveness in High-Rise Living

When window views in high-rise living environments are obstructed, creating an oppressive feeling. Appropriate planning measures—staggered building layout, increased building spacing, and maximizing natural views—improved urban residents' visual quality and mental well-being.

The staggered building layout alleviates the problem of obstructed window views for most residents, especially those living in the center of the buildings. Meanwhile, the staggered

building layout lessens visual monotony and provides windows with a wider variety of interesting views. For residents living at both ends of the building, a combination of buildings of different widths and heights is designed to enhance the sense of visual openness and reduce the feeling of oppression. At the same time, the quality of the window view can be improved by strengthening the natural plant configuration at both ends of the building. Building layouts designed with thoughtfulness disrupt the rigid patterns of high-rise structures, introducing visual vitality and spatial depth while enhancing indoor comfort by getting more sunlight.

The quality of window views in high-rise constructions is enhanced by increasing building spacing. Wider sightlines and less sense of congestion are made possible by greater spacing, which lowers the density of visual obstructions. Additionally, this architectural element enhances indoor environmental quality and energy efficiency by promoting natural ventilation and daylighting. Architects can improve spacing in heavily crowded urban settings by incorporating open courtyards or green spaces between buildings.

Optimizing natural views from windows requires capturing neighboring scenery, such as parks, lakes, or mountains. Architects can achieve this goal by orienting buildings and window locations to complement the surrounding natural elements. Furthermore, even in limited urban environments, adding biophilic design features—like rooftop gardens or living walls visible from windows—can strengthen inhabitants' ties to the natural world.

The dense buildings prevent residents from having a broad view of natural light or the sky. This study suggests that staggered buildings and increased building spacing reduce the perception of crowding and oppression. In addition, natural elements around high-rise buildings enhance psychological well-being and reduce oppressiveness.

7.2.3. Facade Design for Psychological Comfort in High-Rise Buildings

This study investigates the effects of facade characteristics—window-to-wall and height-to-width ratios—on the perceived oppressiveness of high-rise building window views. The results showed that a higher window-to-wall ratio reduces the sense of oppression, while a higher height-to-width ratio intensifies it.

Higher window-to-wall ratios in surrounding buildings enhance visual openness and create a sense of spaciousness. At the same time, glass structures contribute to a feeling of lightness compared to heavier materials like concrete. Higher window-to-wall ratios reduce feelings of confinement and promote psychological comfort, particularly in high-density urban settings where expansive views are often limited. In contrast, increased height-to-width ratios intensify oppressiveness because verticality dominates the visual field. This effect is especially noticeable in places where tall, narrow buildings are grouped together because they can make the region visually unpleasant and put occupants under psychological stress.

Adequate window-to-wall ratios should be incorporated into surrounding structures to improve visual permeability. Meanwhile, the impact of dense urban constructions can be mitigated by adding rooftop plants, vertical gardens, or other restorative components. Urban planning should also promote a variety of building heights and forms and discourage the misuse of higher height-to-width ratios to create a more dynamic and harmonious skyline that lessens monotony and psychological discomfort. This study encourages architects and urban planners to balance window-to-wall and height-to-width ratios to enhance the positive psychological effects of high-rise buildings.

7.2.4. Nonlinear Relationship Between Viewing Floor Level and Perceived Oppressiveness in High-Rise Design

The nonlinear relationship between floor level and perceived oppressiveness provides a reference in designing high-rise buildings. Oppressiveness increases at first with the rise of

viewing floors; after reaching a certain threshold, oppressiveness decreases with increased viewing floors. The higher perceived oppressiveness of the middle floors may be attributed to the different visual elements in the window views, such as the sky, greenery, and buildings.

High-rise buildings, especially on the middle floors, give people a sense of oppression and require a comprehensive strategy that combines building layout, aesthetic intervention, and environmental integration. By providing broader and less obstructed views, staggered building layouts and greater building spacing can significantly reduce the visual dominance of nearby buildings. Appropriate building layout provide a more open and comfortable living space by enhancing access to natural light and lessening the feeling of enclosure.

The aesthetic intervention improves the residents' visual experiences. The vertical gardens and green facade create a peaceful, natural setting that lowers stress and enhances mental well-being. In the same way, middle-floor balconies and terraces offer private outdoor spaces that break up the monotony of the constructed environment and give a sense of the outdoors.

Environmental integration is another essential element in lessening perceived oppression. Near high-rise constructions, urban greenbelts, parks, and water features provide middle floors with calming vistas while counteracting the dominance of the surrounding buildings. For interiors, skylights and light wells provide access to natural light and maintain a connection to the external environment, even in spaces with limited outward views. High-rise building occupants' mental health can be improved, and oppression can be decreased by incorporating these strategies.

7.3. Limitations

This study has several limitations that may affect the broader applicability of its findings. Firstly, using VR headsets and smartphones to simulate environments presents a significant limitation. These devices are effective at recreating visual stimuli but fail to capture other

crucial sensory inputs, such as sound, smell, or temperature, which are essential for fully understanding the environmental impacts on mental health. Moreover, limitations such as screen resolution, device size, and the inability to provide complete immersion may have influenced participants' experiences and responses.

Secondly, the experimental design is limited to using fixed indoor viewpoints. Specifically, this design did not account for the variability in perspectives in real indoor environments, where the observer's position can significantly affect how they perceive and interact with the space. In addition, the simulated environments were presented within a fixed time frame without considering variations across different times of day (e.g., nighttime), seasons, long-term exposure, and outdoor viewpoints. These factors could have influenced participants' perceptions and responses.

Furthermore, the sample used in this study limits its demographic characteristics. In particular, the study focused exclusively on university students, which reduces the diversity of perspectives and may not reflect the experiences of broader populations.

Finally, the study's focus on specific environmental features limits its scope. For example, it primarily examined roof types, planning measures, and facade characteristics, neglecting other potential factors, such as dynamic external environments or auditory stimuli, which could also influence mental health.

7.4. Future Research

Further research will build on the doctorate study, examining the relationship between built environments and mental health. In particular, the study will conduct the effects of various garden roof designs on mental health, emphasizing specific design tactics. Variations in spatial arrangements, such as linear versus centralized layouts, vegetation density and layering, and adding features like seating areas, shade pavilions, and water features, are some

examples of these tactics. Further research will also explore the psychological effects of biodiversity within rooftop gardens, examining whether a mix of flowering plants, shrubs, and trees contributes to more significant stress reduction and mental restoration compared to uniform vegetation types.

Additionally, future research will explore broader planning measures to understand the relationship between urban configurations and psychological outcomes. The broader planning measures will include large-scale urban planning approaches, such as the spatial distribution of green spaces within city blocks, and the study of building combinations, such as clustered versus dispersed arrangements. Future research will assess vegetation placement with pedestrian pathways, windows, and communal areas to identify optimal strategies for integrating greenery into urban environments.

Furthermore, future research will expand to examine the possibilities of facade design in more detail. The psychological impact of material properties such as reflectivity, texture, color, and transparency will be analyzed, which may vary depending on cultural context or environmental conditions. The complexity of facade elements will also be explored, including pattern, structure, and the interplay of light and shadow.

8. Conclusion

This study, through the three experiments, highlights the relationship between urban citizens' subjective impressions and surrounding architectural features. Although high-rise buildings solve the issue of limited urban space, they negatively impact the living experience due to crowded surroundings and obscured window views. This study explores reasonable methods to improve psychological well-being. Integrating roof types, planning measures, and facade characteristics creates psychologically sustainable urban environments. Cities can be made healthier and more livable by improving surrounding architectural features, which will help to maintain a balance between urban growth and the well-being of citizens.

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Appendix 1

Questionnaire of Experiment 1

Q1. Please rate the *Perceived Sensory Dimensions (PSDs)* for this image.

The items are rated based on the level of agreement or disagreement using a 5-point Likert-type scale, ranging from "Strongly Disagree (= 1)" to "Strongly Agree (= 5)."

1. Nature dimension

- 1-1. An environment with natural qualities.
- 1-2. An environment with wild and untouched qualities.
- 1-3. Free growing vegetation.

2. Culture dimension

- 2-1. An environment with cultural features, such as fountains, statues.
- 2-2. An environment has the characteristics of a city park.
- 2-3. Decorated with ornamental plants or flowers.

3. Prospect dimension

- 3-1. An environment with open views.
- 3-2. Vistas over the surroundings.
- 3-3. Plane and well-cut grassy surfaces.

4. Social dimension

- 4-1. Possible to watch entertainment or exhibitions.
- 4-2. An abundance of people and movements in the environment.
- 4-3. There are several seats and benches.

5. Space dimension

- 5-1. The environment is experienced as spacious and free.

5-2. The environment has lots of trees.

5-3. Places where people can gather.

6. Rich in Species dimension

6-1. Various species of plants.

6-2. Feeling exist various animals, such as birds, insects, etc.

7. Refuge dimension

7-1. An environment with many bushes.

7-2. It feels safe in this environment.

8. Serene dimension

8-1. The environment is silent and calm.

8-2. The density of buildings and plants is moderate, uncrowded.

8-3. Not disturbed by traffic noise.

Q2. Please rate the *Subjective Restoration* for this image.

The items are rated using either a 5-point Semantic Differential (SD) method or a 5-point Likert-type scale. For the Likert-type scale, responses range from "Strongly Disagree (= 1)" to "Strongly Agree (= 5)."

1. How would you describe your emotional response?

1-1. I feel grouchy - good natured.

1-2. I feel anxious - relaxed.

2. How would you describe your cognitive response?

2-1. I am interested in the present scene.

2-2. I feel attentive to the present scene.

3. How would you describe your physiological response?

3-1. My breathing is getting faster.

3-2. My hands are sweating.

4. How would you describe your behavioral response?

4-1. I would like to visit here more often.

4-2. I would like to stay here longer.

Q3. Please provide your basic information.

Age

Gender (Male/Female)

Education level (High school / Bachelor / Master / Doctor / Other)

Major

Current living floor level

Ideal living floor level (Total of 30 floors)

Appendix 2

Questionnaire of Experiment 2

Q1. Please rate your *subjective impressions* of the window views.

The items are assessed using a pairwise Semantic Differential (SD) method with a 7-point rating system.

1. How much oppressiveness do you experience?

(Very oppressive - Not at all oppressive)

2. How dissatisfied are you with the level of oppressiveness?

(Very dissatisfied - Not at all dissatisfied)

3. How much openness do you experience?

(Very open - Not at all open)

4. How dissatisfied are you with the level of openness?

(Very dissatisfied - Not at all dissatisfied)

5. How much pleasantness do you experience?

(Very pleasant - Not at all pleasant)

6. How much do you prefer your experience?

(Strongly prefer - Not at all prefer)

Q2. Please provide your basic information.

Age

Gender (Male/Female)

Grade (Bachelor / Master / Doctor / Other)

Major

Appendix 3

Questionnaire of Experiment 3

Q1. Please rate your *subjective impressions* of the window views.

The items are assessed using a pairwise Semantic Differential (SD) method with a 7-point rating system.

1. How much oppressiveness do you experience?

(Very oppressive - Not at all oppressive)

2. How much do you prefer your experience?

(Strongly prefer - Not at all prefer)

3. How interesting do you find your experience?

(Very interesting - Not at all interesting)

4. How much relaxation do you experience?

(Very relaxing - Not at all relaxing)

5. How much complexity do you experience?

(Very complex - Not at all complex)

6. How spacious do you find the experience?

(Very spacious - Not at all spacious)

Q2. Please provide your basic information.

Age

Gender (Male/Female)

Grade (Bachelor / Master / Doctor / Other)

Major

Appendix 4

Published papers for thesis

[1] Wang, F., & Munakata, J. (2024). Assessing effects of facade characteristics and visual elements on perceived oppressiveness in high-rise window views via virtual reality. *Building and Environment*, 266, 112043. <https://doi.org/10.1016/j.buildenv.2024.112043>

[2] Wang, F., & Munakata, J. (2024). Exploring perceived oppressiveness of high-rise window views: A virtual reality assessment of planning measures and visual elements' influence. *Journal of Building Engineering*, 96, 110476. <https://doi.org/10.1016/j.job.2024.110476>

[3] Wang, F., & Munakata, J. (2023). Simulated window views from different building floors: How roof types of surrounding buildings associate with subjective restoration. *Urban Forestry & Urban Greening*, 89, 128096. <https://doi.org/10.1016/j.ufug.2023.128096>