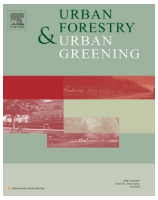
Urban Forestry & Urban Greening 76 (2022) 127730

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

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



How do humans value urban nature? Developing the perceived biophilic design scale (PBDs) for preference and emotion

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ARTICLE INFO

Handling Editor: Tenley Conway

Keywords:
Built environment
Human-nature relationship
Preference
Positive and negative affect schedule
Landscape design

ABSTRACT

With the growth of urbanization and the increasingly hectic pace of life, exposure to urban nature within blue-green infrastructure is greatly impacting human health and well-being. Biophilia, an evolutional concept, conveys the initial connection between humans and nature; biophilic design transfers into design attributes to indicate the relationship between humans and the environment. A significant advantage of experiencing nature is positive restoration; however, only limited research has been conducted on connecting biophilic design and mental health. This study adopted our perceived biophilic design items (PBDi) to examine the relationship between landscape preferences and emotional states in urban green spaces. Online surveys (valid total $n = 477$) examining these biophilic items, landscape preferences, and emotional states were conducted. Seven aspects—(1) evolved human–nature relationships, (2) place-based relationships, (3) visual aesthetic quality, (4) state of natural change, (5) environmental perception, (6) sense of compatibility in the built environment, and (7) natural form of design method —were confirmed through exploratory factor analysis (EFA), with 64.35 % of the cumulative variance, and confirmatory factor analysis (CFA) demonstrated good convergent validity and discriminant validity. The overall perceived biophilic design scale (PBDs) with 28 items had a Cronbach's α of 0.91. In addition, it was found that PBDs significantly explained landscape preferences and positive emotional states within urban nature. The findings provide an alternative tool for measuring human biophilic perceptions that influence environmental experiences. In addition, each item in the scale could be used as a biophilic guideline for designers and planners to reinterpret nature in cities and to enhance our connection to nature in general.

1. Introduction

Humans use sensory experiences to comprehend the environment, urban areas being no exception. Biophilia, which is associated with a love for nature, describes a psychological state that, through the evolutionary process of survival, reacts to the physical environment and generates a tendency to connect with nature (Kellert and Wilson, 1993; Wilson, 1984). The biophilia hypothesis, as relevant to the five biophilic values—naturalism, aesthetics, symbolism, humanism, and moralism—is connected with contact, beauty, meaning, emotion, and compassion, all of which predict the connection between nature and the physical environment and associated health benefits (Lumber et al., 2017; Lumber et al., 2018). One of the more intriguing questions prevalent throughout the last few decades is what biophilic design is and how it impacts our perception of nature and well-being.

Landscape designers use natural elements and topography to balance nature and the built environment, thereby making urban environments more livable and appealing. Such a design approach is related to biophilic design. The biophilic design proposed by Kellert et al. (2008) is a landscape architectural method that includes natural elements, patterns, and ecologies, such as trees, water, and natural lines, in the built environment. It contains two dimensions: (1) "organic or naturalistic," which refers to environmental features, natural shapes, forms, patterns, and processes, and (2) "place-based or vernacular," which refers to place-based relationships and evolved human–nature relationships (Kellert et al., 2008). These concepts indicate that integrating the biophilic into life is an approach to providing a sense of comfort and connection, as well as health benefits (e.g., attention restoration, positive emotion, reducing physiological and psychological stress) (Browning et al., 2014; Gillis and Gatersleben, 2015; Hung and Chang, 2021;

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https://doi.org/10.1016/j.ufug.2022.127730
Received 15 September 2021; Received in revised form 29 August 2022; Accepted 8 September 2022
Available online 13 September 2022

Kellert et al., 2008).

One study used eight perceived sensory dimensions (i.e., prospect, refuge, species, culture, nature, social, space, and serene) as a tool to comprehend how humans interact with urban nature and to predict one's preference, attitude, and willingness to use in the urban green space (Chen et al., 2019). This research recommended applying biophilic design with natural features and settings to support the connection with urban nature in social, ecological, and individual aspects. Other studies indicated that urban aesthetic attributes (Hidalgo et al., 2006), which refer to the biophilic—the visual quality of plants, elements, and spaciousness—could be important in urban natural design to foster a sense of harmony, preference, and restorativeness (Berto et al., 2015; Wang et al., 2019). Several review studies have examined the effects of human experience with nature via different landscape typologies, the duration and frequency of connecting to nature, and green activities on physiology and psychological health (Barbiero and Berto, 2021; Bratman et al., 2019; Collins et al., 2020; Meredith et al., 2020). In addition, various studies have tested restorative benefits, preferences, and emotional states, but few studies have sought to precisely explain which perceived biophilic attributes could affect the human–nature relationship. Therefore, to strengthen the value of exposure to nature and health, we argue that there is a tendency to put the biophilic into practice.

As Kellert et al. (2008) (p. 5) stated, "restorative environmental design, an approach that aims at both a low-environmental-impact strategy and a positive environmental impact or biophilic design approach that fosters beneficial contact between people and nature in modern buildings and landscape." In contrast, there is a gap between perceived biophilic design and human health due to the lack of a measurement scale. Therefore, in the following, from the above reasoning and related descriptions, we discuss evidence-based studies on landscape and human health that have developed the perceived biophilic design scale (PBDs) in the context of the built environment.

1.1. Theories related to human experience with nature

For more than 30 years, research on nature-related experiences has continued to expand dramatically. The relationship between landscape and human health has roots in evolutionary theories. The prospect and refuge theory of how humans observe environmental information immediately and without being seen infers our basic survival skills in the biosphere (Appleton, 1975), which could influence one's perceptions and preferences. For example, a savanna-like environment provides an open terrain with scattered trees, and visual accessibility is what humans prefer. Moreover, it could compel humans to explore and obtain resources (e.g., water, vegetation, flowers, trees). In addition, this kind of landscape could influence emotional reactions and survival instincts (Balling and Falk, 1982; Heerwagen & Orians, 1993; Orians and Heerwagen, 1992). These theories indicate that part of biophilia is based on evolution (Barbiero and Berto, 2021), which explains the benefits of natural connection, such as attention restoration and stress reduction for a better life. The related theories on environmental psychology, perceptions, and reactions are listed below:

A. Attention restoration theory (ART): Exposure to a natural environment with restorative characteristics—being away, fascination, extent, and compatibility—could restore direct attention from fatigue. Specifically, fascination includes involuntary aspects and aesthetic experiences, which play a role in attracting human attention directly from information richness and lead us to explore and discover the place. The above statements relate to landscape preference ratings (Kaplan and Kaplan, 1989) and to understanding and exploring the content and spatial configurations in the environment (Kaplan, 1987; Kaplan and Kaplan, 1989). It also refers to the aspects of the evolved human–nature relationship in biophilic design.
B. Stress reduction theory (SRT): SRT emphasizes that viewing or visiting the natural environment after stressful situations could restore one's emotional and physiological processes to a better state (Ulrich, 1984). Studies have shown that exposure to nature reduces the level of physiological and psychological stress (Berto, 2014; Shuda et al., 2020; Yao et al., 2021). Moreover, one study pointed out that, in contrast to non-biophilic buildings, large parks with plants bolster restorativeness and reduce negative emotions and perceived stress (Martínez-Soto et al., 2021). These statements indicate that nature in urban or public spaces with water features, plants, trees, etc., affects one's restorativeness and health.
C. Sense of place or spirit of place: Recognizing and connecting to a site enhances a psychological state related to the relationship between humans and place (Relph, 1976). The psychological place connection in the built environment could be inferred from the use of materials, cultural aspects, geographical context, etc., which is related to the aspect of the place-based relationships in biophilic design.
D. Traditional environmental Qi: Taoism, Confucianism, and Feng Shui are the central philosophical and environmental concepts that deeply affect the relationship between the environment and humans in the East. Chou et al. (2020) determined the composition and configuration of natural elements and their microclimates in their surroundings. The balance between organic and inorganic in a Qi setting could elicit health benefits.
E. Emotional states: Natural landscapes provide either positive affection (i.e., biophilia) or negative emotion (i.e., biophobia), which influences subjective experiences when evaluating and responding to stimuli (Kellert and Wilson, 1993; Ulrich, 1993). Ulrich (1983) argued that aesthetic experiences (like-dislike) and emotional experiences (e.g., wakeful relaxation by detecting the alpha wave and positive emotion) directly affect experiences with nature.

1.2. Shreds of evidence on the built environment, favorite places, and psychological perceptions and emotions

Urban nature relative to the urban environment is now widely recognized as fulfilling human needs and providing health benefits. The benefits of experiencing natural environmental attributes in urban settings, such as the degree of awareness of greening (Lin et al., 2014) and indigenous materials with a sense of place bonding (Liu et al., 2020), are considered to have an essential connection to psychological benefits. Researchers have stressed that different emotional meanings within landscapes regulate users' behaviors in green spaces and the benefits they receive from them (Korpela and Ylén, 2007). Most health-related studies in urban nature focus on restorative benefits and aesthetic perception. At the same time, it is worth linking the perceived design methods with better knowledge of the effects of perceived physical attributes, landscape preferences, and positive emotions in the built environment.

On the other hand, having a favorite place means that the effects of places with emotional connections are different from those of other built environments and are associated with restorative attributes (Korpela and Hartig, 1996). Schebella et al. (2017) stated that favorite outdoor places could be national parks, community parks, linear parks, botanical gardens, etc., which correspond closely to the fascination attribute provided by nature. Orderliness with visual accessibility reflects a state in the environment that provides a sense of safety, fosters landscape preferences, and influences emotional states (i.e., positive/negative affect) (Bakker et al., 2014; Kaplan and Kaplan, 1989). Well-maintained green spaces, such as urban forests, parks, gardens, and watersides, tend to be preferred over those without natural elements in one's favorite place and affect one's restorative experiences (Korpela and Hartig, 1996; Korpela et al., 2009). In summary, researchers infer that the built environment provides fascination and natural elements with coordination of information richness, which could stimulate sensory perception and lead to human affectional attraction to urban nature.

1.3. Aim of the research

Less attention has been paid to how to measure the benefits of bringing nature to life as a "biophilic design method." The specific aim of this research is to develop the first version of the PBDs to measure the human–nature experience in the built environment. In addition, favorite places can evoke strong perceptions and elicit emotional affection. Therefore, we hypothesized that the perceived biophilic design scale could elucidate the biophilic features concerning landscape preferences and emotional responses in the built environment based on characterized landscape attributes and the relationship between humans in nature.

2. Materials and methods

The Research Ethics Committee approved this study from National Taiwan University (202103HS019). All participants signed an online informed consent form via the data collection platform. During the COVID-19 pandemic, an online survey was used to collect data through snowball sampling via social media from the platform of communication groups containing graduates and students at National Taiwan University, National Chung Hsing University, and National Pingtung University of Science and Technology from May 16 to July 13, 2021.

2.1. Research procedure

The bilingual online surveys were composed of four parts. First, participants were asked to upload photos of their favorite built environments (e.g., urban parks, campuses, excluding national parks, natural reserves, oceans) to identify their perceptions about landscape attributes and psychological feelings. The photos should have represented the harmonious feeling between buildings/artificial structures and nature that supported the participants' physical and psychological needs on a daily basis. The guidelines for taking the photos were as follows: (1) no close-up portraits, (2) no close-up, single-element photos (e.g., azaleas, squirrels), (3) at least three elements in the photos to form a scene, and (4) the photos must have been taken clearly in the daytime, and the location must have been noted. The photo files had to be in PNG, JPG, or JPEG format and had to be smaller than 16 MB.

The second part of the survey consisted of 59 perceived biophilic items designed (Hung and Chang, 2020) so that the participants' perceptions of their uploaded settings could be reviewed. The third part asked participants to assess their emotional states as evoked by the photos. Finally, the last part included basic personal information regarding gender, age, nationality, and career. After finishing the survey and being confirmed by the researcher as a valid sample, the participants were each given a 3.6 USD gift card.

2.2. Participants

According to the research ethics approval guidelines, we invited individuals aged 20–65 to participate in our research through the online social media platform. The inclusion criteria included the following: (1) good mental health and patience, (2) normal vision (e.g., not being color blind), (3) not having dyslexia, and (4) willingness to share self-taken photos. The exclusion criterion was being unable to complete the 10–15-minute-long questionnaire.

2.3. Scales measured by psychological questionnaires

2.3.1. Perceived biophilic design items (PBDi)

The 59 perceived biophilic design items (PBDi) broadly included the idea of the elements in the outdoor, built environment or landscape and/or generated the interaction with human beings. The questionnaires were extracted from Kellert et al. (2008) with conceptual and content analysis within three professional group discussions and pretests on participants whose backgrounds were not in landscape. The development and convergence of the concepts, semantics, and word accuracy in PBDi are shown in Appendix A (Hung and Chang, 2020). The five environmental attributes were (1) environmental features (e.g., plants, water), (2) natural shapes and forms (e.g., leaf shape, natural lines), (3) natural patterns and processes (e.g., passage of time or phenomenon of aging), (4) place-based relationships (e.g., connection with geographical location), and (5) evolved human–nature relationships (e.g., enriching the sensory experience, exploring). These attributes are shown in Appendix B with details about the 59 items (Hung and Chang, 2020). We then measured participants' perceptions of the biophilic that matched their psychological feelings through a Likert scale, ranging from one (very slight or not at all) to five (extremely high).

2.3.2. Landscape preference

As people experience the environment, they explore, understand, and infer spaces and elements in the setting, including a sense of coherence, complexity, legibility, or mystery (Kaplan, 1987). These perceptions of the physical environment are related to the degree of landscape preference. Kaplan (1987) stated that landscape preferences refer to psychological responses and the evaluation of the environment in information processing theory. Therefore, the researchers used an overall evaluation statement ("I like the setting very much") to measure general landscape preference through a Likert scale, ranging from one (the lowest feeling) to five (the highest feeling), to understand the effect on perceived biophilic design.

2.3.3. Positive and negative affect schedule (PANAS)

Emotions comprise the subjective experiences and evaluations of human beings in response to stimuli, which can be accompanied by a series of physiological reactions and behaviors (Gross, 1998). Watson et al. (1988) developed a two-factor emotion model called the Positive and Negative Affect Schedule (PANAS), which includes 10 adjectives of positive emotion (PA) and 10 adjectives of negative emotion (NA) to measure one's emotional state in different time frames (e.g., moment, today, past, year, general). This study used PANAS to describe the subjects' emotional states as determined from the settings in the photos they uploaded via a Likert scale, ranging from one (very slight or not at all) to five (extremely high), and the total scores ranged from 10 to 50. A high PA (Cronbach's $\alpha = 0.86$) represented high energy, full concentration, and feeling pleasurable engagement in a comfortable built environment. A high NA (Cronbach's $\alpha = 0.91$) represented distress and having unpleasant engagement in an uncomfortable built environment.

2.4. Data analysis approach

This study used exploratory factor analysis (EFA) to build the scale, as no research had previously been conducted in this area. First, we used item analysis to remove the items that did not meet the criteria, such as low item–scale correlations, low communalities, and low factor loadings (Wu, 2009). According to the EFA for constructing the scale, the best-known ratio of items and participants for predictive sample power is 1:5 (Stevens, 2002), or 300 participants (Tabachnick and Fidell, 2013). As with conducting EFA, factor loadings lower than 0.40 were deleted (Hair et al., 2014; Wu, 2009). Next, at least 100–150 samples were determined as the minimum sample size needed to confirm the PBDs in the confirmatory factor analysis (CFA) (Ding et al., 1995). We set up the number of bootstrap samples at 2000 with a 95 % confidence level. Therefore, the study used 300 valid datasets to build the PBDs and 177 datasets to confirm the PBDs. In addition, we used the factor score in each component to generate linear regression models with the "enter method" and to test the effects of PBDs on landscape preference and emotion. The data collected from the psychological questionnaire were coded in Excel. All data were analyzed using IBM SPSS Statistics ver. 25 and IBM SPSS AMOS ver. 20.

3. Results

The online data collection system (SurveyMonkey) registered 760 subjects, including 50 participants who declined to complete the questionnaire, 161 who provided incomplete data, and 549 who completed the study. Three participants completed the questionnaire more than once, leaving 546 (71.84 %) participants with complete data for further analysis. With a preliminary check of valid questionnaires with the guidelines' criteria (e.g., no conflicting answers between items), 477 pieces of accurate data were obtained.

A total of 477 valid pieces of data, with 78.62 % of photos uploaded in Taiwan and 21.38 % abroad, were measured in the following statistical analysis process. The participants ($N = 477$; 181 males (37.95 %), 296 females (62.05 %); mean age = 33.33 years; $SD = 11.20$) were mostly from Taiwan ($n = 461$, 96.65 %) and represented different demographics (students, $n = 133$ [27.88 %]; public servants, $n = 91$ [19.08 %]; service industry, $n = 59$ [12.37 %]; industry, $n = 35$ [7.34 %]; freelance or retired, $n = 35$ [7.34 %]; technology industry, $n = 31$ [6.50 %]; financial industry, $n = 22$ [4.61 %]; medical professionals, $n = 17$ [3.56 %]; landscape architecture and designers, $n = 15$ [3.14 %]; housewives, $n = 13$ [2.73 %]; office workers, $n = 12$ [2.52 %]; researchers, $n = 8$ [1.68 %]; new media workers, $n = 4$ [0.84 %]; agricultural workers, $n = 2$ [0.42 %]). The results showed no significant differences between males and females with respect to landscape preferences ($t = 0.21$, $p = 0.84$) and positive ($t = 0.16$, $p = 0.88$) and negative emotional states ($t = 0.23$, $p = 0.82$). Although the photos of Taiwan and abroad showed no significant differences in terms of negative affect ($t = 1.09$, $p = 0.28$), there was a significant difference in landscape preferences ($t = -4.80$, $p < 0.001$; mean score in Taiwan: 4.39, $SD = 0.66$; mean score abroad: 4.69, $SD = 0.53$) and positive affect ($t = -3.83$, $p < 0.001$; total average score in Taiwan: 33.75, $SD = 5.89$; total average score abroad: 36.24, $SD = 5.49$).

3.1. Exploratory factor analysis (EFA) of building the perceived biophilic design scale

EFA was employed to analyze the 477 valid datasets. After performing item analysis, we reduced 14 items according to the critical criterion index: (1) excluding non-significant p-values in t-tests between the high-low group; (2) correlation values lower than 0.4 in the corrected item-total analysis; (3) the deleted item of the Cronbach's α value was higher than 0.94; (4) total inappropriate items greater than three; and (5) the low factor loading (< 0.45) (Wu, 2009). The results of the item analysis are presented in Appendix C.

Principal component analysis with varimax rotation was used to analyze the 45 items. A total of 17 items were deleted step by step through EFA for those who did not meet the factor loadings of 0.40. The Kaiser-Meyer-Olkin (KMO) test showed meritorious sampling adequacy (KMO = 0.88, Bartlett's Sphericity Test $\chi^2 = 3824.25$, $p < 0.001$) (Kaiser, 1974), and the average communality was 0.64. With an eigenvalue over 1.00, we selected seven factors of the total percentage of variance explained for 64.35 %. Initial eigenvalues for one to seven factors were 8.79, 2.48, 1.82, 1.32, 1.29, 1.19, and 1.13, respectively, which were named as evolved human–nature relationships (EHNR), place-based relationships (PBR), visual aesthetic quality (VAQ), state of natural change (SNC), environmental perception (EP), sense of compatibility in the built environment (SCBE), and natural form of design method (NFDM) (see Table 1). Each factor loading is shown in Appendix D. The overall internal consistency reliability for the full scale was 0.91, and the ANOVA test among items was $F = 72.50$, $p < 0.001$ (for the sub-scales, see Table 1).

3.2. Confirmatory factor analysis (CFA) verifies perceived biophilic design scale

According to the EFA, we found that seven factors explained 64.35 % of the variance in PBDs. We then used CFA to confirm convergent validity and discriminant validity. Fig. 1 shows that the model met the standard for good convergent validity within a standardized factor loading of 0.40–0.89 and a discriminant validity under 1. The composite reliability (CR) values that confirmed the internal consistency of the items were suggested to be at least 0.70 or higher. Our results revealed that the values were between 0.72 and 0.87; the average variance extracted (AVE) values indicated that the amount of variance that the model captured was higher than 0.50, meaning few errors remained in the items (Hair et al., 2014), while our acceptable values were shown to be between 0.42 and 0.69 (see Table 2). Furthermore, the null model's goodness-of-fit was as follows: $\chi^2 = 770.82$, $df = 329$, $\chi^2/df = 2.34$, CFI = 0.82, RMSEA = 0.09, PNFI = 0.64, PCFI = 0.72, PGFI = 0.62 (Fig. 1). This PBD scale is associated with the effect of the built environment on human psychological feelings.

3.3. The effect on perceived biophilic design scale, landscape preferences, and emotion

The Pearson correlation coefficients between the seven environmental attributes in biophilic and landscape preference ranged from − 0.11–0.53, $p < 0.05$ (see Appendix E). A significant linear regression model with the seven environmental attributes of the PBDs predicted landscape preference (F (7, 469) = 63.79, $p < 0.001$, $R^2 = 0.49$) (Fig. 2). Collinearity issues were below 10 (average VIF = 1). All of the PBD attributes showed a positive relationship with landscape preference—except the natural form of design method attributes, which presented a significant negative relationship ($r = -0.11$, $p < 0.05$). This explained 49 % of the variance of landscape preference in the model (Fig. 2).

The seven environmental attributes in biophilic were strongly correlated with emotion (i.e., positive and negative affect) ($r = -0.20$ to 0.48, $p < 0.001$; see Appendix E). A significant linear regression model with the seven environmental attributes of PBDs predicted PA (F (7, 469) = 64.37, $p < 0.001$, $R^2 = 0.49$) and NA (F (7, 469) = 4.50, $p < 0.001$, $R^2 = 0.06$) (Fig. 3a and Fig. 3b). Collinearity issues were below 10 (average VIF = 1). All of the PBD attributes—evolved human–nature relationships ($\beta = 0.48$, $p < 0.001$), place-based

Table 1
The Component and the percentage variance of perceived biophilic design scale in exploratory factor analysis.

Components	Initial eigenvalues			Rotation sums of squared loadings			Cronbach's alpha
	Sum	% variance explained	% Cumulative variance	Sum	% variance explained	% Cumulative variance	
EHNR	8.79	31.39	31.39	3.46	12.35	12.35	0.83
PBR	2.48	8.85	40.24	3.20	11.44	23.79	0.82
VAQ	1.82	6.50	46.74	2.37	8.45	32.25	0.76
SNC	1.32	4.72	51.47	2.36	8.41	40.66	0.74
EP	1.29	4.62	56.09	2.34	8.34	49.00	0.83
SCBE	1.19	4.23	60.32	2.21	7.89	56.88	0.76
NFDM	1.13	4.03	64.35	2.09	7.47	64.35	0.69

Note: $n = 300$; evolved human-nature relationships (EHNR); place-based relationships (PBR); visual aesthetic quality (VAQ); state of natural change (SNC); environmental perception (EP); sense of compatibility in built environment (SCBE); natural form of design method (NFDM)

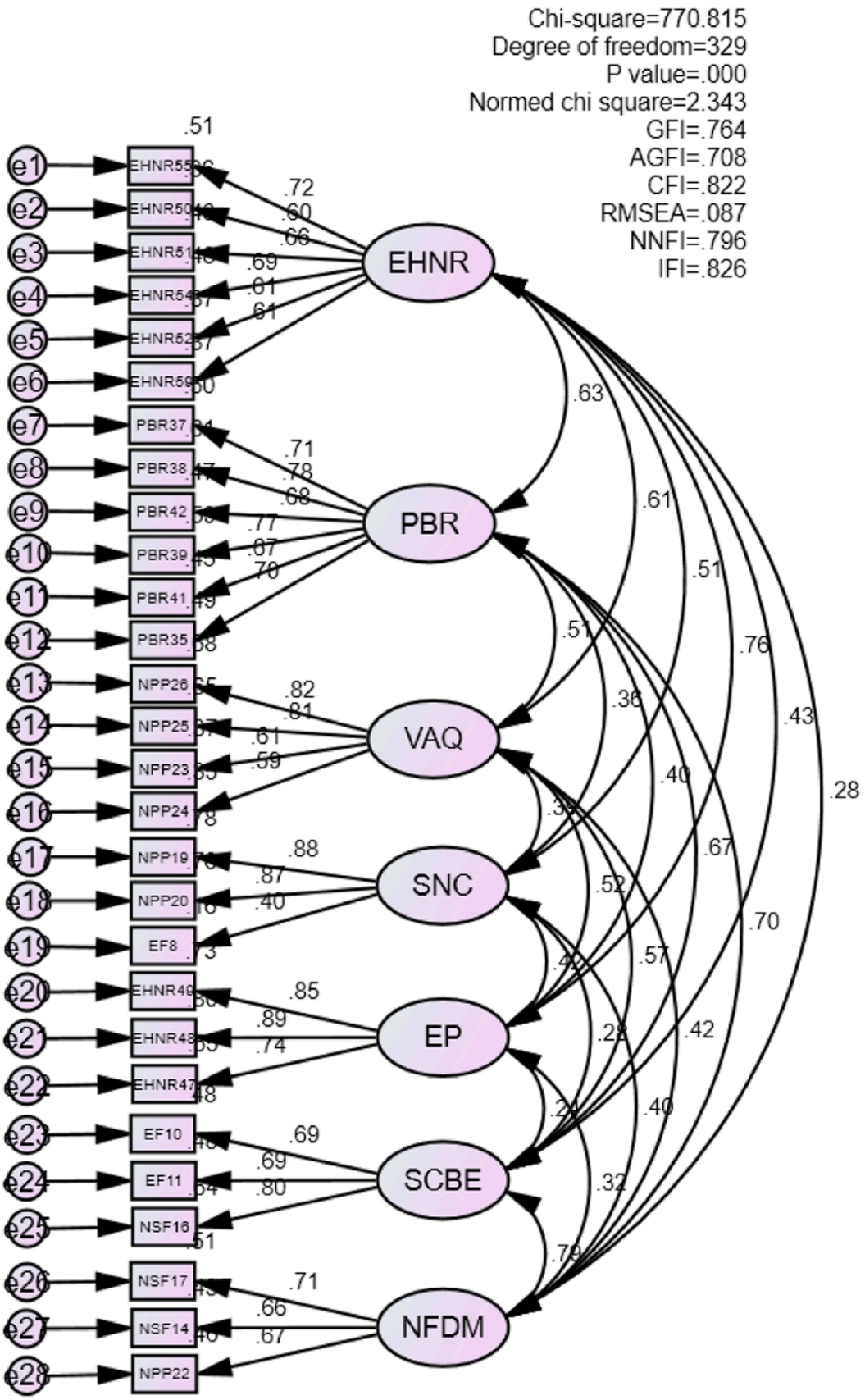

Fig. 1. The confirmatory factor analysis model with the standardized estimates in the perceived biophilic design shows good convergent validity and discriminant validity. Note: $n = 177$; evolved human-nature relationships (EHNR), place-based relationships (PBR), visual aesthetic quality (VAQ), state of natural change (SNC), environmental perception (EP), sense of compatibility in built environment (SCBE), and natural form of design method (NFDM).

Table 2
Composite reliability and average variance extracted on perceived biophilic design scale.

Factors	Number of Questions	CR	AVE
Evolved human-nature relationships (EHNR)	6	0.81	0.42
Place-Based Relationships (PBR)	6	0.87	0.52
Visual aesthetic quality (VAQ)	4	0.80	0.51
State of Natural Change (SNC)	3	0.78	0.56
Environmental Perception (EP)	3	0.87	0.69
Sense of compatibility in built environment (SCBE)	3	0.77	0.53
Natural form of design method (NFDM)	3	0.72	0.46

Note: $n = 177$

relationships ($\beta = 0.22$, $p < 0.001$), visual aesthetic quality ($\beta = 0.37$, $p < 0.001$), state of natural change ($\beta = 0.19$, $p < 0.001$), environmental perception ($\beta = 0.12$, $p < 0.001$), sense of compatibility in the built environment ($\beta = 0.14$, $p < 0.001$)—showed significant relationships with PA, apart from the natural form of design method attributes. These attributes explained 49 % of the variance of PA in the model (Fig. 3a). The evolved human–nature relationships attribute ($\beta = -0.20$, $p < 0.001$) presented a significant negative relationship with NA (Fig. 3b).

4. Discussion

This study provided evidence based on the development of a measurement scale of biophilic design factors through conceptual and statistical analysis to explain how nature in the life of the design method influences human perceptions. According to EFA and CFA, our PBDs yielded seven aspects within 28 items that could be employed to interpret the concept of biophilic attributes of human–nature experience in the built environment.

4.1. A perceived biophilic design (PBD) Scale

The major findings of this study are that the concept in the original aspects of evolved human–nature relationships could be separated into two parts—human-nature relationship and environmental perception. Visual aesthetic quality and state of natural change are marked as the design method of natural design patterns and the phenomenon of a landscape. Integrating and connecting the balancing of the natural and the man-made features are inferred to be a sense of compatibility in the built environment. Environmental features (e.g., water, plants) are associated with the physical attributes in spaces, which could be integrated into overall perception as experienced in the environment. Some environmental characteristics in natural patterns and processes (e.g., bounded spaces, transitional spaces) and scales (e.g., fractals) are related to the details of design methods. Those attributes might be complex for the subjects to identify by their perceptions. A possible explanation could be that these attributes are united in the dynamic balancing of the configuration and the composition as humans perceive the environment. The senses of prospect and refuge, mastery and control, sensory variability, and others represent highly abstract emotional states. Such a moving experience may be hard to elicit in the built environment, even in the favorite place uploaded by subjects.

Human experiences in nature could be linked to a sense of restoration and to a positive connection to the built environment. Our findings are linked to previous theories, as shown in Fig. 4. The evolved human–nature relationship and environmental perception were related to the setting, which provides information richness that allows humans to understand, explore, and predict settings, which might foster a sense of safety, security, and curiosity. Moreover, a sense of complexity and coherence with well-organized landscape elements refers to the legibility and orientation in landscape design, influencing one's landscape preference (Kaplan, 1987; Kaplan and Kaplan, 1989) and healthy Qi perceptions (Chou et al., 2020). Finally, a sense of attachment to nature is associated with a sense of place (Hammitt et al., 2006; Relph, 1976).

Place-based relationships are associated with connection to culture, history, and local materials, and landscape orientation infers an attachment to the setting and the feeling of a sense of place (Hammitt

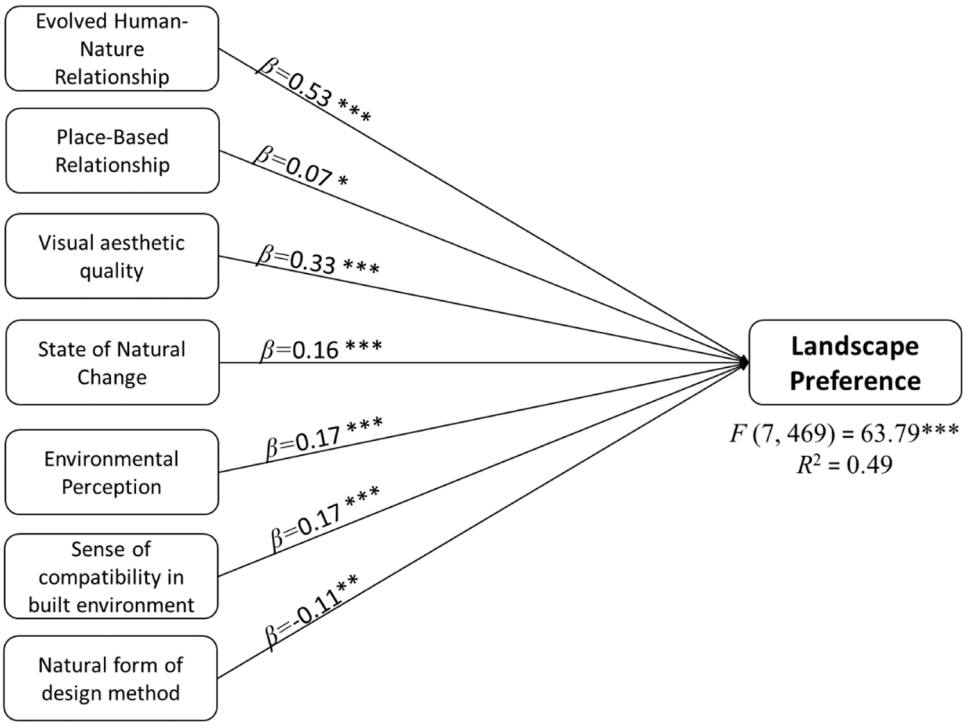

Fig. 2. Regression between the seven environmental attributes in biophilic and landscape preference. Note: $n = 477$; p < 0.001 ***, p < 0.01 **, p < 0.05 *.

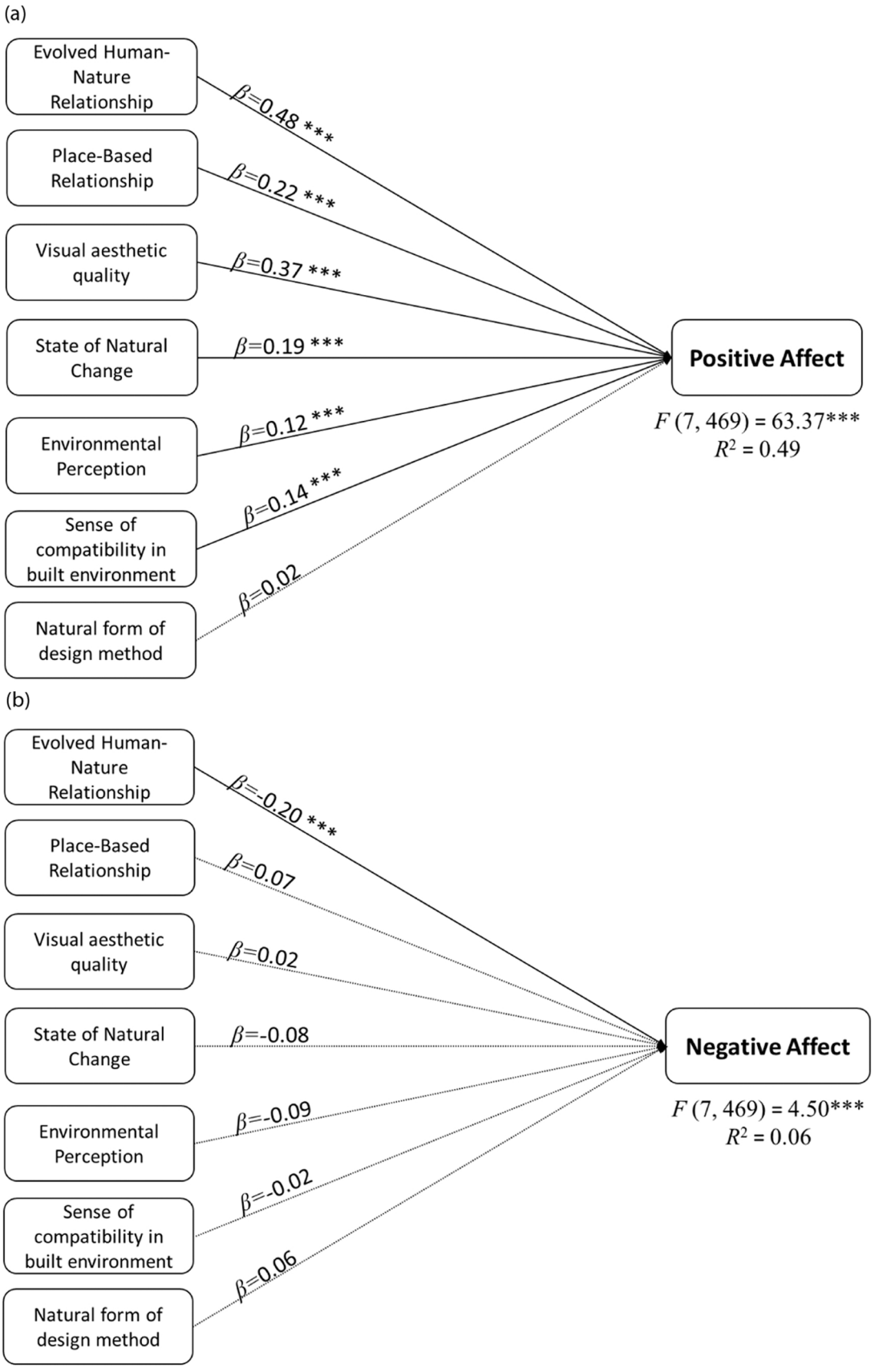

Fig. 3. a. Regression between the seven environmental attributes in biophilic and positive affect. Note: $n = 477$; $p < 0.001$ ***. b. Regression between the seven environmental attributes in biophilic and negative affect Note: $n = 477$; $p < 0.001$ ***.

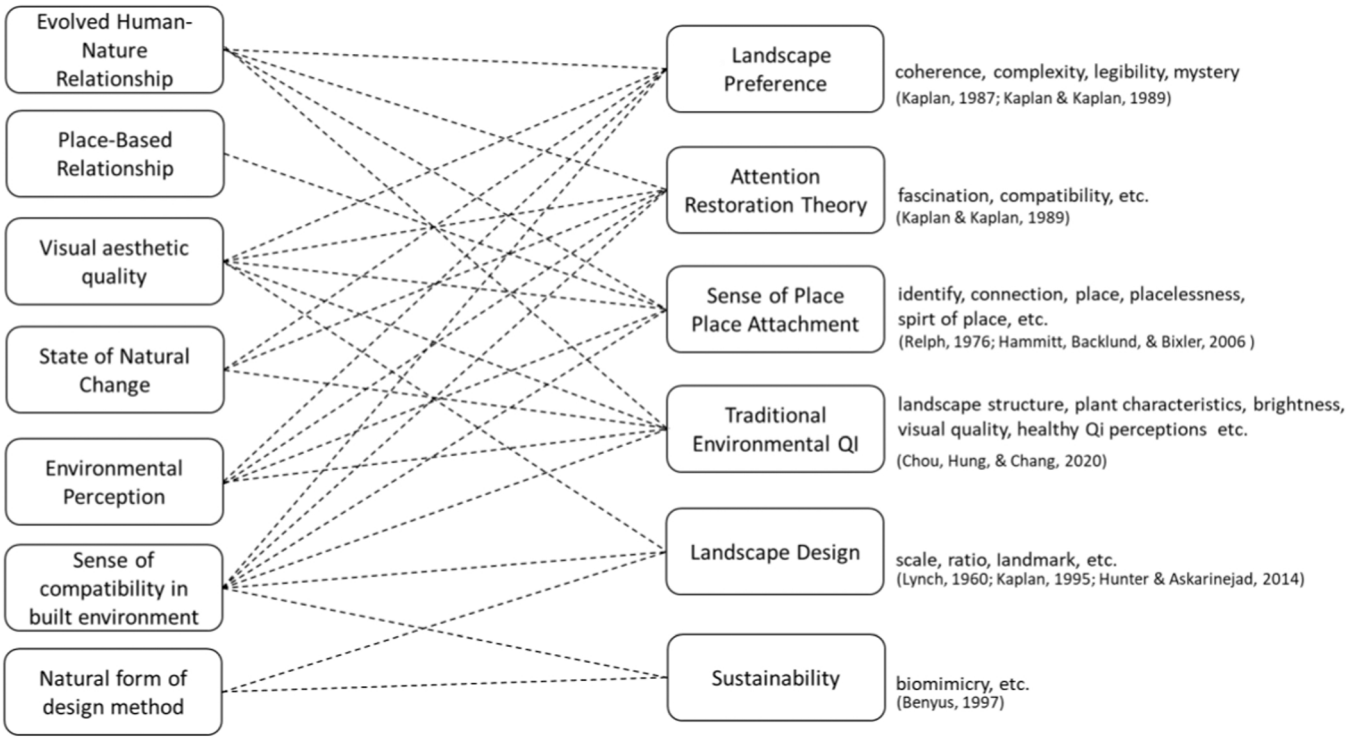

Fig. 4. The seven aspects of perceived biophilic design scale and the related environmental psychological theories and perception.

et al., 2006; Relph, 1976). A place with local environmental attributes not only fosters one's experience and memories but also positively influences place dependence, place identity, and restorativeness (Liu et al., 2020). Local elements evoke the meanings of the place and could extend to the surrounding landscape design (Liu et al., 2020). That is, the favorite built environment with nature and special attributes might contribute to restorativeness, a sense of spirit of place, and the trait of sustainability.

Visual aesthetic quality is related to the perception of scope and to a sense of distance, light, and shadow in the space. Furthermore, the natural form of the design method is associated with natural shapes and conditions, such as round flower beds, waterscapes, and bird feeders. Finally, a sense of compatibility in the built environment refers to compatibility, coherence, and harmony in the setting with nature and artificial facilities or buildings. Therefore, the visual aesthetic quality, natural form of the design method, and sense of compatibility in the built environment are relevant to the spatial configuration and composition of a design method (Hidalgo et al., 2006; Hunter and Askarinejad, 2015; Kaplan et al., 1998; Lynch, 1960), such as biomimicry methods (Benyus, 1997) and visual quality (Chou et al., 2020), to coordinate these structures into the natural environment and to feel a sense of restorativeness, preference, and health (Berto et al., 2015; Chou et al., 2020; Kaplan and Kaplan, 1989).

The state of natural change entails growth, development, and quasi-evolutionary sequence changes, which evoke one's perceptions of and preference for the landscape. Such a statement aligns with humans being unconsciously attracted to the environment and feeling a sense of being away, as well as fascination (Kaplan and Kaplan, 1989), and seeing the vegetation characteristics (Chou et al., 2020) with seasonal changes in the environment. Above all, landscape design methods and environmental perceptions of the built environment could influence sustainable design, restorativeness, and health benefits. Besides, the PBDs take a more holistic perspective and are precise when explaining biophilic design on human interactions with nature.

4.2. Explanations of the perceived biophilic design scale (PBDs) that positively predict landscape preferences and emotional states

We found significant relationships between perceived biophilic design, landscape preferences, and emotional states. A strong relationship between evolved human–nature relationships, place-based relationships, visual aesthetic quality, state of natural change, environmental perception, and a sense of compatibility in the built environment positively predicted landscape preferences. In contrast, the natural form of the design method had a negative effect on landscape preferences. Therefore, to explain landscape preference, this study discussed the results in two respects: physical design methods and the related human–nature relationships.

The positive relationships between visual aesthetic quality, a sense of compatibility in the built environment, and a state of natural change could suggest that the settings are well organized with a balance between artificial structures and nature, in which parts of both are integrated into the whole. In addition, these findings confirm the previous concept that subjective aesthetic visual preferences for landscape attributes are related to personal experience (e.g., curiosity, identity) (Hammitt et al., 2006; Kaplan, 1987), landscape perception (Zube et al., 1982), and the balancing of perceived naturalness (Ode et al., 2009; Tveit et al., 2006) (e.g., skylines with mountainous) (Zacharias, 1999) in the built environment. These considerations are critical because of urban aesthetic attributes, such as vegetation, visual richness, harmony, and spaciousness, which are associated with attractive urban places, highlight the need for biophilic design in built environments (Hidalgo et al., 2006; Nasar, 1994), and generate a sense of landscape preference and restorativeness (Berto et al., 2015; Wang et al., 2019). On the other hand, the design method of biological/ecological forms presented a negative relationship with landscape preferences. One possible reason for natural elements existing in the physical environment is that they provide more of a sense of attraction than biomimicry elements in the built environment.

Most importantly, the attributes in environmental perception, evolved human–nature relationships, and place-based relationships

refer to how people process environmental information through cognition, such as understanding, imagination, and affiliation, to extract the information required to gain a sense of security and connection, which provides evidence about how humans interpret urban nature (Appleton, 1975; Kaplan, 1987; Kaplan and Kaplan, 1989; Kellert et al., 2008; Kellert and Wilson, 1993). Our findings imply that places with fascinating qualities arouse human appreciation of nature and the desire to explore. In addition, traditional environmental Qi values a harmonious, holistic relationship between humans and nature with the appropriate space and scale, natural forms and terrain, and landscape views that impart a biophilic experience and promote health (Chou et al., 2020; Hung et al., 2021).

These results are consistent with the research hypothesis that exposure to urban nature and perceived biophilic design evoke positive emotions: Humans have positive feelings in response to urban nature (Barbiero and Berto, 2021; Berto et al., 2015). Our findings could be explained by the biophilic traits that value emotional states and nature. The naturalistic experience enhances the type of satisfaction and creativity that can be directly connected to nature; the aesthetic experience indicates one's appeal to natural beauty and the perception of a sense of harmony; and the symbolic experience reflects the function and communication of thought by natural design. The humanistic experience is relevant to the deep emotion connected to the attributes in the natural environment; the moralistic experience is related to ethics and a responsibility toward nature (Kellert and Wilson, 1993).

These biophilic traits refer to pathways connecting humans with a strong affection as being "natural" in the built environment (Kellert and Wilson, 1993; Lumber et al., 2017). Specific attributes (e.g., static water, vegetation, flowers) create comfortable atmospheres, landscape preferences, and a sense of safety to attract humans invisibly (Lis et al., 2019; Polat and Akay, 2015; Suppakittpaisarn et al., 2019). The beauty and good conditions of environmental attributes provide a pleasant atmosphere for humans to experience nature, fostering positive emotions, and vice versa (Wilkie and Stavridou, 2013). The relationship between humans and the built environment elicit restorativeness through the sensory perception experience (Kaplan and Kaplan, 1989) and is related to psychological and physical health (Chou et al., 2020) in the Qi perception. Therefore, to define specific landscape types, further research is needed on perceived biophilic, traditional environmental Qi, and positive emotional states.

4.3. Limitations of the research

First, the convenience sample method might have produced a less-biased sample to infer the results from a specific population, whereas our study broadly implied the environmental perceptions of the general population aged 20–65. From the demographic information, mainly participants aged 20–40, only 20 % of those aged 40–65 joined this study. Future research is needed to investigate the specifics of age groups worldwide and their relationship to environmental perceptions of biophilic and health. Second, particularly challenging was the requirement for participants to upload their favorite built environment photos during the COVID-19 pandemic. Participants could still reduce the frequency of contact with nature during pandemics. Much work on green space and health has reduced the impacts of human perception on negative emotions and has provided positive benefits. Moreover, the researchers found that a higher ratio of green space reduced COVID-19 infections (Lu et al., 2021). Therefore, future research might expand to on-site surveys to understand the relationship between the dose of nature and biophilic, indicating the release of stress and the impacts on health. Third, the uploading of photos does not limit participants to using current images instead of past ones. In contrast, this study broadly investigated the types of built environments (i.e., 21 % of photos abroad) to represent one's favorite built environment place and perception. This method created a pathway for participants to connect to their favorite places and thereby evoke their psychological feelings concerning the perceived biophilic in the built environment. Even though individuals differ in their landscape preferences and positive emotions at the location, the construction of biophilic attributes within the scope of the built environment is not affected. The definition of biophilic design strengthens the scope of the built environment; however, an extended discussion of natural landscapes is beyond the scope of this study. Despite these limitations, this perceived environmental perception scale is an exciting first step to determining the existence of biophilic design within human perception.

4.4. The values of biophilic design

A more green environment that is close to nature is good for health. At the same time, how we feel about the environment can affect our positive emotional experience with nature. Therefore, it is essential to design environments in a way that a sense of compatibility and comfort is present in space and time. The concept of environmental perception of nature in the built environment in the PBDs contributes to transforming such abstractions into design as guidelines for future researchers, planners, designers, and managers to address and evaluate how biophilic in the built environment impacts human health. The four dimensions in PBDs—visual aesthetic quality, state of natural change, sense of compatibility in the built environment, and the natural form of design methods—provide insights into design, such as the overall suitability of landscape materials, species to be planted, color and seasonality, with according to the on-site environmental situation and the scale on urban parks, green pathways, or playgrounds to adjust. The other three features—evolved human–nature relationships, environmental perception, and place-based relationships—are tied with humans' experience with nature to elicit cognitive perceptions. For example, in landscape design, aspects of local characteristics can include items of historical and cultural significance to evoke a connection with a specific place and meet the individual's expectations from their environment. By adapting local conditions and life or life-like elements in the design, it may be possible to create a healthy and therapeutic environment. Therefore, the seven aspects refer to perceived biophilic design are not only linked with restorativeness but also to landscape design and resultant health benefits. In addition, the PBDs could broadly apply to the green-blue spaces in the built environment. It might serve as an alternative tool to promote urban nature as an essential part of our lives to enhance health.

5. Conclusion

Bringing nature back into the city is not a new idea and is a critical issue for health. Our research developed PBDs to evaluate what landscape attributes urban nature provides to us and how humans comprehend biophilic features through their perceptions. The PBDs presented good reliability and validity as an alternative scientific tool to examine human interpretations and perceptions of the built environment. In addition, the tool reveals to the general population that humans perceive a harmonious atmosphere in holistic built environments that contain "nature" rather than focusing on each detail of landscape features. The empirical results support previous concepts and applications of biophilia, restorativeness, and preference. The results indicate that greening, urban parks, campuses, and blue-green spaces in urban areas convey a sense of being "biophilic." Vegetation, waterscape, sky, etc., with the appropriate landscape layout, create a kind of fascination, an important component that attracts involuntary attention and influences human perception and positive emotions. More research is needed that will measure environmental perceptions in human–nature experiences to enhance positive psychological states. Alternatively, this is a continuing practical application for landscape architects and designers to create a universal perception of the biophilic within the built environment and to promote health benefits for citizens every day.

CRediT authorship contribution statement

Shih-Han Hung: Conceptualization, Methodology, Formal analysis, Investigation, Validation, Data curation, Writing – original draft. **Chun-Yen Chang:** Conceptualization, Validation, Supervision, Project administration, Funding acquisition.

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.

Data Availability

The authors do not have permission to share data.

Acknowledgements

This study was supported by the Ministry of Science and Technology (109-2410-H-002-170-MY2), Taiwan. This article was modified from a doctoral dissertation, "A Comprehension of Perception of Human-Nature Experience and Health Benefits in Urban Green Space." The authors thank the editor and the reviewer for their insightful feedbacks. We also thank all participants for joining the online experience during the Covid-19 period.

Appendix A–E. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2022.127730.

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