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Psychophysiological Responses of Young People to Soundscapes in Actual Rural and City Environments

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To investigate the psychophysiological effects of soundscapes in different actual environments, rural and city landscapes were selected as experimental sites, and 30 students were enrolled in this study. The effects of soundscapes were revealed through measured systolic and diastolic blood pressure, heart rate, and electroencephalography of participants before and after introducing soundscape elements to the landscape environment, and the participants rated their preferences. In this study, nature, light music, and symphony soundscape elements decreased systolic and diastolic blood pressure, slowed the heart rate, and increased the β/α index in the participants, while traffic soundscape elements showed the opposite effects. Furthermore, there were certain differences in the psychophysiological effects of soundscape elements in different landscape scenes, manifested by the result that nature soundscape elements had a greater effect on participants in the rural landscape environment, while light music soundscape elements had a greater effect on participants in the city landscape environment. In addition, men and women presented certain differences in psychophysiological responses to soundscape elements; that is, men preferred symphony soundscape elements in the city landscape environment, and women were more susceptible to the negative effects of traffic soundscape elements in rural or city landscape environments.

0 INTRODUCTION

With rapid social and economic development in China, people's living standards are gradually improving, while pressure and anxiety are also increasing. Previous studies have shown the benefit of suitable soundscapes for people to recover from stress [1,2]. The soundscape [3,4] refers to sound(s) that people perceive from an immersive environment; it emphasizes perception with a pleasing and relaxing function and has become a relatively new interdisciplinary subject in recent years [5].

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Comprehensive research based on vision and hearing has been very helpful to modern humans in further exploring perceived places. The initial soundscape research mainly focused on the treatment and prevention of noise pollution [6,7]. In recent years, research on soundscapes has mainly focused on their different types and the psychological impact of soundscapes on people in environments and subsequent stress responses [8–10]. People have different perceptions and preferences for different types of soundscape elements [11,12]. Natural sounds, such as insect or animal sounds, can cause people to feel relaxed and happy [13]. People like music since it can evoke the feelings of human emotions, the rhythm of the body, and the perception of good things [14], although there is still controversy regarding the emotivist position or the cognitivist position regarding music [15]. The sound of traffic is often considered to be unpleasant [16]. For a single soundscape, the difference in type is very important for cognitive and emotional interpretations [17]. However, must these types of sound elements match a specific environment?In different landscape environments, do different types of sound elements still evoke the same feelings?

Human emotion perception or responses to stimuli require some standard to measure [18]. In soundscape studies, psychological feelings indicating people's perceptions of the soundscape are usually the main measures, and subjective evaluation methods are primarily adopted. A rating on an analog scale is usually based on people's pleasure, vitality, and excitement as it relates to the semantic dimension of the score [19,20]. When using this method, because of the subjective and individual sensory differences among the subjects, it is necessary to have a relatively large number of subjects to have better accuracy. In addition, people's subjective psychological feelings have certain effects in describing emotional experiences [19,21,22].

When people perceive visual and sound stimuli that cause certain psychological feelings, the human body also undergoes a variety of physiological changes according to the perception of emotions. These physiological changes will be manifested in the somatic, visceral, and central nervous systems, and the measurement of these physiological changes has usually been manifested in several common physiological indicators, such as heart rate (HR), heart rate variability (HRV), skin conductance level (SCL), respiratory rate (RR), electromyography (EMG), and electroencephalography (EEG). In research on the physiological effects of the soundscape, methods such as SCL, HRV, RR, HR, and EMG have been commonly used. Alvarsson et al. [23] evaluated sympathetic nervous system (SNS) activation by measuring SCL and parasympathetic nervous system (PSNS) activity by measuring HRV. Gomez and Danuser [24] reported physiological changes in 80 subjects after presentation of 18 various sound clips following silence; there was a tendency for RR and EMG to increase and HR to decrease. Recording facial EMG can indicate changes in somatic parameters; measuring SCL and HR can reflect changes in visceral parameters. According to the research of Bradley et al., subjects' facial EMG activity and skin conductance increased when they were unpleasantly stimulated compared with neutral stimuli [19,25].

The nervous system response is more responsive than the above somatic changes. Using event-related brain potentials technique, [26] reported that a late positive voltage change was observed only 200–300 ms after presentation of an emotional picture, and it maximized approximately 1 s after picture presentation. Differences in brain frequency waves reflect responses to stimuli from different brain regions [27]. Thus, measuring changes in brain waves can further accurately and quickly reflect the subtle electrophysiological activity of the listener in a response to a soundscape. Psychological effects and physiological effects are two parts of the psychophysiological effects of soundscapes. In addition, it not yet known whether there are particular correlations between psychological feelings and physiological responses caused by soundscape elements.

The psychological and physiological recovery effects of soundscapes in humans have been revealed by previous research [28,29], but the experimental sites for examining these physiological effects have mostly been limited to laboratories. There are certain differences from the actual environments in which people live, and these differences are mainly reflected in the laboratories being maintained in controlled silence, while the real environment simultaneously contains foreground and background sounds that are perceived differently depending on environment and people's attention [30]. In addition, there are usually no additional interference factors in the laboratory to ensure that the subjects focus on the soundscape elements being examined in the experimental process, whereas in the real environment, subjects perceive the overall environment, and their attention is relatively less focused on the soundscape because not only the soundscape exists but also the landscape. Based on this, some studies of recent decades have been done in immersive environments, integrating audio, visual, smell, and microclimate, as well as background noise, which has also been used in laboratories.

However, there are still differences between the actual environment and the immersive environment. A previous study compared differences in the perception of the same soundscape elements in the laboratory and in the actual environment and suggested that laboratory evaluations cannot fully express how subjects' stressfulness and comfort are affected by soundscapes because full immersion in the environment is important [31].

People in the actual environment enjoy a soundscape due to its masking effect; in particular, a pleasant soundscape covers up the existing noise that is more or less present in the natural environment, and this fact affects people's landscape impression [21]. In addition, pleasant soundscapes can be integrated well with the environment to be toured to create a more three-dimensional environment. The urban soundscape has been the focus of recent research on soundscapes, and the studies of urban soundscapes have been diverse. The development of research on urban soundscapes is very important for comprehensive improvement in the urban public green space environment. In addition, there have been a few studies on soundscapes in rural landscapes, and they have been limited to questionnaire surveys and acoustic environment research [32,33].

Positive soundscapes are cognitively and physically restorative, and the restorative potential of rural soundscapes is greater than that of urban soundscapes [10]. With the rise of rural tourism in China, an increasing number of urban residents have come to the rural environment to find inner pleasure and calm. However, the development of China's rural landscape environment has usually occurred without a good plan, especially the shaping of the soundscape, which is essentially lacking in the development of China's rural landscape.

The aim of this study was to answer three questions: a) Does introducing soundscape elements in different actual environments lead to different perception? b) Are there different perceptions of different types of soundscape elements between the rural and city environments? c) Do gender differences exist in soundscape perception in actual environments? Therefore, the effects of different soundscape elements on young males' and young females' psychophysiological responses were accessed in actual rural and city landscape environments and determined the correlation between the two parts of psychophysiological effects.

1 METHODS

1.1 Study Sites

We chose the rural landscape environment and city landscape environment, which are common experimental environments used as study sites. A map shows the experimental setting (Fig. 1). These two landscape environments are very familiar to residents, and there are no soundscape elements. Based on a previous field survey conducted to find typical experimental sites, we selected the Linpan (as shown in Fig. 2(a)), one of the most representative rural landscapes in western Sichuan, China, as the rural experimental site for this study. Every spring in Sichuan, residents perform traditional Chinese customs called "TaChun," which means hiking in the wilderness along the outskirts and performing various activities, and they flood into the Linpan to see the beautiful scenery. Therefore, the Linpan is a familiar and representative rural landscape in Sichuan. We selected a landscape square (as shown in Fig. 2(b)) on campus as a city experimental site, since the campus landscape is a familiar artificial landscape environment for the participants.

The Linpan is located in a suburban village, which is approximately 10 km from the urban district. The environment of the Linpan is characterized by wild, nondesigned, and few buildings; abundant vegetation; and natural features. The campus is located in an urban district. The environment of the landscape square is characterized by the modern features of designed and structured landscape elements, and it is surrounded by typical high-rise buildings. To control the environmental conditions to the maximum extent, we determined the experimental dates of March 22 (Friday, from 9:00 a.m. to 4:00 p.m.; the experiment was conducted in the rural environment) and 23 (Saturday, from 9:00 a.m. to 3:30 p.m.; the same participants performed the same experiment in the city environment as on the previous day) in 2019, based on the recent weather forecast and field exploration before the experiment started. This selection of the Linpan usually has fewer interference factors, such as people and cars, during the workday. The campus experimental site has many interference factors during the workday, so we conducted the experiment over the quiet weekend.

The clear weather conditions on the days of the experiment included a wind speed of 1.29 m/s, an average temperature of 23 °C, a relative humidity of 42%, and an intensity of illumination of 680 lux at the rural experimental site and a wind speed of 0.87 m/s, an average temperature of 21 °C, a relative humidity of 51%, and an intensity of illumination of 620 lux at the city experimental site. We recorded the values of the weather conditions every 5 min during experimental period, and the above weather conditions were average values over the period.

We measured the ambient sound pressure level at the target sites of the subject every 5 min while the experiment progressed. The average sound pressure levels were 52.1 dB(A) and 54.3 dB(A) for the rural and city environments, respectively. During the two days of the experiment, no obvious changes interfered with the experimental process; that is, there were no sudden other sounds, no people or cars making obvious sounds, and no violent changes in the weather. Since the experimental sites were in the wild, not the quiet environment chosen for usual soundscape research, we used an audio player to play the soundscape elements, instead of using headphones, to preserve the original sound interference from the environment.

1.2 Participants

The participants were all students and recruited from a university in China. All of them were informed about experimental content and process and agreed to volunteer for the experiment. They self-reported as healthy and had no history of mental illness. The characteristics of the participants are shown in Table 1.

1.3 Stimulus Material

The soundscape was classified into three components from the perspectives of acoustic ecology: keynote sounds, sound signals, and soundmarks [4]. We used nature sounds as keynote sounds, traffic sounds as sound signals, and music as soundmarks. Based on these three soundscape components, we edited a natural sound clip, which mixed birdsong, ocean, and wind through trees, and a traffic sound clip, which mixed frequent sounds from urban roads, car horns, engines, and brakes. Considering different types of music can evoke people's different emotional responses in public spaces, such as pleasant, exasperating, and inspiring feelings [34]. We selected famous light music ("Snowdream" by Bandari) with a slow melody and a famous symphony ("Yellow River Piano Concerto" by the Asian Cultural Symphony Orchestra) with an impassioned melody as the music sound clips, because generally, considering a slow and soothing melody light music causes people to feel relaxed, while the impassioned melody of the symphony causes people to feel inspired. These two music sounds are usually played in the local leisure squares, so people are familiar with them. That's the reason why we choose these two types of music sounds as stimulus materials. All of the sound clips were 1 min long; the raw materials for sound clip editing were obtained from and freesound.org [35]; the music was played online.

1.4 Measurements

The EEG measurements were obtained using a wireless Mind Wave EEG Headset (Beijing Oriental Creation Technology Co., Ltd.) connected to a computer by Bluetooth, and it collected brain waves of four frequencies (α, β, θ, and

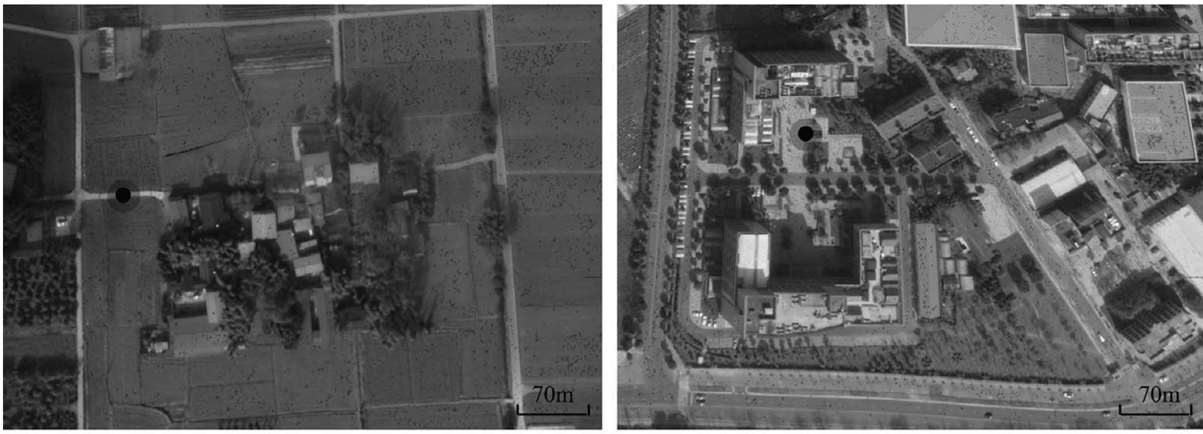

Fig. 1. The experimental environments of rural (left) and city (right) show in map.
Note: The markings by the black dots in the figure are the experimental site.

δ) over the whole stimulation. The ratio of EEG measures (e.g., β/α, θ/β, and θ/(α + β)) can quickly reflect the subject's changes in emotional perception of external environmental stimuli. We used the β/α index to present participants' psychological responses, because the β/α index was reported to be most suitable indicator in physiological responses [36,37], yet it has rarely been previously used to evaluate the physiological effects of soundscapes.

The blood pressure was measured in participants' left arms using a sphygmomanometer (HEM-7011, Omron), and we obtained the instantaneous values of systolic blood pressure (SBP) and diastolic blood pressure (DBP); the instantaneous HR values were measured by electrocardiogram (RR intervals) using a portable HR meter (AC-301A, GMS Corporation).

1.5 Experimental Procedure

Each student was informed of the experimental content and methods, and their consent was obtained during recruiting. Briefly, students were informed that the research content was collection data of physiological and psychological responses to soundscapes in two places, but they were not informed of the soundscape elements' details, to avoid the subjective preimpressions of soundscape elements. The participants were asked to avoid strenuous activities before and during the experiment, and they sat quietly with their eyes closed for a minute before starting. The experimental procedure is illustrated in Fig. 3.

First, the participants wore an HR sensor, a sphygmomanometer on their left hand, and an EEG headset on their head with the sensor clipped to their left ear. Then, they

Fig. 2. The experimental sites: (a) rural and (b) city.

Table 1. Experimental Participants' Characteristics.

Gender	N	Age	N	Educational Background	N	Major	N
Male	15	18–19	2	Undergraduate	21	Relevant to study	11
Female	15	20–21	19	Graduate	7	Not relevant	19
		22–23	7	Ph.D.	2		
		>23	2				
Total	30						

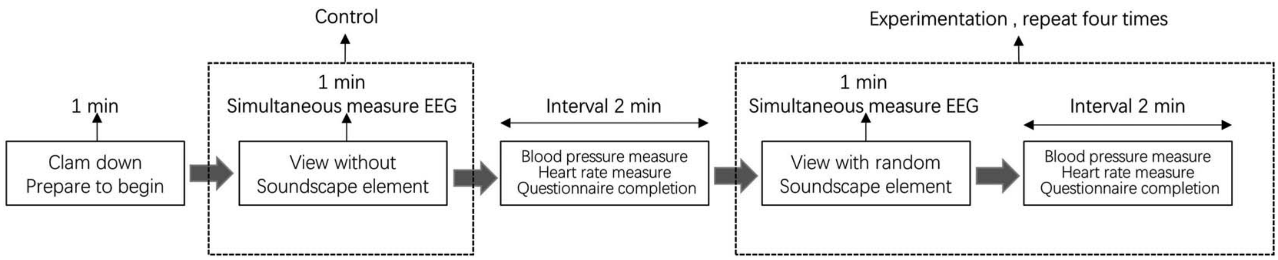

Fig. 3. Experimental flow diagram.

conducted the experiment under the control condition; that is, they randomly viewed (to avoid causing tension by asking them to look ahead) the landscape in front of them without soundscape element stimuli for 1 min, while their EEGs were recorded using a Mind Wave EEG Headset (Fig. 4(a)–(d)). After viewing, the experimental assistant volunteers immediately measured the participants' blood pressure and HRs, and then, the participants completed the response sheets with a seven-point numerical scale questionnaire (Fig. 5) according to their feelings on the overall acoustic environment.

Then, following the above procedure, the participants viewed the landscape with four sound clip stimuli presented in random order, and the time interval between the sound clip stimuli was 2 min. In brief, the students viewed the landscape while receiving 67 dB(A) of sound clip stim-

Fig. 4. The experimental process during electroencephalography (EEG) collection. (a)–(b) Rural experimental site; (c)–(d) city experimental site.

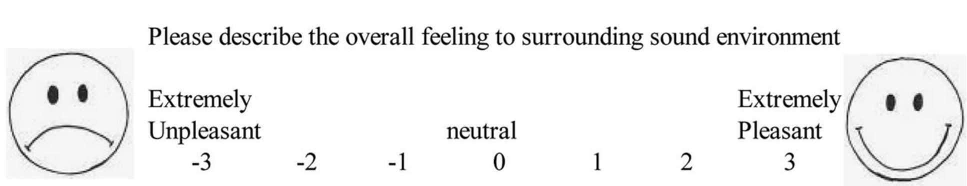

Fig. 5. Preference score on a seven-point numerical scale.

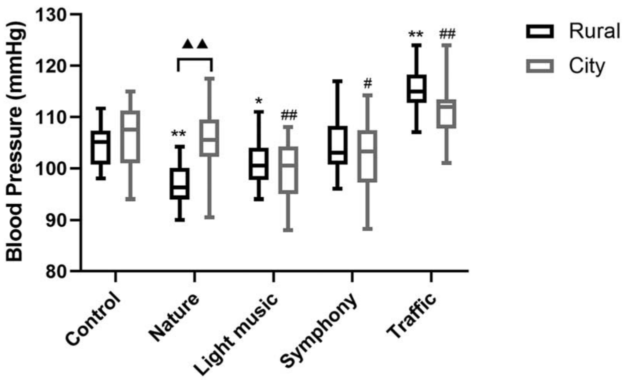

Fig. 6. All participants' systolic pressure changes in rural and city environments.
Note: Compared with control condition in the rural area, $^{*}p < 0.05$, $^{**}p < 0.01$; compared with the control condition in the city, # $p < 0.05$, ## $p < 0.01$; data compared between the rural area and city with the same soundscape element, ▲ $p < 0.05$, ▲▲ $p < 0.01$. This note also applies to subsequent Figs. 7–10.

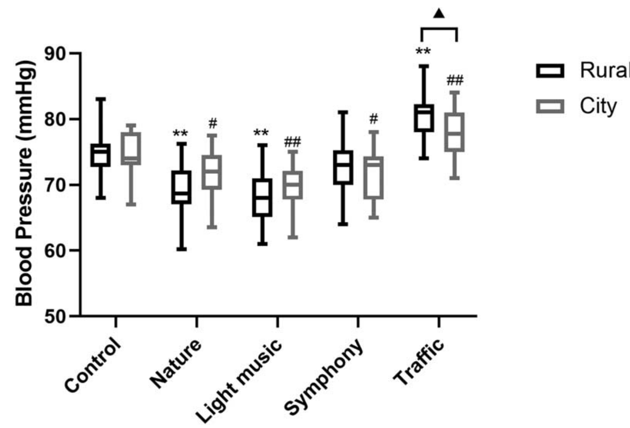

Fig. 7. All participants' diastolic blood pressure changes in the rural and city environments.

ulation for 1 min from the multichannel wireless audio player (SD55, Philips Co., Ltd) placed approximately 1 m of distance behind them. This received sound pressure level could be heard by participants at the study position, and the distance to the player was determined by preliminary experiment. The preliminary experiment was carried out in the same place without interference. After placing the audio player, the sound pressure level on the position where the students will conduct the experiment was detected while playing the sound clip. The playback parameters of the player system were determined and recorded when the sound pressure level received was 67 dB(A) so as to ensure that the students could hear the same sound pressure levels of four kind of sound clips using these parameters during the experiment. As described above, EEGs were measured during viewing, and the blood pressure and HR were measured after each viewing with a sound clip and conducted questionnaire. The sound pressure level of sound clips was determined according to the research design of Hume and Ahtamad [38].

1.6 Data Analysis

If the study data were normally distributed, all of the data were analyzed by two-sample *t* test to compare differences between sound elements, between rural and city experimental sites, and between men and women; otherwise, they were analyzed by non-parametric testing. Pearson correlation between aspects of the psychophysiological data were analyzed using Statistical Product and Service Solutions software, version 26 for Windows.

2 RESULTS

2.1 Blood Pressure, Heart Rate, and Brain Wave Changes

Fig. 6 shows the SBPs of all participants with or without soundscape element stimulation in the rural and city environments. The results of the control conditions (rural: 104.5 ± 4.1 mmHg; city: 106.3 ± 5.7 mmHg) show that the SBPs of participants were not significantly different between the rural and city environments when there was no soundscape element. The SBPs of participants with the nature clip in the rural environment (96.7 ± 3.9 mmHg) was significantly lower ($p < 0.01$) than that in the control condition and significantly lower ($p < 0.01$) than that in the city environment (105.0 ± 6.9 mmHg). After listening to the light music clip, the SBPs of participants in the rural environment (101.1 ± 4.6 mmHg) and the city environment (99.5 ± 5.5 mmHg) were both significantly lower ($p < 0.05$) than in the control condition. Only the SBPs of participants in the city (102.7 ± 6.2 mmHg) were significantly lower ($p < 0.05$) than that in the controls after listening to the symphony clip. In contrast, the SBPs of participants listening to traffic clips in the rural environment (115.2 ± 4.3 mmHg) and the city environment (111.5 ± 5.1 mmHg) were significantly higher ($p < 0.01$) than that in the control condition.

The main effects of soundscape elements on DBP in the rural and city environments are illustrated in Fig. 7. Similar to SBP, DBP in the control condition in the rural environment (74.5 ± 3.3 mmHg) was not obviously different than in the city environment (74.6 ± 3.3 mmHg). After listening to the nature clip, light music clip, and symphony clip, the DBPs of participants in the rural environment and the city environment were significantly lower ($p < 0.05$) than in the control condition, except for the symphony clip in the rural environment (in the rural, nature: 69.2 ± 3.8 mmHg; light music: 68.1 ± 4.3 mmHg; symphony: 72.4 ± 4.3 mmHg; in the city, nature: 71.9 ± 3.1 mmHg; light music: 69.8 ± 3.0 mmHg; symphony: 71.7 ± 3.6 mmHg). The DBPs of the participants in the rural environment (80.7 ± 3.5 mmHg) and the city environment (77.7 ± 3.2 mmHg) were significantly higher ($p < 0.01$) than in the control condition after listening to the traffic clip. A significant difference ($p < 0.05$) was observed between the rural and city environments.

The results of the effects of the soundscape elements on HR are shown in Fig. 8. It indicates that there were no significant differences in participants' HRs in rural (77.9

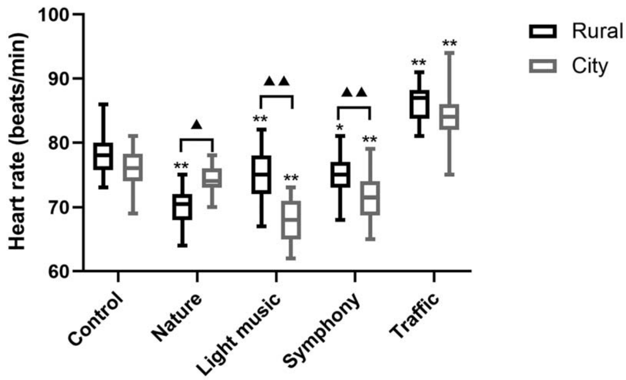

Fig. 8. All participants' heart rate changes evoked by soundscape elements.

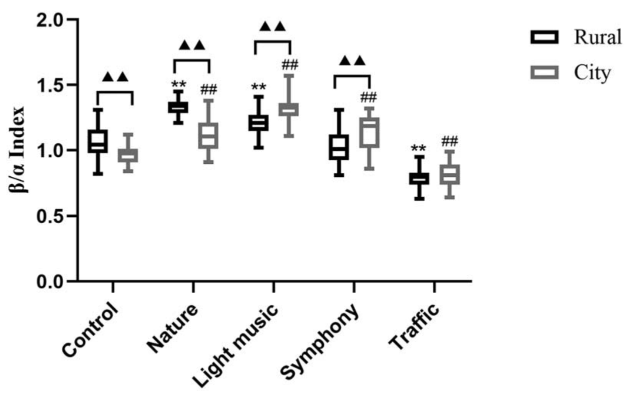

Fig. 9. All participants' electroencephalogram changes evoked by the soundscape elements.

± 3.2 bpm) and city environments (76.2 ± 2.7 bpm) in the control condition. Compared with HRs in the control condition, the HRs of participants in the rural (nature: 69.9 ± 2.8 bpm; light music: 75.0 ± 3.6 bpm; symphony: 75.3 ± 3.3 bpm) and city (nature: 74.1 ± 1.9 bpm; light music: 67.8 ± 3.2 bpm; symphony: 71.3 ± 3.6 bpm) environments were significantly decreased ($p < 0.05$) after introducing the nature clip, light music clip, and symphony clip into the environment, with the exception of the nature clip in the city. In addition, the HRs of participants in the rural environment were significantly lower ($p < 0.05$) than in the city environment after the nature clip was introduced, while the HRs of participants in the city environment were significantly lower ($p < 0.01$) than in the rural environment after the light music clip and symphony clip were introduced. The HRs of participants in the rural (86.1 ± 2.9 bpm) and city (84.4 ± 3.9 bpm) environments significantly increased ($p < 0.01$) after presentation of the traffic clip stimulus.

We analyzed the EEG indices in response to the soundscape element stimuli, and the results (Fig. 9) indicated an even more marked change than the above two physiological indicators. They showed significant changes in brain waves (β/α index) before and after introducing the soundscape elements; that is, there was a significant difference ($p < 0.01$) in the β/α indices of participants between the rural (1.07 ± 0.12) and city (0.97 ± 0.08) environments, even in the

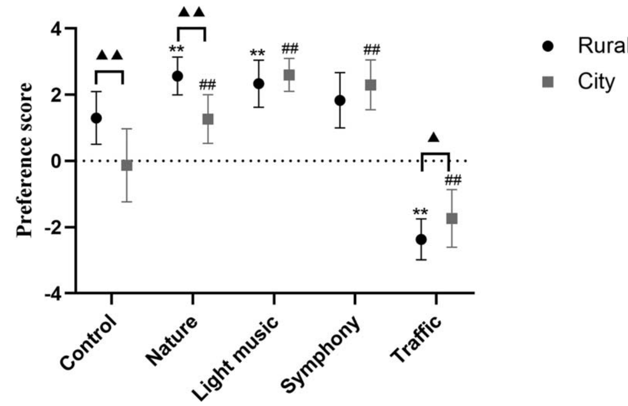

Fig. 10. All participants' preference scores for soundscape elements.

control condition. With the exception of the symphony clip in the rural environment, the β/α indices of the participants were significantly increased ($p < 0.01$) in both the rural and the city environments after the presentation of the nature clip (rural: 1.33 ± 0.06; city: 1.11 ± 0.12), light music clip (rural: 1.21 ± 0.10; city: 1.32 ± 0.09), and symphony clip (rural: 1.02 ± 0.12; city: 1.14 ± 0.15), as well as decreased ($p < 0.01$) in the rural and the city environments after presentation of the traffic clip (rural: 0.79 ± 0.07; city: 0.81 ± 0.08) compared with those in the control condition. In addition, the β/α indices of participants in the rural environment were significantly higher ($p < 0.01$) than that in the city after the nature clip was introduced, while the β/α indices of participants in the rural were significantly lower ($p < 0.01$) than those in the city after the light music clip and symphony clip were introduced.

2.2 Preference Changes in the Rural and City Areas

The participants were asked to complete the preference rating for the overall feeling before and after listening to each soundscape element, and the results are illustrated in Fig. 10. In the rural environment, the highest mean preference score soundscape element was the nature clip (2.57 ± 0.57), second was the light music clip (2.33 ± 0.71), third was the symphony clip (1.83 ± 0.83), and the lowest was the traffic clip (–2.37 ± 0.62). In the city environment, the scores in order from high to low were the light music clip (2.60 ± 0.50), symphony clip (2.30 ± 0.75), and nature clip (1.27 ± 0.74); similarly, the lowest was the traffic clip (–1.73 ± 0.87). The preference scores of the participants in the rural and city environments were all significantly higher ($p < 0.01$) after listening to the nature clip, light music clip, and symphony clip than those in the controls, with the exception of the symphony clip in the rural environment. In addition, the preference scores with the traffic clip in the rural and city environments were significantly lower ($p < 0.01$) than those in the controls. The results in the controls showed that the preference scores of the participants in the rural environment (1.30 ± 0.8) were significantly higher ($p < 0.01$) than those in the city environment (–0.13 ±

1.11). The preference for the nature clip was significantly higher ($p < 0.01$), and the preference for the traffic clip in the rural environment was significantly lower ($p < 0.05$) than in the city environment.

2.3 The Difference in Psychophysiological Responses on Soundscape by Gender

To investigate whether there was a gender difference in the effect of soundscapes on human psychophysiology in rural and city environments, we reanalyzed the data according to gender, and the results are shown in Fig. 11. In the control condition and following the nature clip, light music clip, and symphony clip in the rural and city environments, the men's SBP and DBP were significantly or slightly higher than the women's SBP and DBP, except for after listening to the symphony clip in the city. After listening to the traffic clip, the men's and women's SBP and DBP values became very similar.

Women's HRs were significantly higher ($p < 0.01$) than men's after presentation of the symphony clip stimuli in the city environment. Under the rest of the conditions, before and after presentation of the four soundscape element stimuli in the rural and the city environments, a tendency appeared that the women's HRs was slightly higher than the men's HRs, although there was no statistically significant difference in HR between men and women.

Similarly, the women's β/α index was slightly higher than the men's β/α index in the rural environment. In the city, the men and women had smaller differences in β/α index before and after undergoing soundscape element stimulation. Specifically, the men's β/α index was significantly higher ($p < 0.01$) than the women's after stimulation with the symphony clip in the city.

Finally, Fig. 12 shows that men's preference score for the symphony clip in the city was significantly higher ($p < 0.05$) than women's preference score, and no significant differences were observed between men and women with the remaining soundscape elements.

2.4 The correlations between the psychological and physiological effects

The psychological and physiological data were subjected to Pearson correlation analysis, and the results are shown in Table 2. There was a significant correlation ($p < 0.01$) of preference scores with the SBP, DBP, HR, and β/α index; the correlations of preference scores with blood pressure and HR were negative, and those correlations between preference scores and β/α index were positive.

Table 2. The results of correlation analysis.

Site	Item	R	R^2	Sig
Rural	Preference score vs. SBP	–0.7136	0.5093	0.000
	Preference score vs. DBP	–0.6905	0.4768	0.000
	Preference score vs. HR	–0.7506	0.5634	0.000
	Preference score vs. β/α index	0.7677	0.5893	0.000
City	Preference score vs. SBP	–0.5007	0.2507	0.000
	Preference score vs. DBP	–0.5553	0.3084	0.000
	Preference score vs. HR	–0.7708	0.5941	0.000
	Preference score vs. β/α index	0.7234	0.5233	0.000

SBP, systemic blood pressure; DBP, diastolic blood pressure; HR, heart rate; β/α index, the ratio of beta waves to alpha waves.

3 DISCUSSION

For this study, the similar psychological and physiological responses in the participants to 1-min soundscape element stimuli in rural and city environments were observed. According to the results of the present study, there were obvious psychophysiological effects of the soundscape on humans; that is, emotional preference and relevant physiological changes occurred with changes in the soundscape elements. In addition, the emotional and physiological appeal to humans of the different surroundings were affected by different types of soundscape elements. Different genders also had different psychological and physical responses to the different soundscape elements and the comprehensive landscape demands of the different scenes. Therefore, developing overall comprehensive situational feelings requires different scenes and different populations during soundscape shaping to better integrate soundscapes and landscapes in different scenes, resulting in a specific scene feeling.

3.1 Psychological Effect

In this experiment, the research site was split into two specific landscape environments. Introducing four specific soundscape elements into these two landscape environments has certain significant effects on the participants' emotional perception changes. First, in the control condition, without the introduction of soundscape elements, the participants had different emotional perceptions between rural and city environments; that is, almost all of the preference results indicated that the participants had better mental pleasure in the rural environment. This outcome was consistent with previous studies showing that people prefer natural landscape over cities [39].

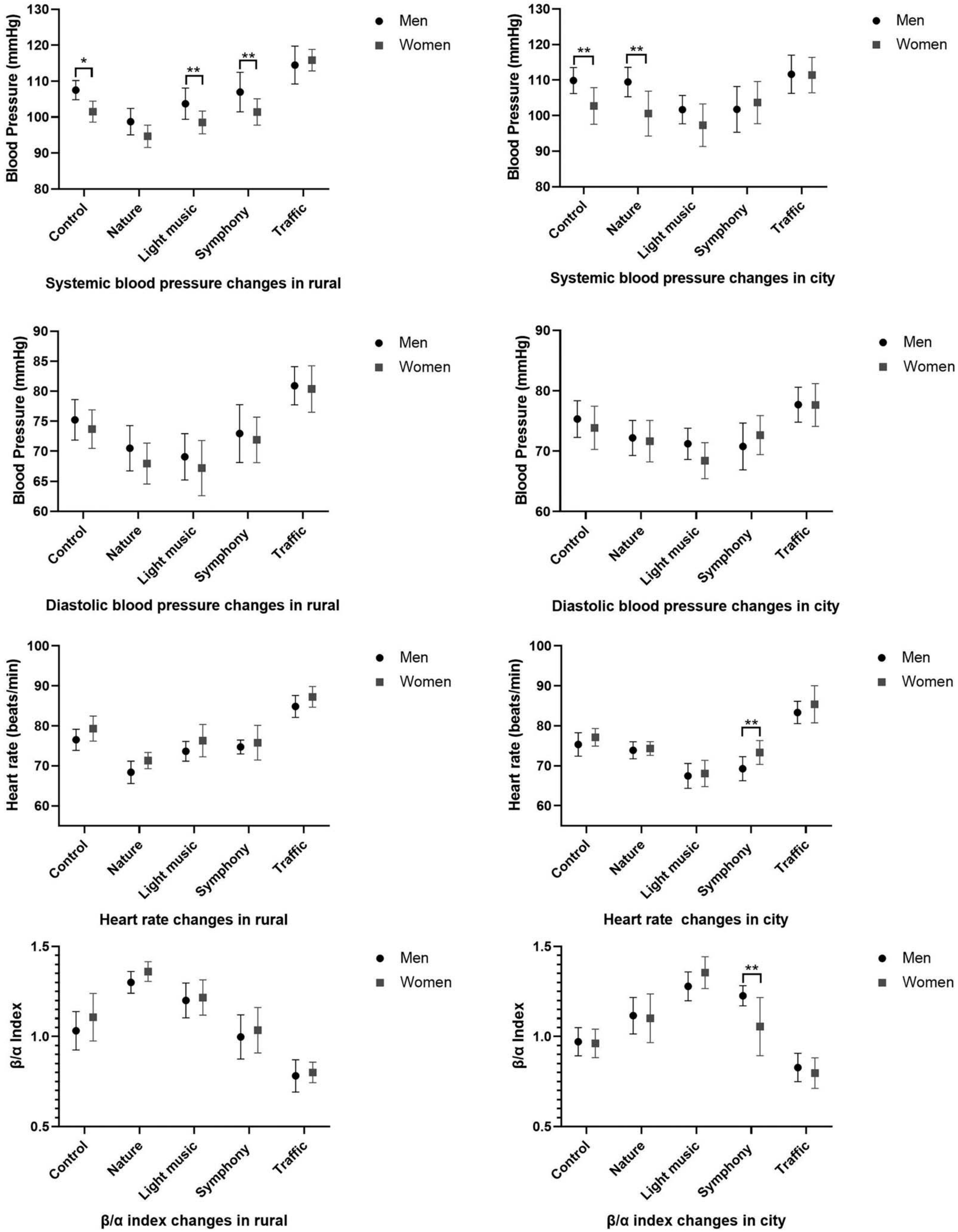

Fig. 11. The gender differences in physiological effects of soundscape elements.
Note: The * symbol shows a statistically significant difference between men and women in the same soundscape element, * $p < 0.05$, ** $p < 0.01$. This note also applies to the subsequent Fig. 12.

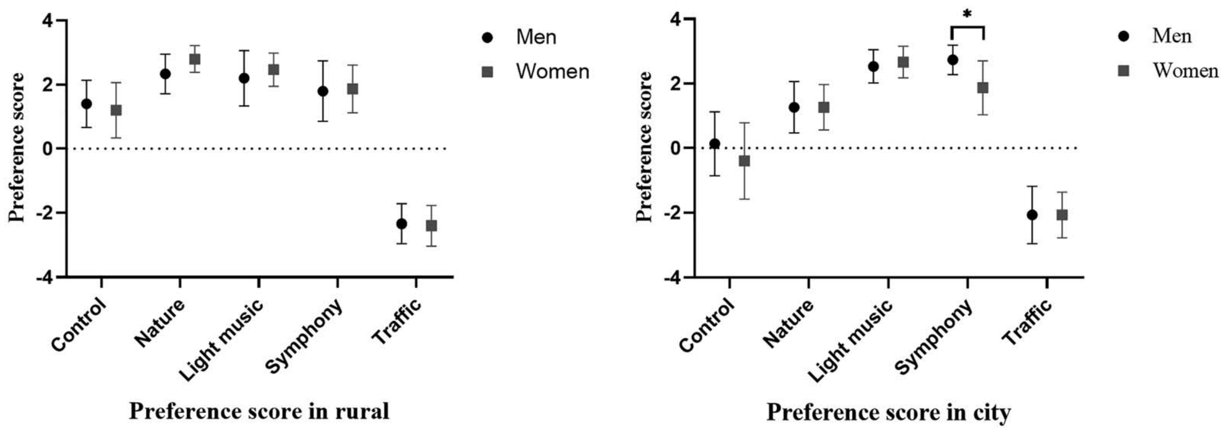

Fig. 12. The gender differences in the psychological effects of soundscape elements.

The significantly increasing preference score showed that the nature clip, light music clip, and symphony clip brought the participants a pleasant feeling. The participants' pleasant perceptions of the nature clip presented the most obvious difference between the two landscape environments in the overall preference score, since the changes in score (score after sound clip minus score of control) to the nature clip was greatest in the rural environment and smallest in the city environment. People like nature sounds because these sounds can bring people a natural feeling of pleasure and relaxation. It was an interesting phenomenon to evaluate the feelings of people in response to a soundscape that usually occurs in an experimental situation, e.g., focusing on listening to soundscape elements in an otherwise silent room. This study introduced nature soundscape elements into the actual landscape environment and found that the nature soundscape elements in the rural natural environment could bring participants a good mental experience, whereas the nature soundscape elements in the city environment did not bring a unique and profound emotional experience. This finding is an instance of a combination of the soundscape and different landscape showing different effects. The nature clip originates from nature and is a natural soundscape without artificial components; perhaps it fits the rural natural environment more and therefore brings a better psychological experience.

The evaluation of light music was the best among the subjective evaluations of soundscape elements in the city environment. Although urban landscapes are also integrated places with planned landscapes, because of the inherent environmental feelings and the degree of familiarity with the places, the participants generally emotionally perform and require a strong sense of relaxation in an urban environment. This light music soundscape element, which can cause people to feel comfortable and relaxed, was favored by the participants. In addition, this soundscape element also presented a good psychological experience in the rural environment, so it could be speculated that the light music soundscape element is able to adapt to more landscape scenes and can be well integrated into various types of landscape environments, bringing a high-quality, comprehensive emotional experience.

The preference evaluation of the symphony clip in the city landscape environment was better than in the rural environment, which also shows that different soundscape elements can reflect the specific atmosphere of different landscape places and result in significant differences in feelings. The symphony clip was full of rhythm and emotional music, which can generally present a lively and encouraging mood. In cities, where people feel more pressure, this soundscape could be better accepted than in rural environments.

Noise, as the symbol sound in soundscapes, is an indispensable comparison element and a major focus in soundscape research. Many studies have focused on masking or eliminating noise through, for example, physical means [40]. Traffic sounds are very common in cities and usually seem to be noisy. People's specific knowledge of the environment and their familiarity with noise render traffic elements less stimulating in the city environment. In rural environments, people are more susceptible to being more abruptly affected by noise in the environment. Familiarity with and habituation to noise in city environments might be why the preference score of the traffic clip was significantly higher, as well as why the decline in scores of traffic clips were smaller in the city environment than in the rural environment.

3.2 Physiological Effects

In terms of the physiological effects of soundscape elements, the results presented were somewhat similar to psychological subjective evaluations, but they also showed slight differences in different physiological measurements.

The SBP and DBP of the participants were significantly reduced with the soundscape elements with the exception of traffic stimuli in the rural and city environments, indicating that these soundscape elements caused the participants to feel relaxed and pleasant because the physiological indicator of blood pressure can to a certain extent reflect emotional changes in people's perceptions of the soundscape [41].

In contrast, after being stimulated by the traffic clip in the rural and city environments, the SBP and DBP of the participants significantly increased, indicating that the traffic clip might have caused people to feel a certain pressure and dysphoria. This finding was similar to the results of a previous study in which sounds of road traffic sources were more likely to be judged as annoying noise [42], and noise can induce an increase in blood pressure [43]. In addition, the participants' DBP was significantly higher following the traffic clip stimuli in the rural environment than in the city environment, also consistent with the psychological effect of traffic in the participants described above; that is, people were more sensitive to traffic in rural environment than in city environment.

The DBP of the participants significantly decreased after listening to the nature clip in the rural and city environments. This outcome shows that the natural soundscapes had a decreased effect on DBP in the rural and city environments.

After listening to light music, the blood pressure changes in the participants were more consistent between the rural and city environments. Whether in the city environment or the rural environment, the soundscape element of light music has a significant effect on reducing blood pressure and producing relaxation.

In the rural environment, the symphony soundscape element had no obvious effect on the SBP and DBP of the participants, but it significantly reduced the SBP and DBP of the participants in the city environment, indicating that the physiological effect of the symphony soundscape element on people in different environments was significantly different.

HR is a common physiological indicator for assessing the effect of soundscapes on physiology, and it is controlled by the vagus and sympathetic nerves through the intracardiac plexus. HR changes when people are nervous, anxious, irritable, or relaxed. Based on this study, after being stimulated by the nature clip, light music clip, and symphony clip, the HRs of the participants decreased to varying degrees, and the HR increased after stimulation with the traffic clip. Previous studies have revealed that exposure to sounds with positive connotations induced a decrease in HR, and exposure to sounds with negative connotations caused HR to increase under experimental settings [44,45]. The decrease in HR could indicate that the participants feel happy and relaxed; in contrast, increased HR could reflect that the participants feels irritable or physically stressed. Listening to natural soundscape elements in the rural environment caused the participants' HR to decrease most significantly, while the introduction of light music soundscape elements in the city environment resulted in the best HR reduction effect.

In addition, the nature clip, light music clip, and symphony clip had significant differences in the effect on HR in participants in different landscape environments; that is, nature clip exposure significantly reduced the participants' HRs in the rural environment and had no obvious effect on HR in the city environment. Listening to light music and symphonies led to a significant decrease in HR in both the rural and the city environments, but the extent of the decrease in the city environment was significantly greater than in the rural environment, while light music and symphony soundscape elements were more harmonious in the city environment. For traffic, it appears that the participants were upset, since HR increased in both rural and city environments.

Studies have usually used the ratio of alpha and beta waves to reflect the arousal of the brain or the response to fear or stimulation [46]. A higher ratio reflects more excitation, and a lower ratio indicates irritation or fear. In this study, the results of the β/α index presented a more significant physiological effect of soundscape elements. In the control condition, without soundscape element stimulation, the β/α index was significantly higher in the rural environment than in the city, indicating that the participants were more active in the rural environment.

After introducing the nature clip, light music clip, and symphony clip, the β/α index in the participants was significantly higher than in the control condition, indicating that the introduction of these soundscape elements in rural and city environments caused the participants to feel more pleasure and more activity. In addition, the comparison of the same soundscape element in rural and city environments showed that the nature clip caused people to feel better in the rural environment, and the light music clip and symphony clip caused people to feel better in the city environment. These results once again indicated that natural soundscape elements are more suitable to add to natural environments, while light music and symphony soundscape elements are more suitable to add to city environments.

In addition, the β/α index significantly decreased in the rural and city environments after the introduction of the traffic stimuli compared with the control condition, suggesting that the traffic clip caused the participants to feel bad and reduced brain activity. In addition, the results indicated that the participants in the rural environment were largely negatively affected by the traffic element and that the participants in the city were more tolerant of the traffic element, in consideration of the significant difference in the control conditions themselves, although the participants' β/α indices were not significantly different between the rural and the city environments after the traffic clip stimulation.

3.3 Gender Difference

It is well known that there are certain congenital differences in physiological indicators between men and women, e.g., men's resting HR is approximately 5–10 bpm lower than women's resting HR and men have higher blood pressure than women at the same age [38,47]. Our study results were also consistent with this fact; that is, in the control condition, without soundscapes, SBP in the men was significantly higher and DBP was slightly higher than in the women, and HR was lower in the men than in the women.

After being stimulated by four types of soundscape elements in the rural and city environments, regardless of what changes in blood pressure and HR appeared, the blood pressure in the men was generally higher and the HR lower than those values in the women. Men and women have some differences in HR changes caused by soundscape stimuli in the rural environment, while the HR responses in the city environment were roughly the same, with the exception of the symphony clip.

Interestingly, we found that the symphony clip in the city environment was a special soundscape element. The men preferred the symphonic soundscape element, especially when the symphonic soundscape element was in a city environment, and the men presented a more obvious preference and emotional response via their physical and psychological measures. The blood pressure of men and women was reversed with the symphony clip in the city environment, becoming slightly higher for the women than for the men after the symphony clip was presented in the city.

In addition, after stimulation with a symphony clip in the city environment, the HR of the women was significantly higher than that of the men, while the β/α index and preference score of the men were significantly higher than those of the women. The exceptional changes induced by the symphony clip in the city might indicate that symphony sounds in the city for the women represented a dissonant soundscape element or, in contrast, that the symphony sounds in the city were more pleasant for men. This outcome stems from the specific scene feelings of different genders; that is, the sense of rhythm, passion, and encouragement in the symphony were very suitable for the men's perception so that they can be more encouraged in the stressful environment of the city, while women were not, and their overall feelings of the symphony were not sensitive.

The EEG results reflected that the excitement of the women was slightly higher than that of the men in the rural environment, and the EEG results were similar in the city environment. The preference ratings in the control condition showed that the women's mean score was higher than the women's score in both the rural and city environments and that differences between the men and women were greater in the city (men's and women's scores in the rural environment were 1.40 and 1.20, respectively; in the city, the scores were 0.13 and –0.40, respectively). For the women, their preference for soundscape had more emotional colors than for the men in city squares [48]. This finding could indicate that women are more sensitive to the environment and have higher requirements for environmental perceptions and a greater need for more emotional resonance. In addition, this difference was even greater in the city, which might be due to the familiarity of the participants to city environments, and the stimulus of the soundscape in this environment was not strong for some individuals, which might be the reason why the soundscape in this experiment cannot bring the best psychological feeling.

The traffic clip, as a special soundscape element in this study, aroused a different response between the men and women after they were introduced to different environments. In particular, after undergoing traffic clip stimulation, the blood pressure of both men and women increased to almost the same level, but since the blood pressure of men and women in the control condition was originally different, it can be speculated that the effect of traffic soundscape elements on the blood pressure of men and women was somewhat different. This gender difference in blood pressure changes has two possible causes: men are relatively less affected by traffic soundscape element, and women are relatively more affected and vice versa.

Chang et al. [49] investigated the ambulatory blood pressure effects of a 5-dB(A) increase in noise exposure in 24 h in 30 men and 30 women using a portable automated monitoring and recording system, and they found that women were more sensitive and more susceptible to noise. Another study showed that there are some physiological differences in the hearing-related structures of male and female brains; that is, the female brain has better connectivity between the prefrontal cortex and the auditory cortex than the male brain [50]. Based on the previous studies above, we speculated that the women were relatively more affected by traffic soundscape elements and men were relatively less affected in actual rural and city environments in this study. An investigation of the sensitivity to landscape pollution conducted in Poland suggested that women were generally more sensitive to landscape pollution than men [51]. Noise pollution can also be a considerable factor affecting people's perceptions of the soundscape [52]; similarly, women might be more sensitive to noise pollution than men.

The environment of this study was located in two landscape environments that constituted the actual environment in which we live. It was different from the scenes often established in the laboratory in many soundscape studies, and the results that we obtained were somewhat different from what we expected earlier. Because the factors that affect people's psychology and physiology in the real world are diverse and complex and the human body itself is also a very sensitive machine, the response to emotional perception is also limited by scene perception and familiarity. This fact causes these experimental results to be different from those found in a controlled environment in a laboratory. In this study, the psychological perception and the physiological response of participants to soundscape elements were somewhat similar, but the results with the physiological indictors were more diverse. The experimental data also reflect that not every soundscape can cause emotional changes and resonance with each subject. One male participant did not even have an obvious physiological response to each soundscape element in the city, but the psychological preference in his questionnaire changed because familiarity with the scene leads to weakening of the stimulus after the introduction of the soundscape.

3.4 The Correlations Between Psychological and Physiological Effects

The above results show that the introduction of soundscape elements caused significant changes in preference scores and physiological indicators in this experiment. In addition, Pearson correlation analysis results showed that there were significant correlations between psychological scores and physiological indicators. The mechanisms of such correlations are not clearly stated in the literature.

Soundscape stimulation has two effects on people: sensory attributes and emotional content. The hair cells in the human cochlea receive soundscape stimulation and then produce nerve impulses to transmit to the brain, which then decomposes sound signals in different areas to produce different responses. The ascending auditory system responds to acoustic information itself, while the paralimbic system is evoked by emotional content [44]. The preference scores were the participants' subjective evaluations of soundscape elements, which show the "valence," one term for the emotional experience. In a particular environment, it has been postulated that valence depends on whether the soundscape elements are suitable or unsuitable [53], which might be why the responses to soundscape elements in rural and city environments were roughly the same but slightly different.

3.5 Limitations and Future Works

There are several limitations of the present study. First, the subject of this study was the psychophysiological effects of soundscapes, but the psychological indicator only uses subject preference scoring, which reflects participants' overall feelings regarding soundscape elements. In fact, there should be many subtle psychological changes in the participants' responses to the soundscape stimuli. In future works, we can improve by conducting more intensive study of various aspects of soundscape psychological effects, such as stress restoration. Next, the participants whom we recruited were young students of the same age, and the research object was relatively concentrated and targeted, but it also lacked representativeness. We will consider increasing the number and type of participants to enrich future studies.

Finally, this study was conducted in an actual outdoor environment. Although we tried our best to maintain a stable physical environment of the experiment site, some interference inevitably occurred during the experimental process, mainly caused by a few cars and pedestrians passing by occasionally. Although we concluded that this interference would not have a significant impact on the experimental results, there was no denying the existence of such an influence.

4 CONCLUSIONS

In modern society, people's stress continues to accumulate and increase. Pleasant soundscapes can relax people's emotions well, realize changes in psychological and physical levels, and achieve relaxation results. According to the results of this study, the physiopsychological effects of soundscapes were further proved in actual environments based on previous demonstrative laboratory literature; that is, introducing soundscape elements in rural and city environments leaves participants with a better perception than viewing landscapes without soundscapes. People's perceptions of the same soundscape element presented similar but somewhat different phenomena in rural and city environments. The soundscape elements of nature were welcoming, while soundscape elements of traffic were undesirable both in rural and city environments; the effects of musical soundscape elements varied according to the environment. Furthermore, men and women showed a generally similar perception of soundscapes, but introducing a symphony clip to the city environment was an exception, indicating that the perceptions of soundscapes between men and women are different in some cases. Thus, the EEG types of major participants should be considered to better integrate soundscapes with human perceptions and emotions.

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