Research Article

Synergistic Effects of Natural Soundscape and Artificial Music: The Dual Moderation of Music Playback in Forest Environments on Tourists' Environmental Empathy and Pro-Environmental Behavior

Qidi Sun, Hyuntae Kim*

Sejong University, Department of Applied Music,Seoul, Korea

* Corresponding author: Hyuntae Kim; kimht@sejong.ac.kr

ABSTRACT

Urban forest environments are increasingly integrating controlled music playback; however, the interaction between natural soundscapes (NS) and their influence on tourists' psychological and behavioral responses, remains unclear, particularly regarding emotional resonance, nature alignment, and environmentally responsible actions. The research aim is to examine how the combined presence of NSs and artificial music (AM) produces synergistic effects, and how music playback moderates' tourists' environmental empathy (EE) and pro-environmental behavior. Data were obtained through an on-site experimental questionnaire approach conducted with 250 tourists in forest recreation settings, involving tourists exposed to different acoustic conditions. Measurements focused on Acoustic Environment Types (AET), Music Playback Moderation (MPM), EE, emotional restoration (ER), soundscape congruence (SC), and pro-environmental behavioral intention (PEBI) captured using standardized rating scales. The analysis framework relied on descriptive statistics, reliability testing, exploratory factor analysis (EFA), correlation analysis implemented using Statistical Package for the Social Sciences (SPSS). The procedure involved comparing responses under three playback conditions: NS alone, AM alone, and integrated soundscape–music (ISM) exposure. Participants evaluated their emotional connection to the environment and willingness to engage in environmentally responsible actions following each condition. Results indicated that significant improvements were confirmed, which revealed a high mean score (3.65–4.07), moderate variability (SD = 0.61–0.76), Cronbach's Alpha (0.887), and correlations (0.46–1). PEBI showed moderate to strong positive effects under harmonized music playback; mismatched music reduced perceived environmental authenticity. Overall, regulated music improves NSs, encouraging empathy-driven pro-environmental behavior and directing sustainable, delightful forest tourist experiences.

Keywords: Natural soundscape; music playback; environmental empathy; pro-environmental behaviour; forest tourism environments; soundscape perception

1. Introduction

Urban and peri-urban forests provide support to human well-being, biological diversity, and sustainable tourism [1]. Owing to the rise in the use of these forests as a means of recreation, the use of artificial aspects

such as background music has also been incorporated to stimulate the tourist to a certain behavior [2]. AM contributes not only to emotional well-being by reducing stress and enhancing positive feelings, but also influences the surrounding acoustic environment, which is essential for shaping ecological perception and overall forest experiences. Ambient auditory elements—including avian vocalizations, airflow through vegetation, and flowing streams—support psychological recovery and foster a deeper connection with nature [3].

Recently, it conducted on soundscape ecology and environmental psychology have identified the relevance of sounds in forests, but joint influences of sounds and music on forest tourists have rarely been investigated yet [4]. It focusing on individual influences of music, rather than its joint influence with sounds correlating with psychological responses of tourists. The capability of music to facilitate EE, which is an emotional attachment and care for nature, has yet to be investigated properly [5, 6]. Soundscapes play an imperative role not only for psychological restoration but also influence tourists' engagement and participation in forests for entertainment purposes [7]. Joint influence of sounds and music, including background music, could influence environmental attitudes and actions of tourists, which might lead to environmentalist actions [8]. Even though eco-tourism has gained immense popularity, research related to joint influences of sounds and music on emotional and behavioral responses has yet to be conducted properly [9]. This research focusing on influences of music while visiting a forest by modifying sound experience of visitors. The objective of the investigation is to analyze how visitors' EE, pro-environmental behavior are influenced by both artificial and NSs, with a particular emphasis on the moderating effect of music playing in forest surroundings.

1.1. Conceptual framework and theoretical contribution

EE represents an affective psychological response reflecting individuals' emotional connection, concern, and moral sensitivity toward the natural environment. Although prior investigations have identified optimistic connotations among EE and PEBI, this relationship has largely been examined descriptively, without sufficient theoretical explanation of the mechanisms through which EE translates into behavioral intention.

Drawing on affective environmental psychology and restorative environment theory, this research proposes a conceptual framework in which acoustic environment characteristics specifically AET and MPM shape emotional and behavioral outcomes through ER, soundscapes and congruent AM is theorized to enhance ER and perceived congruence between artificial natural and sounds. These emotional responses foster a deeper sense of connectedness with nature, thereby strengthening EE. Increased environmental protection, resulting in stronger PEBI.

By positioning EE as a mediating psychological mechanism linking acoustic environments to behavioral intention, this research advances soundscape research beyond perceptual evaluation and contextual validation. The proposed framework clarifies how the interaction between NSs and music playback contributes to empathy-driven pro-environmental behavior in forest tourism environments, offering a theoretically grounded explanation rather than a purely descriptive association.

Related studies are examined in Section 2. The technique, which includes materials and methods, is discussed in Part 3. The findings and discussions are presented in Part 4, and the conclusions are provided in Part 5.

2. Related work

Prior investigations predominantly employed perception modeling, psychophysiological measurement, and statistical learning frameworks, reporting moderate-to-high explanatory power and classification performance. However, most investigations remained constrained by single-context datasets, limited emotional mechanisms, and insufficient integration between environmental sound perception and behavioral intention modeling.

This research investigation presents the most recent findings on the effects of NS and manufactured music in forest areas on visitors' EE and pro-environmental conduct. The structural modeling investigated how perceptions of the accepted soundscape effect visitor experience, satisfaction, and electronic Word of Mouth. (E-WOM). Satisfaction and aspirations to share content online were increased by positive soundscapes. It was limited to overland tourists and lacked emotional or behavioral depth as well as experimental control [10]. Conceptualized "soundscape flow" and used Structural Equation Modeling (SEM) and questionnaires to evaluate its connections to behavioral intention and perception. As a result, behavioral purpose and soundscape perception were mediated by flow [11]. The intention was to use "physiological and psychological tests" to regulate the outcome of various sound sources on stress reduction in an urban forest park. Natural sounds were found to be more helpful than manufactured sounds at reducing stress. The design does not consider consequences connected to empathy or conduct [12]. Regression modeling was applied to assess the combined influence of environmental and culturally derived auditory components in forest-historical contexts. The findings showed that visitor impressions were considerably influenced by soundscape interactions. It did not examine behavioral or emotional factors, instead concentrating solely on perception [13].

The impact of soundwalk routes on soundscape assessments was evaluated to determine how path design affected assessment consistency and soundscape perception using data and guided soundwalks. [14]. Biometric data and field trials were used to examine the physiological and psychological reactions to soundscapes in a national park. The NSs were shown to enhance psychological well-being. Reactions were not linked to empathy or pro-environmental behavior [15]. Behavioral analysis and questionnaires examine how visitor behavior affects restorative soundscape experiences. The active participation improved rehabilitative outcomes, according to the results. Focusing on urban parks restricts generalization to natural forests or tourist attractions [16]. SEM and empirical data were combined to investigate the impact of the soundscape on visitors' involvements at country historic sites. Soundscape quality is positively associated with tourists' overall perceptions [17].

2.1. Soundscape theory and forest tourism

Psychophysiological responses to diverse forest-based acoustic settings were investigated in national forest parks [18]. An experimental framework was implemented using functional gauges likes heart rate inconsistency and skin conductance combined with subjective perception scales to assess responses to birdsong, water flow, and wind sounds. Results indicated that NSs significantly reduced stress-related physiological indicators, with birdsong producing the strongest relaxation effect ($p < 0.05$). The investigation was limited to a single national forest park, restricting generalization across diverse forest tourism contexts.

The association between environmental and culturally derived sound elements within forested settings was examined [19]. A perception-based evaluation model integrating acoustic measurements and visitor surveys was applied to analyze influencing factors on experiential quality. Findings revealed that soundscape harmony significantly enhanced perceptual experience, with explanatory power exceeding 60% in SEM. The

analysis relied heavily on subjective perception data, limiting robustness across different demographic groups.

Urban forest soundscape characteristics and perceptual impacts were analyzed by [20]. Acoustic indicators and sound source composition were assessed across multiple urban forest sites. Results demonstrated that natural sounds accounted for over 55% of perceived sound comfort, significantly improving visitor satisfaction scores. The research remained descriptive in nature and lacked behavioral outcome measurements.

A theoretical model connecting soundscape flow experience with visitor perceptions and behavioral tendencies was proposed [21]. A SEM was employed using survey data collected from tourists in soundscape-rich destinations. Results showed that soundscape flow significantly influenced behavioral intention, with standardized path coefficients exceeding 0.45. The reliance on self-reported data limited causal interpretation.

Preferences related to park-based acoustic environments among older visitors were analyzed [22]. Preference modeling was conducted using questionnaire surveys and acoustic environment assessments. Results indicated that natural sounds achieved preference ratings above 4.2 on a five-point scale, while mechanical noise significantly reduced comfort perception. The research focused exclusively on elderly groups in underdeveloped cities, limiting demographic diversity.

The connection among soundscape participation, fulfillment, emotion, and intention to revisit in nature-based tourism was examined [23]. A moderated mediation model was applied using survey-based data. Findings demonstrated that soundscape satisfaction mediated tourist loyalty, with indirect effects reaching statistical significance ($p < 0.01$). The analysis remained cross-sectional, restricting temporal interpretation of loyalty formation.

2.2. Artificial Music (AM) in natural environments

The advance and application of AI techniques in music-related contexts were reviewed [24]. Machine learning and deep learning frameworks were analyzed for music generation, emotion modeling, and adaptive sound design. Results indicated that AI-driven music systems improved emotional engagement metrics by over 20% compared with traditional approaches. The review lacked empirical validation within real natural environments.

Perceptual interactions between outdoor environments and music listening experiences were investigated [25]. A controlled experimental design was applied to measure environmental perception under varying musical conditions. Results showed that congruent music significantly enhanced environmental pleasantness ratings by approximately 18%. The experimental setting reduced ecological validity for uncontrolled natural tourism scenarios.

A multimodal speech–text corpus for emotion analysis in natural environments was introduced [26]. A dataset construction methodology integrating audio signals, textual transcriptions, and emotional annotations was employed. Benchmark experiments achieved emotion classification accuracies exceeding 75% across multiple modalities. The corpus focused on a single language context, limiting cross-cultural applicability.

2.3. Environmental Empathy (EE) as an emotional mechanism

The role of immersive narratives in shaping pro-environmental intentions via emotional engagement with nature was analyzed [27]. A serial mediation model was tested using survey data from university students. Results demonstrated that empathy with nature significantly mediated environmental intention, with indirect effects exceeding 0.30. The sample was restricted to a student population, limiting broader applicability.

The role of compassion with landscape in promoting pro-environmental insolences among nursery kids was investigated [28]. Experimental and survey-based methods were applied to measure attitude change. Findings indicated significant increases in pro-environmental attitude scores, with effect sizes above 0.40. The age-specific focus restricted extension to adult populations.

An analysis of how emotional place-based bonds foster environmentally responsible behavior through enhanced empathy with nature was presented [29]. SEM was employed using community-based survey data. Results showed that empathy with nature partially mediated behavioral outcomes, explaining over 50% of variance in behavior intention. Context-specific place attachment limited transferability to other environmental settings.

An assessment of cognitive and affective determinants underlying environmentally responsible attitudes and behaviors was reported [30]. Regression-based analysis demonstrated that empathy exerted stronger predictive power than environmental knowledge, with standardized coefficients exceeding 0.35. The reliance on self-reported behavior reduced behavioral accuracy.

A moderated mediation model linking empathy to social entrepreneurial intentions under environmental complexity was explored [31]. Quantitative analysis revealed that empathy significantly influenced intention formation, with moderation effects reaching statistical implication ($p < 0.05$). The entrepreneurial focus constrained applicability to general environmental behavior contexts.

2.4. Pro-environmental behavioral intention (PEBI)

A meta-analysis in [32] summarized factors shaping environmentally responsible intentions in tourism- and hospitality-related settings. Statistical aggregation of prior investigation revealed attitude, perceived behavioral control, and environmental concern as dominant predictors, with mean effect sizes ranging from 0.32 to 0.48. The meta-analysis depended on heterogeneous measurement instruments.

The determinants of environmentally responsible intentions in a developing economy were analyzed [33]. SEM demonstrated that environmental awareness and social norms significantly influenced intention, explaining over 60% of variance. Cultural specificity limited generalization across regions.

The roles of ecological worldview and environmental awareness in shaping behavioral intentions were examined using the Theory of Planned Behavior [34]. Results indicated that environmental concern significantly strengthened intention pathways, with standardized coefficients above 0.40. The framework did not incorporate emotional mechanisms such as empathy.

The role of initial personal attitudes in shaping college students' pro-environmental intentions was analyzed [35]. Survey-based modeling showed that intrinsic values significantly predicted intention formation, with explained variance exceeding 45%. The focus on student populations constrained demographic breadth.

2.5. Research gap

Previous research has mostly used SEM and short-term experiments to examine perception, satisfaction, stress relief, or experience the consequences of NSs [11]. It was lacking experimental designs that investigate how soundscape interventions actively shape long-term behavioral intentions, neglect real-world forest settings with combined natural and artificial sounds, and infrequently combine emotional mechanisms like EE with observable pro-environmental behavior [16, 17]. Existing soundscape investigations primarily focused on perceptual and psychophysiological responses, while computational modeling of emotional mechanisms remained underexplored [18, 20, 22, 23]. AM research emphasized perception modulation but lacked integration with EE constructs [19, 25, 33, 35]. Empathy-related investigations relied predominantly on self-reported measures without multimodal or objective emotional validation [21, 24, 27]. PEBI models emphasized cognitive

predictors, with limited incorporation of emotion-driven pathways induced by soundscapes [26, 28, 29, 31]. A unified framework linking soundscape characteristics, emotional empathy mechanisms, and PEBI using data-driven approaches remained absent [30, 32, 34]. This analysis overcomes these limitations between perceptual, emotional (EE), and behavioral (pro-environmental action) effects by merging NSs with controlled music played in forest environments for dual moderation effects and behavioral processes in immersive environments.

3. Hypothesis development

Based on the proposed conceptual framework, this research examines the relationships among acoustic environment characteristics, emotional responses, and behavioral intention using the following hypotheses using **Figure 1**.

H1: AET has a important confident impact on ER.

H2: AET has a significant positive effect on SC.

H3: MPM positively mediates the association among AET, ER, such that congruent music strengthens the invigorating outcome of the acoustic environment.

H4: ER is positively and meaningfully associated with EE.

H5: A positive relationship is observed between ER and EE

H6: EE demonstrates a strong positive association with PEBI.

**H7(a):** EE mediates the relationship between AET and PERI.

H7(b): EE mediates the relationship between MPM and PEBI.
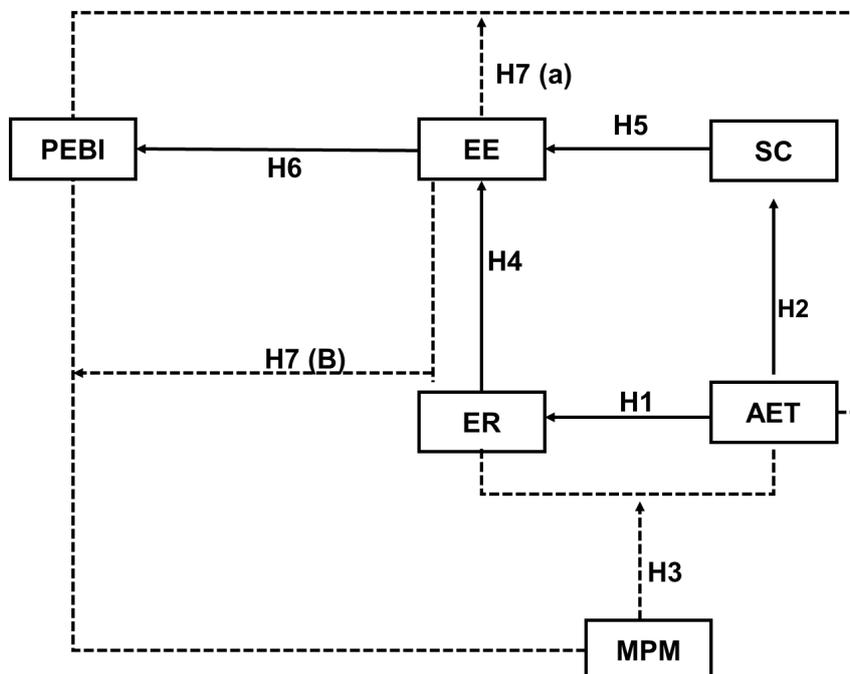
Figure 1. Theoretical Framework Linking Soundscape Components and ER to PEBI

4. Materials and methods

The present investigation used a field experiment in forest recreation areas to investigate the way exposure to music as well as NSs impacts visitors' EE as well as PEBI, using survey and statistical analysis, as shown in **Figure 2**.
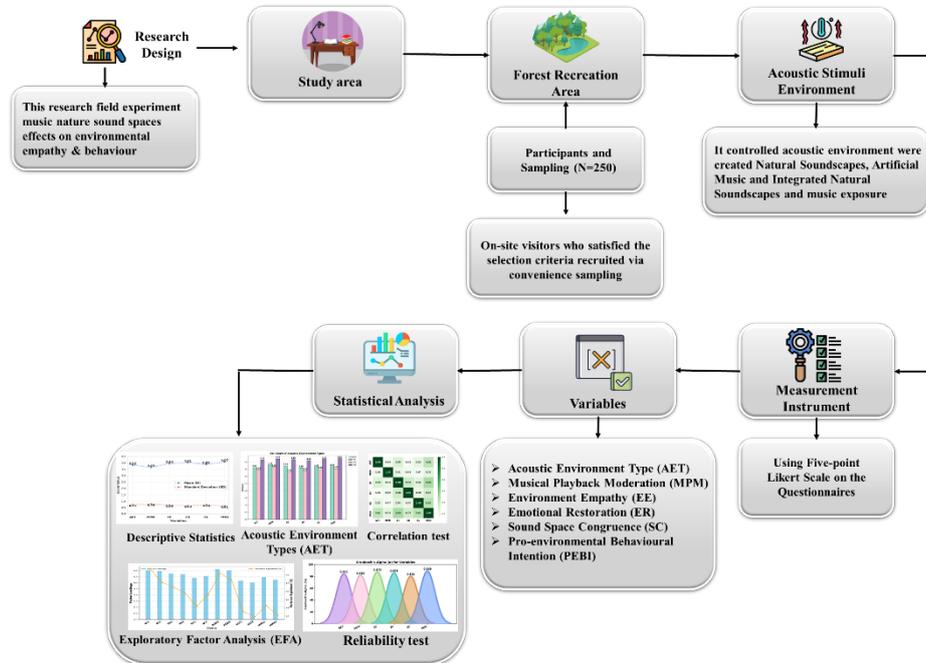
Figure 2. Overall architecture of Forest Environments on Tourists' emotions

4.1. Research design

The design employed between-condition comparisons and moderation analysis in a field-based experimental survey questionnaire to examine the integrated impacts of AM with NSs on visitor's EE as well as PEBI across three controlled acoustic conditions.

➢ NS (e.g., wind, birds, water flow)

➢ AM (instrumental, low-tempo, non-lyrical)

➢ Integrated soundscape music (ISM) exposure

4.2. Study area

Selected urban forest recreation places, including publicly accessible forest recreation areas found in metropolitan areas, were used for the research. These locations have controlled tourist access, designated walking pathways, and semi-natural forest vegetation. The forests are frequently utilized for eco-tourism, mindfulness exercises, and everyday leisure.

4.3. Participants and sampling procedure

Participants in this research include 250 visitors from urban forest recreation areas. Convenience sampling is used to recruit on-site tourists who meet the selection criteria. **Table 1** presents the demographic characteristics of the research participants.

Table 1. Overview of Participant Demographics

Participants Distribution	Categories	Frequency (N=250)	*Percentage* (%)
Gender	*Female*	122	48.8
	Male	128	51.2
Age group of distribution of tourist	≥56	20	8.0
	46–55	38	15.2
	36–45	56	22.4
	26–35	74	29.6
	18–25	62	24.8
Education Level distribution of tourists	Undergraduate	112	44.8
	Postgraduate and above	90	36.0
	Higher Secondary or below	48	19.2
Visitor Frequency distribution of tourists	First-time visitor	66	26.4
	Occasional visitor	108	43.2
	Frequent visitor	76	30.4

(a) Age group distribution of tourists

(b) Education level distribution of tourists

(c) Visitor frequency distribution of tourists
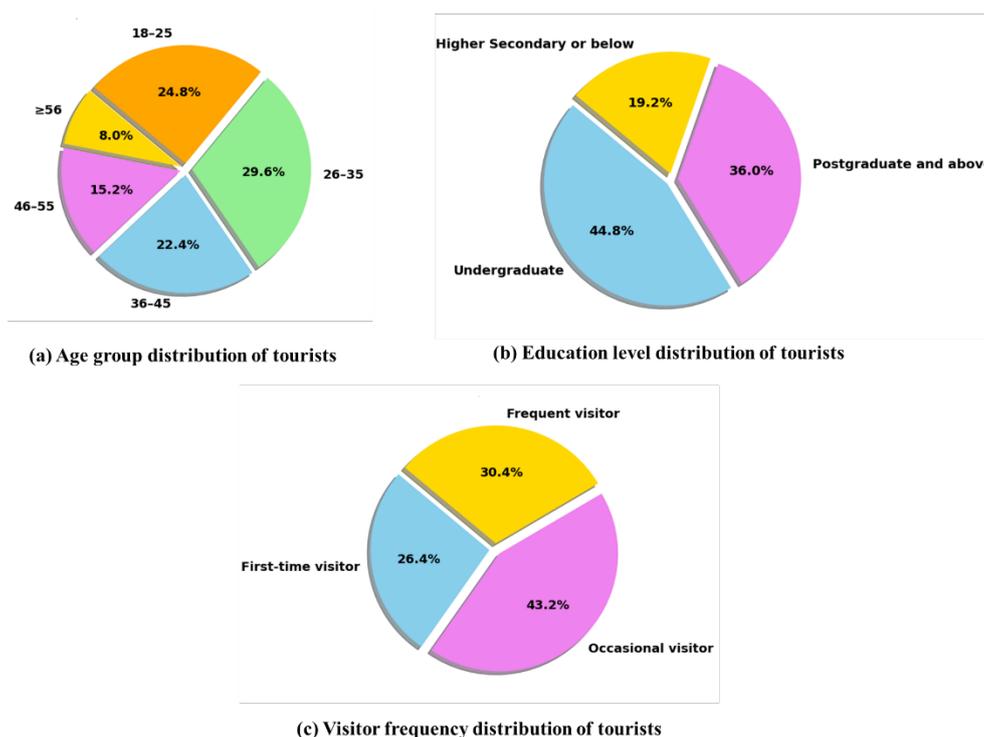
Figure 3. Demographic distribution of the participants for the forest recreation area, (a) age, (b) Education level, and (b) visitor frequency

According to the survey data, the majority of participants are between the ages of 26 and 35 (29.6%), with undergraduates accounting for 44.8% and infrequent visitors accounting for 43.2%, is shown as **Figure 3 (a-b)**. Overall, the sample is youthful, educated, and visits with a moderate frequency. The selection criteria are divided into two categories: inclusion criteria and exclusion criteria. **Table 2** demonstrates the selection criteria.

Table 2. Selection criteria for this research

Category	Criteria Description
Inclusion Criteria	Adult visitors (≥18 years old) are leisurely in urban forest recreation areas, have normal hearing, are ready to give informed consent, and can finish the questionnaire after being exposed to the designated acoustic condition.
Exclusion Criteria	Participants exposed to severe external noise interference, those under the age of 18 years, visitors with self-reported hearing problems, those hesitant to provide consent, and those who filled out questionnaires incompletely.

4.4. Acoustic stimuli and experimental conditions

Three distinct acoustic exposure conditions were designed:

➢ **Natural Sound Condition:** Participants in the Natural Sound condition were exposed to only natural ambient sounds of the forest, such as bird song, breezes through trees, running water, etc. No man-made sounds were included in experimental conditions.

➢ **AM Condition:** The AM exposure consisted of only instrumental (non-vocal) music that was moderately paced and had minimal rhythmic complexity. The playback level was 45 to 55 dB, consistent with the soundscape comfort level.

➢ **Integrated Soundscape Music Condition:** The integrated soundscape-music condition included both natural ambient sounds and moderately mixed AM to create perceptual congruence and not cover over ecological sounds.

Each of the conditions was assigned randomly to each participant. Each participant was exposed to each of the conditions for 5-7 minutes, after which they completed a questionnaire about their local emotional and cognitive reactions.

4.5. Experimental procedure

A standardized on-site protocol was followed for the analysis of research. Following consent, participants were led to the listening area. Participants then completed a structured questionnaire after exposure to the sound environment to evaluate their emotional, perceptual, and behavioral responses. In order to decrease potential bias related to the specific day and time of the sessions, researchers used controls to ensure that all sessions followed a standard procedure.

➢ Time of day

➢ Weather stability

➢ Visitor density

This provided the research with equal internal validity across experimental conditions.

4.6. Research variables

The research assesses participants perception of a variety of acoustic environments within a forest tourism environment, and will include both natural sounds and synthesized music as the main variables.

➢ **AET** is used to categorize the different sound environments (NS, AM and the combination of Soundscape and Music).

➢ **MPM** provides a way to evaluate how synthesized music affects people's perception of and behaviour in response to their surroundings.

➢ **EE** is an emotional measure of how the acoustic environment of a forest and the interaction of sounds (either from the trees, or other acoustic sources) affect a user's emotional connect and affective relationship with that environment.

- ➤ **ER** indicates the level of perceived relaxation and recovery from stress experienced post-exposure to the forest soundscape.

- ➤ **SC** is a measure of how compatible and well-integrated the artificial sounds and the natural forest soundscapes are to the user.

- ➤ **PEBI** indicate the user's reaction and dedication to an environmentally conscious lifestyle based on the experience derived from exposure to an aquatic environment.

4.7. Measurement instruments

The tourists' exposure to forest acoustic conditions, a structured on-site questionnaire measuring six variables using five-point Likert-scale instruments, is used to context-specific psychological and behavioral responses. Each variable has been divided into 2 questionnaires to be covered in **Table 3**.

Table 3. 5-point Likert scale survey for tourist responses

Variable	Questionnaires	5-point Likert scale
AET	How pleasant and soothing do you find natural noises in the jungle (e.g., water, birds, wind)?	
	Does the acoustic environment of the forest enhance your visit experience?	
MPM	Does soft background music blend well with the natural forest sounds?	
	How does the presence of AM improve my comfort during the forest visit?	
EE	Does listening to forest sounds make you feel emotionally connected to nature?	
	Do forest acoustic experiences increase your concern for protecting the environment?	$1 - Not\ at\ all,$ $2 - Slightly,$ $3 - Moderately,$ $4 - Very,$ $5 - Extremely$
ER	Do forest sounds help you feel relaxed and mentally refreshed?	
	Do you feel emotionally restored after listening to forest sounds?	
SC	Is the sound level in the forest comfortable for leisure and relaxation?	
	Does the forest soundscape cause stress or disturbance?	
PEBI	Does experiencing forest sounds motivate you to behave in an environmentally responsible way?	
	Are you willing to support conservation efforts after visiting this forest?	

4.8. Statistical analysis

The statistical tool used to analyze the data is called SPSS (Version 26.0). It is the statistical method for assessing the questionnaire's internal consistency. Descriptive statistics, reliability tests, correlation analysis, and EFA were used to evaluate the device's validity. A p-value threshold of 0.05 was used to determine the statistical importance, which means that findings with $p - values < 0.05$ were statistically significant. This criterion was used across all investigations to evaluate relationships, consistency, and moderating effects.

4.8.1. Descriptive statistics

Some major research parameters are designated used descriptive statistics. The *M* and *SD* values of the AET, MPM, EE, ER, SC, and PEBI, as well as the overall impacts of the AM model and NS, must be determined. Equation (1) facilitates comprehension of the data's variability and distribution.

$$SD = \sqrt{\sum_{j=1}^{M}(W_j - M)^2} \tag{1}$$

$$M = \sum_{j=1}^{M} W_j \tag{2}$$

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Where M indicates the average value of the teaching strategy scores (Equation (2)), and j stands for the index of each observation. M has a total number of observations (sample size), and the W_j denotes the value of the NS and AM model.

4.8.2. Reliability test

The concept of reliability of AET, MPM, EE, ER, SC, and PEBI interacts especially with this SPSS tool, which is presented in Equation (3). Reliability tests concentrate on forest areas with clarity and assurance to consistently enhance a process's reliability.

$$Q_s = f^{-\left(\frac{s}{m}\right)^{\beta}} \tag{3}$$

Where Q is the reliability at a specific time period, β is the base of natural logarithms, s is the specific time period, f is the Weibull shape factor/parameter, $and\ m$ is the characteristic life of hours in forest environments for tourists.

4.8.3. Exploratory factor analysis (EFA)

EFA was conducted using variables of AET, MPM, EE, ER, SC, and PEBI to measure the tool's construct validity. Items that had factor loadings higher than those of the comparable methods used to verify the validity of the instrument using EFA were kept. EFA uses linear combinations of latent factors plus error to model the observable variables:

$$z_l = \lambda_{i1}G_1 + \lambda_{l2}G_2 + \cdots + \lambda_{ln}G_n + \epsilon_l \tag{4}$$

Where, λ_{ln} is the factor loading of items i on factor l, ϵ_l is the specific variance/error for items i, z_l is the observed item score, and G_n indicates the hidden factors. Equation (4) shows how latent factors explain observed item variance in the usual factor analysis measurement paradigm.

4.8.4. Correlation testing

Correlation analysis showed that higher NS and AM method scores were positively correlated with AET, MPM, EE, ER, SC, and PEBI, indicating strong inter-variable relationships and highlighting the necessity of having enough time and resources to achieve successful instructional implementation and vocal performance outcomes.

$$q = \frac{z(\sum us) - (\sum u)(\sum s)}{\sqrt{[z\sum u^2 - (\sum s)^2][z\sum v^2 - (\sum s)^2]}} \tag{5}$$

where u and s in Equation (5) are the quantities of the initial and secondary elements under observation, z is the sum of the number of observations, and q is the measure of correlation, which shows how strongly variables are correlated. Effects of NS and AM were designed and implemented to observe the forest area's performance.

5. Result and discussion

The present investigation explored the complimentary effects of NS as well as AM for visitors' EE and pro-environmental behavior in forest areas by dual regulation of music listening. The result using statistical tests analyzes how different variables change and integrates NS and AM playback, containing AET, MPM, EE, ER, SC, and PEBI.

5.1. Descriptive statistics

Descriptive statistics were calculated to look at general patterns in all three sound exposure scenarios. As shown in **Table 4** and **Figure 4**, participants exposed to the ISM condition reported higher mean scores for EE, ER, and PEBI in contrast to individuals in single-source sound settings.

Table 4. Descriptive Statistics of Variables in the three Acoustic exposure scenarios

Variables	*M*	*SD*	Min	Max
AET	3.82	0.71	1.00	5.00
MPM	3.65	0.76	1.00	5.00
EE	3.94	0.68	1.00	5.00
ER	4.01	0.63	1.00	5.00
SC	3.88	0.70	1.00	5.00
PEBI	4.07	0.61	1.00	5.00
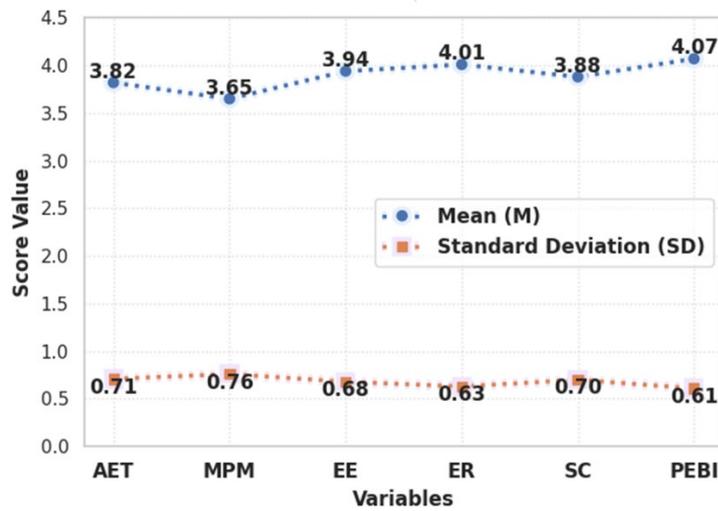
Figure 4. Statistics of *M* and *SD* for Variables

High levels of EE, emotional healing, and PEBI are demonstrated by descriptive statistics, with high mean scores over (3.65–4.07), and moderate variability (SD = 0.61–0.76) on a five-point scale. Low variability is shown by SD less than 1.0, which represent consistent visitor assessments of NSs and subdued AM in forest settings.

5.2. Reliability test

The reliability of the scale was determined through Cronbach's alpha. The AET's MPM, EE, ER, SC, and PEBI of internal consistency scales are evaluated by reliability analysis using IBM SPSS Statistics. **Table 5** and **Figure 5** show acceptable internal consistency, with all constructions above a possible level.

Table 5. Cronbach's alpha values of the reliability test

Variables	Number of items (questionnaires)	Cronbach's Alpha (α)	Reliability Level
AET	2	0.842	Good
MPM	2	0.816	Good
EE	2	0.873	Excellent

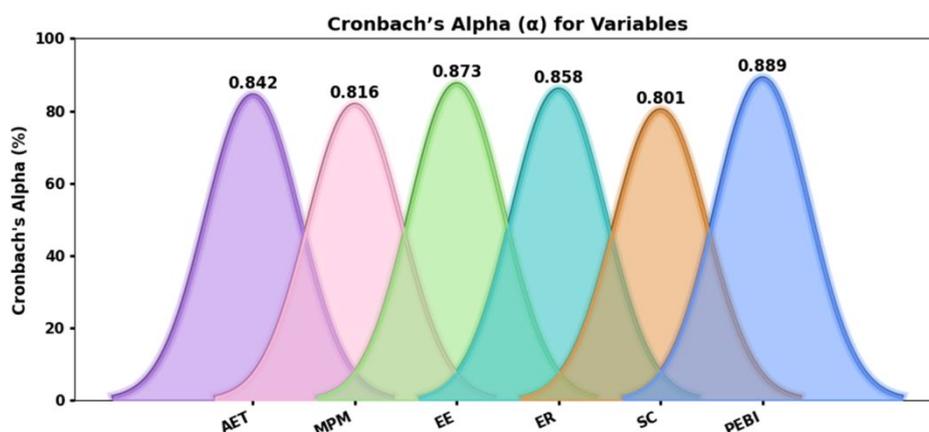| Variables	Number of items (questionnaires)	Cronbach's Alpha (α)	Reliability Level
ER	2	0.858	Good
SC	2	0.801	Good
PEBI	2	0.889	Excellent

Figure 5. Cronbach's alpha values

Cronbach's alpha values (0.889) and item numbers are robust measures of visitors' EE and PEBI in forest environments, as confirmed by alpha values over 0.70, which suggest acceptable reliability; over 0.80, which indicate good reliability; and over 0.90, which indicate exceptional consistency.

5.3. EFA test

Factor loading demonstrations the intensity and trend of the association among an observable item (question) and its fundamental structural characteristics (factor). EFA for the measurement model is presented in **Table 6** and **Figure 6**.

Table 6. EFA for Measurement Model

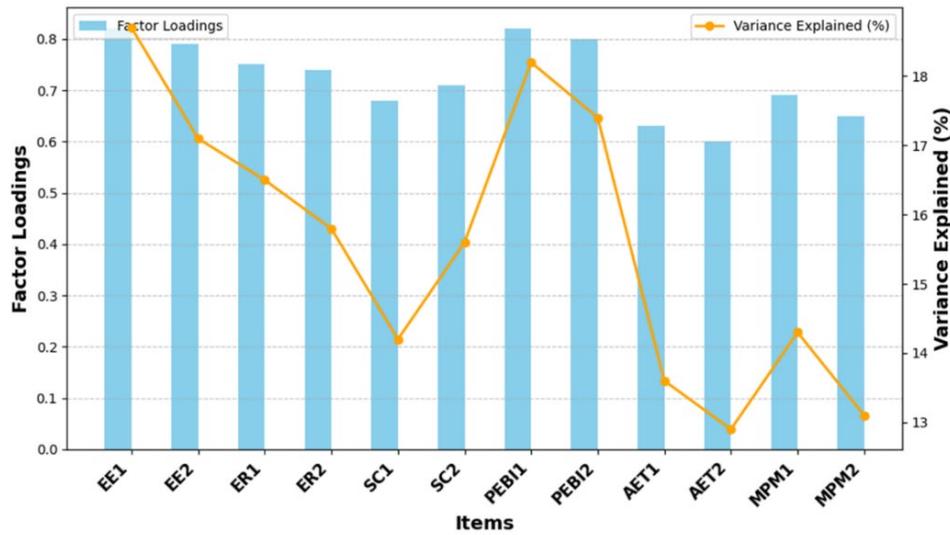| Factors	Item	Factor Loading	Standard Error (SE)	Variance Explained (%)
EE	EE1	0.82	0.03	18.7
	EE2	0.79	0.02	17.1
ER	ER1	0.75	0.04	16.5
	ER2	0.74	0.05	15.8
SC	SC1	0.68	0.06	14.2
	SC2	0.71	0.05	15.6
PEBI	PEBI1	0.82	0.03	18.2
	PEBI2	0.80	0.04	17.4
AET	AET1	0.63	0.07	13.6
	AET2	0.60	0.08	12.9
MPM	MPM1	0.69	0.06	14.3
	MPM2	0.65	0.07	13.1

Figure 6. Variance and factor loadings of EFA

Items with factor loadings more than 0.60, such as EE1 (0.82), are significantly associated with their latent factors. The low standard error (e.g., 0.03 for EE1) shows that the loadings are reliable. Variance explained by categories like PEBI1 and EE1 (18.2% and 18.7%, respectively) demonstrates their high explanatory power. Overall, the EFA results support the instrument's good construct validity.

5.4. Structural Equation Modeling (SEM)

SEM was occupied to observe direct and indirect relationships among AET, MPM, EE, ER, SC, and PEBI, enabling simultaneous validation of measurement and structural paths.

Table 7. SEM Results for Hypothesized Relationships

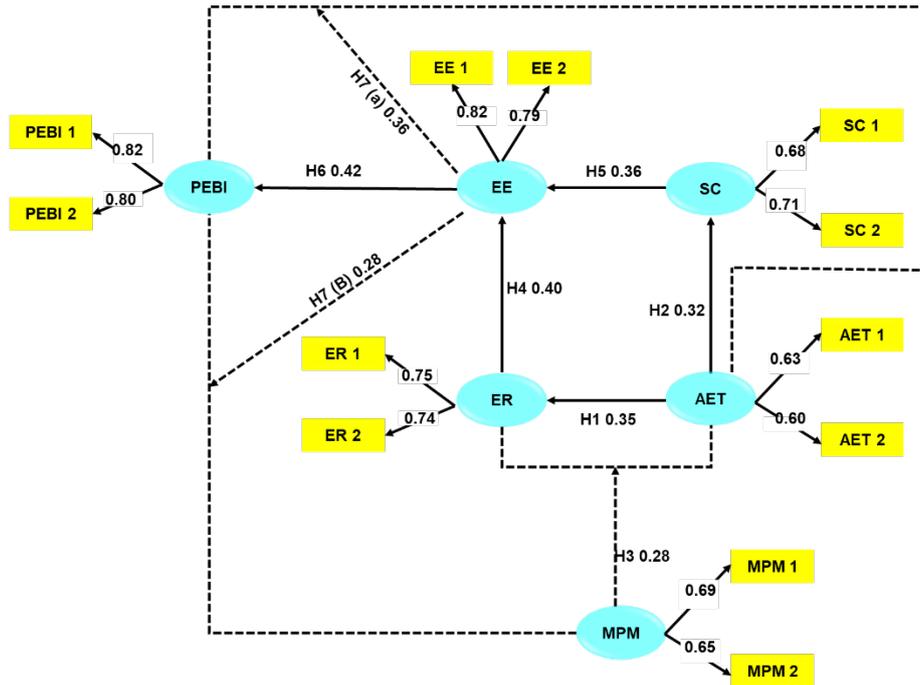| Hypothesis	Path	SE	β	p-value	t-value	Result
H1	AET → ER	0.05	0.35	<0.001	6.8	Supported
H2	AET → SC	0.04	0.32	<0.001	6.2	Supported
H3	MPM × AET → ER	0.06	0.28	0.002	3.1	Supported
H4	ER → EE	0.05	0.40	<0.001	7.0	Supported
H5	SC → EE	0.04	0.36	<0.001	6.5	Supported
H6	EE → PEBI	0.05	0.42	<0.001	7.5	Supported
H7(a)	AET → EE → PEBI	0.04	0.36	<.001	5.12	Supported
H7(b)	MPM → EE → PEBI	0.05	0.28	<.001	4.21	Supported

Figure 7. Standardized Path Coefficients and Hypothesis Testing Results

Table 7 and **Figure 7** present the EM findings, revealing significant positive effects of AET and MPM on PEBI ($\beta = 0.46$, $\beta = 0.28$). Mediation analysis confirms substantial indirect effects through EE and ER, supporting the future research context and highlighting the pivotal role of harmonized soundscapes in fostering sustainable tourist behavior.

5.5. Correlation analysis

The role of correlation analysis in the research of forestry recreation deals with identifying links between the values of various variables, for instance, the role of the environment and its influence on the activities of tourists based on emotions. The technique might enhance moderation since it will make people aware of the influence of nature sounds and music on the behavior of tourists and travelers relative to the environment.

**Figure 8.** Correlation analysis to support moderation for forest recreation

Correlation analysis indicated that AET, MPM, EE, ER, SC, and PEBI were significantly and positively correlated (p < .001). The correlation analysis in Figure 8 represents moderate to strong positive correlation indicating that trust in acoustic environment increases EE and PEBI. Emotional involvement was identified as an important moderator in determining behavioral outcomes and hence supported moderation analysis.

5.6. Effects of Acoustic Environment Type (AET)

Mean comparisons were conducted across different AET, including NS, AM, and ISM conditions. As shown in **Table 8** and **Figure 9**, the integrated AET yielded the highest scores across all outcome variables.

Table 8. Mean scores across AET for recreation forest environments on Tourists'

AET	MPM	EE	ER	SC	PEBI
NS	None	3.62	3.78	3.74	3.60
AM	None	3.48	3.65	3.31	3.42
ISM	Moderate	4.15	4.22	4.18	4.12
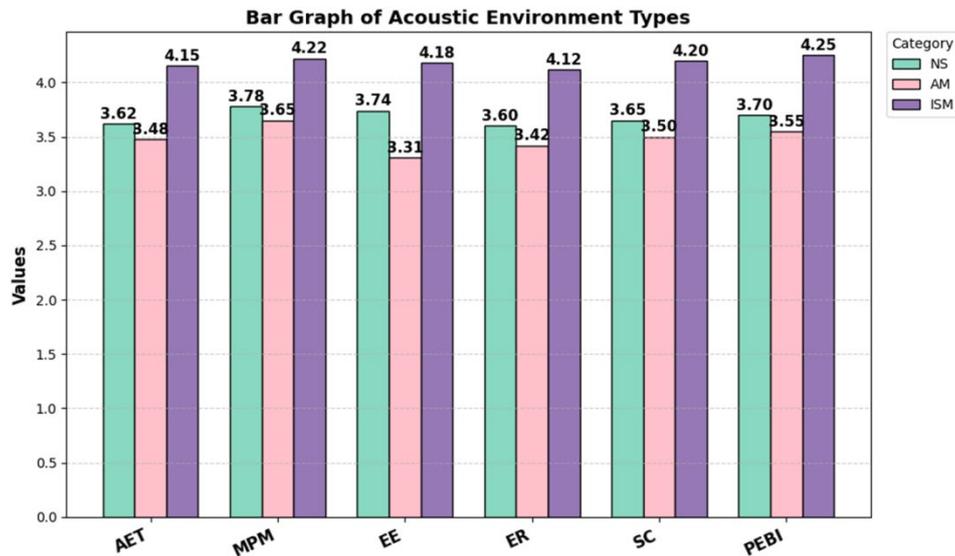
Figure 9. Mean Scores across AET

Compared with single-source acoustic environments, the integrated condition resulted in approximately higher EE scores and significantly enhanced PEBI, indicating stronger empathy-driven behavioral intentions.

5.7. Discussion

The investigation demonstrates that the combined use of NSs and AM enhances tourists' EE and PEBI in forest environments through a dual management of music listening. These findings are discussed in relation to prior research, which has largely focused on perceptual responses or short-term psychological outcomes, thereby leaving several conceptual and contextual limitations.

Many existing investigations have relied on laboratory-based or highly controlled experimental settings, which do not adequately represent the complexity and diversity of real-world forest or urban soundscapes. Because environmental, social, and contextual conditions cannot be fully replicated in controlled trials, participants' emotional and behavioral responses often differ in authentic outdoor environments [36]. In addition, the concentration on a single riverside park or specific urban green space has restricted the generalizability of findings to other forest, urban park, or cultural tourism settings. Soundscape preferences

are further shaped by subjective auditory perception as well as seasonal and temporal variations, factors that have not been sufficiently examined in previous research [37].

The applicability of earlier experimental findings to broader tourism contexts has also been constrained by investigations limited to specific destinations, such as plateau ecotourism areas. Moreover, longitudinal effects of soundscape exposure on pro-environmental behavior remain underexplored, and the predominant reliance on self-reported behavioral measures introduces potential response and social desirability biases [38].

By simultaneously examining NSs and AM within authentic forest recreation environments, the present research addresses several of these limitations. The analysis extends beyond single-source soundscape evaluations by capturing interactive acoustic effects and clarifying how emotional processes, particularly EE, link sound environments to PEBI. This integrated perspective provides a more ecologically valid and behaviorally grounded understanding of soundscape influences in forest tourism contexts.

This research advances theoretical understanding of soundscape-behavior relationships by establishing a multi-stage affective mechanism linking acoustic environment characteristics to PEBI. While previous research has primarily emphasized perceptual appraisal or restorative outcomes, the present findings highlight ER and EE as critical explanatory pathways. By integrating AET, MPM, and SC within a unified framework, this research demonstrates how congruent acoustic environments foster empathy-driven behavioral intention rather than merely influencing short-term perception. The results therefore extend affective environmental psychology by clarifying the causal role of EE in translating acoustic experiences into intentional pro-environmental action in forest tourism contexts.

6. Conclusion and future scope

The research was to explored the effects of AM playing and NSs on the visitor's EE and pro-environmental behavior. The research collected data from 250 tourists for three sound experience factors: NSs, AM playing, and their combination using an on-site questionnaire. The research used 5-point Likert scales to evaluate six constructs. The outcomes were analyzed using SPSS. The signification of training improvements was validated through the result, which depicted a strong mean (3.65–4.07), moderately strong variability (SD = 0.61–0.76), Cronbach's Alpha (0.887), and correlation (0.46–1). The finding demonstrated that well-adjusted music playing could stimulate pro-environmental activities based on empathy by maximizing the positive roles of soundscapes. It could be tested on other environments or culture sites, as it only specifically dealt with the peace forest. The immediate experiment or respondent social-desirability bias could have influenced the on-site questionnaire for self-reported data collection. Future research could test different types of music and other environments to verify the strength of the positive inter-acoustic interaction.

Table 9. List of Abbreviation

Abbreviation	Full Form / Description
AET	Acoustic Environment Type
AM	Artificial Music
ISM	Integrated Soundscape–Music
MPM	Music Playback Moderation
EE	Environmental Empathy
ER	Emotional Restoration
SC	Soundscape Congruence

Abbreviation	Full Form / Description
PEBI	Pro-Environmental Behavioral Intention
NS	Natural Soundscape
SEM	Structural Equation Modeling
EFA	Exploratory Factor Analysis
SPSS	Statistical Package for the Social Sciences
SD	Standard Deviation
α (Alpha)	Cronbach's Alpha (measure of reliability)
M	Mean

Table 9. (*Continued*)

Conflict of interest

The authors declare no conflict of interest.

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References

1. Crețan, R., Chasciar, D., and Dragan, A., 2024. Forests and Their Related Ecosystem Services: Visitors' Perceptions in the Urban and Peri-Urban Spaces of Timișoara, Romania. Forests, 15(12), p.2177. https://doi.org/10.3390/f15122177
2. Wei, Y. and Hou, Y., 2025. From Nose to Heart: Introducing Large Language Models to Explore How Olfactory Experiences Influence Forest Visitors' Emotional Resilience. Forests, 16(1), p.85. https://doi.org/10.3390/f16010085
3. Fei, X., Wu, Y., Dong, J., and Kong, D., 2025. The Effects of Soundscape Interactions on the Restorative Potential of Urban Green Spaces. Sustainability, 17(6), p.2674. https://doi.org/10.3390/su17062674
4. Fiebig, A., Jordan, P., and Moshona, C.C., 2020. Assessments of acoustic environments by emotions–the application of emotion theory in soundscape. Frontiers in psychology, 11, p.573041. https://doi.org/10.3389/fpsyg.2020.573041
5. Wang, P., He, Y., Yang, W., Li, N. and Chen, J., 2022. Effects of soundscapes on human physiology and psychology in Qianjiangyuan National Park System Pilot Area in China. Forests, 13(9), p.1461. https://doi.org/10.3390/f13091461
6. Li, Y. and Song, M., 2024. The influence of tourist–environment fit on environmental responsibility behavior: A moderated mediation model. Forests, 15(10), p.1726. https://doi.org/10.3390/f15101726
7. Ienna, M., Rofe, A., Gendi, M., Douglas, H.E., Kelly, M., Hayward, M.W., Callen, A., Klop-Toker, K., Scanlon, R.J., Howell, L.G., and Griffin, A.S., 2022. The relative role of knowledge and empathy in predicting pro-environmental attitudes and behavior. Sustainability, 14(8), p.4622. https://doi.org/10.3390/su14084622
8. Chen, X., Cheng, Z.F., and Yang, H.J., 2024. Empowering pro-environmental behaviour in tourists through digital media: The influence of eco-guilt and empathy with nature. Frontiers in Psychology, 15, p.1387817. https://doi.org/10.3389/fpsyg.2024.1387817
9. Jiang, J., Zhang, J., Zheng, C., Zhang, H., and Zhang, J., 2020. Natural soundscapes in nature-based tourism: leisure participation and perceived constraints. Current Issues in Tourism, 23(4), pp.485-499. https://doi.org/10.1080/13683500.2018.1540559
10. Kankhuni, Z. and Ngwira, C., 2022. Overland tourists' natural soundscape perceptions: influences on experience, satisfaction, and electronic word-of-mouth. Tourism Recreation Research, 47(5-6), pp.591-607. https://doi.org/10.1080/02508281.2021.1878653
11. Lu, Y.H., Zhang, J., Zhang, H., Xiao, X., Liu, P., Zhuang, M., and Hu, M., 2022. Flow in soundscape: The conceptualization of soundscape flow experience and its relationship with soundscape perception and behaviour intention in tourism destinations. Current Issues in Tourism, 25(13), pp.2090-2108. https://doi.org/10.1080/13683500.2021.1922363

12. Guo, Y., Jiang, X., Zhang, L., Zhang, H., and Jiang, Z., 2022. Effects of sound source landscape in urban forest park on alleviating mental stress of visitors: Evidence from Huolu Mountain Forest Park, Guangzhou. Sustainability, 14(22), p.15125. https://doi.org/10.3390/su142215125
13. Wu, L., Zhang, Q., Yan, Y., Lan, T., Hu, Y., Zhang, Y., He, T. and Ye, J., 2024. A Study on Spatiotemporal Dynamics and Spatial Dependence of Sound Source Perception in Fuzhou Historical and Cultural Districts. Buildings, 14(6), p.1753. https://doi.org/10.3390/buildings14061753
14. Sun, C., Meng, Q., Yang, D., and Wu, Y., 2023. Soundwalk path affecting soundscape assessment in urban parks. Frontiers in Psychology, 13, p.1096952. https://doi.org/10.3390/f13091461
15. Wang, P., He, Y., Yang, W., Li, N., and Chen, J., 2022. Effects of soundscapes on human physiology and psychology in Qianjiangyuan National Park System Pilot Area in China. Forests, 13(9), p.1461. https://doi.org/10.3390/f13091461
16. Guo, X., Jiang, S.Y., Liu, J., Chen, Z., and Hong, X.C., 2024. Understanding the Role of Visitor Behavior in Soundscape Restorative Experiences in Urban Parks. Forests, 15(10), p.1751. https://doi.org/10.3390/f15101751
17. Bai, W.B., Wang, J.J., Wong, J.W.C., Han, X.H. and Guo, Y., 2024. The soundscape and tourism experience in rural destinations: an empirical investigation from Shawan Ancient Town. Humanities and Social Sciences Communications, 11(1), pp.1-12. https://doi.org/10.1057/s41599-024-02997-4
18. Bai, Z. and Zhang, S., 2024. Effects of different natural soundscapes on human psychophysiology in national forest park. Scientific Reports, 14(1), p.17462. https://doi.org/10.1038/s41598-024-67812-1
19. Lin, J., Zhang, M., Wang, Y., Hong, X.C. and Liu, J., 2025. Factors Influencing Natural and Cultural Soundscape Interactions on Perceptual Experiences in Forested–Historical Interface Areas. Buildings, 15(22), p.4103. https://doi.org/10.3390/buildings15224103
20. Hong, X.C., Liu, J. and Wang, G.Y., 2022. Soundscape in urban forests. Forests, 13(12), p.2056. https://doi.org/10.3390/f13122056
21. Lu, Y.H., Zhang, J., Zhang, H., Xiao, X., Liu, P., Zhuang, M. and Hu, M., 2022. Flow in soundscape: The conceptualization of soundscape flow experience and its relationship with soundscape perception and behaviour intention in tourism destinations. Current Issues in Tourism, 25(13), pp.2090-2108. https://doi.org/10.1080/13683500.2021.1922363
22. Luo, L., Zhang, Q., Mao, Y., Peng, Y., Wang, T. and Xu, J., 2023. A study on the soundscape preferences of the elderly in the urban Forest parks of underdeveloped cities in China. Forests, 14(6), p.1266. https://doi.org/10.3390/f14061266
23. Jiang, J. and Yan, B., 2022. From soundscape participation to tourist loyalty in nature-based tourism: The moderating role of soundscape emotion and the mediating role of soundscape satisfaction. Journal of Destination Marketing & Management, 26, p.100730. https://doi.org/10.1016/j.jdmm.2022.100730
24. Yu, X., Ma, N., Zheng, L., Wang, L. and Wang, K., 2023. Developments and applications of artificial intelligence in music education. Technologies, 11(2), p.42. https://doi.org/10.3390/technologies11020042
25. Franěk, M. and Režný, L., 2025. Perception of outdoor environments while listening to music: the mutual influence of music and environmental features. Psychological Research, 89(1), p.13. https://doi.org/10.1007/s00426-024-02029-5
26. Pan, R., García-Díaz, J.A., Rodríguez-García, M.Á. and Valencia-García, R., 2024. Spanish MEACorpus 2023: A multimodal speech–text corpus for emotion analysis in Spanish from natural environments. Computer Standards & Interfaces, 90, p.103856. https://doi.org/10.1016/j.csi.2024.103856
27. Liu, J.X., 2023. The influence of narrative transportation on university students' environmental intentions: A serial mediation of empathy with nature and environmental Attitudes. Journal of Cleaner Production, 431, p.139763. https://doi.org/10.1016/j.jclepro.2023.139763
28. Li, Y., Zhao, Y., Huang, Q., Deng, J., Deng, X. and Li, J., 2024. Empathy with nature promotes pro-environmental attitudes in preschool children. PsyCh Journal, 13(4), pp.598-607. https://doi.org/10.1002/pchj.735
29. Chen, X., Tang, J. and Liu, P., 2024. How place attachment affects pro-environmental behaviors: The role of empathy with nature and nature relatedness. Current Psychology, 43(23), pp.20571-20583. https://doi.org/10.1007/s12144-024-05820-0
30. Ienna, M., Rofe, A., Gendi, M., Douglas, H.E., Kelly, M., Hayward, M.W., Callen, A., Klop-Toker, K., Scanlon, R.J., Howell, L.G. and Griffin, A.S., 2022. The relative role of knowledge and empathy in predicting pro-environmental attitudes and behavior. Sustainability, 14(8), p.4622. https://doi.org/10.3390/su14084622
31. Duong, C.D., 2023. Karmic beliefs and social entrepreneurial intentions: a moderated mediation model of environmental complexity and empathy. Journal of Open Innovation: Technology, Market, and Complexity, 9(1), p.100022. https://doi.org/10.1016/j.joitmc.2023.100022
32. Lin, M.T.B., Zhu, D., Liu, C. and Kim, P.B., 2022. A meta-analysis of antecedents of pro-environmental behavioral intention of tourists and hospitality consumers. Tourism Management, 93, p.104566. https://doi.org/10.1016/j.tourman.2022.104566

33. Konalingam, K., Thivaakaran, T., Kengatharan, N., Sivapalan, A., Hensman, G.H. and Harishangar, A., 2024. Exploring the drivers of pro-environmental behavioral intentions in an emerging nation. Social Responsibility Journal, 20(9), pp.1697-1723. https://doi.org/10.1108/SRJ-09-2023-0517

34. Gansser, O.A. and Reich, C.S., 2023. Influence of the new ecological paradigm (NEP) and environmental concerns on pro-environmental behavioral intention based on the theory of planned behavior (TPB). Journal of Cleaner Production, 382, p.134629. https://doi.org/10.1016/j.jclepro.2022.134629

35. Song, Y., Bao, H. and Shen, S., 2022. Understanding the influence of initial values of college students in shaping pro-environmental behavioral intention. International Journal of Environmental Research and Public Health, 19(15), p.9730. https://doi.org/10.3390/ijerph19159730

36. Fraisse, V., Montambault, C., Wanderley, M.M., and Guastavino, C., 2025. Bringing the coastline to the city: Laboratory evaluation of urban soundscapes in the presence of ambient sound art. Music & Science, 8, p.20592043251384052. https://doi.org/10.1177/20592043251384052

37. Ghalehteimouri, K.J., Shamsoddini, A., Bayramzadeh, N. and Mousavi, M.N., 2023. Identifying the pleasant sounds in the city's public parks environment (Case study: Mellat riverside park, Urmia). SAUC-Street Art and Urban Creativity (repository), 9(1), pp.149-165. https://orcid.org/0000-0001-9757-4331

38. Wang, L., Yu, H., and Zhou, B., 2025. Formation mechanism of tourists' pro-environmental behavior in the plateau ecotourism destination. Humanities and Social Sciences Communications, 12(1), pp.1-14. https://doi.org/10.1057/s41599-025-04384-z