LAF | https://doi.org/10.15302/J-LAF-2026-0047
Volume 14 / Issue 5 / 260047 / 2026
Received Date | 2026-01-25 Accepted Date | 2026-06-26
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Pathways and Health Benefits of Biodiversity Perception: An Audio–Visual Collaboration Study

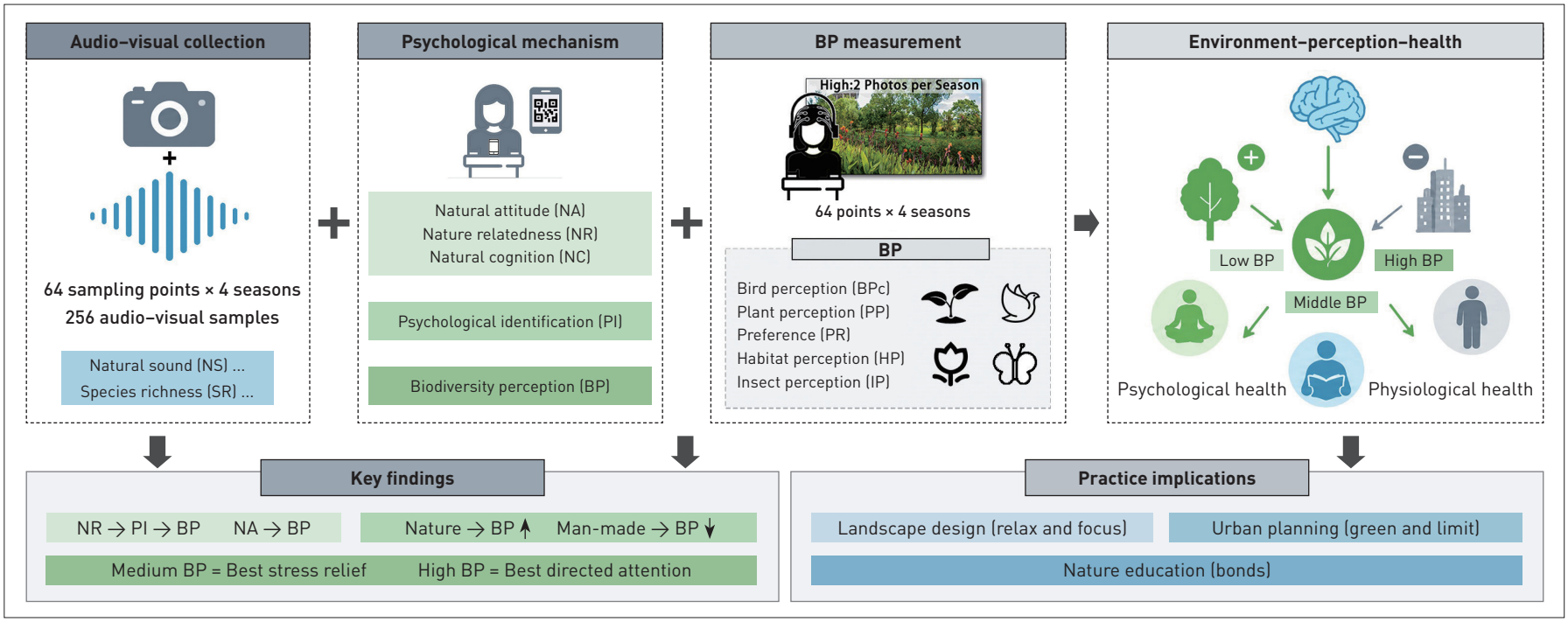
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GRAPHICAL ABSTRACT



ABSTRACT

Biodiversity is a key evaluation criterion of natural environments, and its positive effects on human health are well-documented. Some recent studies suggest that biodiversity perception (BP) may play a crucial role in explaining the relationship between biodiversity and health. This study introduces the "Environment–Psychology–Perception–Benefit" theoretical framework, grounded in audio–visual integration, to investigate how BP influences both physical and mental health. A total of 380 participants were recruited for this research. Structural equation modeling (SEM) was employed to examine how nature relatedness, nature attitude, and nature cognition impact BP through psychological identification (PI). Pearson's correlation analysis was also conducted to explore the relationships between BP, actual biodiversity, and environmental perception factors. Additionally, the recovery benefits of different levels of BP on physiological indices were evaluated through controlled experimental conditions. The results show that nature

attitude is significantly positively correlated with BP, and nature relatedness positively influences BP via PI; BP notably enhances psychological recovery, attention, and stress reduction; Medium BP environments provide the highest levels of relaxation and recovery, while high BP environments significantly enhance attention restoration. This study offers an in-depth exploration of the mechanisms and benefits of BP, advancing the theoretical understanding of BP and offering foundational support for biodiversity conservation, utilization, and nature-based therapeutic practices.

KEYWORDS

Biodiversity Perception; Audio–Visual Collaboration; Response Pathway; Health Benefit; Structural Equation Modeling (SEM)

HIGHLIGHTS

- This study constructs the path of biodiversity perception (BP) from audio–visual synergy
- Psychological identity is a mediator between nature relatedness and BP
- Green view and natural sounds promote BP, while buildings and artificial noise inhibit BP
- Medium BP relieves stress best, and high BP improves directed attention

RESEARCH FUNDS

- National Natural Science Foundation of China (No. 32501722)
- National Natural Science Foundation of China (No. 52578104)
- Talent Initiation Program of the Scientific Research Development Fund of Zhejiang A&F University (No. 2025LFR007)
- Management Committee of Hangzhou West Lake Scenic Area Science and Technology Development Plan Project (No. 2023-012)

1 Introduction

The Biophilia Hypothesis posits that humans have an innate tendency to connect positively with natural environments and perceive nature's life and processes through multiple sensory channels (e.g., sight, hearing, smell)[1]. Extensive research confirms that nature contact—physical proximity to natural environments—significantly promotes psychological and physiological well-being[2–4]. However, accelerated global urbanization has caused habitat destruction and degradation[5], reducing human nature contact opportunities[6]. This is particularly prominent in developing nations' cities, where socioeconomic factors often bar nature contact[7–8]. Nature contact deprivation may weaken individuals' perception, understanding, and emotional connection to nature[9–10], triggering physical and mental health issues[11].

As a core criterion for evaluating natural environments, biodiversity's role in human health is gaining increasing attention. Healthy, stable ecosystems rely on biodiversity. Highly biodiverse ecosystems better respond to climate change[12] and provide vital ecosystem services such as air purification and pollution mitigation[13]. These services influence human health directly or indirectly, via rich sensory stimuli (e.g., visual, auditory, olfactory) that help humans perceive biodiversity's value[14]. Investigating how individuals' subjective perceptions of biodiversity (not just objective levels) influence health is particularly crucial.

This study explores a crucial yet ill-defined dimension: biodiversity perception, an individual's subjective awareness, recognition, and evaluation of environmental biodiversity (e.g., species richness, ecosystem complexity). Emphasizing cognitive and evaluative levels, it refers to the subjective interpretation of "life diversity" in natural environments and is a potential key mediator of nature experiences' impact on health. A series of abbreviation is used in this manuscript for laconic narrative (Table 1).

1.1 Biodiversity Perception

Health and well-being improvements do not always depend directly on actual biodiversity, but are closely linked to people's BP[14–17]. Studies using combined subjective and objective measurements have increasingly revealed the central role of "perception" over "objective existence." For example, Georgina E. Southon et al. combined questionnaires with ecological assessments and found that while artificial meadows did not directly improve respondents' physical and mental well-being, self-reported BP correlated significantly positively with site satisfaction and nature connection[15]. This raises a key question: does perception predict health benefits more effectively than objective reality? Mathew P. White et al. supported this via experimental manipulation of biodiversity in photographs and videos: in a large sample, coastal environments perceived as more biodiverse were rated as more restorative[18]. More recently, Lingshuang Meng et al. reinforced this conclusion, who used multilevel regression to analyze green space

Table 1: Abbreviations used in this manuscript

Abbreviation	Full item name	Abbreviation	Full item name
AGFI	Adjusted Goodness-of-Fit Index	NS	Natural sound
ANOVA	Analysis of variance	MS	Mechanical sound
ART	Attention Restoration Theory	PGFI	Parsimony Goodness-of-Fit Index
AS	Artificial sound	PI	Psychological identification
BP	Biodiversity perception	POMS	Profile of Mood States
BPc	Bird perception	PP	Plant perception
BVI	Building view index	PR	Preference
CFI	Comparative Fit Index	PRS	Perceived Recovery Scale
EEG	Electroencephalography	RMSEA	Root Mean Square Error of Approximation
GFI	Goodness-of-Fit Index	SEM	Structural equation modeling
GVI	Green view index	SMC	Squared multiple correlation
HP	Habitat perception	SR	Species richness
IP	Insect perception	SRT	Stress recovery theory
NA	Natural attitude	SVF	Sky view factor
NC	Natural cognition	TLI	Tucker-Lewis Index
NFI	Normed Fit Index	TMD	Total Mood Disturbance
NNFI	Non-Normed Fit Index	TMT	Trail Making Test
NR	Nature relatedness	VR	Virtual reality

visitors' nested data, and showed mental health indicators correlated only with perceived SR, not actual measured SR or diversity[19].

These studies collectively indicate that subjective BP is a more direct variable influencing health benefits. However, inconsistencies exist regarding perception accuracy and its influencing factors. Jufang Hao et al. experimentally showed plant diversity perception depends more on visual cues than actual SR, and forest SR correlates positively with perceived restoration[20]. Joel Methorst et al., using cross-sectional analysis of German national data, found mental health correlates with actual plant and bird SR, suggesting different biological groups influence perceived restoration and mental health via distinct pathways[21]. Additionally, bird song diversity alleviates stress[22], enhances well-being[23], and improves attention[24]. Similarly, insect diversity—a key component of the natural soundscape[25]—exerts similar positive effects on physical and mental well-being[26]. Plant diversity boosts well-being via SR, morphological variation, and vegetation structure[27]. Forest SR correlates closely with student cognition, PR, and perceived recovery, while plant SR positively impacts mental health[21].

Previous studies establish this research's theoretical foundation: subjective BP is a core mediator linking actual biodiversity to health benefits, though its formation mechanisms and pathways need further analysis. Thus, this study investigates how actual diversity and audiovisual environmental factors shape BP, and how these perceptions influence mental health.

1.2 Mediating Factors in BP

In recent years, researchers have increasingly explored the mediating mechanisms by which biodiversity influences health, identifying multiple potential pathways. Jake M. Robinson et al. proposed that biodiversity may confer health benefits via five factors: biological, psychological, social, physical activity, and environmental buffering[28]. Supported by extensive literature, this study focuses on psychological mediating mechanisms, particularly key variables in the core pathways of affect and cognition—PR, PI, NA, NR, and NC[15–17,19–20,29–35] (Table2). These variables were selected as mediators due to their established conceptual status in existing theories and their ability to capture differentiated psychological responses individuals have to natural environments.

1.3 Audio–Visual Collaboration

Building on the exploration of psychological mechanisms by which BP influences health, we must further consider multisensory integration, particularly the pivotal role of audiovisual interaction in nature perception. Among sensory pathways, vision and hearing are the primary, most researched channels for humans to perceive natural information[36]. As a core pathway for nature perception,

Table 2: Definitions of key terms and supporting literature

Key term	Definition	Supporting literature
PR	Refers to an individual's positive inclination and degree of fondness towards specific natural environments or biodiversity characteristics, typically manifested as their selection bias and subjective evaluation	Refs. [15,29]
PI	Measured through four dimensions, including individual reflection, place attachment, identity identification, and connections to the past	Refs. [15–17,30–31]
NA	Refers to stable and enduring evaluative tendencies and behavioral intentions individuals hold towards natural environments and biodiversity	Ref. [32]
NR	Reflects the strength of cognitive, emotional, and experiential bonds between individuals and the natural world	Refs. [15,19–20,33]
NC	Denotes individuals' fundamental knowledge and understanding of natural environmental systems, biodiversity, and their ecological functions	Refs. [34–35]

audiovisual collaboration not only helps individuals comprehend their environment but also enhances immersion and perceived realism through multisensory coordination[37–38], thereby amplifying the effects of the aforementioned psychological mediating pathways (e.g., PR, PI).

In recent years, to enhance research ecological validity, scholars have increasingly used audio–visual synchronized stimuli to simulate natural environments, deepening investigations into their health-enhancing effects[36]. Empirical findings show that synergistic integration of visual and auditory information at the perceptual level yields more pronounced restorative benefits than single sensory channels[39]. The greater the consistency between soundscapes and visual landscapes in content, rhythm, and semantics, the more they enhance individuals' aesthetic PR and emotional engagement[40], providing theoretical support for further research into the psycho-physiological mechanisms underlying BP.

1.4 Research Content and Objectives

Based on a systematic literature review, this study constructs a theoretical framework for examining how BP impacts physical and mental health, and designs two logically progressive experiments accordingly.

Experiment 1: Investigating BP pathways based on audio–visual collaboration. It quantitatively analyses the influence of individual psychological traits and environmental physical characteristics on BP and its mechanisms, addressing two key questions: 1) To what extent do individual psychological traits (NR, PI, NA, NC) directly influence BP levels, and which play a significant mediating role in perception formation? And 2) is there a significant correlation between BP values and objective biodiversity indicators (e.g., SR), physical environmental characteristics (e.g., GVI, proportion of NS), and what are its degree and direction? This experiment clarifies the psychological formation mechanisms of BP.

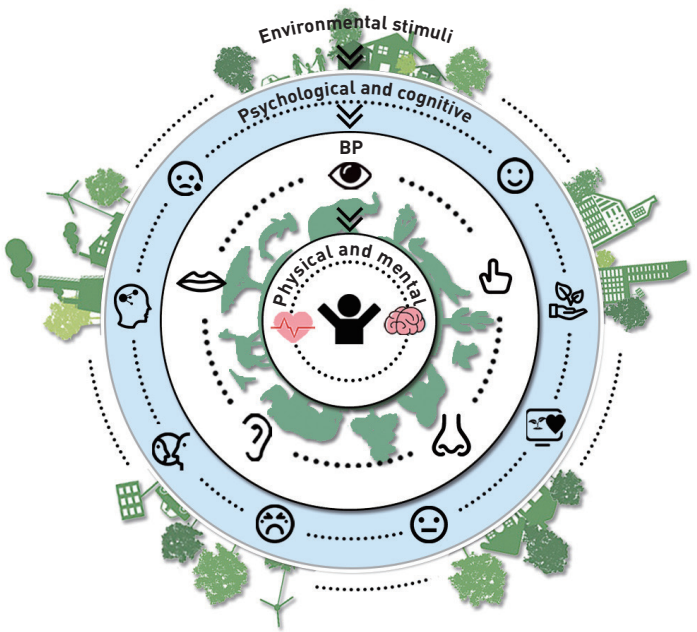
Experiment 2: Research on the health benefits of BP based on audio–visual collaboration. Building on Experiment 1's findings, it explores differential health benefits of varying BP levels and tests the framework's core hypotheses, answering that compared with low BP environments, do medium and high BP environments show significant differences in improving participants' psychological recovery (e.g., PRS scores), emotional states (e.g., POMS scores), attention, and physiological indicators (e.g., heart rate, EEG), and what are the effect sizes and recovery trends? This experiment validates BP's specific impact on health outcomes.

The two experiments follow a clear logic: Experiment 1 identifies key antecedent variables and psychological mediating pathways of BP by focusing on perception formation; Experiment 2 validates BP's health benefits by focusing on perception's health effects. Together, they establish a comprehensive evidence chain from "perceptual response" to "health benefits" (Fig. 1), elucidating BP's core mediating role in human–nature interactions' health-promoting process.

2 Experiment 1: Investigating BP Pathways Based on Audio–Visual Collaboration

2.1 Study Area and Material Preparation

This study was conducted on a university campus in Hangzhou,



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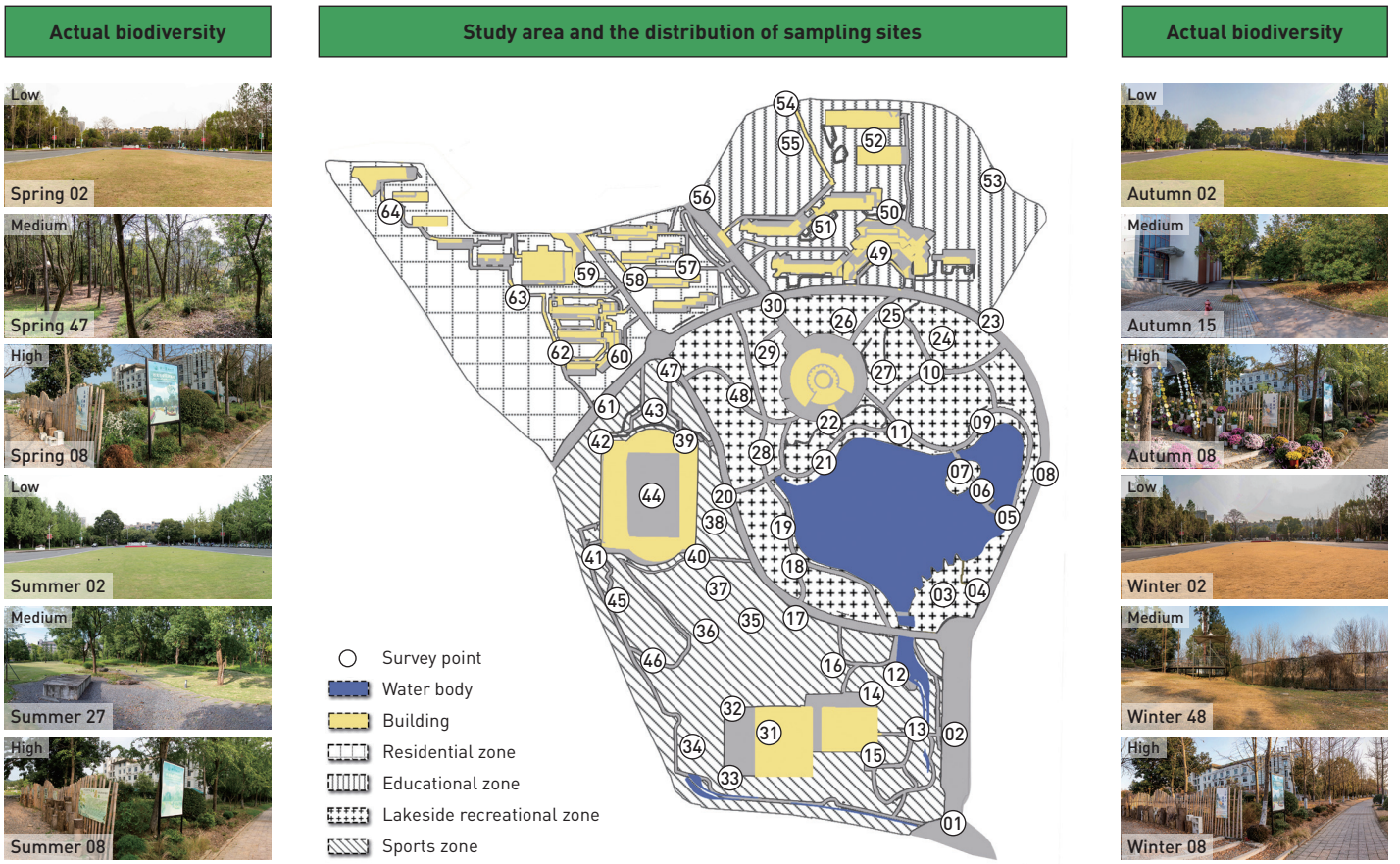
covering an area of approximately 58 hm^2 (including 5.2 hm^2 of water bodies). To comprehensively cover diverse campus ecological environments, 64 sampling points were set across residential, teaching, sports, and recreational zones, representing varied plant diversity levels. High diversity in northwest/southwest urban forest patches and lakeside areas; moderate diversity around buildings, landscaped gardens, and campus entrances; and low diversity at sports fields, plazas, and high-human-activity sites (Fig. 2).

To quantify actual biodiversity for Experiment 1, 10 m × 10 m plant survey plots were set at each sampling point. Plant diversity was selected as the primary indicator for three reasons: 1) vision is humans' dominant environmental perception channel, and plants are the most common, prominent natural elements in visual landscapes[41]; 2) animal diversity (e.g., birds, insects) relies more on auditory perception[42], hard to capture via static imagery; and 3) plant diversity correlates positively with insect and bird diversity[43], serving as an effective actual biodiversity indicator. Surveys included species identification and count of all trees, shrubs, herbs, and groundcover in each quadrat, with SR as the core metric.

To ensure high-fidelity audio–visual data, all collection was conducted on sunny, stable weather days (14 August 2023; 28–31 October 2023; 3–5 January 2024; 25–29 March 2024).

For visual data, a Canon 700D camera (resolution 5,184 × 3,456) was used at each sampling point, with uniform settings (1.60 m height, 18 mm focal length)[44]. A total of 256 panoramic photographs were captured and synthesized into panoramic slideshows (Experiment 1) and videos (Experiment 2) as visual stimuli.

For soundscape data collection, synchronous recordings



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Fig. 1 Research framework diagram. This framework illustrates how audiovisual stimuli influence individuals' psychological mediating variables (PI, NA, NR) and cognitive mediating variable (NC), thereby driving BP, and ultimately impacting physical and mental health outcomes.

Fig. 2 Distribution of sampling points and research instrumentation. The on-site photos show the actual biodiversity levels (high, medium, low) during different seasons (image extracted from panoramic photograph).

were made using a Sony Zoom H5 audio recorder (sampling specification: 24 bit/96 kHz). Recording commenced concurrently with photography at each sampling point, with each audio segment lasting one minute. These recordings served as auditory stimuli. Recordings underwent noise reduction processing using Adobe Audition 2023, with NS, AS, and MS subsequently extracted. To maintain ecological validity and immersion, all soundscape stimuli employed in the experiments comprised complete recordings, synchronized with their corresponding panoramic visual materials. During quantification, we decomposed the recordings into acoustic components, calculating the percentage of NS, AS, and MS within the total soundscape via Eq. (1):

$$f_i = \frac{n_i}{\sum_{j=1}^{k} n_j}, \tag{1}$$

where f_i refers to the relative frequency of the i-th sound type; n_i refers to the occurrence count of the i-th sound type; and k refers to the total number of sound categories.

The processed sound data effectively enhance the simulation of natural environments[45]. Numerous studies have confirmed the sound validity of such audio–visual-coordinated natural environment simulation methods[39–40].

To precisely manipulate and measure audio–visual collaboration effects in BP, this study employed a combination of panoramic photography and spatial audio to simulate natural environments. Specifically, panoramic images were presented via flat-screen displays, complemented by high-fidelity spatial audio playback to deliver an ecologically valid audio–visual environment. Compared with fully immersive VR techniques, the flat-screen display approach employed herein—devoid of head-mounted devices or virtual interaction capabilities—offers the advantage of providing reproducible audio–visual synchronization stimuli under uniform conditions. This medium significantly enhances the overall perceived authenticity and engagement with natural environments[46], and similar approaches have been widely adopted in environmental perception research[47].

Based on 256 high-definition panoramic photos and corresponding one-minute environmental audio recordings collected from preliminary field surveys, a total of 16 sets of audio–visual synchronous stimulus materials were created. Each set comprised 16 photographs presented in a fixed sequence (with consistent sampling points but differing seasons within each set, 4 photographs for each season). Each slide was strictly synchronized with its corresponding authentic environmental audio recording, lasting one minute. This duration was set to faithfully reproduce the soundscape environment at the time of sampling, while offering participants sufficient time to observe the panoramic photographs' details, thereby eliciting more comprehensive biodiversity information (Fig. 3).

2.2 Questionnaire Design

This study used a questionnaire survey to measure key psychological constructs and their intrinsic relationships in BP formation via a multidimensional scale system. Scale selection was based on the theoretical framework that an individual's BP is jointly influenced by stable personal traits and immediate psychological states from external environmental stimuli. Two separate questionnaires were designed to measure these variable categories and reveal their interaction in shaping BP.

Questionnaire A measures participants' intrinsic, stable personal traits—the long-term psychological foundation for interpreting environmental information and forming perceptions.

1) NR: The 6-item NR-6 scale revised by existing research[19,33] was used to measure the strength of an individual's emotional and cognitive connection to nature.

2) NA: An NA scale adapted from the research by Masashi Soga et al. assessed participants' emotional inclinations towards nature[48].

3) NC: Measured via subjective knowledge assessment (e.g., self-evaluation of biodiversity understanding) and objective competency testing (biodiversity fundamentals and species identification).

Questionnaire B measures participants' immediate psychological states induced by environmental stimuli—direct responses to the

Fig. 3 Examples of the panoramic photographs as visual stimulus materials.



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interaction between personal traits and the environment, serving as proximal mediators in BP formation. To ensure cohesion and reduce redundancy, items closely related to environmental connection were extracted from original scales across four dimensions: reflection, place attachment, identity formation, and connections to the past[15–17].

1) Reflection: individuals' deep contemplation and evaluation of their relationship with the environment (e.g., "In this place, I contemplate the connection between nature and my life").

2) Place attachment: positive emotional bonds to a specific location, including feelings of security, comfort, and emotional attachment.

3) Identity formation: personal and societal self-definition and social belonging developed through environmental interactions.

4) Connections to the past: temporal continuity and narrative coherence between individuals and environments via personal history, memory, and tradition.

Additionally, PR, as a key mediating variable was included, adopting a scale used in previous research[49] to assess participants' aesthetic and emotional PR towards the environment (e.g., degree of PR for the experienced environment) (Fig. 4).

Both questionnaires used a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

BP was measured via a graded anchoring approach to assessing subjective judgments of biodiversity richness across multiple taxa and dimensions. This method aligns subjective perceptions with objective indicators using options based on actual biodiversity ranges, reducing assessment ambiguity[17].

1) Auditory—BPc: e.g., "The SR/abundance of birds in this environment." Option 1: < 5 species; Option 2: 5–9 species; Option 3: 10–19 species; Option 4: 20–30 species; Option 5: > 30 species.

2) Auditory—IP: e.g., "The SR/abundance of insects in this environment." Option 1: < 4 species; Option 2: 4–7 species; Option 3: 8–13 species; Option 4: 14–20 species; Option 5: > 20 species.

3) Visual—PP: e.g., "The SR/abundance of plants in this environment." Option 1: < 10 species; Option 2: 10–30 species; Option 3: 31–50 species; Option 4: 51–100 species; Option 5: > 100 species.

4) Visual—HP: e.g., "Number of habitat types." Option 1: < 2 types; Option 2: 2–4 types; Option 3: 5–7 types; Option 4: 8–10 types; Option 5: > 10 types.

2.3 Participant Recruitment and Experimental Procedure

This study recruited 320 participants (mean age 23 years; 246 females, 74 males) via course enrolment. All were current students at the institution, including 257 environmental studies majors

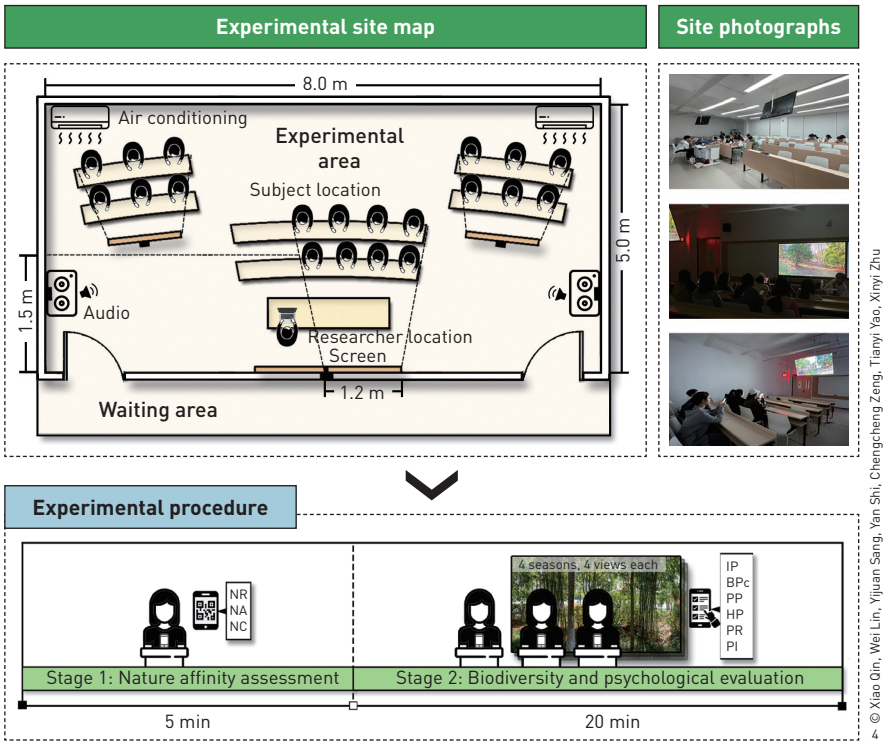


Fig. 4 Experiment site and experiment procedure.

(80.3%) and 63 non-environmental majors (19.7%) (Table 3). To ensure data reliability and internal validity, recruitment exclusion criteria were established.

1) No history of severe physical or mental illness (e.g., cardiovascular disease, neurological disorders, anxiety, depression) to avoid interference with BP measurement and psychological benefit assessment.

2) No visual/auditory impairments (or corrected to normal) to ensure accurate reception of audio–visual biodiversity cues.

3) No prolonged hormonal medication use (e.g., glucocorticoids, thyroid hormones) in the past six months to exclude hormone-induced impacts on emotional stability.

4) No smoking or alcohol addiction to avoid distorted environmental PR judgements caused by addictive substances.

5) No high-caffeine food consumption (e.g., coffee, strong tea, energy drinks) within 24 h pre-experiment to minimize caffeine-induced fluctuations in alertness and physiological indicators.

The experiment was conducted in a soundproofed classroom (13–18 May 2024) with room temperature maintained at 26 °C. Participants first scanned a QR code to complete Questionnaire A (5 min) assessing baseline nature affinity. The formal experiment followed: three screens displayed 1-minute audiovisual slides, during which participants completed Questionnaire B. The experiment lasted approximately 25 min (Fig. 4).

Table 3: Statistics of participant information (*N* = 320)

Category	Number of participants	Percentage
Gender		
Male	74	23.1%
Female	246	76.9%
Education level		
Undergraduate	85	26.6%
College (3-year)	2	0.6%
Master's student	232	72.5%
Ph.D. student	1	0.3%
Major		
Environment-related	257	80.3%
Other majors	63	19.7%
Self-rated NC (mean = 3.07, *SD* = 0.85)		
1 (very low)	11	3.4%
2 (low)	57	17.8%
3 (moderate)	172	53.8%
4 (high)	62	19.4%
5 (very High)	18	5.6%

Sample size validity was verified via G*Power 3.1 software (SEM-based power analysis). Using the "Linear multiple regression: Fixed model, R2 deviation from zero" test (α = 0.05, Power = 0.8, 4 predictors: NR, NA, NC, PI; medium effect size $f^2 = 0.15$), the minimum sample size was 129. The final effective sample size (*N* = 5,120; 320 participants × 16 scenario evaluations) far exceeded this requirement, ensuring high statistical power (> 0.99) for reliable effect detection and stable model parameter estimation, providing a robust foundation for SEM analysis.

2.4 Data Analysis Methods

A total of 640 pre- and post-experimental questionnaires were collected with no missing data. Reliability analysis showed all scales had good internal consistency.

Questionnaire A: NR scale (α = 0.720), NA scale (α = 0.706);

Questionnaire B: BP scale (α = 0.857), PI scale (α = 0.927), all exceeding the 0.7 acceptable threshold.

2.4.1 SEM Analysis

To explore BP's psychological pathways, a SEM was constructed based on the theoretical framework (Fig. 5). NR, NA, and NC served as exogenous latent variables, PI as a mediating latent variable, and BP as an endogenous latent variable. Analyses were performed using Amos 26 (*N* = 5,120), with the following hypotheses.

Hypothesis 1 (H1): NR is positively associated with BP.

Hypothesis 2 (H2): NA is positively associated with BP.

Hypothesis 3 (H3): NC is positively associated with BP.

Hypothesis 4 (H4): NR, NA, and NC exert a positive mediating effect on BP through PI.

2.4.2 Pearson's Correlation Analysis

To explore the quantitative relationship between actual biodiversity, audio–visual environmental factors, and BP, Pearson's correlation analysis (IBM SPSS Statistics 27) was used. Three core categories of objective indicators were included (Fig. 6).

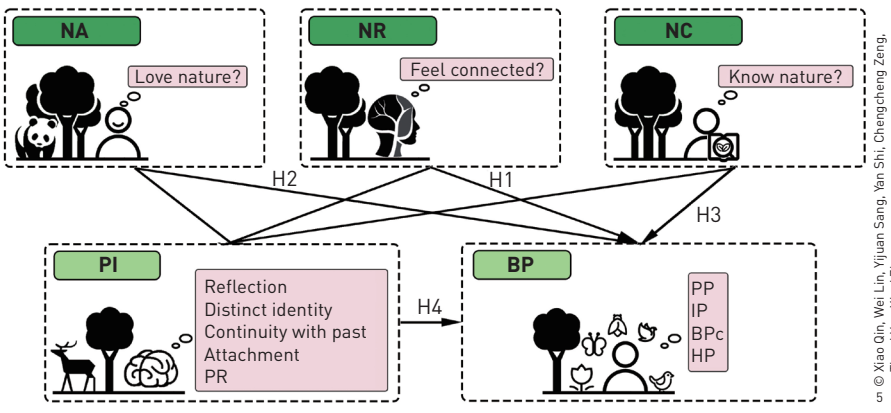
1) Actual biodiversity indicator: plant SR (total plant species per sampling plot, obtained via plot surveys).

2) Visual environment indicators: GVI, BVI, and SVF, calculated via a lightweight semantic segmentation model.

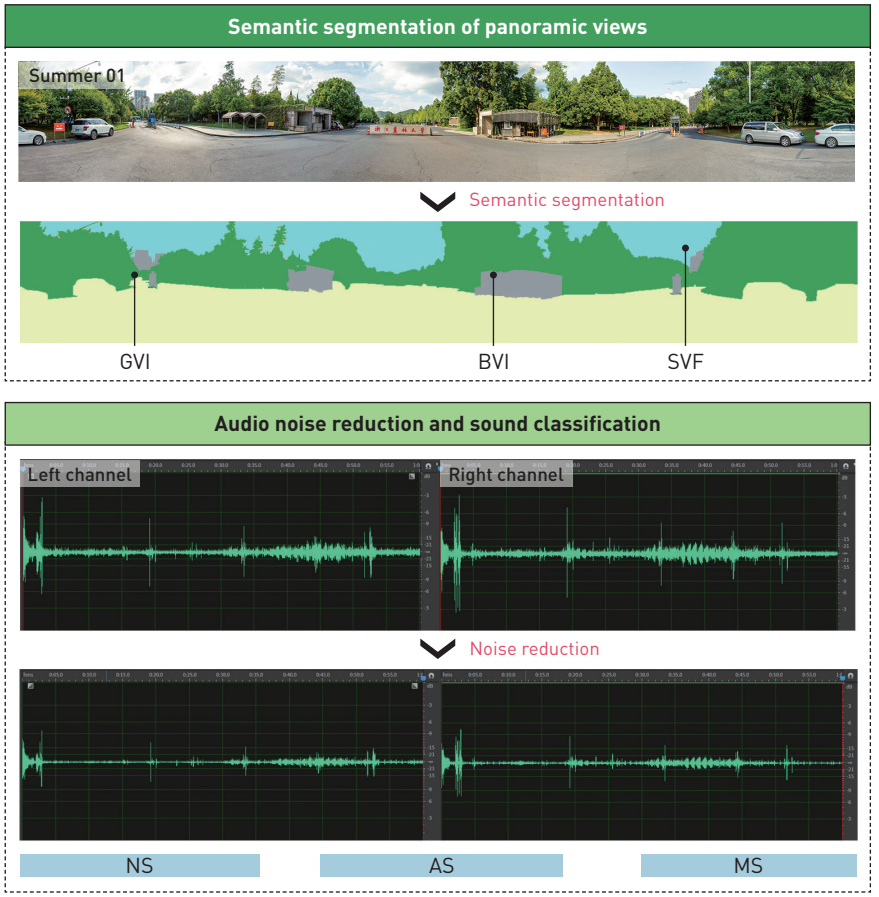
3) Soundscape composition metrics: NS proportion (natural sound duration percentage), AS proportion (human activity sound duration percentage), and MS proportion (mechanical sound duration percentage), calculated using Eq. (1).

These objective indicators were correlated with two subjective perception dimensions: 1) BP metrics (PP, IP, BPc, HP) and 2) environmental PR indicator (overall PR rating).

Fig. 5 Path diagram of the BP hypotheses.



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Fig. 6 Quantification indicators for panoramic photograph and audio processing.

To reduce individual variation-induced random errors, 5,120 individual evaluations were averaged into 64 sampling points. Additionally, ArcMap 10.7's spatial analysis module was used for spatial interpolation visualization to explore spatial distribution and clustering characteristics of environmental indicators and perception variables.

2.5 Results

2.5.1 SEM Results

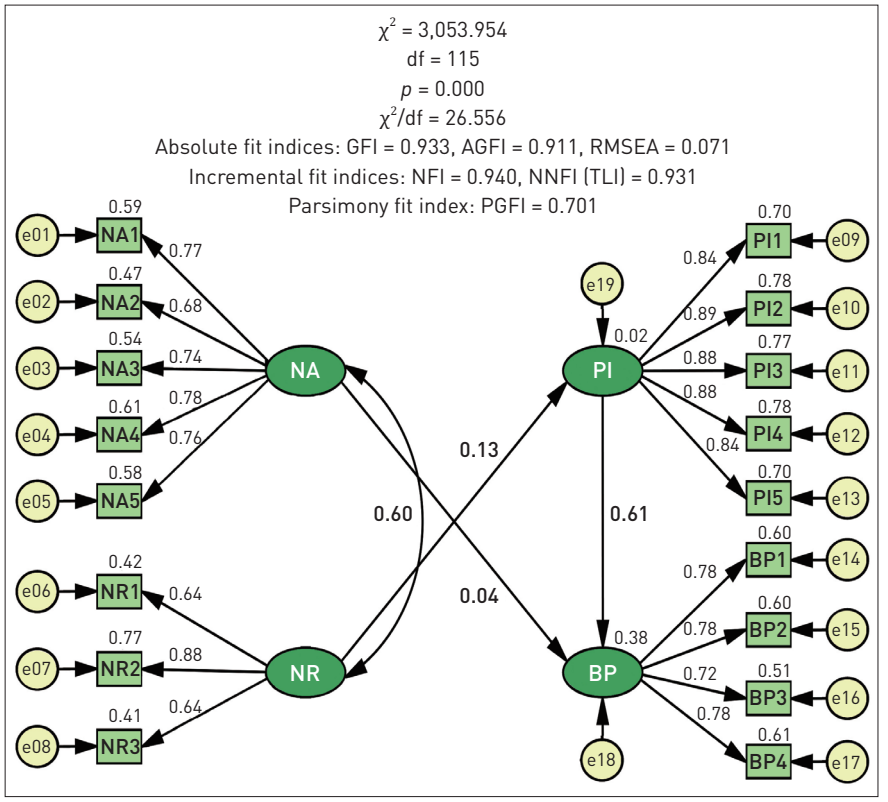
The SEM was analyzed using IBM SPSS Amos 26 software with the Maximum Likelihood estimation method[50]. The analysis revealed that all observed variables (measure items) exhibited standardized factor loadings on their corresponding latent variables exceeding the recommended threshold of 0.60 (range: 0.643–0.885, $p < 0.001$). Moreover, the SMC reflecting the reliability of each item exceeded 0.40 (range: 0.414–0.784), indicating that the observed variables were effectively explained by their latent variables and that the measurement model possessed sound convergent validity. This systematic modelling process ensured the theoretical soundness and statistical reliability of the final model (Fig. 7).

Model fit indices were adequate: $\chi^2 = 3{,}053.954$, df = 115, $\chi^2/df = 26.556$; RMSEA = 0.071 (< 0.08); GFI = 0.933, AGFI = 0.911 (> 0.9); NFI = 0.940, NNFI = 0.931, CFI = 0.942 (> 0.9). These indices (except χ^2) meet recommended values, indicating good model fit. It should be noted that the χ^2 statistic is highly sensitive to sample size in large samples and may exhibit significant overestimation[51]. Therefore, multiple indicators should be considered collectively for comprehensive judgement. Despite the elevated χ^2 value, all other fit indices supported the model's sound fit.

In the path analysis, standardized and unstandardized path coefficients were estimated using AMOS software, with significance tests conducted to assess support for each hypothesis. Specific results are presented in Tables 4 and 5.

Through path coefficient significance tests, we validated the research hypotheses. The analysis revealed that all hypotheses except H2 were supported by the data, as detailed below:

Fig. 7 SEM results of the BP pathway. Ellipses denote latent variables, boxes denote observed variables, and circles denote error variables (the numbers represent questionnaire item numbers; see Supplementary Table 2). Unidirectional arrows denote causal pathways between variables: 1) arrows from latent variables to observed variables represent factor loadings; 2) arrows between latent variables indicate standardized path coefficients; and 3) arrows from error variables to observed variables signify measurement error or unexplained variance. Bidirectional curved arrows indicate correlations between variables, typically linking exogenous latent variables to denote significant associations between them.



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Table 4: Path coefficients between latent variables and hypothesis testing results (* $p < 0.001$)**

Latent variables	Standardized path coefficient	Unstandardized path coefficient (B)	S.E. (Standard Error)	*p*	Whether support the hypothesis
NA → BP	0.045	0.045	0.014	***	H2 Support
NR → PI	0.133	0.206	0.025	***	H4 Support
PI → BP	0.608	0.538	0.014	***	H4 Support

H1: The direct positive correlation between NR and BP was not supported. However, a significant positive correlation existed between NR and PI (β = 0.133, $p < 0.001$), indicating that NR exerts a significant positive influence on PI.

H2: The positive correlation between NC and BP was not supported.

H3: The positive correlation between NA and BP was supported (β = 0.045, $p < 0.001$), indicating that positive NA exert a significant positive influence on BP.

H4: The hypothesis that NR exerts an indirect positive effect on BP via PI is supported (β = 0.608, $p < 0.001$), indicating NR

Table 5: Factor loadings and reliability indices of the measurement model (* $p < 0.001$)**

Observed variable	Latent variable	Standardized path coefficient (β)	Squared multiple correlations	Unstandardized path coefficient (B)	S.E.	*p*
PI1: Continuity with the past	PI	0.838	0.702	1.023	0.013	***
PI2: Place attachment	PI	0.885	0.784	1.000		
PI3: Reflection	PI	0.879	0.772	1.028	0.011	***
PI4: Distinct identity	PI	0.881	0.776	1.049	0.012	***
PI5: Preference	PI	0.837	0.700	0.923	0.011	***
BP1: Plant perception	BP	0.778	0.605	1.000		
BP2: Insect perception	BP	0.776	0.603	1.226	0.023	***
BP3: Bird perception	BP	0.717	0.514	1.014	0.020	***
BP4: Habitat perception	BP	0.779	0.608	1.120	0.021	***
NA1: I value natural environments because they are visually pleasing.	NA	0.768	0.590	1.174	0.022	***
NA2: I value natural environments because I enjoy the changes in seasons.	NA	0.682	0.466	0.831	0.018	***
NA3: I value natural environments because they make me feel better.	NA	0.737	0.543	0.588	0.011	***
NA4: I value natural environments because they give me more opportunities to connect with nature.	NA	0.778	0.605	0.811	0.015	***
NA5: I value natural environments because they are lively and beautiful.	NA	0.759	0.575	1.000		

(Continued)

Table 5: Factor loadings and reliability indices of the measurement model (* $p < 0.001$) (Continued)**

Observed variable	Latent Variable	Standardized path coefficient (β)	Squared multiple correlations	Unstandardized path coefficient (B)	S.E.	*p*
NR1: Nature and the environment contribute to my spiritual life.	NR	0.645	0.416	1.045	0.028	***
NR2: My connection with nature is an important part of who I am.	NR	0.877	0.769	1.223	0.030	***
NR3: I feel a strong connection to all living things on Earth.	NR	0.643	0.414	1.000		***

significantly and positively influences BP through PI.

To verify the significance of the mediating effect, we employed the Bootstrap method (2,000 repeated samples) to calculate the bias-corrected confidence interval for the indirect effect (NR → PI → BP). Analysis revealed an unstandardized effect size of 0.111 for the indirect effect, with a 95% confidence interval of 0.083–0.138 that did not include zero ($p < 0.001$). This indicates that the indirect effect of natural connectivity on BP via PI is statistically significant ($p < 0.05$), further supporting H4.

In summary, H3 and H4 are supported by the data, validating that NR positively influences BP through PI, and that NA is positively correlated with BP.

2.5.2 Indicator Correlation Results

The correlations between measured environmental variables and perceptual variables were analyzed using a correlation heatmap, with the specific results presented in Figs. 8–10. Key findings are summarized below:

High correlation among perceived variables: PP, IP, BPc, HP, and PR exhibited very strong positive correlations ($r \geq 0.8$①, $p \leq 0.001$), with HP and PR showing a correlation as high as 0.95. This indicates that different dimensions of BP are closely interrelated.

Positive influence of GVI: GVI exhibits significant positive correlations with IP, HP, and PR ($0.48 \leq r \leq 0.55$, $p \leq 0.001$), suggesting that higher GVI contributes to enhanced IP, HP, and PR.

Negative effects of BVI: BVI exhibited weakly significant negative correlations with PP, IP, HP, PR, and GVI ($-0.29 \leq r \leq -0.32$, $0.01 \leq p \leq 0.05$), and a significant negative correlation with BPc ($r = -0.32$, $0.001 \leq p \leq 0.01$). This indicates that higher BVI suppresses BP.

Associative characteristics of SR: SR showed a significant

① *r* stands for correlation coefficient.

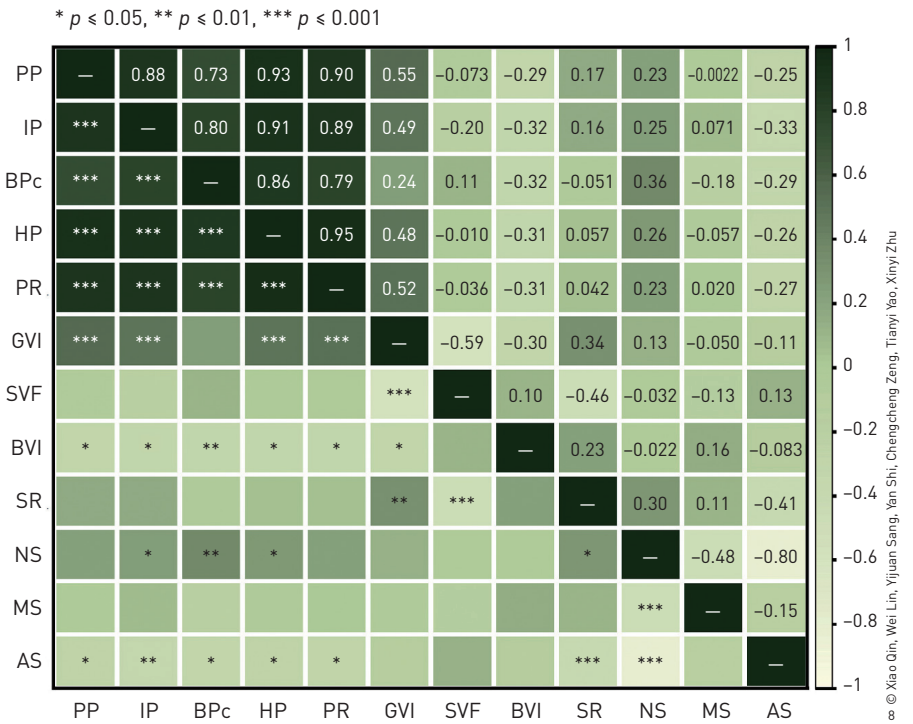
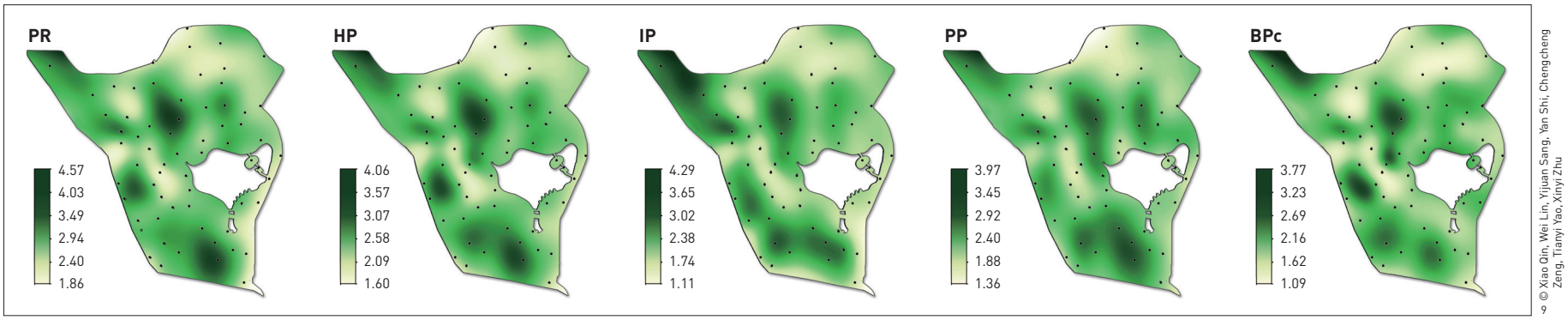


Fig. 8 Correlation heatmap between actual biodiversity, audiovisual environmental factors, and perceived biodiversity.

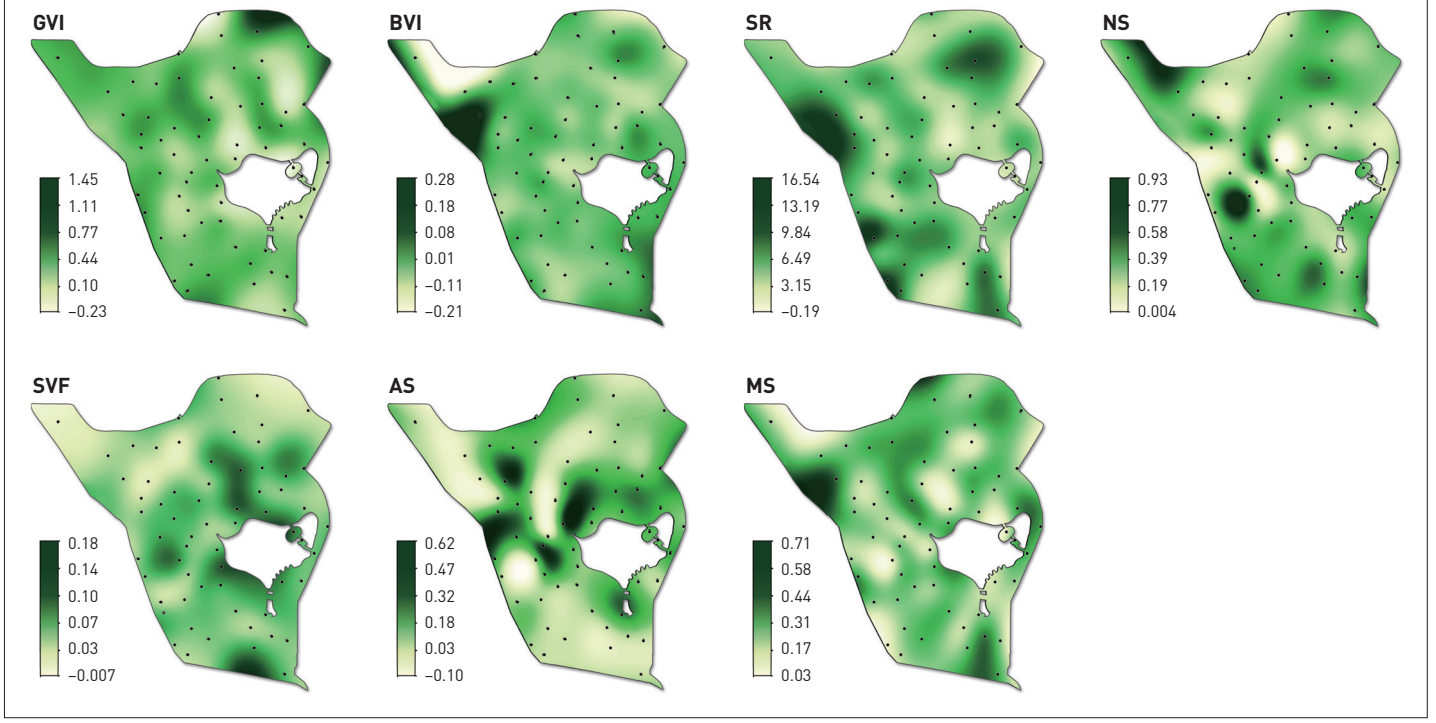
positive correlation with GVI ($r = 0.34$, $p < 0.01$) and a significant negative correlation with SVF ($r = -0.46$, $p \leq 0.001$).

Facilitative effect of NS: NS exhibited weakly significant positive correlations with IP, HP, and SR ($0.25 \leq r \leq 0.30$, $p < 0.05$), and a significant positive correlation with BPc ($r = 0.36$, $p < 0.01$). This indicates that the presence of NS enhances BP.

Disturbance effect of AS: MS exhibited a strong significant negative correlation with NS ($r = -0.48$, $p \leq 0.001$). AS exhibited weakly significant negative correlations with PP, BPc, HP, and PR ($-0.25 \leq r \leq -0.29$, $p < 0.05$), a significantly negative correlation



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Fig. 9 Perceived biodiversity heatmap.
Fig. 10 Heatmap of actual biodiversity and audiovisual environmental factors.

with IP ($r = -0.33$, $p < 0.01$), and a significantly negative correlation with SR ($r = -0.41$, $p \leq 0.001$). Furthermore, AS exhibited a strong significant negative correlation with NS ($r = -0.80$, $p \leq 0.001$). These findings indicate that MS and AS exert negative effects on perceptions of natural environments.

Overall, natural elements such as GVI and NS enhanced BP, whereas artificial elements including BVI, MS, and AS suppressed such perceptions.

3 Experiment 2: Research on the Perceived Health Benefits of BP Based on Audio–Visual Collaboration

3.1 Experimental Materials and Design

Video materials for Experiment 2 were derived from Experiment 1. Based on participants' BP ratings of each site, all sites were divided into high, medium, and low BP groups. Eight representative sites were selected from each group (covering four seasons, two videos per season), forming 120° horizontal field-of-view panoramic scrolling videos (no zoom) with synchronously embedded on-site environmental soundscapes.

The experiment was conducted in a 5 m × 5 m classroom with an external waiting area. Participants viewed videos alone to ensure undisturbed data collection; researchers only entered briefly for pre-experiment guidance (device setup), post-experiment assistance (device removal), and specific operations (e.g., blood pressure measurement) before leaving immediately. A 1.5 m × 2 m display screen was used, with participants seated 2.4 m from the screen.

Primary equipment included: YUWELL YX306 pulse oximeter, OMRON U15 sphygmomanometer, and Emotiv EPOC X EEG device.

Scales used were PRS and POMS (Chinese Version of the State-Trait Affective Scale)[52]. These instruments collected participants' blood pressure, blood oxygen saturation, brain electrical activity, and affective state metrics (Figs. 11, 12).

3.2 Participant Recruitment and Experiment Procedure

Experiment 2 recruited 60 participants (15 male, 45 female), randomly assigned to three groups with 20 participants each.

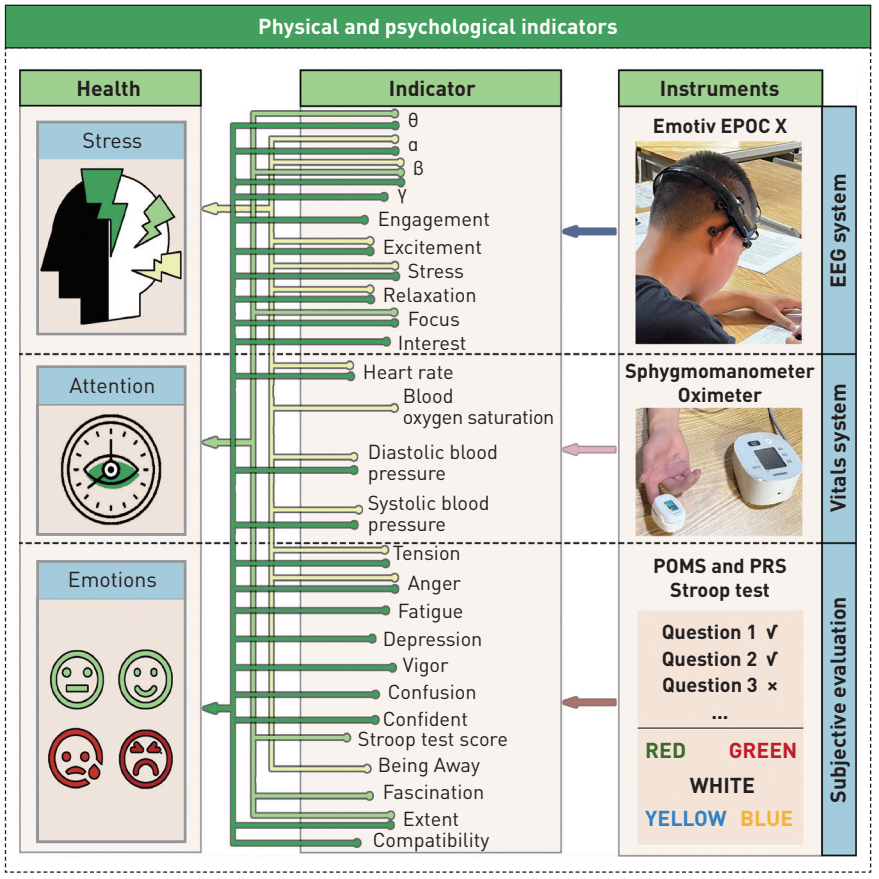


Fig. 11 Instruments and measurement indicators employed—physiological indicators (EEG, blood pressure, blood oxygen saturation, etc.) and psychological indicators (mood and restorative indicators based on PRS and POMS).

Fig. 12 Experimental procedure and timeline.

Recruitment criteria were consistent with Experiment 1.

The experiment was conducted 11–16 June 2024, with room temperature maintained at approximately 24 °C. Participants received detailed procedure explanations and provided written informed consent.

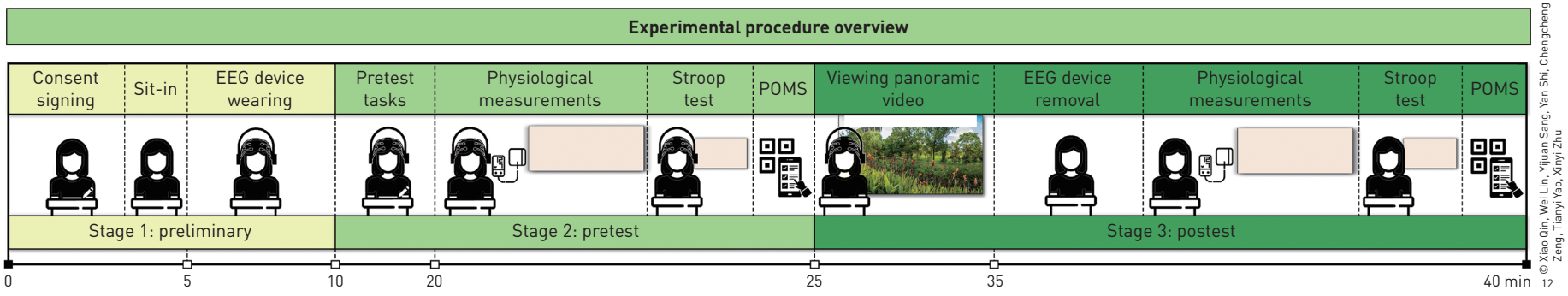
In the pre-experimental phase, participants fitted with EEG equipment before completing a 10-minute learning task and TMT. They then underwent physiological measurements (heart rate, blood oxygen, blood pressure), the Stroop test, and POMS questionnaire. Next, they viewed a 10-minute BP-level-specific video, after which physiological measurements, Stroop test, and POMS were repeated, plus the PRS questionnaire. EEG signals were continuously recorded from the learning task to video viewing conclusion.

Sample size validity was verified via G*Power 3.1 (one-way ANOVA for intergroup comparisons). Parameters: $\alpha = 0.05$, power = 0.80, 3 groups, large effect size $f = 0.40$. The minimum sample size was 66 (22 per group). The final effective sample size (60 total, 20 per group) closely matched the estimate, providing a reliable statistical foundation for variance analysis and high sensitivity for detecting intergroup differences.

3.3 Data Analysis Methods

3.3.1 EEG

This experiment employed the Emotiv EPOC X non-invasive headset for EEG signal acquisition, with data recorded via the Emotiv Lab toolbox. This device has been extensively employed in mental health assessment research, demonstrating good reliability and validity[53]. The device features 14 channels (AF4, AF3, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, and O2), covering the four major brain regions: frontal, temporal, parietal, and occipital lobes. This study focuses on analyzing EEG activity in the temporal lobes (T7, T8, associated with auditory, visual memory, and language processing) and occipital lobes (O1, O2, responsible for visual information processing)[54].



Five EEG waveforms were analyzed to evaluate brain activity and emotional states: θ (4–8 Hz, meditation/light sleep), α (8–13 Hz, calm wakefulness), low-frequency β (β_L, 13–20 Hz, focus/cognitive activity), high-frequency β (β_H, 20–30 Hz, tension/anxiety), and γ (> 30 Hz, high cognitive functions)[53]. Mean values of the five waveforms were calculated at T7, T8, O1, O2; median differences between video-viewing and task periods were determined, followed by ANOVA on these differences.

3.3.2 Other Physiological and Psychological Indicators

In addition to EEG signals, this study concurrently collected physiological indicators such as blood pressure and blood oxygen saturation. Psychological states were assessed using the POMS mood scale and Stroop test. To evaluate the intervention's efficacy, we calculated the differences in each indicator before and after the experiment and employed ANOVA to compare differences among the three groups.

The Stroop test requires participants to name the ink color of Chinese characters rather than their semantic meaning (e.g., seeing the character for "blue" printed in red ink necessitates correctly responding "red"). The number of correct responses within one minute was recorded to objectively evaluate executive function and attentional control levels[55]. In this study, the Stroop test was administered alongside the POMS scale to comprehensively evaluate changes in participants' cognitive function and emotional state before and after the intervention, examining complementary dimensions of "objective behavioural performance" and "subjective emotional experience".

The Chinese version of POMS (40 adjectives, 5-point scale: 1 = hardly ever, 5 = very often) measured emotional states, including negative (tension, anger, depression, fatigue, confusion) and positive dimensions (energetic). TMD was calculated as:

$$\text{TMD} = \begin{aligned}&\text{Tension} + \text{Anger} + \text{Depression} + \\ &\text{Fatigue} + \text{Confusion} - \text{Energetic} + 100.\end{aligned} \quad (2)$$

Following video-viewing, participants additionally completed the PRS questionnaire. This scale comprises four dimensions: Being Away (e.g., "In this place, I feel liberated"), Fascination (e.g., "The stories of this place are utterly captivating"), Extent (scored inversely, e.g., "These places contain too many distractions"), and Compatibility (e.g., "This place suits me perfectly"). The total PRS score or individual dimension scores undergo direct ANOVA.

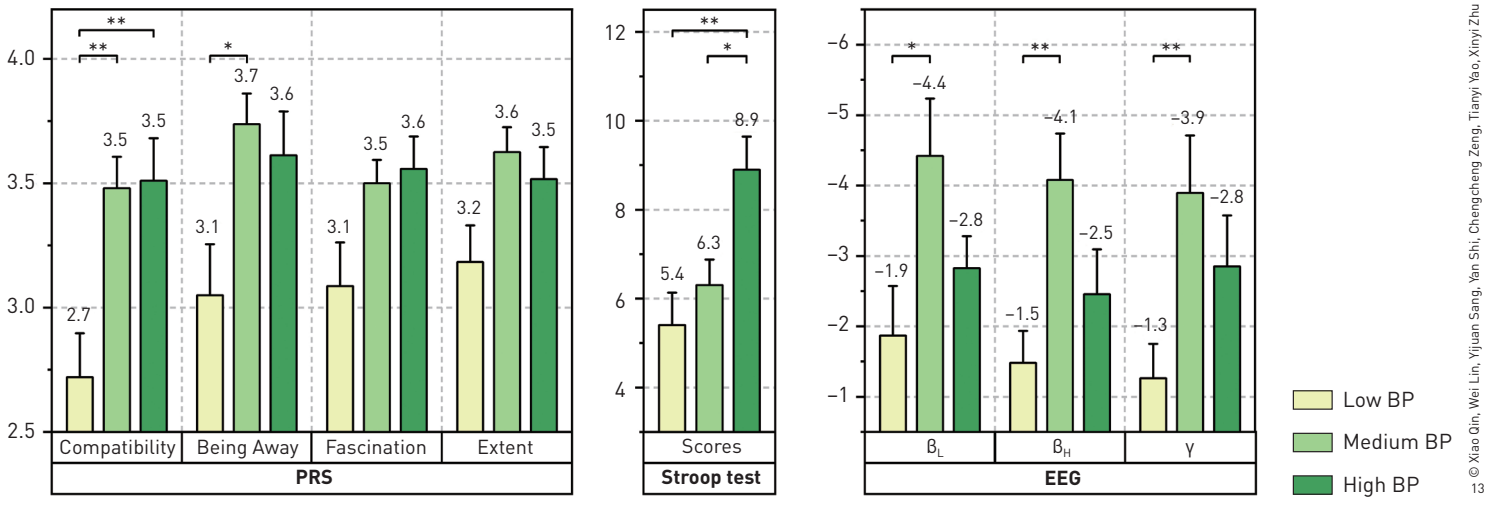
3.3.3 ANOVA and Post-hoc Tests

ANOVA was conducted on pre-post differences of psychophysiological indicators and PRS results, focusing on significant indicators. Post-hoc tests were performed for significant indicators to further analyze intergroup differences.

3.4 ANOVA Results

ANOVA results (Fig. 13) indicate that significant differences exist across the three BP groups for eight variables.

Specifically, the four dimensions of PRS—Compatibility ($p \le 0.001$, $\eta^2 = 0.217$, large effect size), Being Away ($p \le 0.05$, $\eta^2 = 0.138$, medium effect size), Fascination ($p \le 0.05$, $\eta^2 = 0.109$, medium effect size), and Extent ($p \le 0.05$, $\eta^2 = 0.103$, medium effect size). Post hoc comparisons revealed: 1) in Compatibility scores, the medium BP group significantly outperformed the low BP group ($p = 0.004$), while the high BP group also significantly outperformed the low BP group ($p = 0.003$); and 2) in Being Away, the medium BP



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Fig. 13 Bar chart of ANOVA results (* $p < 0.05$, ** $p < 0.01$).

group significantly outperformed the low BP group (p = 0.019).

Regarding Stroop test scores, significant intergroup differences were observed ($p \leq 0.01$, $\eta^2 = 0.196$, large effect size). The high BP group achieved the highest scores, significantly exceeding both the low BP group (p = 0.002) and the medium BP group (p = 0.03). This indicates that environments with heightened BP exert a more pronounced enhancement on attentional functions.

Regarding EEG metrics, intergroup differences were observed in the reduction of power across the β_L ($p \leq 0.05$, $\eta^2 = 0.113$, medium effect size), β_H ($p \leq 0.05$, $\eta^2 = 0.148$, large effect size), and γ ($p \leq 0.05$, $\eta^2 = 0.114$, medium effect size) bands. Post hoc analyses revealed that the moderate perception group exhibited significantly greater power reduction across all three bands compared with the high and low BP groups (β_L: p = 0.01; β_H: p = 0.003; γ: p = 0.009). This suggests that moderate levels of BP may induce a more profound state of relaxation.

Integrating the aforementioned results, the influence of different BP levels on restorative benefits exhibited distinct patterns: The medium BP group demonstrated optimal performance in feelings of distance, sense of scale, and EEG metrics (β_L, β_H, γ), indicating that environments with moderate BP more readily induce states of calm relaxation while providing heightened Being Away and Extent. The high BP group demonstrated superior performance in compatibility, Fascination, and Stroop test scores, suggesting environments associated with heightened BP are more conducive to enhancing attention, while exhibiting greater compatibility and appeal; the low BP group exhibited the weakest restorative effects across all metrics.

4 Discussion

4.1 BP Are Shaped by Integrated Psychological and Cognitive Influences: From Hypothesis Testing to Mechanistic Interpretation

This study systematically tested four hypotheses via SEM, revealing complex psychological mechanisms of BP formation. Key findings: NR does not directly affect BP (H1 rejected) but exerts an indirect influence through full PI mediation (H4 accepted, β = 0.111, Bootstrap 95% CI [0.083–0.138], p = 0.001). This challenges traditional simplified models treating NR as a direct predictor, urging re-examination of affect-cognition interplay in BP.

The mediating role of PI reflects the psychologically constructed nature of the individual-environment relationship. High NR fosters deep place attachment and ecological identity[19,28], integrating nature into self-concept. This enhances attentional sensitivity and emotional responsiveness to biodiversity, boosting perceptual capacity. High NR individuals are more likely to gain mental health benefits from biodiversity[20], and childhood nature exposure strengthens adult nature connectivity[56], supporting long-term resilience shaping via early nature engagement[57].

Further analysis shows PR significantly influences PI: higher NR correlates with stronger biodiversity PR, thereby enhancing BP—consistent with prior research that forest SR and PR positively correlate with BP[20], and SR influences plant PR[58]. Unlike existing studies focusing on NR's direct impact on biodiversity, this study uses path modeling to confirm PI as a crucial mediator between NR and BP. This may be because high NR enhances place attachment, reflection, and identity identification, promoting BP—resonating with restorative environmental theory's Compatibility and Fascination pathways[59], where robust PI deepens individual–environment integration, intensifying perceptual and restorative experiences.

Notably, NA exerted a significant direct positive influence on BP (H2 upheld, β = 0.045, $p < 0.001$), aligning with prior findings (e.g., positive nature attitudes correlate with BP[15], positive bird evaluations associate with perceived SR[60]). Nature exposure and positive attitudes towards nature/animals facilitate biodiversity understanding[61].

NC's influence on BP was not supported (H3 rejected), potentially due to participants' similar educational backgrounds (predominantly environmental specialists) leading to minimal cognitive variation—a speculation supported by the limited variance in NC (Mean = 0.707, SD = 0.130) observed among this predominantly environmental-specialist sample. Despite this, high statistical power ($1 - \beta > 0.99$) ensured the reliability of the primary PI pathway, providing robust evidence for the mediating mechanism between NR and perceived resilience.

4.2 BP and Actual Biodiversity: From Objective Measures to Subjective Experience

Addressing the second research question, correlation analysis examined relationships between subjective BP, objective biodiversity indicators, and physical environmental characteristics. Natural elements (GVI, SR, NS) correlated positively with BP, while artificial/mechanized elements (BVI, MS, AS) correlated negatively—indicating natural environments enhance BP, and artificial settings diminish it. This aligns with the biophilic hypothesis[1], confirming innate PR for natural elements and artificial elements' disruptive effect on restorative experiences. The positive SR–BP correlation is consistent with prior research,

identifying SR as a key BP influencer among students[20].

Notably, no significant SR–BP correlation emerged, aligning with studies showing BP does not always correspond to actual biodiversity[16–17]. From a cognitive ecology perspective, humans infer biodiversity via "readable" natural signals rather than objective metrics. Students' BP, a complex psychological construct, relies more on multi-sensory (visual/auditory) experiences than objective ecological data. Visually prominent GVI and distinct NS (e.g., birdsong) serve as cognitive shortcuts for biodiversity inference. For example, some high-SR sites had low BP due to roadway proximity and lack of maintenance, creating a visually cluttered environment that reduced restorative experiences despite diverse species.

Artificial elements exerted significant negative effects on BP. Intensified built environments and noise reduce natural settings' restorative effects, lowering positive BP. This reflects urbanization's disruption: urban noise harms soundscapes and reduces biodiversity[62]; highly urbanized areas decrease avian diversity[63] and disrupt animal behaviors[64]; consistent with urban current resilience research, artificial environment encroachment diminishes both actual biodiversity and natural settings' psychological restorative potential[65].

Urbanization-induced habitat fragmentation, pollution, and land-use changes threaten biodiversity[66]. Fragmentation impacts species survival[67], and reduces human perception of natural diversity; urban noise, pollution, and human activity lower biodiversity[63], hindering diversity perception. A positive trend between BPc and SVF was observed, potentially due to greater sky openness facilitating bird observation. However, factors such as cultural background and prior nature exposure experiences may modulate perceptual intensity.

4.3 Health Benefits of BP: From Psychological Recovery to Physiological Responses

Addressing the third research question, this study identified distinct BP-level influences on environmental restorative benefits. EEG results showed significant reductions in β- and γ-waves post-video exposure, indicating physiological relaxation and stress alleviation: β-wave reduction reflects a shift from concentration to relaxation[68], while γ-wave reduction signals a transition from high-stress to low-activity states—supporting natural environments' stress-reducing effects[69]. Notably, moderate BP scenes exhibited the most pronounced restorative effect, likely due to "moderate stimulation": sufficient natural complexity for positive psychological engagement (e.g., non-directional attention capture) without high-biodiversity information overload[70]. This balance is optimal for promoting autonomic nervous system equilibrium and stress reduction, further corroborating the SRT[71] and ART[59].

PRS ANOVA results confirmed all scenarios had restorative qualities—consistent with prior research that BP enhances attentional recovery, reduces stress[72], and boosts perceived recovery[20]. Significant inter-group differences existed: moderate BP scenes excelled in "escape" (detaching from daily pressures) and "coherence" (fostering immersion via complex, coherent environments); high BP scenes outperformed in "compatibility" and "Fascination," satisfying diverse psychological needs through abundant ecological niches and sustaining exploration via varied visual elements (e.g., diverse vegetation forms), dynamic changes (e.g., bird activity), and spatial structures[29,73].

These align with restorative environmental theory: moderate BP promotes relaxation and immersion (consistent with SRT[71]), while high BP leverages compatibility and fascination for stronger perceptual recovery—reducing stress, enhancing positive emotions, improving attention, and boosting well-being. This supports the inverted U-shaped recovery effect hypothesis[74], where moderate biodiversity yields optimal benefits, and extreme ecological complexity diminishes efficacy.

Post-hoc analysis of Stroop test results revealed that all scenarios enhanced participants' attentional performance, consistent with prior research demonstrating that exposure to natural environments promotes attentional recovery[75]. However, the greatest attentional enhancement occurred in the high BP scenarios, diverging from the neuroaffective findings. This discrepancy may arise because the Stroop test measures directed attention, whereas neuroaffective measures assess undirected attention. While viewing scenes with varying BP levels, participants' undirected attention diminished, whereas directed attention was enhanced through the restorative effect of natural scenes—particularly pronounced in the high BP scenarios. This finding deepens our understanding of the mechanisms underlying nature-based recovery, suggesting biodiversity may influence distinct attentional subsystems through separate pathways. This insight provides a more refined theoretical basis for designing nature-based interventions.

These findings advance existing frameworks: 1) confirming innate positive responses to biodiversity cues[1] with systematic variations across BP levels; 2) extending ART[59] and SRT[76] by showing different BP levels activate distinct pathways (moderate BP: Being Away/Extent; high BP: Compatibility/Fascination);

and 3) integrating EEG and psychological assessments to bridge subjective experiences with physiological responses, enriching restorative environment theory and specifying differential health outcomes across biodiversity gradients.

4.4 Applications

This study's findings have both theoretical significance and practical implications for biodiversity conservation, sustainable utilization, and nature-based healing:

1) Conservation practice: PI mediates NR's influence on BP, so conservation should strengthen knowledge dissemination, cultivate students' emotional bonds with nature and ecological identity via nature-based experiential activities to enhance intrinsic conservation motivation and PI.

2) Planning and utilization: Natural elements (SR, GVI) enhance BP, while artificial elements exert negative effects. Urban green space planning should prioritize diverse plantings, minimize artificial disturbance, and optimize ecological recreation experiences to synergize ecological and human service benefits.

3) Nature-based healing: Moderate BP is optimal for stress reduction, while high BP better stimulates positive emotions and cognitive function—providing empirical support for tailored "nature-prescriptions" and restorative environmental design.

4.5 Limitations

This study has several limitations, with corresponding future research directions.

1) Limited sample representativeness. Participants were predominantly environmental-major university students, with homogeneous cognitive levels, limiting generalizability. Future research should include diverse populations (adolescents, elderly, non-environmental majors) to test cross-group applicability.

2) Monolithic ecological context. Study sites were confined to urban parks in a single climate zone, excluding forests, wetlands, etc. Future research should conduct comparative studies across multiple ecosystems to improve spatial generalizability.

3) Insufficient seasonal dynamics consideration. Seasonal variations in BP (e.g., vegetation phenology, animal migration) were not examined, despite four-season data collection. Future research should use long-term tracking with larger samples to test seasonal effects.

4) Inadequate environmental factor interaction analysis. Interactions between natural components (e.g., lawns, woodlands) and artificial elements were not detailed. Future studies should use granular categorization and advanced models to explore these interactions.

5) Single actual biodiversity indicator. Plant SR was the sole measure, ignoring animal/microbial diversity, species evenness, and functional diversity. Future research should adopt multi-taxon indicators to capture biodiversity complexity.

6) Limited laboratory ecological validity. Audio–visual simulations (photos/videos) differ from real immersive natural experiences. Future research should validate findings in real-world settings to enhance ecological validity.

Despite these limitations, the study provides a robust empirical foundation for understanding BP's psychological mechanisms and health benefits through rigorous experimental design and statistical control. Future work should address these gaps to advance the field.

5 Conclusions

This study constructs an integrated theoretical framework encompassing environment, psychology, perception, and health, advancing BP theory in two key aspects. First, it reveals that NR indirectly promotes BP via PI mediation, while confirming NA's direct positive influence on BP. Among environmental factors, natural elements (GVI, NS) correlated significantly positively with BP, whereas artificial elements (BVI, MS) had significant negative effects. Second, the study further validates BP's positive role in stress reduction, attentional restoration, and perceived restorativeness: moderate BP environments most effectively induce relaxation and psychological recovery, while high BP settings significantly enhance directed attention functions.
By integrating audiovisual simulation, SEM, psychometric assessment, and multimodal physiological indicators, this study systematically clarifies BP's formation mechanisms and health benefit pathways. It deepens theoretical understanding of human–nature interactions and provides empirical evidence and scientific guidance for biodiversity conservation, urban ecological planning, and nature-based healing practices.

ELECTRONIC SUPPLEMENTARY MATERIAL

Supplementary material is available in the online version of this article at https://doi.org/10.15302/J-LAF-2026-0047.

ETHICS STATEMENTS

This study conforms strictly to the Declaration of Helsinki. All experimental procedures were reviewed and approved by the university's Human Subjects Ethics Committee (Approval No. 20240067; Date: 10 May 2024). Prior to participation, all participants received comprehensive research briefings and provided written informed consent. Privacy protection principles were rigorously upheld to ensure the security of personal information and experimental data throughout the study.

Competing interests | The authors declare that they have no competing interests.

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LAF | https://doi.org/10.15302/J-LAF-2026-0047
第14卷 / 第5期 / 260047 / 2026
收稿日期 | 2026-01-25　录用日期 | 2026-06-26
中图分类号 | TU986　文献标识码 | A

生物多样性感知的路径与健康效益：一项视听协同研究

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摘要

生物多样性是自然环境的关键评价标准，其对人类健康的积极影响已有充分文献记载。近期一些研究表明，生物多样性感知（BP）可能在解释生物多样性与健康之间的关系中发挥关键作用。本研究引入以视听协同为基础的“环境–心理–感知–效益”理论框架，探讨BP如何影响身心健康。本研究共招募380名参与者，采用结构方程模型（SEM）检验自然联结、自然态度和自然认知如何通过心理认同（PI）影响BP。同时采用皮尔逊相关分析，探讨BP、实际生物多样性与环境感知因素之间的关系。此外，通过控制实验条件，评估不同水平BP对生理指标的恢复效益。结果表明，自然态度与BP显著正相关，自然联结度通过PI正向影响BP；BP显著促进心理恢复、注意力和压力缓解；中等BP环境提供最高水平的放松与恢复，而高BP环境显著增强注意力恢复。本研究深入探讨了BP的机制与效益，推进了对BP的理论理解，并为生物多样性保护、利用和基于自然的疗愈实践提供基础支持。

关键词

生物多样性感知；视听协同；响应路径；健康效益；结构方程模型（SEM）

文章亮点

- 研究从视听协同视角构建生物多样性感知（BP）的作用路径
- 心理认同在自然关联性与BP之间发挥中介作用
- 绿色视野与自然声景可提升BP，建筑与人工噪声则会抑制BP
- 中等水平的BP对压力缓解效果最优，高水平BP有助于提升定向注意力

基金项目

- 国家自然科学基金（编号：32501722）
- 国家自然科学基金（编号：52578104）
- 浙江农林大学科研发展基金人才启动项目（编号：2025LFR007）
- 杭州西湖风景名胜区管委会科技发展计划项目（编号：2023-012）