Landscape and Urban Planning 220 (2022) 104336

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Sit down and rest: Use of virtual reality to evaluate preferences and mental restoration in urban park pavilions

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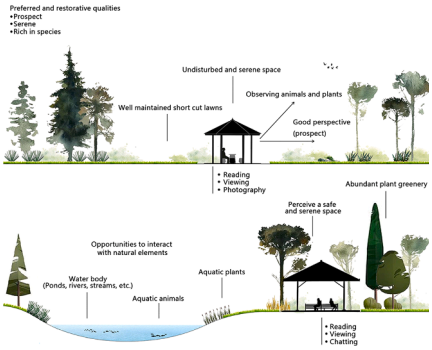
HIGHLIGHTS

- Using VR to simulate the experience of sitting in a pavilion of an urban park.
- Prospect, Serene and Rich in species are important dimensions.
- It is feasible to use VR to simulate pavilion settings for relaxation and recovery.
- Experience and the presence of certain physical aspects make a place restorative.
- Constructed a generalized preference and restorative environment setting.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Urban parks
Pavilion
Mental restoration
Preference
Virtual reality
Perceived sensory dimensions

ABSTRACT

Natural experiences in urban parks have a positive impact on the well-being and quality of life of people living in urban settings. Thus far, studies focused on urban parks have primarily surveyed general urban park spaces. There is a lack of research on specific rest environment settings, especially for leisure facilities such as pavilions. This study used virtual reality (VR) to create a simulation of people sitting in a pavilion, to evaluate the preferences and mental restoration of nine pavilions in Tokyo (N=61). The results showed that VR viewing effectively promoted mental restoration. The enclosure of the pavilion did not significantly affect people's preferences and perceived mental restoration in the environment setting. Moreover, the regression analysis revealed that the prospect and serene dimensions significantly influenced preferences; for restoration, the dimensions of "richness in species" and "serene" were significant predictors. Results indicate that providing visitors with spaces to sit, relax, socialize, read, and view the scenery could be beneficial. Urban park managers could consider adding people's preferred elements in these resting environments to create a generalized restorative environment setting. The results also suggest that VR can be used to simulate different resting environments for relaxation and restoration, as an alternative approach to experience nature.

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https://doi.org/10.1016/j.landurbplan.2021.104336
Received 11 June 2021; Received in revised form 9 December 2021; Accepted 10 December 2021
Available online 18 December 2021

1. Introduction

1.1. Nature experience and restorative measurement

Urbanization increases the importance of natural experiences in cities (e.g., in urban parks or forests; Jeon, Jo, & Lee, 2021). Research has proved that experiences in nature (i.e., observing nature, interacting with natural resources, and activities in the natural environment) positively affect health outcomes. For instance, Shanahan et al. (2016) used a nature-dose framework to study the relationship between urban population health and the duration, frequency, and intensity of exposure to nature. The results showed that long-term visits to green spaces significantly lower incidences of depression and high blood pressure. Another study involving 30 gardeners, who performed a 30-minute gardening and reading task, discovered that outdoor gardening activities could promote the recovery of positive mood (Van Den Berg & Custers, 2011). Urban green spaces are also considered suitable places for residents to encounter biodiversity. Although the population may not be able to accurately identify the actual species richness, well-being is positively correlated with the perceived diversity and richness of species (Dallimer et al., 2012). A Swedish study showed that rehabilitation gardens relieve acute stress and serve as a social space to improve self-esteem (Adevi & Mårtensson, 2013). This evidence points to the health benefits of natural experience.

Among such studies, attention restoration theory (ART; Kaplan, 1995) and stress reduction theory (SRT; Ulrich et al., 1991) have been the main approaches to explain the restorative benefits of natural experiences. ART has emphasized the importance of restoration from attentional fatigue based on cognitive functioning and proposed four components: fascination, being-away, extent, and compatibility. From Kaplan's perspective, the depletion of directed attention can be restored by rest; moreover, the state of reduced fatigue of directed attention is the restorative experience (Kaplan, 1995). SRT is a psycho-evolutionary model that emphasizes the importance of recovering from psychological and physiological stress related to threats or challenges based on affective functioning. Ulrich et al. (1991) theory focuses on physical environments and considers these physical environments as sources of stress or relief.

Based on these two theories, various self-report measures have been developed to assess the degree of perceived restoration in different environments, such as the Perceived Restorativeness Scale (Hartig, Korpela, Evans, & Gärling, 1997), Restorative Components Scale (Laumann, Gärling, & Stormark, 2001), Short-version Revised Restoration Scale (Han, 2003), and Short-version Revised Restoration and Preference Scale (Deng et al., 2020). Therefore, it is feasible to measure the restorative influence of natural experiences using self-report scales.

1.2. Lack of research on pavilions

In densely populated and congested cities, urban parks (as part of urban nature; Razak, Othman, & Nazir, 2016) are valuable to citizens and visitors because they provide a space for physical activity (Mak & Jim, 2019; McCormack, Rock, Toohey, & Hignell, 2010; Ou et al., 2016), natural experiences (Kabisch et al., 2021), mental and physical recovery (Rahnema, Sedaghathoor, Allahyari, Damalas, & El Bilali, 2019; Masullo et al., 2021a), and social interaction (Guan et al., 2021; Peters, Elands, & Buijs, 2010). However, most of these studies have focused on exploring general aspects of urban parks (i.e., in parks) and not on specific resting environment settings.

Resting environments (also known as restorative environments) provide resting activities, relaxation, and recovery (Wang, Zhao, Meitner, Hu, & Xu, 2019). Many studies have attempted to discover the benefits of different resting environments. For instance, Wang, Shi, Zhang, and Chiang (2019) considered forests as a type of resting environment and stated that forest rest often includes physical relaxation, body scanning, and meditation. Herzog, Ouellette, Rolens, and Koenigs (2010) argued that worship houses as resting environments enable the occurrence of psychologically meaningful activities (e.g., reflection, quiet prayer, socializing). Pals, Steg, Siero, and Van der Zee (2009) measured the perceived restorative characteristics of two zoo attractions (i.e., butterfly garden and baboon attraction). Thus, studying various specific resting environment settings (e.g., lawns, pavilions, ponds, understory spaces, and trails) in urban parks is significant.

Among them, pavilions are common facilities in urban parks and attract visitors and tourists to rest and relax (Mu et al., 2021). Pavilions have a long history within the field of architecture. In ancient China, many garden designers used this traditional building as a space for resting and viewing landscapes. Some garden owners gave pavilions specific names to express their emotions and ambitions (Yinong, 1999; Xie, 2016). Similarly, in early Europe, the term "Pavilion" was derived from the Old French language, and initially referred to a square tent that was often used as a pleasure-house or summerhouse in a garden (Drew, 2006). The forms of pavilions and materials used to create them have diversified over time, and some variations include the timber pavilion (Aras, 2013), the glass pavilion (Schneider & Nordenson, 2008), and the steel pavilion (Gutschow, 2006). Apart from providing rest and decoration, the pavilion can also be used to hold an exhibition (Schneider & Nordenson, 2008) and for commemorative events (Ryoo, 2018). In addition, Xu, Hong, Mi, and Yan (2018) found that pavilions are windproof measures in urban parks that help slow wind speed and improve thermal comfort. Meggers et al. (2017) designed an experimental pavilion to explore indirect evaporative cooling usage and radiant cooling geometric reflection. The study used thermal imaging cameras and a novel scanning MRT sensor and found that the mean radiant temperature inside the pavilion was significantly lower. However, despite their importance as a place to rest and take in the view of urban parks, few studies have directly measured the restorative influence of pavilions.

1.3. Restorative evaluations using virtual reality

Not everyone has access to the natural environment (Browning, Mimnaugh, van Riper, Laurent, & LaValle, 2020). As time constraints due to long work hours may hinder opportunities for natural experiences, alternatives to recovery need to be explored (Reese, Kohler, & Menzel, 2021). Virtual reality (VR) is an effective medium for inducing emotions (Moura, Barros, & Ferreira-Lopes, 2021) and can simulate highly realistic environments (Mattila et al., 2020). Furthermore, Reese et al. (2021) indicated that images, videos, and VR can elicit psychological effects, which indicates that visual stimuli are sufficient to elicit recovery. VR emphasizes "immersive experiences" rather than just "viewing" (Portman, Natapov, & Fisher-Gewirtzman, 2015). Thus, VR experiences are considered highly similar to the physical experience of nature (Reese et al., 2021), as VR can trigger restorative experiences comparable to real environments (Yin, Zhu, MacNaughton, Allen, & Spengler, 2018), regardless of whether the experience is active or passive (Reese et al., 2021).

VR technology can provide more environmental information and create a more realistic environmental experience than traditional two-dimensional media (such as photos). Thus, there is an increasing use of VR for restorative evaluation, particularly in urban parks (Jeon et al., 2021; Yu, Lee, Lu, Huang, & Browning, 2020; Masullo et al., 2021a). For example, in previous studies, the use of a VR representation of nature reduced the pain experienced and recalled by patients (Tanja-Dijkstra et al., 2018) and six minutes of exposure to VR improved mood (Browning et al., 2020). Moreover, natural scenes presented through VR were able to provide objective and subjective relaxation and recovery after stressful experiences (Anderson et al., 2017). VR has also been widely used in the health and medical fields for numerous purposes and impacts, including motor rehabilitation (Sveistrup, 2004), functional recovery after stroke (Merians, Poizner, Boian, Burdea, & Adamovich, 2006), stress relief (Wang et al., 2019), psychological restorative efforts

for middle-aged and older adults (Yu et al., 2020), and reduced negative emotions by viewing forest environments (Yu, Lee, & Luo, 2018). More importantly, combining nature (e.g., forest, botanical garden) and VR, and introducing it into healthcare settings can be an effective alternative to analgesics, thus reducing additional medical applications (Tanja-Dijkstra et al., 2018). In summary, experiencing nature through VR is effective for improving mental health, reducing pain, and relieving stress. This fact substantiates the use of VR simulations of pavilion settings in different urban parks to evaluate mental restoration in this study.

1.4. Using VR to perceive restorative qualities

Exploring the ability of different environmental features to provide restoration is important for evidence-based health design (Memari, Pazhouhanfar, & Grahn, 2021). These qualities can be characterized based on people's experience and perceptions of these features (Chen, Qiu, & Gao, 2019). Expert judgment is a widely used technique for assessing natural environments based on vision. Studies have often used landscape features, such as the number of elements, shapes, colors, topography, scale, and visual focus (see Arriaza, Cañas-Ortega, Cañas-Madueño, & Ruiz-Aviles, 2004; Deng et al., 2020; Wang, Zhao, & Liu, 2016; Wang et al., 2019; Yao et al., 2012). However, the stimuli used in these studies were two-dimensional visual media (images), which may be inaccurate for expert judgment in a VR environment. In addition, the use of this technology has been criticized for ignoring the user's perspective (Penning-Rowsell & Hardy, 1973). Consequently, a completely bottom-up approach called Perceived Sensory Dimensions (PSD) is widely used to evaluate environmental qualities (Memari et al., 2021). Moreover, Grahn and Stigsdotter (2010) identified eight different PSDs from a representative sample of the Swedish population: 1) social (suitable for social activities and entertainment), 2) prospect (preference for vistas over the surroundings), 3) rich in species (consisting of many animals and plants), 4) serene (an undisturbed, silent, and calm environment); 5) culture (artificial elements and decorations); 6) space (a spacious and free setting); 7) nature (feeling and experience of being in the natural environment); and 8) refuge (sense of safety). These eight qualities are experiential and based on multiple theories, including ART, SRT, biodiversity theories, and social quality theories. Thus, they are widely applicable across landscapes (Memari et al., 2021), such as urban parks (Qiu & Nielsen, 2015), small public urban green spaces (Peschardt & Stigsdotter, 2013), urban forests (Chen et al., 2019), and natural forests (Stigsdotter, Corazon, Sidenius, Refshauge, & Grahn, 2017). Although there is no direct evidence on the use of VR to investigate PSD, a study using a photo-elicitation approach demonstrated the feasibility of indirectly perceiving these eight qualities through the medium (Memari et al., 2021). Xiang et al. (2021), Shi, Honjo, Zhang, and Furuya (2020), and Reese et al. (2021) believe that virtual reality is highly consistent with on-site surveys and can replace on-site surveys in most cases. Therefore, we believe that 360° immersive environments (such as those presented in virtual reality) allow users to effectively perceive the qualities of restorative environments.

1.5. The current study

This study used VR to assess the preference and mental restoration of different pavilion settings. In addition, we explored the association of divergent restorative qualities (i.e., PSD) with preference and restoration.

Vision is a major component of human sensory perception (Portman et al., 2015) and visual information is considered most important when visiting natural environments, such as urban green spaces (Grahn & Stigsdotter, 2010). Anderson et al. (2017) stated that the absence of background noise in the test environment is important because sound can provide relaxation independent of visual stimuli. In addition, other studies have demonstrated that both touch (Ikei, Song, & Miyazaki, 2017) and smell (Ikei, Song, Lee, & Miyazaki, 2015) trigger independent restoration. Therefore, to focus on the purpose of this study (sitting in a pavilion to view and recover), only vision is used for evaluation, to exclude information interference from touch, hearing, and smell.

There have been no studies using VR to directly measure pavilion preference and restoration; moreover, there is still a lack of discussion on the association of pavilion enclosure with preference and restoration. Therefore, this study outlined three research questions. First, can using VR to simulate sitting in a pavilion and viewing allow the subject to perceive restoration? Furthermore, according to evolutionary theory, humans tend to favor access to shelter possibilities (Lindal & Hartig, 2013), which leads to the understanding that enclosure affects human preference for the environment (Herzog, 1992) and perceived recovery (Galindo & Hidalgo, 2005). Second, does the enclosure of the pavilion affect preference and perceived restoration? Research has demonstrated that PSDs are correlated with restoration and preference (Chen et al., 2019; Grahn & Stigsdotter, 2010; Peschardt & Stigsdotter, 2013; Stigsdotter et al., 2017). Third, which PSDs predict restoration and preference in pavilion settings?

Furthermore, Zhang, Liu, and Li (2019) indicated that experience and the presence of certain physical aspects make a place restorative. Hence, we conducted a qualitative study and semi-structured interviews to address the following two additional questions:

4) Which elements can promote the preference and mental restoration of the scene?

5) How was the experience of viewing these resting environments with VR?

2. Materials and methods

2.1. Participants

Participants were recruited using a social networking platform (Line). The inclusion criteria were normal vision and no cognitive or mental disorders. The volunteers included 61 students from the Faculty of Horticulture, Chiba University: 32 women (52.4%), 29 men (47.6%); average age 25.5 (±1.53). The participants were predominantly from the following departments: Landscape Planning, Garden Design, and Greenspace Environment. All participants voluntarily participated in the study and provided verbal consent. Each person was presented with a small gift as a token of appreciation upon experiment completion. This study was conducted with the approval of the Ethics Committee at Chiba University.

2.2. Study site and stimuli

During the desk research, the authors compiled information on all pavilions in Tokyo. Open traditional gardens and semi-open traditional gardens within urban parks were selected as the study area. To avoid repeated investigation of pavilions in similar environments during the field investigation (September 1–20, 2020), the three researchers investigated 24 pavilions across 14 urban parks in Tokyo (Fig. 1). A GoPro Fusion 360 (with 9 megapixels and a sensor size of 6.17 × 4.55 mm) was used to capture the panorama. To ensure consistency, we chose similar weather and light conditions for photography (Fig. 2). While shooting, the GoPro was placed on the seat in the pavilion, and the lens was in line with the sitting height of the human eye (1.2 m). In addition, to avoid distortion of the stitched panorama, the closest object surface (such as walls and pillars) to the lens exceeded the minimum stitching distance (20 cm). A total of 37 panoramas were taken (1–3 per pavilion). However, viewing all panoramas could be difficult for the participants. Therefore, after discussion, nine pavilions from seven urban parks were selected for the study (i.e., Rikugien Garden, Shinjuku Gyoen National Garden, Edogawa Heisei Garden, Mejiro Garden, Hibiya Park, Kyu-Furukawa Garden, and Kyu-shiba-rikyu Garden; Fig. 3). The criteria were as follows: 1) unique environmental settings, 2) sufficient natural

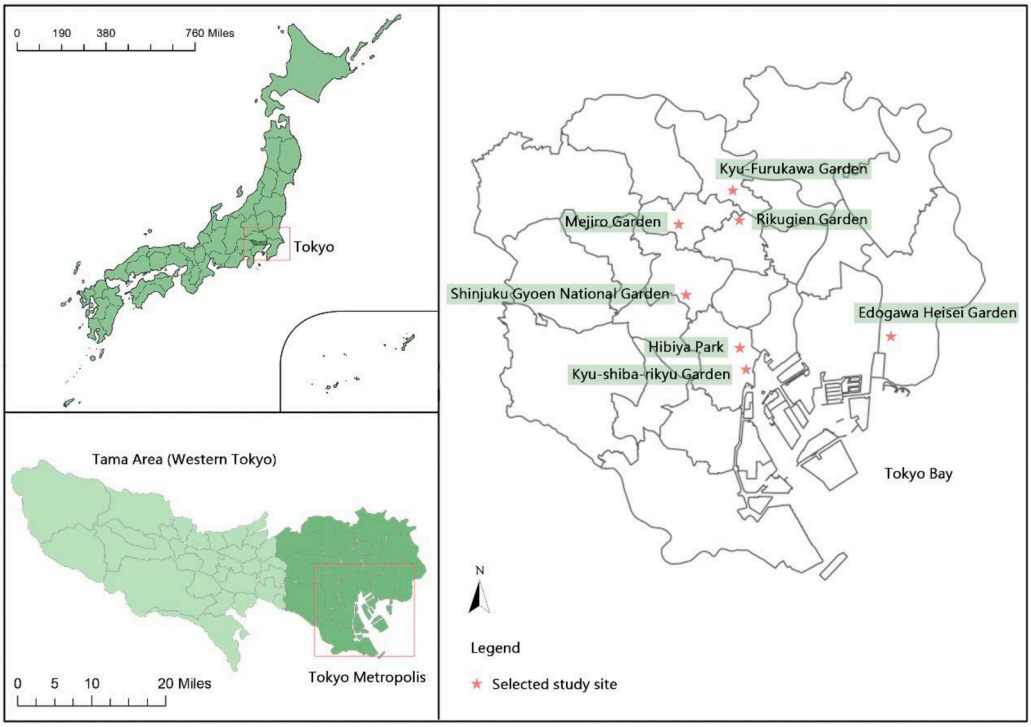


Fig. 1. The location of the study site.

Fig. 2. Collected panorama in Rikugien Garden.

environment outside the pavilion, 3) different pavilion shapes and enclosure levels, and 4) no magnificent landscape outside the pavilion.

2.3. Measures

Self-report scales were used to measure restorative experiences. Mental restoration can be measured in three dimensions: restorative experiences, positive emotions, and stress reduction (Wan, Shen, & Choi, 2020; Hartig et al., 1997; Korpela, Ylén, Tyrväinen, & Silvennoinen, 2008; Pasanen, Neuvonen, & Korpela, 2018). All descriptions were adapted to meet the purposes of this study. Restorative experiences, positive emotions, and stress reduction were measured using three, two, and three items, respectively. All items were rated on a 5-point Likert scale, ranging from 1 (*completely disagree*) to 5 (*completely agree*; Table 1). The mental restoration score of each pavilion is the mean value of these three dimensions.

In addition, an item measured the participants' preference for different pavilion settings: "Here the landscape is attractive to me" (1 = *completely disagree*, 5 = *completely agree*). The participants were told to focus on the natural environment outside the pavilion rather than on the architectural space.

Chen et al. (2019) and Peschardt and Stigsdotter (2013) used the PSD scale to explore how participants perceive varied natural environment settings (1 = *completely disagree*, 5 = *completely agree*; Table 2). This scale is composed of eight different dimensions, has proven reliability, and is often used to describe the characteristics of various natural environments (Chen et al., 2019; Peschardt & Stigsdotter, 2013; Stigsdotter et al., 2017; Qiu & Nielsen, 2015). A description was added after each dimension to enable the participants to understand these dimensions. All measurement tools were translated into Japanese, English, and Chinese versions for participants from different countries.

2.4. The generalized preference and restorative environment setting

The participants were requested to complete an additional questionnaire after viewing each pavilion to find a generalized preference and restorative environment setting (Deng et al., 2020). The questionnaire contains two items (both multiple choice): (1) "What do you want to do in this scene?" and (2) "Which elements are your favorite in this scene?"

2.5. VR viewing experience

Inspired by previous research (Yu et al., 2020), after each participant viewed all the pavilion settings, we conducted a simple semi-structured interview (approximately 5–10 min) to evaluate the VR viewing experience. It comprised three questions: "Did you experience physical symptoms, such as cyber sickness or dizziness?" "How did you feel when viewing these pavilion settings?" and "Does VR viewing make you want to visit these pavilions on-site?"

2.6. Procedure

The VR viewing experiment was carried out in the Landscape Planning Research Room from April 20-May 20, 2021. Each participant was instructed not to drink any alcoholic beverages for 12 h before the experiment onset. A freely rotatable chair was provided after the

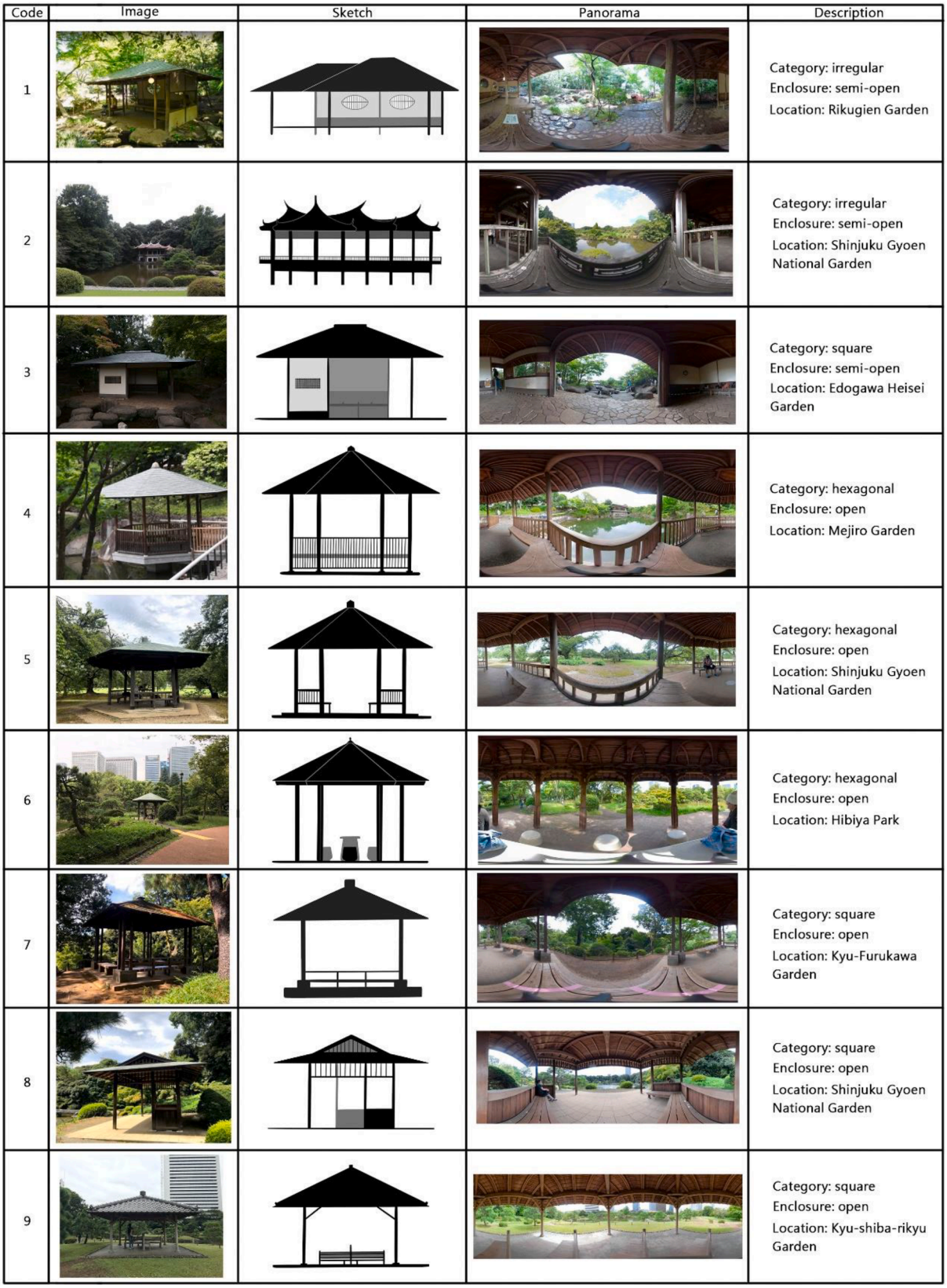


Fig. 3. Image, sketch, panorama, and description of the nine selected research pavilions.

participants arrived in the research room. Meanwhile, a researcher explained the procedure and purpose of the investigation to all participants, following which their verbal consent was obtained. The participants were told that they were free to withdraw at any point, should they face any discomfort during the experiment. The head-mounted display (Oculus Go) was placed for the participants and adjusted to ensure comfortable viewing of the panorama (Fig. 4b). Next, they were permitted to freely view each panorama of the pavilion setting without a

Table 1
Mental restoration measure.

Dimension	Item	Scale				
Restorative experiences	I feel restored after sitting here.	1	2	3	4	5
	I forget everyday worries after sitting here.	1	2	3	4	5
	Sitting here gives me a break from my day-to-day routine.	1	2	3	4	5
Positive emotions	Sitting here makes me happy.	1	2	3	4	5
	I feel energized after sitting here for a while.	1	2	3	4	5
Stress reduction	I feel relaxed after sitting here.	1	2	3	4	5
	Sitting here makes me feel calm.	1	2	3	4	5
	Sitting here helps me reduce stress.	1	2	3	4	5

Table 2
Perceived Sensory Dimension scale.

Dimension	Description	Scale				
Social	Here is an environment suitable for social activities.	1	2	3	4	5
Space	This is a spacious and undisturbed environment.	1	2	3	4	5
Nature	Sensation of wilderness and nature.	1	2	3	4	5
Refuge	Here is an enclosed and safe environment.	1	2	3	4	5
Prospect	Here is an open space with a wide view.	1	2	3	4	5
Serene	Here is a silent and peaceful environment.	1	2	3	4	5
Culture	There are many artificial elements decorating here.	1	2	3	4	5
Rich in species	Many animals and plants around here.	1	2	3	4	5

time limit and were requested to complete the questionnaire. Only once the current pavilion questionnaire had been completed could the next pavilion be viewed. During this phase, the participants were informed that they were in this environment. They were asked not to stand up or slide the chair; only a slight swing of the chair was allowed, but the head could be freely turned to watch (as if sitting on a pavilion seat) (Fig. 4c). After the participants had viewed all nine pavilions, a researcher conducted a simple semi-structured interview with the participants to evaluate the VR viewing experience. Finally, the participants were rewarded with a gift and thanked for their participation. To eliminate potential interference, silent conditions were ensured for VR viewing. The entire experiment (for one individual) took approximately 15–20 min.

2.7. Analyses

The experimental data were compiled and statistically analyzed using Microsoft Excel. Correlation analysis was used to examine the relationships among restoration, preference, and PSD. Further, according to the degree of enclosure, the pavilions were divided into two categories in the following analysis: semi-open (pavilions 1–3) and open (pavilions 4–9). A one-way analysis of variance (ANOVA) was performed to examine the differences between open and semi-open pavilions. In addition, ordinal logistic regression was used to analyze the correlation between PSD and enclosure, and the results were presented as odds ratios (ORs) with 95% confidence intervals (Qiu & Nielsen, 2015). Finally, stepwise multiple linear regression analysis was used to explore the PSD predictors that affect mental restoration and preference. We did not analyze the differences between the sociodemographic characteristics because this aspect was not among the stated research questions of this study. All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS; version 20.0; SPSS Inc., Chicago, IL, USA), and the level of significance was set at $p < 0.05$. The effect size was measured by Cohen's d, which indicated that the d values of the small (0.2), medium (0.5), and large (0.8) effect quantities (Cohen, 1988).

3. Results

3.1. Reliability analysis

The reliability of PSD and mental restoration were calculated. According to Landis and Koch (1977), a Cronbach's alpha value greater than 0.8 indicates good internal consistency. Therefore, our results show that both PSD (Cronbach's alpha = 0.836) and mental restoration (Cronbach's alpha = 0.890) have good reliability.

3.2. Overall evaluation across the nine selected pavilions

As shown in Fig. 5, Pavilions 1 (3.97 ± 0.63) and 6 (3.74 ± 0.92) have the highest restoration and preference scores, while Pavilions 3 (3.33 ± 0.61), 4 (3.33 ± 0.84), and 5 (3.26 ± 0.82) demonstrate lower restoration scores. Pavilions 3 (3.23 ± 0.88), 4 (3.23 ± 0.88), 5 (3.20 ± 0.97), and 7 (3.16 ± 0.96) are the least preferred. However, all restorative scores exceeded 3, indicating that the majority of participants rated this restorative experience positively (Jeon et al., 2021).

The PSD results perceived by the participants are shown in Fig. 6. First, Pavilions 4 (3.34 ± 1.04), 8 (3.34 ± 1.02), and 9 (3.34 ± 1.04) can be perceived along the social dimension, whereas 1 (2.90 ± 1.20) and 3

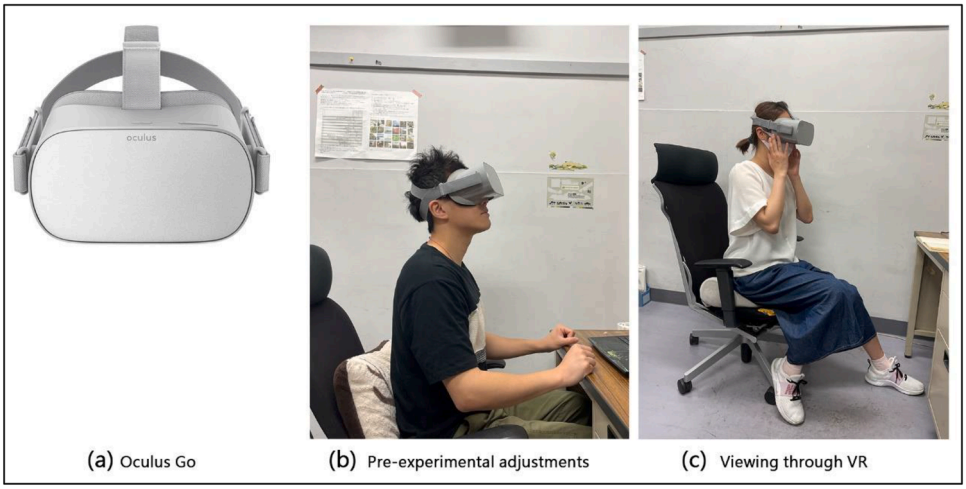


Fig. 4. (a) Oculus Go; (b) Participant viewing the panorama through the head-mounted display.

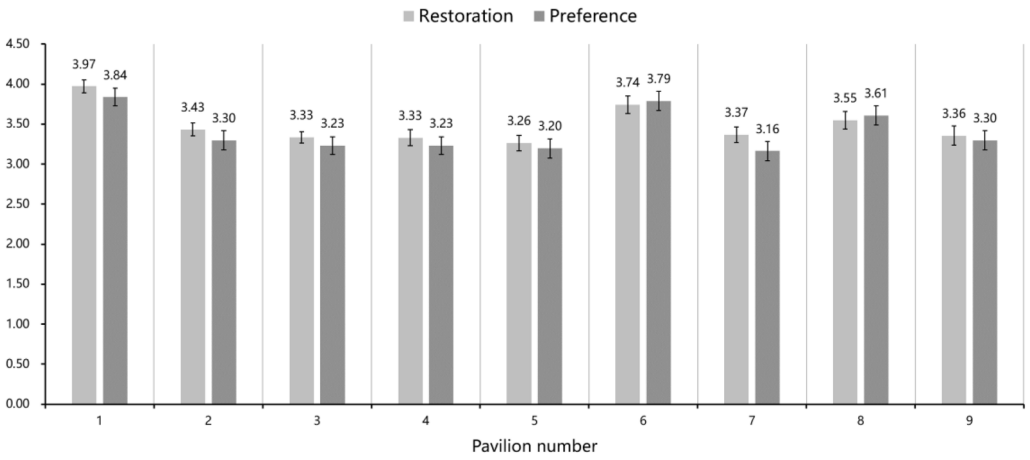


Fig. 5. The mental restoration and preference score of nine selected pavilions. N = 61; Mean ± Standard deviation.

(2.80 ± 1.05) have the lowest scores. For space, Pavilion 5 (3.93 ± 0.81) was the highest, whereas 3 (2.57 ± 1.02) was the lowest. In the nature dimension, the Pavilion 1 setting had the highest degree of naturalness (3.98 ± 0.88), whereas 4 had a more artificial environment (3.00 ± 0.81). In terms of refuge, Pavilion 3 had the highest score (3.34 ± 1.09). However, the six pavilion settings did not exceed the score of 3, which indicates that this dimension is not obviously perceived; in this context, Pavilion 5 had the lowest score (2.30 ± 0.91). For the prospect dimension, Pavilions 2 (3.84 ± 0.85), 5 (3.90 ± 0.88), 6 (3.82 ± 0.78), and 9 (3.93 ± 0.81) had higher scores, whereas 1 (2.69 ± 1.02) and 3 (2.62 ± 0.81) had the lowest scores. In the serene dimension, all pavilions exceeded 3, among which Pavilion 1 (4.43 ± 0.71) was considered the most peaceful environment, and 5 (3.13 ± 0.93) had the lowest score. In addition, only Pavilions 2 (3.08 ± 1.12) and 6 (3.33 ± 0.99) exceeded the score of 3 in the culture dimension, thus signifying that the participants could not clearly perceive this dimension. Rich in species is another dimension that is strongly perceived; Pavilions 1 (3.92 ± 0.80), 6 (3.75 ± 0.92), and 7 (3.66 ± 0.83) had higher scores, yet Pavilion 5 had the lowest score (3.03 ± 0.90).

3.3. Difference between open and semi-open pavilions

For further comparison, in the following analysis, the pavilions are divided into two categories according to the enclosure degree: semi-open pavilions (1–3) and open pavilions (4–9). An ANOVA was performed to analyze the differences. As shown in Fig. 7, most PSDs showed significant differences. Specifically, the two pavilion categories were significantly different across the dimensions of social ($F_{(1,120)} = 3.968$, $p = 0.049$, Cohen's $d = 0.36$), space ($F_{(1,120)} = 13.042$, $p < 0.001$, Cohen's $d = 0.65$), refuge ($F_{(1,120)} = 11.711$, $p = 0.001$, Cohen's $d = 0.62$), prospect ($F_{(1,120)} = 44.993$, $p < 0.001$, Cohen's $d = 1.21$), serene ($F_{(1,120)} = 17.570$, $p < 0.001$, Cohen's $d = 0.76$), and richness of species ($F_{(1,120)} = 4.137$, $p = 0.044$, Cohen's $d = 0.37$). However, there was no significant difference between mental restoration and preference, indicating that both pavilions have the same preference and mental restoration.

Furthermore, to explore the relationship between the two pavilion categories and PSD, ordinal logistic regression analysis (with the semi-open pavilion as the reference group) was performed. According to the results shown in Table 3, the model has a good degree of fit ($\chi^2 = 84.084$, $p < 0.001$, Chen et al., 2019). The prospect dimension was more likely to be perceived (OR greater than 1, $p < 0.001$) in the open-pavilion category; in contrast, the serene dimension was more likely to be perceived (OR < 1, $p = 0.002$) in the semi-open pavilion category.

3.4. PSD predictors of preference and mental restoration

Two stepwise multiple linear regression analyses were performed to

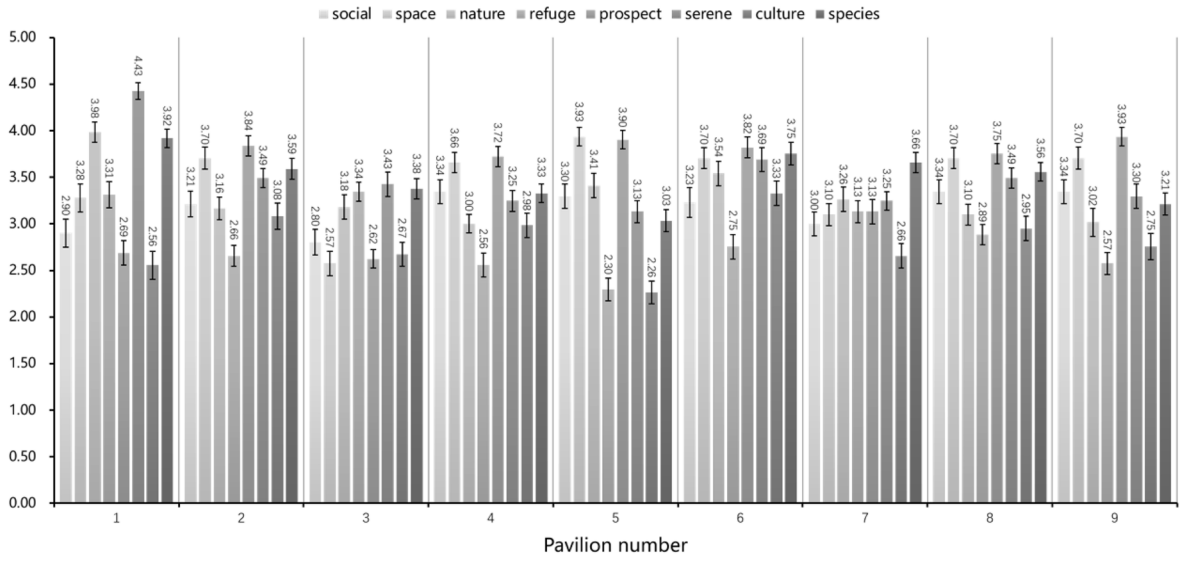


Fig. 6. The PSD evaluation of nine selected pavilions. N = 61; Mean ± Standard deviation.

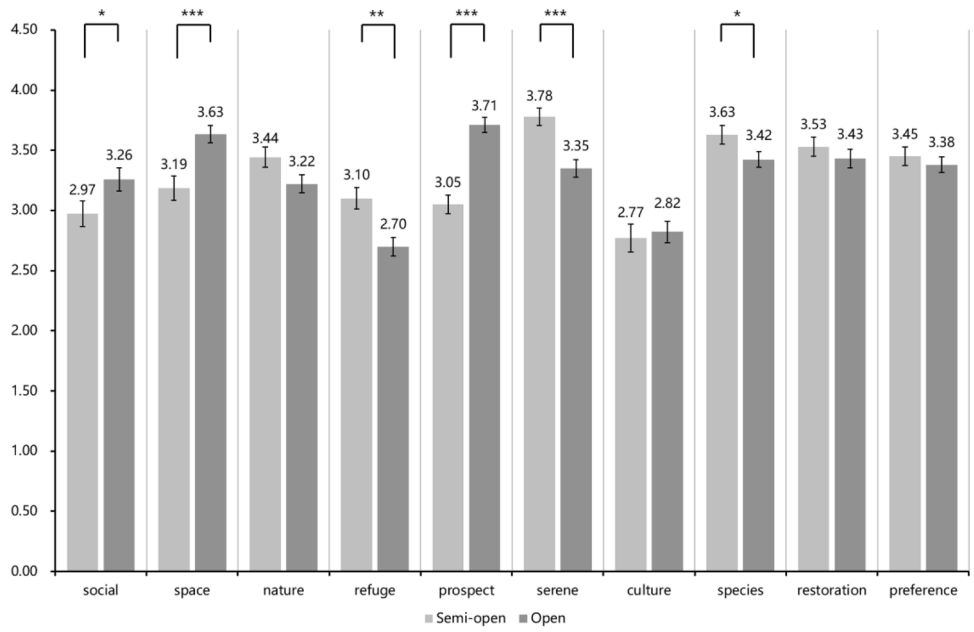


Fig. 7. Differences in assessment of open and semi-open pavilions.

Table 3
Ordinal logistic regression analyses results.

PSD	B	Standard error	OR	95% CI	Sig.
Social	0.172	0.130	1.188	(0.922–1.532)	0.184
Space	0.271	0.166	1.311	(0.946–1.817)	0.103
Nature	−0.197	0.143	0.821	(0.620–1.088)	0.170
Refuge	−0.201	0.132	0.818	(0.631–1.059)	0.127
Prospect	0.702	0.161	2.018	(1.473–2.765)	<0.001
Serene	−0.538	0.172	0.584	(0.417–0.818)	0.002
Culture	−0.055	0.130	0.947	(0.734–1.222)	0.675
Rich in species	0.046	0.169	1.047	(0.753–1.457)	0.783
$\chi^2 = 84.084$					
Df = 8					
$p < 0.001$					

Note: a bold font indicates $p < 0.05$.
Reference group is the semi-open pavilion.
OR, odds ratio; CI, confidence interval; Df, degree of freedom.

explore the PSD that affects recovery and preference. The dependent variables of the two regression models were overall preference and mental restoration. The correlation analysis results (Table 4) indicate that restoration would increase with preference; all PSDs, except for the social dimension, showed a significant correlation with preference and restoration.

The results demonstrate that these variables can be used to build regression models. First, we examined the normality of model residuals, ANOVA, and multicollinearity using the Kolmogorov –Smirnov (KS) test to solve the multicollinearity problem between the predictor variables. The test results show that the residuals follow a normal distribution (for social, K-S Z value = 0.501, p = 0.963; for space, K-S Z value = 1.091, p = 0.185; for nature, K-S Z value = 0.789, p = 0.563; for refuge, K-S Z value = 0.769, p = 0.595; for prospect, K-S Z value = 0.619, p = 0.839; for serene, K-S Z value = 0.517, p = 0.952; for culture, K-S Z value = 0.574, p = 0.897; for species, K-S Z value = 1.075, p = 0.198; for mental restoration, K-S Z value = 0.572, p = 0.899; for preference, K-S Z value = 0.814, p = 0.522). In addition, the variance analysis results show a linear correlation between PSD and preference ($F = 20.213$, $p < 0.001$) and mental restoration ($F = 51.284$, $p < 0.001$). Lastly, the occurrence of a model tolerance of < 0.2, or a variance inflation factor (VIF) > 10, is indicative of a potential multicollinearity problem (Arriaza et al., 2004). Thus, the current model results are acceptable (lowest tolerance = 0.724 and highest VIF = 1.380).

As shown in Table 5, "prospect" and "serene" significantly influence preference, explaining 39% of the variance, whereas for restoration, "rich in species" and "serene" are significant predictors, thus explaining 62.6% of the variance. In sum, with regard to preference or mental restoration, the serene dimension is consistently a significant predictor of the model.

3.5. The generalized preference and restorative environment setting

After viewing each pavilion with VR, the participants were asked to

Table 4
Overall correlation results.

	Social	Space	Nature	Refuge	Prospect	Serene	Culture	Species	Restoration
Social	1								
Space	0.67**	1							
Nature	0.09	0.39**	1						
Refuge	0.32*	0.41**	0.47**	1					
Prospect	0.34**	0.67**	0.44**	0.43**	1				
Serene	0.04	0.33**	0.59**	0.56**	0.36**	1			
Culture	0.31*	0.46**	0.39**	0.46**	0.56**	0.53**	1		
Species	0.18	0.40**	0.57**	0.37**	0.24	0.53**	0.45**	1	
Restoration	0.20	0.42**	0.62**	0.53**	0.42**	0.75**	0.43**	0.63**	1
Preference	0.18	0.37**	0.46**	0.46**	0.46**	0.58**	0.43**	0.44**	0.62**

Note: * $P < 0.05$; ** $P < 0.01$.

Table 5
Significant PSD predictors of overall preference and mental restoration.

Dependent	Independent	Unstandardized Beta	Standardized Beta	t	Sig.	Collinearity statistics	
						Tolerance	VIF
Preference (Adjusted $R^2 = 0.390$)	(constant)	0.500		1.056	0.295		
	Serene	0.491	0.475	4.403	<0.001	0.873	1.146
	Prospect	0.341	0.293	2.713	0.009	0.873	1.146
Mental restoration (Adjusted $R^2 = 0.626$)	(constant)	−0.330		−0.853	0.397		
	Serene	0.679	0.575	6.203	<0.001	0.724	1.380
	Species	0.413	0.330	3.558	0.001	0.724	1.380

complete an additional questionnaire to share what they wanted to do most in each scene (Fig. 8), as well as their favorite elements in each panorama (Fig. 9). Specifically, sitting (335), reading (228), chatting (387), and viewing the scenery (281) were among the favorite activities reported by most participants, while others also chose sleeping (72). In addition, lush plants (362), water bodies (267), buildings (232), natural trails (172), and meadows (159) were considered the most preferred elements within the panoramas, while animals (65), rockery (71), and artificial roads (85) were the least preferred. These results indicate that providing visitors with a space to sit, rest, socialize, read, and view the scenery is key to the preference environment setting. Moreover, adding elements such as dense vegetation, water bodies, and meadows to these environments could be considered to build a generalized preference and restorative environment setting.

3.6. Qualitative assessment of semi-structured interviews

In the final stage, a simple semi-structured interview was conducted to evaluate the VR viewing experience. Only one participant reported feeling slightly uncomfortable during the viewing: "(for pavilion 1) *I can see the stream outside, but I feel a little uncomfortable at the beginning because of the still water in the picture…*" In addition, participants generally described the viewing experience as "relaxing," "calm," "attractive," and "a novel experience." However, few interviewees stated that some panoramas had unclear details in the distance, which may have resulted in a lower score. In addition, 38 participants (62.3%) hoped to visit these pavilions on-site (such as pavilions with 1, 6, and 9) after viewing. The quotes illustrating this fact are as follows.

(For Pavilion 1) "*…it makes me feel peaceful. I really want to sleep here.*"

(For Pavilion 6) "*…Awesome! Those high-rise buildings look just like a background, blending perfectly with the surrounding landscape.*"
(For Pavilion 9) "*The black pine on the grass is beautiful… Here is the Kyu-shiba-rikyu Garden? I will go to this place.*"

4. Discussion

4.1. Restoration through VR viewing of pavilion settings

Urban nature has become increasingly important to humanity, with the influx of migration to cities. Moreover, increasing risks of pandemics might motivate people to explore regional and urban lives, rather than long-distance travel. Several studies have discussed the health benefits of visiting urban parks, including its contributions to psychological health (Wan et al., 2020), social health (Hartig, Mitchell, De Vries, & Frumkin, 2014), physical health (Kaczynski, Potwarka, & Saelens, 2008), stress relief (Ulrich et al., 1991), and direct attention restoration (Kaplan, 1995). However, urban parks are extensive in scope when considered as a concept, and research on specific settings related to them is lacking. Furthermore, most studies that have explored urban parks are based on the perspectives of standing (Karacan, Kombeiz, & Steidle, 2021; Mostajeran, Krzikawski, Steinicke, & Kühn, 2021) and walking (Bielinis, Simkin, Puttonen, & Tyrväinen, 2020); moreover, few have simulated people sitting and resting in these natural environments. Research has employed virtual reality technology to view and recover from a variety of environments, including coastal (Tanja-Dijkstra et al., 2018), forests (Yu et al., 2018), biophilic indoor environments (Yin et al., 2018), and even VR urban (Jeon et al., 2021). Arguably, as any environment has restorative potential, all potentially restorative environmental settings should be carefully examined (Kaplan, 1995).

In this study, a self-report scale containing three dimensions was

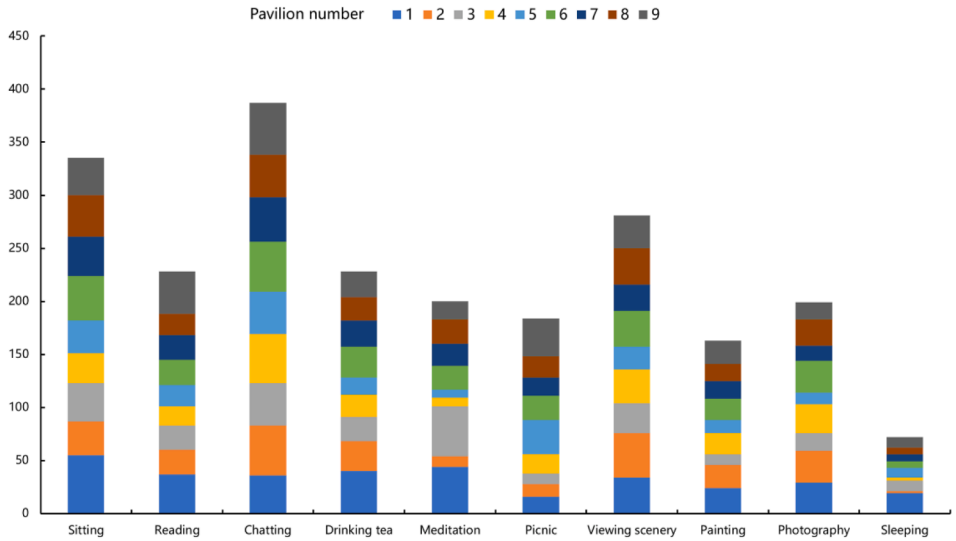


Fig. 8. Participant responses to "What do you want to do most in this scene?" (Multiple responses).

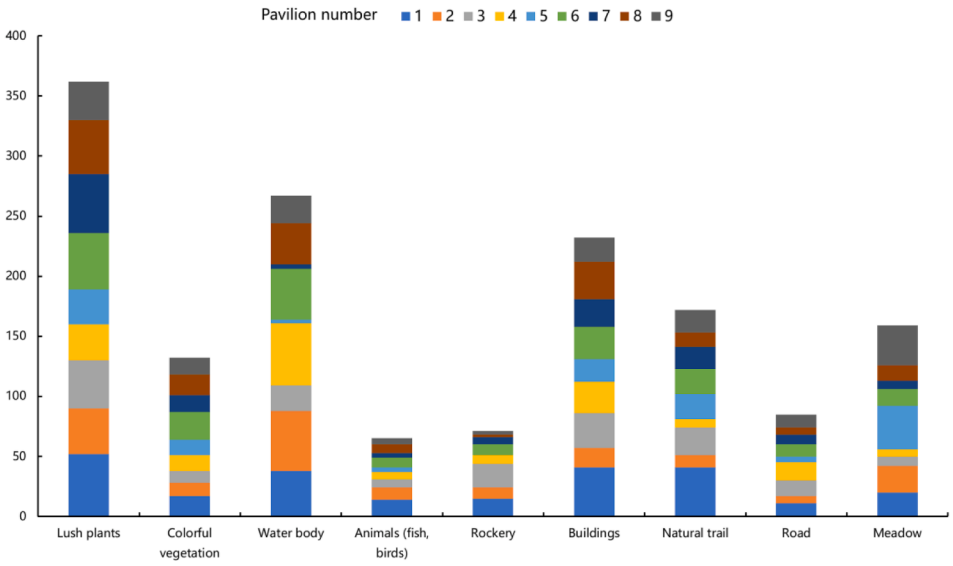


Fig. 9. Participant responses to "What is your favorite element in this scene?" (Multiple responses).

used to measure restorative experiences. The psychological recovery score for each pavilion was the average of these three dimensions. Consistent with the findings of Wan et al. (2020), the Cronbach's alpha value for this scale was greater than 0.8, indicating good reliability. The results of this study indicated that all nine pavilion settings had a mental restoration score of over 3, thus implying that most participants affirmed the restorative effect of viewing the pavilion settings (Jeon et al., 2021). Pavilions 1, 6, and 8 achieved high mental restoration scores (Fig. 5). The participants were able to observe water bodies and dense vegetation through VR. Meanwhile, according to the result of "favorite elements in the scene" (Fig. 9), lush vegetation, water bodies, and meadows were the desired elements identified by the participants. In contrast, Pavilion 5 was evaluated as the least restorative environment, which may be attributed to the lack of a water body and scant vegetation in the scene. Therefore, the result can be proven by the correlation between preference and restoration (Table 4); that is, people perceive mental recovery from favorite scenes (Deng et al., 2020), whereas inadequate physical environments could cause stress (Kaplan, 1995). It can be inferred that spending time in these VR natural environments could lead to mental restoration (Tsunetsugu et al., 2013). This result addresses the first research question posed in this study.

4.2. *The role and impact of the pavilion enclosure*

The nine pavilions were divided into open and semi-open categories according to the enclosure, and the ANOVA results indicated no significant difference in the preferences and mental restoration between the two types of pavilions. This suggests that pavilion enclosure does not affect these two variables. Although this result answers the second question, we also found that enclosure significantly influenced PSD.

The overall results (Fig. 6) show that unlike previous studies (Qiu & Nielsen, 2015; Chen et al., 2019), the highly perceived dimensions in this study were *prospect*, *serene*, and *rich in species*. Among these, *serene* and *rich in species* were strongly perceived dimensions, which aligns with those of prior research examining small public urban green spaces (Peschardt & Stigsdotter, 2013).

However, the dimension of culture was perceived to be weak across all pavilions, which is inconsistent with previous findings on other urban green spaces (Qiu & Nielsen, 2015). The culture dimension is generally considered to be related to a large number of artificial elements, such as fountains, sculptures, kitchen plants, and ornamental plants (Stigsdotter et al., 2017), which were rare in the environments of this study. Pavilion 6 received the highest score (3.33) in this dimension, which may be because Hibiya Park is a modern urban park (Fig. 10). Here, participants could view a fountain with crane sculptures and some wetland ornamental plants (e.g., less bulrush). Research has discussed restorative elements related to culture, such as artistic elements (Scopelliti, Carrus, & Bonaiuto, 2019) and historical sites (Masullo, Ozcevik Bilen, Toma, Akin Güler, & Maffei, 2021b). The high restoration score of Pavilion 6 appears to be related to this aspect. However, due to the limitations of the survey sample, caution should be exercised when interpreting the results.

In addition, compared with the differences between open and semi-open pavilions (Fig. 7), the results show that the six dimensions of the eight PSDs reveal significant differences: social, space, refuge, prospect, serene, and rich species. However, the ANOVA showed only a difference in PSD. Therefore, ordinal logistic regression analysis was performed. According to Table 3, participants were more likely to perceive the prospect dimension in the open-pavilion category; the serene dimension was more likely to be perceived in the semi-open pavilion category. These results are reasonable. The prospect dimension can be summarized as having open and flat areas (Grahn & Stigsdotter, 2010), emphasizing no visual obstruction. In the study samples, an open pavilion enabled a broader vision compared with the semi-open pavilion, which allowed participants to see the distance and provide an overview of the surroundings (Stoltz & Grahn, 2021). The serene dimension signifies an undisturbed, not crowded, quiet, and safe environment (Grahn & Stigsdotter, 2010; Bengtsson & Grahn, 2014), and was perceived to a greater extent in the semi-open pavilion context, which is inconsistent with previous research conclusions. For instance, in a Swedish study, most interviewees experienced serene dimensions in relatively large green areas (Qiu & Nielsen, 2015). However, the viewer in the semi-open pavilion is usually in a narrow space, and a part of the view is obstructed. Therefore, this enclosed space can increase the sense

Fig. 10. View from pavilion 6.

of security and create a retreat environment (Grahn & Stigsdotter, 2010). Arguably, the size of the space does not affect the user's experience of serenity (Peschardt & Stigsdotter, 2013), but the degree of enclosure does. Moreover, Bengtsson and Grahn (2014) indicated that the presence of an enclosure can separate the exterior from the interior environment, thus creating a safe and private space (undisturbed). Accordingly, even though the pavilion is semi-open, it can still reinforce the user's perception of serenity.

4.3. PSD predictors driving restoration and preference

Many studies have confirmed the association between PSD and users' perceived restoration and preference (Chen et al., 2019; Grahn & Stigsdotter, 2010; Peschardt & Stigsdotter, 2013; Stigsdotter et al., 2017). Our results (Table 5) indicate that the dimensions of prospect and serene significantly affect preference; for mental restoration, the dimensions of species richness and serene were significant predictors.

According to Appleton (1975), when ancient humans searched for habitable environments, prospect was considered an essential quality. People instinctively choose environments conducive to survival, and one of the most critical elements is the visual control of the environment, which allows them to discern danger. The prospect is usually characterized by flat and well-cut grass surfaces and vistas (Peschardt & Stigsdotter, 2013). Therefore, a good view unobstructed by vegetation (an overview of the surroundings) can boost the user's preference. Conversely, a lower prospect may mean a weakened sense of security and lesser preference among users to sit and rest in this environment.

Serene was found to be an important predictive PSD dimension of mental restoration and preference, which is consistent with the findings of a previous study (Peschardt & Stigsdotter, 2013). Usually, participants can experience a sense of security in these resting environments and in private spaces created by dense vegetation. The absence of people seems crucial for this dimension (undisturbed and not crowded). Therefore, the results show that creating a tranquil atmosphere free from external interference is important for a restorative environment (Memari, Pazhouhanfar, & Nourtaghani, 2017). This observation may raise some concerns because our experiments were conducted in a silent environment. However, Pheasant, Horoshenkov, Watts, and Barrett (2008) established that a sense of tranquility can be created using only static visual stimuli. Serene is considered a cognitive quiet, suggesting a coordination between mental and physical space, and is highly associated with natural features (Pheasant et al., 2008), such as water and greenery that provide relaxation (Bengtsson & Grahn, 2014). In this study, the participants' perception of serenity was a "pure" tranquility, which is different from what is commonly referred to as quiet. For example, viewing images of crowded streets and forests (without sound) may bring a different sense of tranquility. In addition, it has been shown that high-decibel natural sounds (birdsong, water flow) are more tranquil than low-decibel artificial noise (Jeon et al., 2021). Thus, the perception of serenity is not measured solely by sound level; visual factors must also be considered. Therefore, understanding the sense of serenity induced by visual stimuli is valuable for the design and management of the physical environment of these restorative spaces.

Finally, species richness is another important predictor of mental restoration. Humans can accurately perceive species richness, and aesthetic appreciation of settings increases with species richness (Lindemann-Matthies, Junge, & Matthies, 2010). According to the theory of evolution, diversified vegetation usually represents a complex environment and the possible abundance of food in this setting (Zhao, Wang, Cai, & Luo, 2013). Thus, having more animals and plants is important for maintaining a restorative environment (Deng et al., 2020). For example, abundant plants (i.e., trees, bush, grass, and hydrophytes) have the effect of spatial isolation and help create a relaxing scene (Du, Zhou, Cai, Li, & Xu, 2021). Multifarious expressions of life (i.e., trees, flowers, fruits, animals, insects) can provide users with more opportunities to interact with natural elements, thus promoting well-being and recovery (Bengtsson & Grahn, 2014).

4.4. The generalized preference and restorative environment setting

According to Fig. 8, the participants liked to perform gentle leisure and social activities in the resting environments, which include sitting, reading, chatting, taking pictures, and viewing the scenery for recovery and relaxation. These results indicate that providing visitors with such a space could contribute to their preference of environment setting. In addition, Fig. 9 shows that lush plants, waterbodies, buildings, natural trails, animals, and meadows are the most preferred elements. These results are consistent with those of Deng et al. (2020), who revealed that people generally prefer environments with biodiversity (dense vegetation, small animals, water bodies, and meadows). This environment is moderately complex and is considered an essential quality of a restorative environment. Therefore, managers and designers should consider adding elements that people prefer in these rest environments to build a generalized restorative environment setting (Fig. 11).

The presence of buildings was an interesting issue in this study. Research has shown that humans generally prefer natural scenery, as it promotes the connection between humans, the natural environment, and natural activities (Zhao, Xu, & Ye, 2018). However, most participants chose buildings as their preferred element, a result consistent with the findings of Chen, Shi, Xia, and Furuya (2020) in Tokyo's Cultural Heritage Gardens. Tourists usually have a tolerant attitude towards high-rise buildings outside these traditional gardens, and more than half of the respondents believe that artificial constructions have a positive impact on the garden landscape. Therefore, arguably, if the balance with nature is maintained, human influences could also be appreciated in these resting environments (Strumse, 1994).

4.5. VR experience and implications

In the final interview phase, only one participant reported mild discomfort during the viewing process, which differed from the results of previous studies (Yu et al., 2020). This deviation could be related to the stimulus in this study, which was a static panorama, compared with the video format used in the study (Yu et al., 2020), with varying results. However, our study does not conclude that still pictures can effectively reduce cybersickness. Further research is required to explore this aspect. Moreover, participants reported that using VR to simulate the experience of sitting in a pavilion was "relaxing," "calming," "attractive," and "a novel experience." Consistently, Chang, Hammitt, Chen, Machnik, and Su (2008) indicated that restorative experiences require psychological and physical distance from one's usual environment. Thus, "entering the pavilion" can produce separation from the outside world, i.e., physical separation (novelty) and psychological isolation (escape), thereby facilitating restoration (Pals et al., 2009). Accordingly, the results indicated that it is feasible to use VR to simulate pavilion settings and other resting environments in urban parks for relaxation and recovery, and that VR viewing seems to motivate people to visit these outdoor natural environments on-site. Thus, VR simulation could be another way of gaining a natural experience (Yu et al., 2020); however, concerns related to image quality and cybersickness (e.g., dizziness and nausea) must be addressed (Calogiuri et al., 2018).

This study contributes to the body of knowledge in this field, highlighting the need for research pertaining to pavilions and other resting environments in the city, such as chairs in the square/parks, houses of worship (Herzog et al., 2010), watersides (Korpela, Ylén, Tyrväinen, & Silvennoinen, 2010), and museums (Kaplan, Bardwell, & Slakter, 1993). These resting environments in urban landscapes have a positive impact on human well-being and quality of life. According to evidence-based medicine, in the design and management of a healthy urban environment, specific evidence should be considered to provide a scientific basis for particular health effects (Tsunetsugu et al., 2013). Therefore, these results are valuable for supporting the development of healthy urban

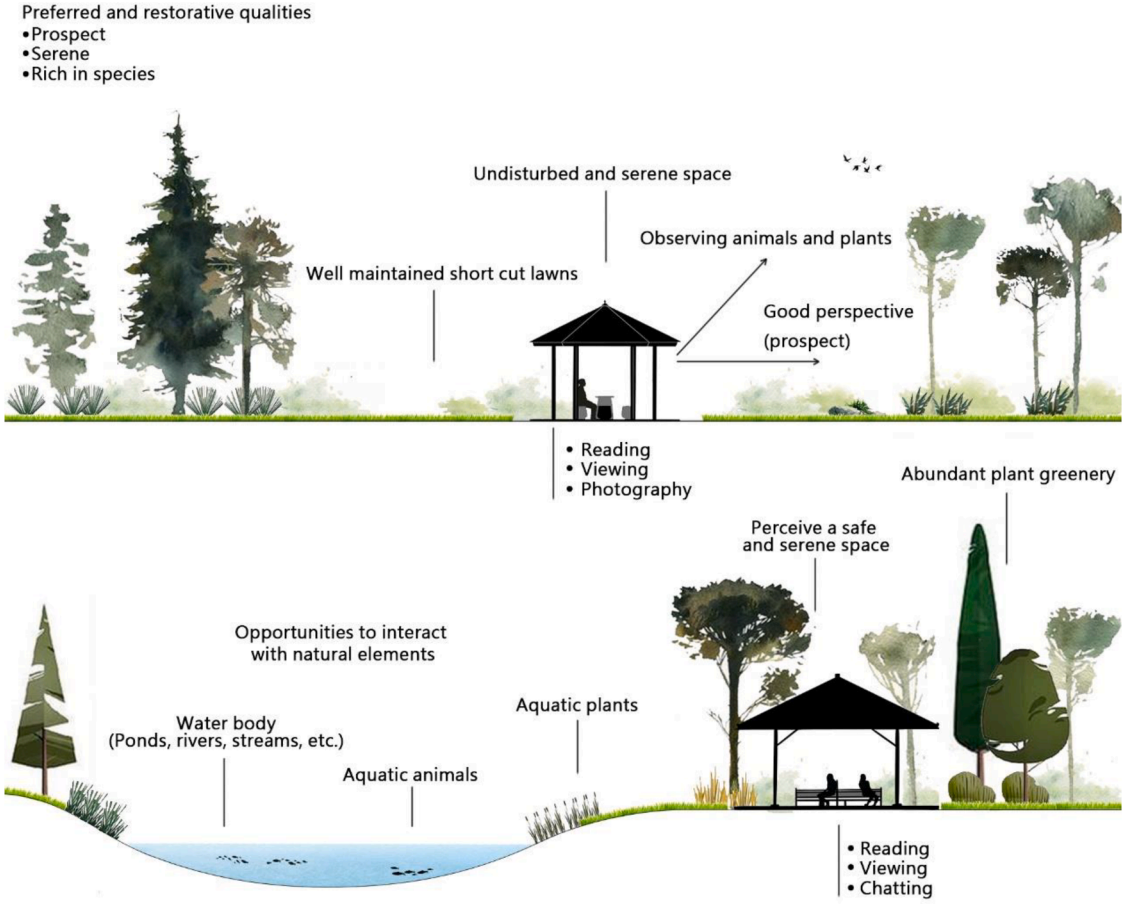


Fig. 11. Illustration of a generalized preference and restorative environment setting.

environments. Finally, restorative VR-based experiences address a growing number of public health challenges. For example, residents are restricted from going out during the COVID-19 pandemic (Xie, Luo, Furuya, & Sun, 2020), office workers look for a short-term respite from the typical office environment (Yin et al., 2018), and there are season-specific hazards (e.g., respiratory diseases and allergic diseases) that are caused by green spaces (Zhang, Dong, & Wang, 2021). The use of VR to remotely visit these resting environments may be a practical solution to the challenges that result from these restrictions. Moreover, we can even design virtual restorative environments in the "metaverse" specifically for psychological recovery, which is an interesting and exciting topic.

4.6. Limitations and future research

This study has some limitations. First, although several pavilion samples were investigated, it was considered difficult for participants to view all the scenes. In the future, a new round of evaluation is necessary to supplement the findings of this study. Second, research that includes participants of different ages, occupations, and cultural backgrounds could be valuable. Third, some participants reported that vagueness in vista/details in the panoramas might have affected their assessment. Panoramas with a higher resolution can reduce these concerns. The factors that lead to recovery in realistic environments are complex, such as smell (Ikei et al., 2015), sound (Deng et al., 2020), and light (Li, Sun, Sun, Yuan, & Li, 2020). Future research could combine more sensory stimuli to produce more powerful restoratives. Furthermore, it may be interesting to discuss the influence of materials, textures, complexity, and styles of different pavilions on restoration/preferences, combined with architectural viewpoints. Finally, due to the limitations of the survey sample, this study only categorized pavilions as open and semi-open. Taking panoramic pictures of pavilions with many variable conditions requires a significant amount of effort. Therefore, creating pavilions with various shapes, height-to-width ratio, and enclosures (high, medium, low) using 3D modeling techniques can save costs, while maintaining a high level of experimental control.

5. Conclusion

Urban parks are essential components of healthy urban environments. However, most research exploring these spaces is generalized and lacks focus-specific settings. This study used VR equipment to simulate the experience of sitting in a pavilion of an urban park to evaluate different pavilion settings' preferences and mental restoration. The results showed that viewing these environmental settings through VR effectively promoted mental recovery. The enclosure of the pavilion did not significantly affect people's preferences and perceived recovery in this environment. The dimensions of prospect and serene significantly influenced preferences; for mental restoration, the richness of species and serene were significant predictors. Therefore, the results of this study suggest that: 1) a lower prospect may mean a weakened sense of security and lesser preference for users sitting and resting in this environment; 2) creating a tranquil atmosphere free from external interference is important for a restorative environment; and 3) the abundance of flora and fauna can provide users with more opportunities to interact with natural elements, thus promoting well-being and recovery. In addition, the results indicated that providing visitors with a space to sit, rest, socialize, read, and view the scenery can help in the development of preference environment settings. Therefore, urban park managers could consider adding elements such as dense vegetation, water bodies, and

meadows to these environments to build a generalized preference and restorative environment setting. If the balance with nature is maintained, artificial elements such as buildings and roads can also be appreciated by visitors. Finally, the results demonstrated that it would be feasible to use VR to simulate pavilion settings and other resting environments in urban parks for relaxation and recovery.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A: The specific location of the selected nine pavilions

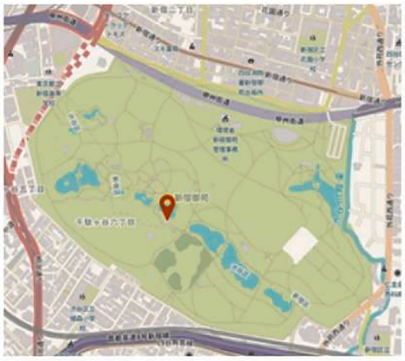
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

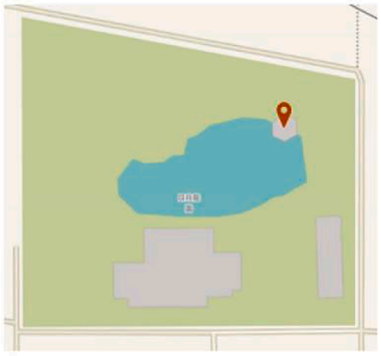
We wish to thank the editor and reviewers for their careful and thoughtful examination of our manuscript and for their valuable comments, which have greatly improved our manuscript. Sincere thanks to all the anonymous participants.

1. Takimi-no-chaya
Rikugien Gardens

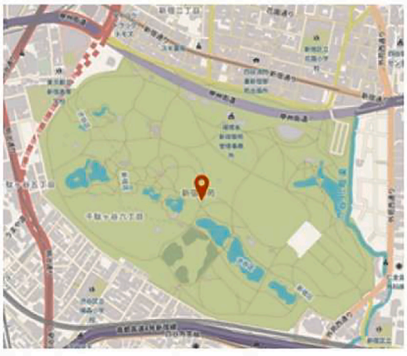


2. Taiwan Pavilion
Shinjuku Gyoen National Garden

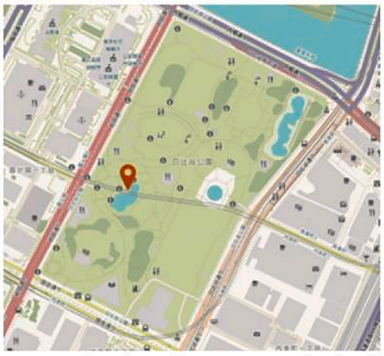
3. Linsentei
Edogawa Heisei Garden



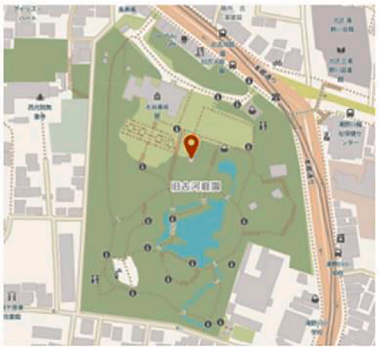
4. Rokkaku-uki-midou
Mejiro Garden



5. Nameless Hexagonal Pavilion
Shinjuku Gyoen National Garden

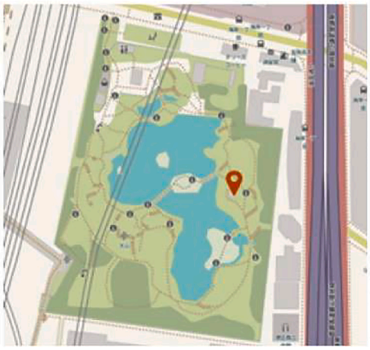


6. Nameless Hexagonal Pavilion
Hibiya Park



7. Observatory
Kyu-Furukawa Gardens

8. Nameless Square Pavilion
Shinjuku Gyoen National Garden



9. Nameless Square Pavilion
Kyu-shiba-rikyu Gardens

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