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Restorative Interior Design to Renew Attention and Reduce Stress in Small Residential Units

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Abstract

The shift in lifestyle due to urbanization and the recent pandemic has increased demand for small residential units suitable for remote work and longer stays. Restorative environments have gained importance within these spaces as they impact productivity, reduce fatigue, and alleviate stress. This study aims to identify effective restorative environments for small residential units, deepening our current understanding about contributions of interior design to personal well-being. Six virtual models combining Rectilinear and Curvilinear forms with Minimal, Natural, and Rustic styles were created. A total of 89 participants with lockdown or remote work experience evaluated these environments using VR devices and a PRS questionnaire. Results showed higher ratings for all virtual restorative environments compared to the non-restorative control design. The Rectilinear form with Minimal style and Curvilinear form with Natural style received the highest ratings. Surprisingly, nature analogues using curves and natural materials did not produce expected outcomes, highlighting the importance of integrating natural elements, considering individual preferences, and ensuring environmental coherence for enhanced restorative attributes. Creating an effective restorative environment extends beyond incorporating nature-based elements. These findings offer insights for designing residential spaces that boost well-being and productivity, especially in the context of remote work and extended stays in compact residential units.

Keywords

Restorative Environment; Small residential units; Biophilic design; Residential interior design; Virtual reality; Attention Restoration Theory

1. Introduction

Over the past decade, the worldwide shift towards urban living has led to a notable increase in the population residing in multi-storey buildings (United Nations, 2022). Consequently, more individuals are choosing to live in compact residential accommodations like apartments, flats, condos, hotels, and dorms (Azmi et al., 2023) (Clinton, 2018). Despite the benefits of urban living, these smaller living spaces often are cramped, deficient in natural light and ventilation, and limited in activity, rendering them less than ideal for prolonged occupancy (Andargie et al., 2019).

The COVID-19 pandemic brought about changes in lifestyles, leading to a notable trend of remote work or study due to quarantine or social distancing and technological advantages (Routley, 2020). As people generally spend about 90% of their time indoors, mainly at home or in work settings (Leech et al., 2002), the transition to remote work has continued even after the pandemic (Gilbert, 2020). This underscores the necessity for effective adaptation to this new working model while also posing several challenges.

Extended periods of working or studying from home while residing in small living spaces, such as studio apartments, can result in various adverse effects, including feelings of isolation, confinement, boredom, reduced productivity, and elevated stress levels (Brodeur et al., 2021). Factors like limited space, inadequate ventilation, subpar lighting, and a lack of access to natural surroundings like gardens can intensify these negative emotions (Zarrabi et al., 2021), making it difficult to maintain a healthy equilibrium between work and personal life and contributing to mental exhaustion. Moreover, not all homes are adequately equipped to handle the challenges of prolonged living and working from home. The most compact living spaces such as one-room efficiencies or studios pose particulardifficulties in this aspect, with occupants reporting increased stress and decreased work efficiency (Amerio et al., 2020).

There are several potential strategies to tackle the difficulties associated with residing and working in compact residential spaces. One strategy focuses on spatial arrangement, including activities such as redecoration, furniture rearrangement, and the addition of new furnishings (Leigh, 2020). This involves establishing distinct boundaries between work and leisure areas using screens, curtains, or colors to create a sense of separation and provide privacy for individuals sharing a living space. Proper lighting and HVAC systems can address concerns about poor ventilation and lighting. (Jarutach, 2022). However, these improvements cannot solve productivity problems caused by mental fatigue and stress. Forcing oneself to focus on work or study for extended periods can lead to mental fatigue, while taking a break in the same confined space is not enough to refresh the mind. Without excursion from the unit or sufficient rest, stress can accumulate (Kaplan, 1995).

Previous research suggests integrating a restorative environment approach, known for regenerating attention from fatigue (Kaplan, 1995) and reducing stress (Ulrich et al., 1991). One can experience restoration by merely viewing elements of a restorative environment, even for a short time. Nature was confirmed to be the most effective solution followed by natural scenes, elements, forms or materials. However, the effectiveness of renewal depends on the limitations of the context. In small residential units, where space and access to outdoor areas are limited, incorporating the restorative approach for interior design presents a valuable opportunity. Reviewing social media for popular decoration styles of small residential units reveals prospective examples such as minimalism, loft or rustic, and green or natural styles. Incorporating elements of a restorative environment with these popular styles could provide a practical solution for developers and an effective solution for the occupants.

The objective of this study is to identify a successful restorative environment suitable for the interior space of a small residential unit. This is achieved by examining design components and attributes that have been studied in restorative-environment research and subsequently integrated them into the popular interior designs of small residential units. This study primarily focuses on the visual aspect of the interior environment that could be managed by the occupants without altering the structure, layout, or size of the space. The aim is to help inform the residents, the designers, or developers about interior design choice that contributes to creating a sense of restoration and improving the psychological well-being of occupants who live, work, or study for extended periods in small residential units.

2. Literature Review

The previous studies of restorative environments are described in three parts, beginning with a review of relevant studies and developments in the field of restorative environments. Secondly, we examine various media used to express restorative environments. Lastly, we discuss measurements to evaluate the effects and outcomes of restorative environments.

2.1. Restorative Environment

The idea of a restorative environment pertains to a setting that enables and encourages the rejuvenation of a person's physical, mental, or emotional health by offering a space for relaxation, rest, and the alleviation of mental fatigue and stressful circumstances (Hartig, 2004).

The concept gained prominence through Attention Restoration Theory (ART), introduced by Kaplan in 1989 and 1995. This theory suggests that an individual's attention is a finite resource that becomes depleted over time due to sustained directed attention, such as engaging in a demanding task that requires intense concentration (Hartig, 2004). This depletion leads to fatigue, stress, and a decrease in cognitive performance. However, exposure to restorative environments can reinvigorate attention and cognitive function, thereby reducing fatigue and stress. The theory suggests that restorative environments have four key components that contribute to the restorative process, namely, being-away, extent, fascination, and compatibility (Kaplan & Kaplan, 1989).

- Being-away involves intentionally distancing oneself from routine activities, aiding in alleviating attention fatigue. Physical separation is essential, but a mental shift away from concerns is equally vital for optimal effectiveness (Kaplan, 1995).
- Extent pertains to the sensation of being transported to a distinct place, engaging fully and immersing oneself in the experience (Kaplan & Kaplan, 1989). Size matters less than coherence, where elements complement each other, providing depth, richness, and a sense of scope (Celikors & Wells, 2022).
- Fascination captures effortless attention, often found in less stimulating activities, enabling reflection and rejuvenation for a fatigued mind (Kaplan, 1995).
- Compatibility refers to how well the environment aligns with an individual's needs, preferences, and goals. A highly compatible restorative environment enhances restoration and recovery, while an incompatible one can increase stress and fatigue (Kaplan, 1995).

Kaplan (1995) concluded that the fundamental elements of a restorative environment typically are found in natural settings or connected with natural aspects. Furthermore, natural environments are widely acknowledged for their restorative qualities based on the Biophilia hypothesis, which suggests that humans have an innate affinity for nature and that nature is crucial for health and well-being, aligning with evolutionary theory principles (Wilson, 1984). Nature acts as the foundational backdrop and has been extensively studied and valued for its ability to enhance restoration. Being in natural settings like parks and forests can have positive impacts on both mental and physical health. For example, Kaplan and Kaplan's (1989) study showed that walking in nature can reduce mental fatigue and enhance focus. Simply viewing natural scenes also can have restorative effects. Ulrich's (1984) research demonstrated that patients with a view of nature had quicker recovery rates compared to those with views of a brick wall. Likewise, patients in hospitals with natural views from their rooms showed lower stress levels and blood pressure (Ulrich et al., 1991). Overall, research consistently indicates that natural

environments and views generally offer more potent restorative effects compared to constructed and urban environments (Hartig et al., 1997).

Nature benefits extend beyond direct contact with the real natural environment. Viewing nature through images or screens also can restore well-being. Berto (2005) noted improved attention was associated with computer-based nature scenes compared to scenes from built environments. Felsten (2009) found simulated nature views, like murals, rated as highly restorative, especially for students. Kim et al. (2018) highlighted enhanced task performance and restorative effects using TV screens with nature views. Furthermore, integrating natural elements or indoor greenery has been observed to produce restorative outcomes. For instance, introducing indoor plants into office spaces has demonstrated considerable benefits for occupants, such as enhanced focus, concentration, creativity, and work efficiency (Hähn et al., 2021; Nieuwenhuis et al., 2014). A recent investigation revealed that having indoor plants or living walls at home during periods of confinement leads to increased positive emotions (Pérez-Urrestarazu et al., 2021).

The rising popularity of Biophilic design is attributed to its numerous benefits in blending nature with built environments. This design concept not only involves integrating various natural elements like indoor plants, nature views, sunlight, and ventilation but also includes mimicking natural elements such as organic shapes, curved lines, random patterns, and the use of materials like wood and stone. Biophilic design has gained attention in recent times and has been incorporated into many architectural endeavors. It is believed that applying Biophilic design principles can improve cognitive function, foster creativity, uplift mood, and decrease stress levels (Browning et al., 2014; Kellert, 2008).

Nevertheless, there are conflicting findings regarding the effectiveness of restorative environments. While numerous studies have highlighted the positive influence of nature on mental well-being, others have suggested that nature may not always have a positive impact. This discrepancy could be due to feelings of discomfort, uncleanliness, fear, or unfamiliarity associated with certain natural settings (Cassarino et al., 2019; Gatersleben & Andrews, 2013). Additionally, contradictory research suggests that well-designed urban spaces can be equally effective as natural environments in promoting rejuvenation (Horvat & Ribeiro, 2023; Karmanov & Hamel, 2008). This may be attributed to the aesthetic appeal and compatibility of well-designed environments, which play crucial roles in determining preferred restorative settings (Deng et al., 2020; Berto et al., 2018). These findings are supported by studies conducted by McSweeney et al. (2021) and Purcell et al. (2001), indicating that individual preferences and experiences significantly influence the ability to combat mental fatigue.

Previous research on restorative environments predominantly has concentrated on outdoor settings, with limited exploration of their applicability within compact residential units, such as studio apartments. Existing indoor environment studies primarily have centered on specific contexts, including offices (Hähn et al., 2021; Yin et al., 2019; Nieuwenhuis et al., 2014), hospital wards (Gao & Zhang, 2020), classrooms (van den Bogerd et al., 2020; Doxey et al., 2009), and working rooms (Yin et al., 2020; McSweeney et al., 2021; Kim et al., 2018). These investigations often underscore the importance of natural elements like indoor plants and outside views in fostering restorative effects. However, it remains uncertain whether these restorative environments and elements produce similar revitalizing outcomes in the unique context of small residential units, which offer a more intimate and compact living experience.

Being a very personal space, the influence of individual preferences is crucial in shaping the restorative experience, while aesthetically pleasing designs also can enhance restorative effects.

However, there are still unanswered questions that need attention to bridge the existing knowledge gaps. First, how much does personal preference affect restoration from fatigue compared to the four components of Attention Restoration Theory (ART)? Second, how effective is the Biophilic method of incorporating simulated or mimicked nature, and what are the best practices for its implementation? Lastly, which approach is the most effective and suitable for compact residential spaces—preference considerations, emphasizing direct nature incorporation, or analogues of nature?

2.2. Media

Media tools play a crucial role in exhibiting restorative environments. To experience the restoration effect, individuals must either see or engage with these environments. Researchers have employed various types of media to replicate environments, such as real-life settings, mock-ups, still images or murals, videos with projectors, and virtual reality (VR) simulations.

Physical on-site environments and mockups are regarded as the most effective means for expressing restorative effects, as they allow participants to fully engage and immerse themselves in the surroundings. However, this method can be costly and time-consuming (Boonteng & Lekagul, 2020). Still images offer a fast and cost-effective way to portray specific environments, yet they lack a perception of three-dimensional depth and may feel synthetic and less immersive. Videos and movable pictures provide a more enjoyable and immersive experience than static images but still lack a sense of three dimensions.

Virtual reality (VR) is the latest tool for creating restorative environments and offers a highly realistic simulation that encompasses the entire visual field, providing the viewer more viewing area and freedom to focus. VR allows researchers to test and experience environments that are still in the conceptual stage, with the ability to exert control over numerous variables (Yin et al., 2019). Research has indicated that VR can offer restorative benefits comparable to real natural settings (Yin et al., 2018). However, challenges include the need for intricate rendering of details to boost realism. Additionally, VR technology still struggles to accurately replicate visual contrast due to the self-luminance of the VR headset (Abd-Alhamid et al., 2019). Furthermore, certain participants may encounter motion sickness if they are not familiar with using VR (Browning et al., 2020).

In summary, media tools are vital for creating restorative environments in research, each method having its strengths and limitations. Virtual Reality (VR) stands out for its potential in creating realistic simulations and testing environments at a reasonable cost. For the benefit of evaluation by comparing the effects of the simulated environments within the same media, all the reviewed media are valid research instruments.

2.3. Measurements

There are three popular approaches to evaluating the effects of a restorative environment: cognitive performance tests, physiological response, and psychological response.

Cognitive performance tests best reflect productivity, since they measure the results of cognitive tasks. Cognitive performance tests such as the Sustained Attention to Response Test (SART) and the M-Digit Symbol Substitution Test (DSST) evaluate attention capacity by measuring focus and memory before and after exposure to environments. Improved scores due to restorative settings are expected. While these tests effectively assess fatigue and stress, they may be susceptible to learning effects (Berto, 2005).

The physiological response involves measuring automatic body reactions to stimuli and considers variables including heart rate, blood pressure, electrodermal activity, or brain wave pattern. It assesses an individual's response signal when experiencing different environments, usually by inducing stress and then observing signal changes before and after exposure to the environments (Yin et al., 2020; Huang et al., 2020; McSweeney et al. 2021). While this approach yields dependable outcomes, it can be responsive to additional factors, such as alterations in the surroundings or the excitement of the study participants (Ulrich et al., 1991).

Psychological responses evaluate the effects of restoration by measuring the perceptions, feelings, or thoughts of individuals in different environments. The Perceived Restorativeness Scale (PRS) is a popular psychological measurement that assesses whether participants believe that the settings led to feelings of restoration. PRS questionnaires are available in diverse versions and lengths, often focusing on the four key components of the Attention Restoration Theory (ART) (Felsten, 2009; Berto, 2005; Hartig et al., 1997). While psychological measurements can provide valuable insights, they may be influenced by individual biases, preferences, and experiences. The reliability of this approach is supported by a strong correlation between physiological and psychological measurements when evaluating restorative effects (Beil & Hanes, 2013; Chang et al.,2008; Kaplan, 1995).

3. Methodology

3.1. Factors and Attributes of Restorative-Environment Design

Building upon the literature review, we have identified several practical restorative environment topics suitable for small residential units, addressing existing knowledge gaps. These topics encompass: (1) the direct use of nature and indoor vegetation, known for their restorative effects (Yin et al., 2020; Pérez-Urrestarazu et al., 2021; Kaplan & Kaplan, 1989); (2) nature-inspired or analogous elements, including natural materials like wood and stone (Dematt**è** et al., 2018; Burnard & Kutnar, 2015), as well as forms inspired by nature (Browning et al., 2014; Kellert, 2008); and (3) preferred designs, which can influence restorative preferences (Purcell et al., 2001). These topics were analyzed, categorized by their characteristics, and further incorporated into forms and styles (Figure 1). These categories were then used to create the simulated environments for the test.

'Form' in this study consists of two categories based on physical attributes: Rectilinear and Curvilinear. Rectilinear form features straight lines and sharp corners, often associated with man-made shapes like rectangles, squares, triangles, or rectangular geometry (Figure 2). In contrast, Curvilinear form includes curved lines and rounded corners (Figure 2), commonly found in nature and associated with nature-inspired or analogous elements (Coburn et al., 2019). A study by Vartanian et al. (2013) noted that Curvilinear forms activate aesthetic perception in the human brain, encompassing curved geometry, freeform, or blob shape.

Regarding 'styles' in this study, they encompass combinations of surfaces, colors, materials, and textures that define the mood, tone, and ambience of spaces. In interior decoration, maintaining consistency in surface and material usage across various spaces can establish a distinctive style. Searching from social media such as Pinterest, three popular styles—Minimal, Natural, and Rustic (Figure 2) that are suitable for small residential units and interior decoration were identified.

The Minimalist style embodies white tones, bright spaces, and light-toned woods, aligning with current trends and popular among young adults in Thailand. This style caters to a preference for a clean look, potentially influencing their sense of restoration (Purcell et al., 2001) while incorporating fewer nature-inspired elements.

The Natural style is characterized by abundant vegetation, indoor plants, living walls, and grass carpets—directly integrating natural elements, proven effective in creating a restorative environment (Huang et al., 2020; Pérez-Urrestarazu et al., 2021; Berto, 2005; Kaplan & Kaplan, 1989).

The Rustic style embraces exposed natural materials and textures like wood and stone in their original state (Demattè et al., 2018; Burnard & Kutnar, 2015). It features rough textures and darker natural tones, presenting an alternative portrayal of nature using raw materials and rustic elements (Browning et al., 2014; Kellert, 2008).

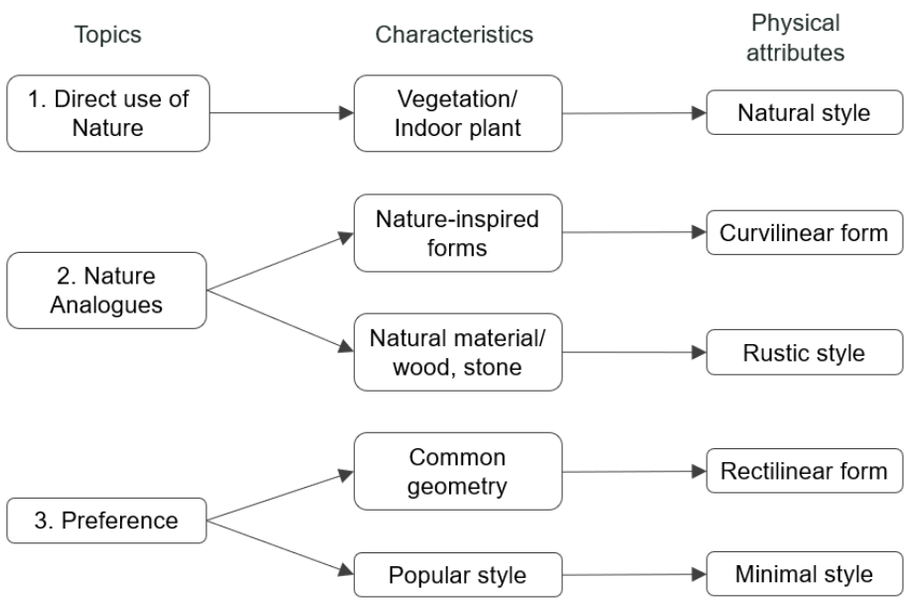

Figure 1. Analysis diagram of selected restorative environment topics to the physical attributes of Forms and Styles.

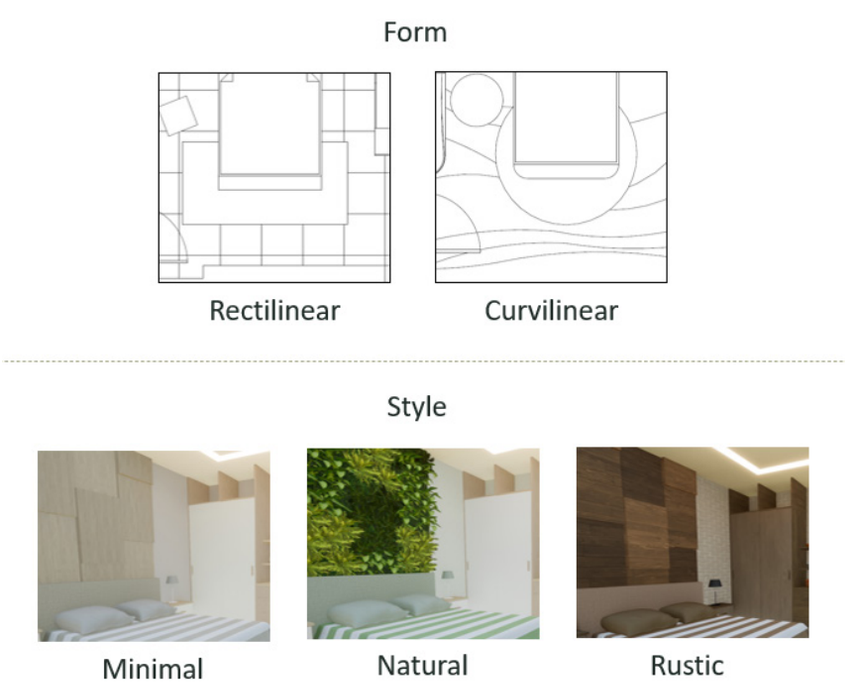

Figure 2. Examples of Forms and Styles considered in this study.

3.2. Hypothesis

Based on the literature review, we formulated hypotheses. Firstly, we hypothesized that all restorative environments for small residential contexts would yield better restoration outcomes than the original room without restorative environment, as indicated by previous studies (Yin et al., 2019; Felsten, 2009; Berto, 2005; Kaplan & Kaplan, 1989). Particularly, in the context of smaller residential spaces, the effects of nature are likely to be greater.

Secondly, we hypothesized that the environments that apply natural elements directly (Natural style) would yield the highest restorative effects, followed by those with nature-inspired features (Rustic style), and the lowest effects would be the preferred environments with minimal use of nature (Minimal style). Thirdly, the same logic applied to the Form category, where the Curvilinear form, resembling natural forms, was expected to have higher restorative effects than the Rectilinear form, representing man-made elements.

3.3. Development of Simulated Restorative-Environment Designs

The chosen case for small residential units was a studio-type dormitory room located in Hariphunchai Campus of Chiang Mai University in Lamphun, Thailand. This particular model was deemed ideal for the study due to its previous use as a quarantine facility for Chiang Mai University students and staff for a period of fifteen days during the COVID-19 outbreak. Additionally, the model environment adhered to standard dimensions and layout, measuring 20 square meters, which is typical for studio-type rooms commonly found in apartment buildings throughout Thailand.

The process of constructing restorative environments involved two primary phases. Initially, the simulated baseline model (referred to as the control model or non-restorative environment) was established by adjusting the original room internal layout, space allocation, and furniture arrangement based on the principles outlined in the space-organization approach (Leigh, 2020). The rationale behind this approach was to establish distinct working and relaxing spaces that would be well-suited for remote work and extended living (Figure 3). The next phase involved crafting the restorative environments, using the baseline model as a foundation, through various combinations of two forms (Rectilinear and Curvilinear) and three styles (Minimal, Natural, and Rustic). This process yielded six models for restorative environments: Rectilinear form with Minimal style, Rectilinear form with Natural style, Rectilinear form with Rustic style, Curvilinear form with Minimal style, Curvilinear form with Natural style, and Curvilinear form with Rustic style (Figure 4). The study encompassed a total of seven virtual experimental environment models.

The six models underwent a thorough examination by a panel of peers and experts from the fields of architecture and interior design to ensure the styles' distinctive characteristics in terms of line, shape, pattern, color schemes, surface textures, materials used, and decorations. These distinctions were evident across multiple elements, such as the floor pattern, door design, ceiling lighting, headboard wall panel, TV wall panel, sideboard, work desk, bookshelf, versatile shelf, wardrobe, bedside table, bed linen design, curtain style, and carpet layout.

Other than the differences mentioned above, the other features were controlled. Natural lighting and view through the window were well studied and confirmed as effective restorative elements by previous research, therefore, excluded from the testing variables. Color of the wall was controlled to be white except the colors of the natural materials representing the styles, such as green walls, wood panels, and brick walls. The lighting color, the brightness levels, and camera perspectives were standardized across all models, as well as ensuring that the placements, dimensions, and quantities of decorative elements and furniture were consistent across all designs.

The experimental environments were constructed using Archicad software and subsequently rendered in 360-degree visual view with 8k resolution quality for VR using Twinmotion software. The VR experience was facilitated through the use of the Meta Oculus Quest 2 head-mounted VR device.

Figure 3. Non-restorative environments (Baseline/Control model).

Figure 4. Six contested restorative environment models generated from the combination of forms and styles.

3.4 Measurements

Psychological response measurement was chosen for this study due to several considerations, including the sample size, the appropriateness for use with VR media, and constraints in accessing physiological measurement tools. The measurement method involved administering a questionnaire divided into two sections. The first section, conducted before the experiment, collected participant details and general information such as gender, age, occupation, education level, experiences during quarantine and lockdown, prior VR experiences, and preferred decoration styles. The second section of the questionnaire assessed the experimental environments using the brief Perceived Restorativeness Scale (PRS) developed by Felsten (2009). This scale was selected because of its compatibility with the experimental setup and its efficiency in terms of time and cost. The PRS consisted of five questions on a rating scale. The first four questions focused on the four components of Attention Restoration Theory (ART): being away, extent, fascination, and compatibility, while the fifth question evaluated the overall perceived restorativeness. An additional question on the rating scale assessed participants' preferences for the restorative environments (Table 1). The rating scale in the second section ranged from 1 ("Not at all") to 7 ("Very much"). After each set of rating questions, an open-ended question was included to gather comments on each experienced environment. All questions were translated from original English into Thai and the translations were validated by experts through back-translation into English (Meethong & Lekagul, 2021). The questionnaire underwent pilot testing, during which participants demonstrated comprehension and provided accurate responses to the questions.

Table 1. The second part of the questionnaire

Perceived Restorativeness Scale Questions	Restorative components
1. Some settings allow you to feel like you are far away from everyday thoughts and concerns. How much does this setting allow you to get away from it all, relax, and think about what interests you?	Being away
2. Some settings, large or small, can feel like a whole world of their own, where you can get completely involved in the setting and not think about anything else. How much does this setting feel like a world of its own?	Extent
3. How much does this setting draw your attention without effort and easily engage your interest?	Fascination
4. How much does these settings make you feel comfortable and at ease?	Compatibility
5. Overall, how much do you agree that this setting would be excellent for taking a break and restoring your ability to study for an exam or work effectively on a demanding project?	Overall perceived Restorativeness
6. How much do you prefer this setting? (additional question from PRS)	Participants' Preferences

3.5 Population and Participants

The target population for this study consisted of university students and employed individuals residing in urban areas, particularly those living in compact residential spaces and encountering difficulties in accessing outdoor green areas. The inclusion criteria were individuals residing in Chiang Mai, Thailand, who had undergone periods of quarantine, remote work, or online education for 7 to 14 days while being alone in small living accommodations. Participants were recruited via social media platforms and posters. The sample size calculation was performed using the G*Power program (Faul et al., 2009) based on our pilot study of the effect size (0.768) with Nonsphericity correction (0.505), alpha of 0.05, and 80% power of the test. This calculation yielded a sample size of 9 samples. Out of the total 101 registrations received, 10 individuals were designated for a pilot test, and 2 were excluded due to data incompleteness. This resulted in a final sample size of 89 participants

(n=89), with 58 identifying as female and 31 as male. The age range of participants spanned from 18 to 42 years, with an average age ($\underline{x}$) of 27. Half of the participants were university students, while the other half were employed individuals. All participants provided their informed consent and received compensation of 300 THB (approximately 9 USD) for their participation. The study protocol underwent review and approval by the Chiang Mai University Research Ethics Committee.

3.6 Data Collection Procedures

The data were collected during May-June, 2022, in a closed room with a comfortable temperature and stable conditions to mitigate any potential distractions. The researchers pre-configured the VR device, connecting it to a computer and establishing VR boundaries for safety. A rotating chair was provided for the participants to explore 360-degree views of the environment. Participants were individually invited to the room for the study, ensuring a disturbance-free environment without interference from others during the test. The data collection commenced upon the participants' arrival. The researchers greeted participants, provided a comprehensive explanation of all study-related steps and procedures, including associated benefits and risks, and secured their agreement through the signing of a consent form. Before accessing the designated space for the study, participants completed the initial section of the questionnaire, covering general inquiries.

Upon entering the room, researchers helped participants put on the VR device and advised them to stay seated for comfort and safety while using it. A two-minute period was allocated for participants to become acquainted with the VR equipment, during which any technical issues with VR signals or screen display were addressed. Following this, the participants were instructed to imagine that they had been living in the real environment for many days, experiencing weariness and mental exhaustion. They then explored virtual environments for about 3-5 minutes each.

Once ready to respond to the second part of the questionnaire, pre-recorded rating questions were played, and participants verbally provided their ratings and comments without removing the VR device. Researchers recorded these responses and switched the VR display to the next virtual environment. To minimize any bias, the order of environments was randomized into three sets. This process continued until all participants had experienced all seven virtual environments.

Upon completing the study, participants took off the VR device and had the option to review and amend their responses if desired. The total duration of the study for each participant ranged from approximately 20 to 30 minutes. The entire experiment was conducted in the Thai language and a total of 623 environment responses were collected.

3.7 Data Analysis

Participants' personal information was encoded to ensure confidentiality. The ratings and comments they provided for each environment were documented and arranged in a spreadsheet. Their ratings on the six questions related to restoration components (being away, extent, fascination, compatibility, overall perceived restorativeness, and preference) were then analyzed to determine the mean scores and standard deviations for each experimental setting using statistical software (Table 2). Subsequently, the mean scores were compared and evaluated using various statistical analyses, including descriptive statistics, t-tests, ANOVA, and correlations. T-tests and ANOVA were utilized to compare rating scores among different experimental environments and scenarios with similar forms and styles (Table 3). Correlation analyses were conducted to investigate relationships between the six variables (Table 4).

4. Results

4.1 Perceived Restorative Score

Referring to Table 2, the baseline model had the lowest scores among the seven experimental models. Among the six restorative environment models, excluding the baseline, the Rectilinear Minimal and Curvilinear Natural consistently scored the highest on most components. Conversely, Rustic style models consistently scored the lowest on most components, while the others had moderate scores in comparison.

Table 2. Means (SDs) of six components on different environment models

Models	Being away	Extent	Fascination	Compatibility	Restorative*	Preference	n
Baseline	3.17 (1.32)	3.85 (1.62)	2.66 (1.39)	3.38 (1.48)	3.34 (1.46) c	3.03 (1.46)	89
Rectilinear Minimal	5.25 (1.23)	5.60 (1.28)	5.45 (1.28)	5.75 (1.08)	5.73 (1.09) a	5.83 (1.30)	89
Curvilinear Minimal	5.18 (1.30)	5.45 (1.27)	5.31 (1.28)	5.52 (1.13)	5.43 (1.28) b	5.57 (1.16)	89
Rectilinear Natural	5.08 (1.25)	5.12 (1.33)	5.04 (1.34)	5.15 (1.29)	5.42 (1.28) b	5.27 (1.30)	89
Curvilinear Natural	5.40 (1.08)	5.52 (1.13)	5.35 (1.28)	5.39 (1.40)	5.66 (1.36) a	5.48 (1.29)	89
Rectilinear Rustic	5.01 (1.31)	5.19 (1.14)	5.07 (1.32)	5.15 (1.20)	5.25 (1.23) b	5.16 (1.41)	89
Curvilinear Rustic	4.96 (1.33)	5.09 (1.38)	5.03 (1.40)	4.92 (1.39)	5.06 (1.41) b	5.01 (1.46)	89

Note: Different letters (a,b,c) in Restorative column (*) show significant differences between groups (a), (b), and (c) ($p < 0.05$)

From Table 2, to determine the restorative effects of the environments, the mean score of the overall perceived restorativeness (restorative) across all seven environments was denoted by three different letters representing groups (a, b and c) to indicate significant differences between groups ($p < 0.05$). Within each group, there were no substantial differences among the individual environments. This indicates that the Rectilinear Minimal and Curvilinear Natural environments (group a) exhibited the significantly higher restorative effect, than the Curvilinear Minimal, Rectilinear Natural, Rectilinear Rustic, and Curvilinear Rustic environments (group b). Conversely, the baseline model (group c) demonstrated significantly lower restorative effect than group b.

4.2 Comparing the Effects of Forms and Styles

The mean scores of the overall perceived restorativeness (restorative) were calculated for each environment to determine the averages of the two forms and three styles (Table 3). For the form category, the mean rating of all scenarios with the Rectilinear form was $\underline{x} = 5.46$ (SD = 0.83) and for the Curvilinear form was $\underline{x} = 5.38$ (SD = 0.72). For the style category, the mean rating for all scenarios with the Minimal style was $\underline{x} = 5.58$ (SD = 0.96), for the Natural style was $\underline{x} = 5.54$ (SD = 1.21), and for the Rustic style was $\underline{x} = 5.15$ (SD = 1.19).

Table 3. Comparing forms and styles in restorative score (n=89)

		Style											
		Minimal			Rustic			Natural			Overall (Form)		
		x	SD	95%CI	x	SD	95%CI	x	SD	95%CI	x	SD	95%CI
Form	Rectilinear	5.73	1.16	5.50, 5.96	5.25	1.23	4.99, 5.51	5.42	1.28	5.15, 5.68	5.46 z	0.83	5.29, 5.63
	Curvilinear	5.43	1.28	5.16, 5.70	5.06	1.41	4.76, 5.35	5.66	1.36	5.38, 5.95	5.38 z	0.78	5.22, 5.55
	Overall (Style)	5.58 x	0.96	5.38, 5.78	5.15 y	1.19	4.90, 5.40	5.54 x	1.21	5.29, 5.79			

Note: Different letters (x,y,z) show significantly different ($p < 0.05$)

According to Table 3, the comprehensive score for form (Rectilinear versus Curvilinear) did not reveal any significant difference ($p > 0.05$). The overall score for style (Minimal versus Natural) exhibited no substantial difference ($p > 0.05$). However, significant differences ($p < 0.05$) were observed between the Minimal and Rustic styles, as well as between the Natural and Rustic styles. This indicates comparable restorative impacts across different forms and a similar effect between Minimal and Natural styles. Notably, the Rustic style displayed a significantly lower restorative effect compared to the other two styles.

4.3 Relationship between the four Components, Overall Restoration and Preference

A correlation analysis was performed to investigate the relationships between all six variables, revealing significant correlations among all six components (Table 4). Among the components of ART, the overall perceived restorativeness (referred to as “restorative”) demonstrated high correlations with compatibility at 0.841, fascination at 0.837, being away at 0.819, and extent at 0.816, respectively, indicating that all components’ contribution were almost equal. Notably, the overall perceived restorativeness demonstrated a strong correlation with preference at 0.890. Moreover, the highest correlation was found between preference and compatibility at 0.912. These suggest that preference and compatibility are the primary components linked to the restorative impact of small residential units.

Table 4. Correlation between each Component of Restoration and Preference

	Being away	Extent	Fascination	Compatibility	Restorative	Preference	n
Being away	1						89
Extent	.805**	1					89
Fascination	.757**	.867**	1				89
Compatibility	.718**	.845**	.895**	1			89
Restorative	.819**	.816**	.837**	.841**	1		89
Preference	.768**	.819**	.890**	.912**	.890**	1	89

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

5. Discussion

According to the findings, each of the six restorative environment models achieved notably higher scores than the non-restorative baseline model across all rating questions. This supports the first hypothesis that restorative environments outperform the non-restorative one. This highlights the effectiveness of the application of restorative environments in residential context.

However, the second hypothesis, stating that direct use of nature environments (Natural style) would receive the highest score followed by nature-inspired environment (Rustic style) and then preferred environment (Minimal style), was not accepted. There was no significant difference between the average scores of Natural and Minimal styles, while that of Rustic style was significantly lower than those of the others. This discovery contradicts prior research findings and questions the assumption that environments incorporating more natural elements would result in greater restoration levels (Huang et al., 2020; Pérez-Urrestarazu et al., 2021; Berto, 2005; Kaplan & Kaplan, 1989). This suggests that the effect of preference is as high as the effect of the highest level of application of natural elements—direct use of nature. This may contradict previous work that highlight the use of indoor plants or a living wall in confined space (Pérez-Urrestarazu et al., 2021) while supporting the work that suggest aesthetically well-designed environment (Deng et al., 2020; Berto et al., 2018) and preferred environments are important sources of restorativeness (McSweeney et al., 2021; Purcell et al., 2001); Purcell et al., 2001). The correlation analysis (Table 4) further supports this observation by revealing strong relationships between preference and compatibility with the overall perceived restorativeness.

The third hypothesis that the Curvilinear form would out-perform the Rectilinear form also was rejected. This indicates that the effect of simple forms as a way to mimic or represent nature was rather weak or it might not have been distinctly noticeable enough to effectively convey the restorative attributes of nature even though it was advocated in biophilic design literature (Browning et al., 2014; Kellert, 2008). Several participants remarked that they did not perceive noticeable distinctions between the Rectilinear and Curvilinear forms, especially when the style remained consistent.

The fact that the Rectilinear Minimal and Curvilinear Natural environments received the most favorable ratings may be related to coherence concept in the ‘extent’ component of Kaplan’s Attention Restoration Theory (ART). Coherence refers to the consistency and harmony of each element within the environments, which could explain why the Rectilinear Minimal and Curvilinear Natural environments received favorable ratings. Most Minimal styles are characterized by rectilinear shapes and straight lines, creating a sense of familiarity and unity in the setting. Similarly, the Curvilinear Natural environment possesses a harmonious blend of actual natural elements with curvilinear lines, resulting in a cohesive overall design. This is further supported by the notably high rating scores on the ‘extent’ component for both of these leading environments (Table 2). Conversely, the same coherence rationale could be applied to the lower scores of the Curvilinear Minimal environment, Rectilinear Natural environment, and the Rustic style environments that received even lower ratings. This discrepancy is attributed to the lack of coherence between these styles and forms, indicating a lack of aesthetic complementarity that evokes a feeling of being ‘out of place’ and unfamiliar.

The coherence among elements within environments can evoke a sense of well-designed aesthetics, influencing the restorative components of extent and preference. This notion finds support in the research conducted by Horvat and Ribeiro (2023) and Karmanov and Hamel (2008), who discovered that well-designed urban elements could be as effective as natural environments in fostering restoration. Celikors and Wells (2022) and Kaplan (1995) further assert that restorative environments and their constituent elements should

demonstrate coherence to engender a feeling of depth, richness, and scope. This coherence fosters engagement and immersion in the environment, facilitating the restoration process.

One potential factor that could have lowered the restorative scores of natural environments is the excessive use of plants, as reported by some participants. This overuse could evoke negative feelings of messiness, dirtiness, or even scariness, aligning with the discoveries of Cassarino et al. (2019) and Gatersleben and Andrews (2013). Similarly, this adverse element might have contributed to a decline in the restorative ratings of environments adopting a Rustic style, which incorporated raw natural materials and textures as analogues of nature. Some participants also reported negative opinions about Rustic environments, perceiving them as dark, old, or dirty. This indicates that the inclusion of specific natural elements could evoke adverse emotions. This discovery challenges the assumption that environments employing indirect representations of nature or nature analogues would deliver greater restoration than environments with fewer natural elements.

In summary, the findings affirm that restorative environments can play a significant role in promoting restoration and relaxation, particularly within the confines of small residential units. Consistent with our hypotheses and previous research, focusing on incorporating direct nature elements has proven to be effective in facilitating restoration. Interestingly, even the environment with minimal natural elements garnered a high restorative rating. This disparity suggests that in compact and intimate settings, the influence of personal preference can lead to restoration outcomes comparable to those achieved in natural environments. Preference and compatibility emerged as key drivers of the restoration process. It is worth noting that negative perceptions regarding excessive vegetation or imitations of nature, along with a lack of coherence between certain styles and forms, may contribute to lower restorative ratings. Coherence plays a vital role in establishing harmony and fostering engagement with the environment, resulting in more aesthetically pleasing and well-designed spaces. Furthermore, our findings indicate that utilizing nature-inspired forms did not significantly enhance restorative qualities compared to focusing on different styles.

The study has some limitations. Firstly, the experimental environments were virtual and not actual physical spaces. Despite VR being highly immersive, the graphics used may have appeared somewhat artificial. Moreover, the fixed view location restricted participants from exploring the environments from different perspectives, potentially affecting their ability to perceive distinct forms accurately. Secondly, participants were not experiencing prolonged periods of living or lockdown during the study, which may have limited their level of mental fatigue or stress. The brief exposure to the environments might not have been sufficient for participants to experience the long-term effects of restoration. Thirdly, the study only examined a specific combination of two forms and three styles, offering a basic representation of designs but excluding other architectural forms and styles. Fourthly, the study did not determine the extent to which preferences and the sense of coherence in well-designed environments influenced restoration. It also did not identify which of these factors had the most significant impact. Fifthly, the measurements relied solely on the Perceived Restorativeness Scale (PRS), which evaluates subjective feelings of restoration and could be influenced by individual biases or preferences. Finally, although color is controlled, each model inevitably portrayed different color scheme through the use of materials with different colors such as green color of Natural style, dark brown color of Rustic style and pastel color of Minimal style. Therefore, the effect of color remains uncertain and needs further investigation.

Future studies should investigate the enduring impacts of restorative environments on individuals residing in extended living or lockdown scenarios through longitudinal research. Expanding the scope to encompass a diverse range of architectural forms, styles, dimensions, and building typologies can yield a comprehensive

understanding of how coherence and preference interact with restoration. Triangulation by employing multiple assessment tools such as psychological evaluations with physiological indicators, or cognitive performance tests, can provide a robust evaluation of restorative attributes. Leveraging advanced virtual reality technologies for more authentic and immersive experiences has the potential to enhance overall validity. Comparative analyses that assess the influence of preference versus coherence on restoration can further enrich our understanding of these factors. Implementing these recommendations could enhance the efficacy of creating and studying various restorative environments.

6. Conclusion

This study aimed to pinpoint restorative environments suitable for small residential units by analyzing past studies and integrating design elements through various forms and styles. Several key conclusions can be drawn from the findings. Firstly, incorporating well-researched restorative elements such as indoor plants and living walls resulted in the creation of one of the highest-rated restorative environments (Curvilinear form with Natural style). Secondly, environments that were aesthetically pleasing and well preferred also received favorable ratings (Rectilinear form with Minimal style). Thirdly, effective restorative environments must exhibit coherence in their design, with elements and settings that harmonize aesthetically, fostering a sense of coherence and extent that facilitates restoration. Lastly, it is crucial to steer clear of elements that appear aged, unclean, dark, mismatched, or out of context, including an excessive use of plants, as these factors could elicit negative emotions and a lack of compatibility.

Based on the findings, recommendations for designing restorative environments for small residential units include considering individual preferences and compatibility, coherence of elements, and overall aesthetics of environments. While applying direct use of nature is beneficial, it should be done in moderation and with attention to aesthetics to prevent the inclusion of elements that might evoke negative emotions. These recommendations underscore the idea that crafting improved restorative environments entails more than just integrating natural elements.

The findings add to the existing knowledge regarding restorative environments and can be beneficial for interior designers, architects, and developers aiming to design indoor spaces that enhance well-being and productivity, particularly for individuals working remotely or spending extended periods in compact residential units.

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References

Abd-Alhamid, F., Kent, M., Bennett, C., Calautit, J., Wu, Y. (2019). Developing an innovative method for visual perception evaluation in a physical-based virtual environment. *Building and Environment, 162*, 106278. https://doi.org/10.1016/j.buildenv.2019.106278

Amerio, A., Brambilla, A., Morganti, A., Aguglia, A., Bianchi, D., Santi, F., Costantini, L., Odone, A., Costanza, A., Signorelli, C., Serafini, G., Amore, M., & Capolongo, S. (2020). COVID-19 lockdown: Housing built environment's effects on mental health. *International Journal of Environmental Research and Public Health, 17*(16), 5973. https://doi.org/10.3390/ijerph17165973

Andargie, M. S., Touchie, M., & O'Brien, W. (2019). A review of factors affecting occupant comfort in multi-unit residential buildings. Building and Environment, 160, 106182. https://doi.org/10.1016/j.buildenv.2019.106182

Azmi, A. U., Chiranthanut, C., & Thungsakul, N. (2023). Comparison of apartment space design and residential standards of Indonesia. *Journal of Architectural/Planning Research and Studies (JARS), 21*(1), 63–74. https://doi.org/10.56261/jars.v21.258092

Beil, K., & Hanes, D. (2013). The influence of urban natural and built environments on physiological and psychological measures of stress- A pilot study. *International Journal of Environmental Research and Public Health, 10*(4), 1250–1267. https://doi.org/10.3390/ijerph10041250

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology, 25*(3), 249–259. https://doi.org/10.1016/j.jenvp.2005.07.001

Berto, R., Barbiero, G., Barbiero, P., & Senes, G. (2018). An individual's connection to nature can affect perceived restorativeness of natural environments: some observations about biophilia. *Behavioral Sciences, 8*(3), 34. https://doi.org/10.3390/bs8030034

Boonteng, P., & Lekagul, A. (2020). Designing restorative environment to restore and improve learning of children with autism in child psychiatric ward, Maharaj Nakorn Chiang Mai Hospital. *Journal of Human Sciences, 21*(2), 120-138. https://so03.tci-thaijo.org/index.php/JHUMANS/article/view/237849

Brodeur, A., Clark, A. E., Fleche, S., & Powdthavee, N. (2021). COVID-19, lockdowns and well-being: Evidence from google trends. *Journal of Public Economics, 193*, 104346. https://doi.org/10.1016/j.jpubeco.2020.104346

Browning, M. H. E. M., Mimnaugh, K. J., van Riper, C. J., Laurent, H. K., & LaValle, S. M. (2020). Can simulated nature support mental health? comparing short, single-doses of 360-degree nature videos in virtual reality with the outdoors. *Frontiers in Psychology, 10*(2667), 1–14. https://doi.org/10.3389/fpsyg.2019.02667

Browning, W., Ryan, C., & Clancy, J. (2014). *14 Patterns of biophilic design: Improving health & well-being in the built environment*. Terrapin Bright Green LLC. https://doi.org/10.1016/j.yebeh.2008.04.024

Burnard, M. D., & Kutnar, A. (2015). Wood and human stress in the built indoor environment: A review. *Wood Science and Technology, 49*(5), 969–986. https://doi.org/10.1007/s00226-015-0747-3

Cassarino, M., Tuohy, I. C., & Setti, A. (2019). Sometimes nature doesn't work: Absence of attention restoration in older adults exposed to environmental scenes. *Experimental Aging Research, 45*(4), 372–385. https://doi.org/10.1080/0361073X.2019.1627497

Celikors, E., & Wells, N. M. (2022). Are low-level visual features of scenes associated with perceived restorative qualities?. *Journal of Environmental Psychology, 81*, 101800. https://doi.org/10.1016/J.JENVP.2022.101800

Clinton, E. (2018). Micro-living: Why occupants choose to live in very small dwellings?. *Australian Planner, 55*(3–4), 189–197. https://doi.org/10.1080/07293682.2019.1632363

Chang, C.-Y., Hammitt, W. E., Chen, P.-K., Machnik, L., & Su, W.-C. (2008). Psychophysiological responses and restorative values of natural environments in Taiwan. *Landscape and Urban Planning, 85*(2), 79–84. https://doi.org/10.1016/j.landurbplan.2007.09.010

Coburn, A., Kardan, O., Kotabe, H., Steinberg, J., Hout, M. C., Robbins, A., MacDonald, J., Hayn-Leichsenring, G., & Berman, M. G. (2019). Psychological responses to natural patterns in architecture. *Journal of Environmental Psychology, 62*, 133–145. https://doi.org/10.1016/j.jenvp.2019.02.007

Demattè, M. L., Zucco, G. M., Roncato, S., Gatto, P., Paulon, E., Cavalli, R., & Zanetti, M. (2018). New insights into the psychological dimension of wood–human interaction. *European Journal of Wood and Wood Products, 76*(4), 1093–1100. https://doi.org/10.1007/s00107-018-1315-y

Deng, L., Luo, H., Ma, J., Huang, Z., Sun, L.-X., Jiang, M.-Y., Zhu, C.-Y., & Li, X. (2020). Effects of integration between visual stimuli and auditory stimuli on restorative potential and aesthetic preference in urban green spaces. *Urban Forestry and Urban Greening, 53*, 126702. https://doi.org/10.1016/j.ufug.2020.126702

Doxey, J. S., Waliczek, T. M., & Zajicek, J. M. (2009). The impact of interior plants in university classrooms on student course performance and on student perceptions of the course and instructor. *HortScience, 44*(2), 384–391. https://doi.org/10.21273/hortsci.44.2.384

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*, 1149-1160. https://link.springer.com/article/10.3758/BRM.41.4.1149

Felsten, G. (2009). Where to take a study break on the college campus: An attention restoration theory perspective. *Journal of Environmental Psychology, 29*(1), 160–167. https://doi.org/10.1016/j.jenvp.2008.11.006

Gao, C., & Zhang, S. (2020). The restorative quality of patient ward environment: Tests of six dominant design characteristics. *Building and Environment, 180*, 107039. https://doi.org/10.1016/j.buildenv.2020.107039

Gatersleben, B., & Andrews, M. (2013). When walking in nature is not restorative—The role of prospect and refuge. *Health and Place, 20*, 91–101. https://doi.org/10.1016/j.healthplace.2013.01.001

Gilbert, N. (2020). *13 Essential work from home trends & predictions for 2022/2023 You Should Know*. FinancesOnline. https://financesonline.com/work-from-home-trends

Hähn, N., Essah, E., & Blanusa, T. (2021). Biophilic design and office planting: A case study of effects on perceived health, well-being and performance metrics in the workplace. *Intelligent Buildings International, 13*(4), 241-260. https://doi.org/10.1080/17508975.2020.1732859

Hartig, T. (2004). Restorative environments. *Encyclopedia of Applied Psychology, 3*, 273-279. https://doi.org/10.1016/B0-12-657410-3/00821-7

Hartig, T., Kaiser, F. G., & Bowler, P. A. (1997). *Further development of a measure of perceived environmental restorativeness* (Arbetsrapport/working paper no.5). Uppsala University: Institute for Housing Research. https://uu.diva-portal.org/smash/get/diva2:130237/FULLTEXT01.pdf

Huang, Q., Yang, M., Jane, H.-A., Li, S., & Bauer, N. (2020). Trees, grass, or concrete? the effects of different types of environments on stress reduction. *Landscape and Urban Planning, 193*, 103654. https://doi.org/10.1016/j.landurbplan.2019.103654

Jarutach, T. (2022). Guidelines for healthy housing development for all. *Journal of Architectural/Planning Research and Studies (JARS), 20*(2), 57–70. https://doi.org/10.56261/jars.v20.251159

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

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology, 5*(3). 169-182. https://doi.org/10.1016/0272-4944(95)90001-2

Karmanov, D., & Hamel, R. (2008). Assessing the restorative potential of contemporary urban environment(s): Beyond the nature versus urban dichotomy. *Landscape and Urban Planning, 86*(2), 115-125. https://doi.org/10.1016/j.landurbplan.2008.01.004

Kellert, S. R. (2008). Dimensions, elements, and attributes of biophilic design. In S. R. Kellert, J. Heerwagen & M. Mador (Eds.), *Biophilic design: The theory, science and practice of bringing buildings to life* (pp. 3–19). Wiley.

Kim, J., Cha, S. H., Koo, C., & Tang, S. keung. (2018). The effects of indoor plants and artificial windows in an underground environment. *Building and Environment, 138*, 53–62. https://doi.org/10.1016/j.buildenv.2018.04.029

Leech, J. A., Nelson, W. C., Burnett, R. T., Aaron, S., & Raizenne, M. E. (2002). It's about time: A comparison of Canadian and American time–activity patterns. *Journal of Exposure Science and Environmental Epidemiology, 12*(6), 427-432. https://www.nature.com/articles/7500244

Leigh, T. (2020, April 21), *How to strike a work/life balance in a tiny apartment, according to design experts*. Dwell. https://www.dwell.com/article/how-to-work-from-home-in-a-tiny-apartment-7923180c

McSweeney, J., Johnson, S., Sherry, S., Singleton, J., & Rainham, D. (2021). Indoor nature exposure and influence on physiological stress markers. *International Journal of Environmental Health Research, 31*(6), 636-650. https://doi.org/10.1080/09603123.2019.1679357

Meethong, P., & Lekagul, A. (2021). Using vertical garden as restorative environment from fatigue in CMED canteen, Maharaj Nakorn Chiang Mai Hospital. *Journal of Architectural/Planning Research and Studies, 18*(2), 101-118. https://doi.org/10.56261/jars.v18i2.243411

Nieuwenhuis, M., Knight, C., Postmes, T., & Haslam, S. A. (2014). The relative benefits of green versus lean office space: Three field experiments. *Journal of Experimental Psychology: Applied, 20*(3), 199-214. https://gwern.net/doc/psychology/nature/2014-nieuwenhuis.pdf

Pérez-Urrestarazu, L., Kaltsidi, M. P., Nektarios, P. A., Markakis, G., Loges, V., Perini, K., & Fernández-Cañero, R. (2021). Particularities of having plants at home during the confinement due to the COVID-19 pandemic. *Urban Forestry and Urban Greening, 59*, 126919. https://doi.org/10.1016/j.ufug.2020.126919

Horvat, K. P., & Ribeiro, D. (2023). Urban public spaces as restorative environments: The case of Ljubljana. *International Journal of Environmental Research and Public Health, 20*(3), 2159. https://doi.org/10.3390/ijerph20032159

Purcell, T., Peron, E., & Berto, R. (2001). Why do preferences differ between scene types?. *Environment and Behavior, 33*(1), 93–106. https://doi.org/10.1177/00139160121972882

Routley, N. (2020, Jun 3). *6 charts that show what employers and employees really think about remote working*. World Economic Forum. https://www.weforum.org/agenda/2020/06/coronavirus-covid19-remote-working-office-employees-employers

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science, 244*(4647), 420-421. https://www.science.org/doi/10.1126/science.6143402

United Nations. (2022). *World Population Prospects 2022: Summary of Results* (DESA/POP/2022/TR/NO. 3). United Nations. https://www.un.org/development/desa/pd/content/World-Population-Prospects-2022

Van den Bogerd, N., Dijkstra, S. C., Tanja-Dijkstra, K., de Boer, M. R., Seidell, J. C., Koole, S. L., & Maas, J. (2020). Greening the classroom: Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality. *Building and Environment, 171*, 106675. https://doi.org/10.1016/j.buildenv.2020.106675

Vartanian, O., Navarrete, G., Chatterjee, A., Fich, L. B., Leder, H., Modrono, C., Nadal, M., Rostrup, N., & Skov, M. (2013). Impact of contour on aesthetic judgments and approach-avoidance decisions in architecture. *Proceedings of the National Academy of Sciences of the United States of America, 110*(Suppl. 2), 10446–10453. https://doi.org/10.1073/pnas.1301227110

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

Yin, J., Arfaei, N., MacNaughton, P., Catalano, P. J., Allen, J. G., & Spengler, J. D. (2019). Effects of biophilic interventions in office on stress reaction and cognitive function: A randomized crossover study in virtual reality. *Indoor Air, 29*(6), 1028–1039. https://doi.org/10.1111/ina.12593

Yin, J., Yuan, J., Arfaei, N., Catalano, P. J., Allen, J. G., & Spengler, J. D. (2020). Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environment International, 136*, 105427. https://doi.org/10.1016/j.envint.2019.105427

Yin, J., Zhu, S., MacNaughton, P., Allen, J. G., & Spengler, J. D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and Environment, 132*, 255–262. https://doi.org/10.1016/j.buildenv.2018.01.006

Zarrabi, M., Yazdanfar, S.-A., & Hosseini, S.-B. (2021). COVID-19 and healthy home preferences: The case of apartment residents in Tehran. *Journal of Building Engineering, 35*, 102021. https://doi.org/10.1016/j.jobe.2020.102021