Study on the impact of public physical and psychological recovery under audio-visual interaction in forest landscape

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Abstract: As a significant venue for public recreation and relaxation, forests serve as vital natural resources in urbanized regions. Drawing upon the physical and mental resilience offered by forest visual landscapes, this study analyzes the interactive perceptual resilience resulting from forest audio-visual interaction post-urban noise stimulation. Three types of forest sounds (artificial, living, and natural) collected around Sedan Mountain in Kunming are utilized as research subjects to quantitatively assess and analyze physiological and psychological indicators pre- and post-exposure to forest landscapes and sounds amidst urban noise. The findings reveal changes in subjects' physiological and psychological indices before and after exposure to forest sounds. Specifically, subjects exposed to various forest sounds following noise stimulation displayed reductions in heart rate and skin conductivity, with natural sounds exerting the most significant impact on these reductions. Moreover, natural sounds exhibited the highest positive effect on psychological evaluation scores. Subjects generally favored natural sounds, as evidenced by significant correlations between all indicators in the correlation analysis of psychological and physiological parameters. The results underscore that different types of sound stimuli alleviate emotional anxiety and physical and mental fatigue to varying extents, with natural sounds demonstrating the most beneficial effect on mitigating human irritability and promoting restoration.

1. Introduction

Forests in urban areas[1] are vital for leisure and relaxation, serving as crucial ecological backdrops and fulfilling residents' desires for natural scenery. In dense urban settings, forests like Mianshan significantly enhance physical health and emotional well-being. Research has extensively explored soundscapes in forests, focusing on their characteristics, composition, changes, and quality. However, there's a gap in understanding the audiovisual interaction between soundscapes[2] and human perception, and its impact on health. Further study is needed on how forest soundscapes influence public physical and mental health.

Soundscape, a key element of our living environment[3], is vital for public health and ecological balance. It differs from traditional noise control by focusing on subjective perception rather than just physical measurements. This approach examines the interactions among humans, sound, and society, aiming to create soundscapes that align with individual needs and preferences. Researching the synergy between soundscape, landscape, and people is crucial for understanding their significance in social, economic, and ecological contexts. Developing urban forest soundscape models can guide the creation of more effective and natural ecological forest landscapes.

This article examines the forest visual landscape of Jiaozi Mountain near Kunming, collecting various forest landscape materials across seasons and three types of auditory restoration materials (artificial, life, and natural sounds). It studies the public's visual perception restoration ability after urban noise exposure. The goal is to understand how forest landscape audio-visual interaction affects physical and mental recovery, providing insights for enhancing urban forest construction[3,7] and creating high-quality soundscapes around urban mountains, focusing on residents' health needs.

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2. Research design

2.1 Research location

The research area is around Jiaozi Mountain in Luquan County, Yunnan Province (26°02′21″-26°09′82″N,102°84′23″-102°85′27″E). The Jiaozi Mountain Scenic Area is rich in acoustic landscape resources, and the natural sound required for this experiment is taken from it. To ensure the representativeness of its acoustic landscape material sampling, the typical sampling method is chosen. Based on the terrain, topography, and vegetation community structure of Jiaozi Mountain, five forest communities with different altitudes and a certain scale are selected as the collection points for sound materials. Determine if the spacing between sample plots is greater than 800m based on the area and scale of Jiaozi Mountain. The surrounding areas of the research site include roads and villages, which serve as collection sites for artificial and living sound materials, respectively. To ensure the independence of artificial sound collection, 5 sound sampling points are randomly chosen, with sample plots spaced more than 2km apart. Simultaneously, 5 sample points are selected from surrounding villages for recording, followed by random sampling to select the experimental audio frequency of life sound, in order to strengthen the randomness of life sound collection.

2.2 Sound Collection Methods and Sound Material Screening

Select clear and breezy weather from April to May 2021 for audio frequency collection, with a single recording time of 5 minutes. During the collection process, place the microphone and other recording equipment on a tripod 1.7m above the ground. To avoid interference from wind noise on the sampling of experimental materials, the fixed direction of the microphone needs to be perpendicular to the wind direction of the day. Sample dual channel wave format audio frequency quantization digits, with a sampling frequency of 44.1KHz and 16 quantization bits. After collecting sound frequency data from various points, they are classified into three categories based on the type of sound source: artificial sound, life sound, and natural sound (Table 1). Finally, select typical sound samples that are not affected by chaotic sounds and have prominent dominant sounds.

Table 1 Types and Classification Basis of Sound Landscape

Serial Number	Sound landscape type	Basic meaning	Name of sound elements
1	Artificial sound	Artificial sound refers to the sound produced by humans in production activities, usually with a faster vibration frequency and larger vibration amplitude of the pronunciation body.	The sound of train whistles, construction noise, car starts, etc.
2	Life Sound	Life sound refers to the sound produced by people in their daily lives, usually with a relatively stable vibration frequency and a relatively small vibration amplitude in the pronunciation body.	Communication, cleaning, running, etc.
3	Natural sound	Natural sound refers to the sound produced in nature without human intervention. The natural environment is variable, so the amplitude, frequency, and shape of the sound wave vary greatly.	The chirping of insects and birds, the sound of wind and lightning, the sound of wind blowing through leaves, etc.

2.3 Sound Stimulating Materials

In order to ensure that the participants maintain a positive attitude towards participation, the total duration of the experiment was controlled within 15 minutes, and various types of audio stimuli were controlled within 64 seconds. At the same time, in order to ensure significant differences in forest audio frequency before and after human testing, a 15 second noise stimulus will be played before various audio frequencies are played. Before the test begins, the participants will be informed of the experimental logic and process to reduce other issues that may arise during the experiment.

2.4 Selection of experimental subjects

This experiment chose a young population with high auditory sensitivity as the subjects, totaling 63 university students (28 males and 35 females). To ensure objectivity regarding the participants' psychological status before the experiment, they were required to complete the "College Student Mental Health Assessment - SCL Scale" beforehand, aiming to quantify their psychological health status. Results indicated that the psychological status scores of all participants surpassed the qualified level, showing no significant difference from the standard ($P>0.05$).

2.5 Physiological and psychological measurement methods

In terms of physiological measurement, heart rate (HR) and skin conductivity (SCL) are detected by Ergo LAB human-machine wearable physiological multi-channel instrument. The heart rate is collected from the earlobe, and the skin electrical activity is collected from the fingertips. The relevant evaluation indicators are then recorded. The psychological state evaluation of the subjects is combined with the Concise Mood State Scale and different types of acoustic environment evaluation scales as evaluation items. I analyzed the physiological and psychological data obtained after the experiment to understand the impact of the forest soundscape on the subjects and the differences in the effects of different types of sound environments on the subjects.

2.6 Physiological and psychological indicators

1) Physiological indicators: The physiological indicators in the experiment include heart rate (HR) and skin conductivity (SC), both of which were measured using physiological instruments (Table 2).

Table 2 Basic significance and measurement equipment of physiological indicators

Physiological index	Abbreviation	Basic meaning
Heart rate	HR	Heart rate refers to the heart rate. When a person is in a state of exercise/stress or emotional excitement, their heart rate increases. Conversely, decrease
Skin conductivity	SCL	Skin conductivity refers to the frequency of voltage/current conduction in the skin of a body part. When a person is in an anxious/high-pressure state, sweat gland activity increases and skin conductance frequency increases; Conversely, decrease

2) Psychological indicators: The Brief Profile of Mood States (BPOMS) and Acoustic Environment Assessment Scale (AEAS) are employed to investigate the influence of forest sounds on subjects' psychology and the differences in the impact of different types of forest sounds. The BPOMS scale primarily assesses individuals' mood, emotions, and emotional states. The AEAS scale primarily evaluates participants' assessment of sound frequency, sound quality, and other characteristics of the acoustic environment.The duration of the experiment was limited to 10 minutes for each subject.

2.7 Experimental process

Table 3 Experimental Flow Chart

Experimental stage	**preparation**	**experiment**					**end**
Experimental content	①Fill out the SCL-90 psychological assessment form ②Process Introduction ③Instrument wearing	Repeat 1 time		Repeat 3 times			①Picking equipment ②Zero adjustment ③disinfect
		BPOMS	Close your eyes and rest	Noise stimulation	Experimental audio	Acoustic Environment Scale	
Duration	60s	120s	180s	15s	64s	120s	30s

As shown in Table 3, before the formal commencement, participants first completed the SCL-90 psychological assessment form. Subsequently, while wearing the physiological sensor, experimenters explained the experimental steps and content to them. After completing the wearing of the testing apparatus and filling out the Brief Mood Scale, participants closed their eyes and rested for 3 minutes. The audio playback commenced, starting with a 15-second urban noise stimulus, followed by a 64-second experimental audio. After the playback, participants filled out the corresponding sound environment assessment scale.

2.8 Data processing and analysis

Using Excel 2020 for data statistics and organization, SPSS 21.0 (IMB SPSS Statistics) was used to process the experimental data. Paired Sample T Test was used to compare the changes in physiological indicators of participants after calm state and noise stimulation. The mean comparison method was used to explore the changes in physiological indicators of participants after different types of forest sound intervention. I constructed positive and negative evaluations to determine the changes in participants' mood states across different types of forest acoustic environments. Pearson correlation analysis was utilized to explore the correlation between changes in mood states and physiological data. Finally, KMO test (Kaiser meyer olkin) and Bart let test of sphericity were used for data validation, and factor analysis was used to evaluate the subjects' subjective cognition of the acoustic environment.

3. Results and Analysis

3.1 Element composition of different forest sound types

I conducted an objective data analysis on the composition and proportion of elements in three types of forest sounds using quantitative statistical methods. Based on the timeline, the duration of urban noise as a stress stimulus is 15 seconds, consisting of whistling, crying, traffic, and other sounds, accounting for 12.1%, 49.2%, 35.5%, and 3.2% respectively. The duration of the three types of forest audio materials is 64 seconds each, among which artificial sound consists of carriage sound, driving sound, motorcycle sound, and other sounds, accounting for 41.2%, 29.8%, 25.6%, and 3.4% respectively; The sound of daily life consists of dog barking, conversation, sweeping, and other sounds, accounting for 22.7%, 47.3%, 26.1%, and 3.9% respectively; Natural sound is composed of insect calls, bird calls, wind and rain sounds, water flow sounds, and other sounds, accounting for 19.8%, 18.6%, 24.1%, 33.7%, and 3.8% respectively.

3.2 The impact of different sound types on human physiological indicators

3.2.1 Heart rate changes

I divided the experimental process into three nodes, namely, in a calm state, after noise stimulation, and after intervention in different forest acoustic environments. Firstly, a paired t-test was conducted on the heart rate values of the subjects in a calm state and after noise stimulation, and $P<0.05$ was obtained, indicating that noise stimulation had an impact on the subjects' heart rate values, resulting in a significant increase in their heart rate values after noise stimulation (Figure 1). The increase in heart rate indicates that the subject is in a high-pressure state of mental tension after noise stimulation.

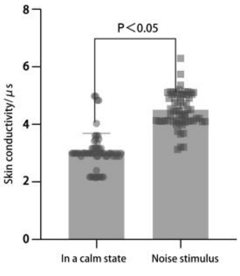

Figure 1 Paired t-test chart of heart rate under calm and noise stimulation

Paired t-tests were conducted on the heart rate values of the subjects after noise exposure and the heart rate values after intervention in various acoustic environments, resulting in artificial sound P=0.018, natural sound P=0.000, and living sound P=0.000. Firstly, P<0.05 indicates that different types of forest sound environments have a certain effect on the changes in heart rate values of participants, causing significant changes. As shown in Figure 2, the heart rate values showed a decreasing trend after experiencing three types of sound. Among them, artificial sound decreased by 3.02%, natural sound decreased by 3.24%, and daily sound decreased by 2.68%, indicating that after noise stimulation, natural sound had the greatest effect on relieving tense emotions and restoring calm state for the participants.

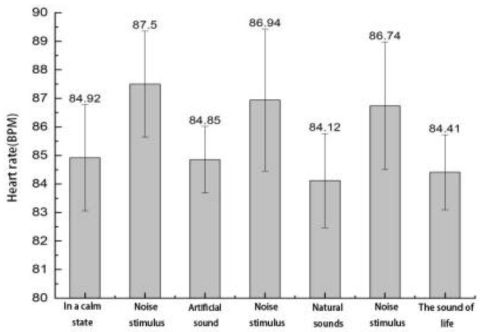

Figure 2 Changes in heart rate of different types of sounds after noise stimulation

3.2.2 Changes in skin conductivity

Skin conductivity can be used as a measure of participants' mental state of relaxation and tension. By conducting paired t-tests on the skin conductivity values of the subjects in a calm state and the skin conductivity values after noise stimulation, P<0.05 was obtained, indicating that noise stimulation had an impact on the skin conductivity values of the subjects, resulting in a significant difference from the skin conductivity values in a calm state. From Figure 3, it can be seen that the skin conductivity significantly increased after noise stimulation, indicating that noise stimulation increased the subjects' tension.

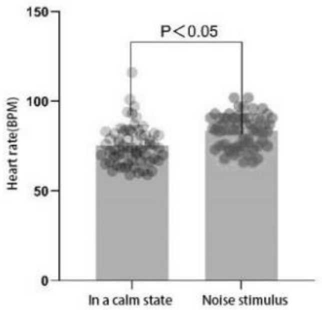

Figure 3 Paired t-test diagram of calm and noise stimulated electrodermal stimulation

Paired t-tests were performed on the skin conductivity values of the subjects after noise stimulation and intervention in different types of acoustic environments. The results indicated that for artificial sound, P=0.07, for natural sound, P=0.000, and for living sound, P=0.000. Notably, artificial sound with P>0.05 suggests that its effect on the changes in skin conductivity of the subjects is insignificant. However, both natural sound and living sound exhibited significant effects on altering skin conductivity values. Illustrated in Figure 4, all three types of sound stimuli led to a decrease in skin conductivity: artificial sound by 16.6%, natural sound by 41.22%, and living sound by 31.3%. The data suggests that natural sound has the most substantial impact on reducing the subjects' skin conductivity, indicating its effectiveness in alleviating stress and promoting relaxation. Following intervention with natural and everyday sounds, the subjects' skin conductivity values approached a state of calmness. The composition of artificial sound elements bears some correlation with urban noise, sharing similar frequency and intensity, thus resulting in a relatively minor effect on emotional relief.

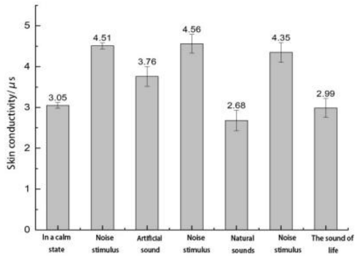

Figure 4 Changes in different types of sound electrodermal changes after noise stimulation

3.3 The impact of different sound types on human psychological indicators

3.3.1 Changes in mood state

In order to study the impact of different sound types on human mood state, a survey questionnaire was designed based on the mood state of participants after intervention in the sound environment, using existing psychological data categories. By collecting feedback data from 63 participants under different sound types of intervention, we further analyze the impact of different sound environments on the psychological situation of participants and propose corresponding strategies and countermeasures. This questionnaire divides its 20 mood state evaluation indicators into positive evaluation and negative evaluation. The higher the positive evaluation score, the stronger the positive evaluation; The higher the negative evaluation score, the weaker the positive evaluation.

According to Figure 5, the participants had the highest positive evaluation of natural sound, with a score of 2.56. The second score is 2.51 for living sound, and the final score is 2.12 for artificial sound. It indicates that under the intervention of natural sound, the positive emotions of the participants are the highest. Negative evaluation showed that artificial voice had the greatest negative emotion on the subjects, with a score of -1.79, followed by daily voice with a score of -1.63, and finally natural voice with a score of -1.46. In summary, it can be seen that the participants have the strongest level of negative emotions under artificial voice intervention.

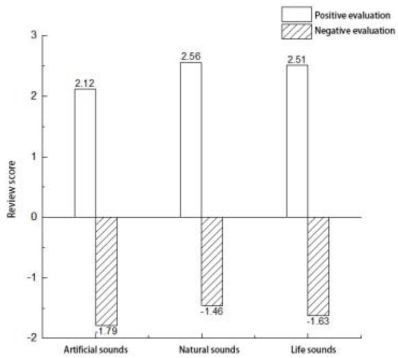

Figure 5 Positive and Negative Evaluation Chart of Mood State

3.3.2 Correlation analysis between mood state and physiological changes

This experiment conducted correlation analysis on the changes in subjects' mood state and physiological indicators, and found that heart rate and skin conductivity are to some extent correlated with changes in mood state. As shown in Table 4, physiological indicators show a significant negative correlation with positive evaluation and a significant positive correlation with negative evaluation. This indicates that the trend of changes in mood state is to some extent consistent with the trend of physiological indicators. In the positive evaluation, the heart rate value $p=0.031$ is negatively correlated at the $p<0.05$ level, and the skin conductivity value $p=0.006$ is highly negatively correlated at the $p<0.01$ level; In the negative evaluation, the heart rate value p=0.014 and the skin conductivity value p=0.027 are both positively correlated at the p<0.05 level. According to the comparison of absolute values of correlation coefficients, it can be concluded that 0.689>0.422, indicating a greater correlation between negative evaluation and skin conductivity. In summary, after noise stimulation, when the subjects' emotions ease, the positive evaluation value increases, while the heart rate and skin conductivity show a downward trend. On the contrary, when the subject is in a state of tension and anxiety, the negative evaluation value increases, and the heart rate and skin conductivity also increase.

Table 4 Correlation analysis between mood state and physiological indicators changes

Project	Heart rate	Skin conductivity
correlation coefficient	-0.434*	-0.711**
Sig.(two-tailed)	0.031	0.006
correlation coefficient	0.422*	0.689*
Sig.(two-tailed)	0.014	0.027

3.3.3 Acoustic Environment Assessment

This questionnaire sets up 25 indicators as sound environment evaluation factors for comprehensive evaluation, aggregating numerous variables into common factors to reduce the difficulty of data analysis. Factor analysis is used to analyze the differences in sound environment evaluation caused by different sound types. The application of KMO test and Bartlett sphericity test, where the KMO detection value is 0.901, and the probability of Bartiett sphericity test is 0, indicates a correlation between the analyzed variables, indicating that the evaluation results are suitable for factor analysis.

After importing data into SPSS for factor analysis, five common factors were extracted. Table 5 shows that Common Factor 1 loaded significantly on indicators like identity, pleasure, and atmosphere, indicating perception changes in forest sound, defined as a perception factor. Common Factor 2 loaded significantly on indicators such as rhythm, undulation, and vitality, reflecting the physical characteristics of forest sound, defined as an acoustic factor. Common Factor 3 loaded significantly on indicators such as abrupt sensation, intermittent sensation, and noise sensation, representing evaluation of forest sound fluctuations, defined as an unstable factor. Common Factor 4 loaded significantly on indicators such as quietness, spatial sense, and openness, highlighting spatial attributes of sound, defined as a spatial factor. Common Factor 5 loaded significantly on indicators such as depression and emotion, representing emotional changes with different sounds, defined as an emotion factor.

Table 5 Proportion of Factor Components

Principal component factor	1	2	3	4	5
Identity	0.83	0.141	-0.163		
valence	0.805	0.151	-0.303		
Sense of atmosphere	0.803	0.227	-0.22		
Sense of rhythm		0.868	0.119		-0.109
relief	0.151	0.673		-0.155	0.192
Vitality	0.263	0.657	-0.202		-0.317
Abrupt feeling	-0.164		0.762	0.224	
Discontinuity	-0.274		0.731	0.219	0.172
A sense of noise	-0.366		0.633	0.322	0.174
Quietness			0.106	0.752	0.121
sense of space		-0.217	0.247	0.724	
Openness			0.132	0.707	0.384
Emotional sensation			0.174	0.404	0.671
A low sense of heaviness	-0.108		0.183	0.287	0.652

The comprehensive scores of different types of forest sounds are calculated based on the variance contribution rate in factor scores (Tables 6 and 7). The data results indicate that people's evaluation scores of the acoustic environment in various aspects can be obtained. According to the comprehensive score, the participants rated natural sound higher, followed by living sound and finally artificial sound. It indicates that people have the best impression of natural sound and have a poor evaluation of artificial sound.

Table 6 Rotational sum of squares loading

factor extraction	Total	Variance percentage	accumulate %
Perception factor	6.63	26.52	26.52
Acoustic factor	3.03	12.12	38.64
Instability factor	2.42	9.67	48.31
Spatial factor	2.28	9.13	57.44
emotion factor	1.71	6.83	64.27

Table 7 Factor Scores

Sound type	Perception factorY1	Acoustic factorY2	Instability factorY3	Spatial factorY4	emotion factor F5	Comprehensive scorey
Artificial sound	-0.02	1.29	0.74	-0.93	0.03	0.22
natural sound	2.18	-0.34	0.32	0.16	1.18	1.03
Life Sound	1.86	-2.74	0.50	1.15	-1.39	0.34

4. Discussion

4.1 The impact of forest soundscape on human physiology and psychology

The forest soundscape showed a downward trend in both heart rate and skin conductivity of subjects under pressure, indicating the forest soundscape's effect on physiological indicators and alleviating subjects' physiological pressure. This aligns with previous research. Following the intervention, subjects' average heart rate decreased by 2.6 beats per minute, with the most significant change observed in natural sound, decreasing by 2.83 beats per minute, consistent with prior research. The average decrease in skin conductivity was 0.82/μS, with the most significant change in natural sound, decreasing by 0.84/μS, suggesting the forest acoustic environment aids skin conductivity recovery post-noise pressure, consistent with Gao Yaling et al.'s study [4].

The positive evaluations of artificial, natural, and life sounds were 2.12, 2.56, and 2.51 points, respectively, while the negative evaluations were 1.76, 1.46, and 1.63 points, respectively. Participants rated forest sound scenery more positively than negatively, inducing positive psychological changes and happiness, consistent with Zhang Weihao et al.'s study, which found that environmental preferences are influenced by physiological and psychological pressures. Hence, urban forest planning should incorporate soundscape scenic spots like water insects' chirping and natural water windmills to enhance landscape naturalness, complexity, and attractiveness, fostering audio-visual interaction.

4.2 The impact of different types of forest soundscapes on the human body

In terms of physiological indicators, natural sound after noise stimulation has the most significant effect on heart rate and skin conductivity recovery, followed by living sound, while artificial sound has the weakest effect. Li Hansen et al.'s findings suggest that different acoustic environments impact participants' perception differently. Additionally, Hong Xinchen[5] et al. found that high-frequency artificial sound has a weaker restorative effect on physiology. Conversely, an overall environment with soothing natural sounds has a strong effect on physiological indicator recovery after noise stimulation, promoting a peaceful state. These results imply that changes in characteristics such as intensity, rhythm, and frequency of different forest sound types influence physiological indicators.

In terms of psychological evaluation, people have the highest evaluation of natural sound and the lowest evaluation of artificial sound. According to the relevant research by Wang Qian et al, when releasing anxiety emotions, high-frequency dominant tones have a greater negative impact on people compared to low-frequency dominant tones. In this study, natural dominant tones are in the low-frequency range. The physical properties of sound have a significant impact on the physiological and psychological well-being of participants. Its voice is melodious and lively, which is quite popular among participants. The urban noise, on the other hand, is in the high-frequency range, with rapid and high intensity sound, which is more likely to cause the subjects to enter a state of irritability. Compared to natural and everyday sounds, artificial sounds also possess such characteristics, so their emotional relief effect on subjects is weakest.

4.3 The correlation between the physiological and psychological effects of different types of forest soundscapes on the human body

Research has shown that different types of forest soundscapes have a certain correlation with the physiological and psychological changes produced by participants, which is consistent with the research results of Prita Indah Pratiwi et al. Physiological indicators to some extent reflect the changes in participants' emotions[6]. The natural sound with the highest positive evaluation score in psychological evaluation scores showed the most significant decrease in heart rate and skin conductivity after forest sound intervention. The artificial voice with the lowest positive evaluation score showed the least significant downward trend in heart rate and skin conductivity. In summary, physiological indicators to some extent reflect people's subjective definition of forest soundscape[7].

5. Conclusion

This article compares the impact of various forest soundscapes on subjects by detecting changes in physiological and psychological indicators. Post-noise stimulation, forest soundscapes positively affect participants' physical and mental recovery. Based on sound source types, the forest sound scene is categorized into natural, life, and artificial sounds. Natural sounds most significantly enhance subjects' physical and mental recovery, while artificial sounds have the least impact. A notable correlation exists between physiological and psychological recovery under high-pressure conditions.

This study systematically quantifies the impact of forest soundscapes on human physiological and psychological well-being. It concludes that various forest soundscapes differ in emotional recovery and stress relief for participants, contributing to the foundation for future research on diverse populations. However, the experiment has limitations, such as scene independence, insufficient variety in soundscape types, and a small sample size. To balance participants' enthusiasm and physiological delay, audio stimulation was limited to about one minute, resulting in inadequate reserve time for a physiological buffer period. Additionally, in the perceptual resilience experiment, precautions were taken to avoid the influence of audio playback order on the results.

In future research, there is a need to further demonstrate and delve into the study of the impact of various combinations of forest sound elements on the human body. Simultaneously, a more detailed classification and comparison of different types of forest sounds will be undertaken, and a comprehensive forest sound environment incorporating multiple senses, including visual analysis, olfactory analysis, and tactile experience, will be developed. A more systematic sound landscape evaluation mechanism will be established, offering increased scientific reference value for future urban forest construction and forest healing and health.

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