24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

A SOUNDWALK STUDY WITH EEG TEST IN THE MOUNTAINOUS URBAN PARK

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As an important environmental element, the soundscape of urban parks might positively affect human comfort and well-being. In mountainous cities, the undulating terrain makes the soundscape more diversified in urban open spaces, such as parks. A typical mountainous park was selected in the urban districts of Chongqing, as the case study area. This paper aims to evaluate the physiological and psychological effects of the soundscape, considering the audio-visual interaction. The soundwalk approach was applied in the on-site investigation, through a series of acoustic measurement, EEG test, and questionnaire. The differences of relative EEG power index in the different audio-visual conditions were obvious relatively for α wave, but that were slight for β wave. For θ wave, the centre zone EEG power showed significant difference among three audio-visual conditions whether in the high-comfort or low-comfort environment, and the other emotion related brain zones (Fz, F3, and F4) also showed large changes. The restorative EEG rhythm would be produced in the high-comfort environment, which means in that environment relative EEG power index of α waves were the dominant in different encephalic regions, and the relative EEG power index of β waves were the lowest.

Keywords: soundscape, soundwalk, EEG, urban park

1. Introduction

The relationship of the urban park environment and human health benefit have reported a large number of positive explorations. The stress recovery theory (SRT) holds that visiting visually pleasant surroundings contributes towards reducing stress by restricting negative thoughts, eliciting positive emotions, and enhancing parasympathetic nervous system activity, as well as then putting forward the concept of ‘recovery garden’ [1, 2]. The changes of human emotion and consciousness might reflect on the physiological parameters. The psychological to restorativeness would relate to the EEG (Electroencephalogram), EMG (Electromyogram), and other physiological index [3]. The relaxation effects of pleasant music can be associated with the EEG power spectrum component changes, especially with the change in the total θ power and possibly with that in the α power in the occipital, and the frequency shift of the peak in the α-range [4]. The unpleasant sounds would lead to the larger startle reflexes, more corrugator EMG activity and larger heart rate deceleration than listening pleasant sound [5].

The on-site study of soundscape in urban parks ordinarily involves the methods of acoustic measurement and subjective evaluation. The soundwalks approach, as a fresh method for soundscape surveys, have been adopted in several urban parks [6, 7]. The evaluation of sound environment is not only related to the noise levels, but also the human multi-perceptual factors, especially the virtual factor [8]. Watts and Pheasant proposed that the tranquil environment would be achieved by the increasing of the natural elements in the visual landscape [9].

However, the traditional methods of environmental acoustic survey could not be appeased with the health benefits study of urban parks, and most of the previous soundwalk researches focused on the subjective or objective evaluations of the soundscape perception, but the human physiological response had be not taken in account. Therefore, this paper aims to evaluate the physiological and psychological effects of the soundscape through the soundwalk approach, considering the audio-visual interaction. The soundwalk observed the feature and change of EEG parameters of the subjects in two sampled sites of different comfort degrees, and in the three random conditions of the audio-visual, auditory-only and visual-only. Lastly, the effect of interaction between the soundscape and visual landscape to the users of the mountainous urban park was discussed.

2. Methods

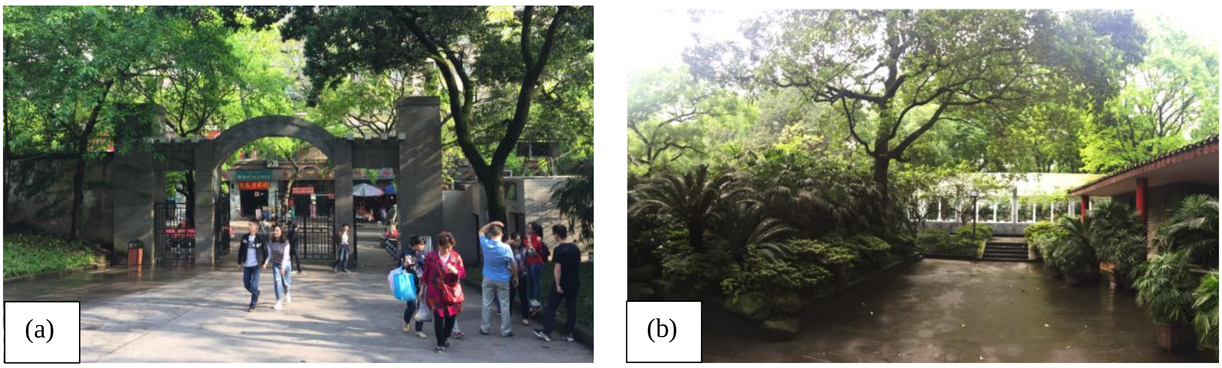
2.1 Case study park

62 parks in the 10 mail urban districts of Chongqing had the on-site survey, through the quantitative evaluation in 4 aspects, namely soundscape diversity index (SDI), visual landscape diversity index (VLDI), activity diversity index (ADI), and mountainous morphology diversity index. Afterwards, the urban park with the highest overall number of points, Eling Park was chosen as the case site for soundwalk, from October to December, 2016. Eling Park, old name courtesy garden, was the earliest private garden (1911) in Chongqing. After the expansion and renovation by the local government in 1958, the park zone had opened to the public. This park is located on the southern foot of Eling hill, covers an area of approximately 0.07 km^2 and the range of altitude are 334-380 m. The relative height difference between the lowest point (park entrance) and the highest point is 46 m.

2.2 Soundwalk approach

2.2.1 Sampled site

The Entrance Zone (S1) and the Flower Garden (S2) were selected as the sampled sites for the field soundwalk with EEG experiment based on the preliminary investigation. The five minutes environmental noise levels measured by I-type sound meter and corresponding sound recording using digital voice recorder. The sound marks and subjective evaluation of soundscape and visual landscape comfort degrees for the each sampled site were also recorded by the observers. The field photos for the sampled sites had took using digital camera, for the visual landscape and the activities of the crowd, as the shown in Fugue 1.



Fugue 1. Sampled sites in Eling Park, (a) S1, Entrance Zone, (b) S2, Flower Garden

Table 1 indicates the environment noise levels, the 9-scale perception parameters of soundscape and visual landscape comfort degrees, heights and the sound marks for the nine sampled sites. It can be seen that the lowest height receiver S1 expressed the highest noise level (L_{Aeq}=59.9 dBA), more than the guided values of relevant standard, and the L_{max} ranked 74.7 dBA which could be contributed by the traffic outside of the park entrance. Both of SCD and VCD of S1 and S2 showed significant difference ($p< 0.01$), as well as the audio-visual composite comfort degree ($p< 0.05$). Based on the audio-visual composite comfort degree (SCD+VCD), the S1 (7.9) and S2 (15.5) would be regarded as the low-comfort and high-comfort environment, respectively.

Table 1. Environment noise level and the 9-scale perception parameters of soundscape and visual landscape comfort degrees, VCD & SCD (uncomfortable to comfortable), as well as the sound marks.

No.	Heights (m)	Noise levels (dBA)			VCD	SCD	Sound marks
		L_{Aeq}	L_{max}	L_{min}			
S1	337	59.9	74.7	51.2	5.2	2.7	traffic, talking
S2	339	52.8	63.5	48.4	7.8	7.7	birdsong

2.2.2 Soundwalk with EEG experiment

Twelve college students (4 females and 4 males, aged 23 ± 1.8 years) with normal hearing, no body disease, right-handed (mean ± SD right hand dominance=90 ±15%) were selected as experimental subjects. Subjects were required no literacy and cognitive impairment, no psychiatric history, and no history of brain trauma. Before the experiment, subjects were not allowed to take any alcoholic drink or medicines which could influence on the EEG test. All the subjects were required to keep hair washed and drying in the experiment, which ensured good electrical conductivity between the electrode and the scalp, and improved the ratio of the signal-to-noise.

On the day of the experiment, the weather conditions during the investigation were stable, with light breeze, no rain and a temperature range of 25–28◦C. The subjects wore the B-Alert-X10 wireless EEG equipment for soundscape experience, with the continuous sampling of EEG parameters for 3 random conditions, including the audio-visual (AV), the auditory-only (AO), and the visual-only (VO), in the low-comfort (S1) and high-comfort environment (S2).

Table 2 shows the arrangement experimental process, it can be seen that an independent experiential process had six phases for individual subject in every receiver point. The condition with EEG test lasted 60 seconds, and the duration of restored time with questionnaire were 30 seconds. The location of B-Alert-X10 9-electrode adopts the international 10-20 lead positioning standard, as the figure 2 shown. The noise levels of each receiver point were also measured at the same time.

Table 2 EEG experimental process arrangement in each receiver point

Phase	Condition A	Restore A	Condition B	Restore B	Condition C	Restore C
Item	EEG	-	EEG	-	EEG	-
Time (s)	60	30	60	30	60	30

(a) (b) (c)

Figure 2. EEG electrode placement (a) Electrode position schematically, considering Fz, F3, F4, Cz, C3, C4, POz, P3, and P4 regions (b) Electrode installation instructions, (c) Field experiment.

2.2.3 Data recording and processing

The sampling rate of EEG signals were set as 256 Hz, the outdoor mode were selected as the experimental mode during the experiment. The recording software were used to record the real-time change of EEG. The B-Alert with AcqKnowledge software can remove the clutter automatically to reduce the interference caused by the outdoor experimental environment, and obtained cleaner EEG data. The real-time EEG data were accessed using AcqKnowledge at the end of the experiments. According to the experimental record and corresponding time, the stabile duration of EEG data for three states had been chosen to analyse the magnitude of power of α, β, θ wave bands of nine channels, based on the power spectral density (PSD), after removing the baseline drift, overflow, eye movements, and EMG interference in EEG. SPSS 19.0 software was adopted for the statistical analysis, in which the Double factor variance analysis was chosen for the difference of EEG data, Pearson correlation was used to analyse the correlated relationship among the visual landscape and categories of the soundwalking data.

3. Results and discussion

The change of particular emotional states would be related to the brain activity. EEG comprise with four types of brain wave: δ wave (1 to 3 Hz), θ wave (4 to 7 Hz), α wave (8 ~ 13 Hz) and β wave (14 to 30 Hz). If the θ wave is dominant, the human spirit would enter a deeply relaxed state with a better creativity. If the α wave ranked the dominant, the human brain would tent to clear, relaxed, hardly fatigued, and easily to concentrate on the work and ignore with the external interference, which is also the best brain state for studying and thinking of humans. If the β is dominant, the human physiology showed the conscious awareness and tension spirit, while the EEG rhythm of great majority adults are in this state. And when the β is dominant, human would be sensitive about surroundings, distractibility, and brain fatigue easily. The δ occurs during the deep sleep in general and the δ might be affected by EOG (Electro-Oculogram, 1 to 3 Hz) or/and ECG artefact (Electrocardiograph artefact, 1.2 Hz approximately), while α and β waves have distinguish at speed. In consideration of this research focus on the physiological and psychological effects of audio or visual factors in the park. The δ wave and the speed of waves would be not followed in this paper, consequently, the average EEG power of α, β and θ waves were selected as the evaluating indicators.

Figure 2 shows the EEG power change of α wave in different encephalic regions electrode placement for three audio and visual conditions. As the shown in Figure 2(a), in low-comfort environment, the relative EEG power index of AV were obviously lower than AO and VO, while the statistical difference ($p< 0.05$) had been raised between AO and AV, except the regions of C3 and C4. As the shown in Figure 2(a), in high-comfort environment, relative EEG power index of AO were the highest of three conditions, and some statistical differences ($p< 0.05$) had been revealed between AO and the other conditions. In particular, the audio-visual interaction could provide the positive awake and relaxed effect for EEG rhythm in the low-comfort environment with relatively poor acoustic and visual factors, but it could not provide the obvious positive effect for EEG rhythm in the high-comfort environment. That is to say, to improve one of acoustic and visual factors would potentially optimise the user's experience in the low-comfort environment.

Figure 3 shows the EEG power change of β wave in different encephalic regions electrode placement for three audio and visual conditions. As the shown in Figure 3(a), in low-comfort environment, the changes of relative EEG power index of β wave in AV, AO and VO were not notable, and no obvious change rules had been found in nine encephalic regions. As the shown in Figure 3(b), in high-comfort environment, the relative EEG power index of β wave in AV were higher slightly than AO and VO. In general, the EEG power change of β wave in different encephalic regions of electrode placement were relatively stable, and no significant had been revealed difference in 3 audio and visual conditions ($p> 0.05$). That is to say, the β wave, as the basic EEG rhythm in the waking state of adults, could be the main evaluation indexes for the EEG effect in the different comfort degree environments.

Figure 4 shows the EEG power change of θ wave in different encephalic regions electrode placement for three audio and visual conditions. As the shown in Figure 4(a), in low-comfort environment, most of the relative EEG power index in AO were higher slightly than AV and VO. As the shown in Figure 4(b), in the high-comfort environment, all of the relative EEG power index in AO were higher slightly than AV and VO, and the relative EEG power index of VO were the lowest in three conditions except the central zone (CZ). Overall, for θ wave, the EEG power changes were prominent in CZ in both of the low-comfort and high-comfort environment, the relationships between AO and VO, AV and VO reflected the significant differences ($p< 0.01$), as well as statistical difference ($p< 0.05$) between AO and AV. Besides, the EEG power changes in Fz, F3, and F4 were also relatively obvious.

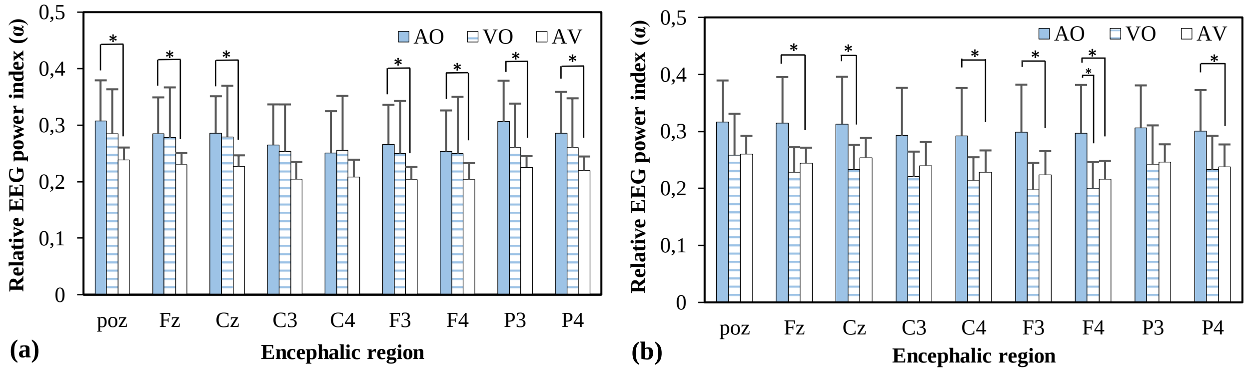


Figure 2. EEG power change of α wave in different encephalic regions electrode placement for 3 audio and visual conditions, (a) in Low-comfort environment, (b) in High-comfort environment.

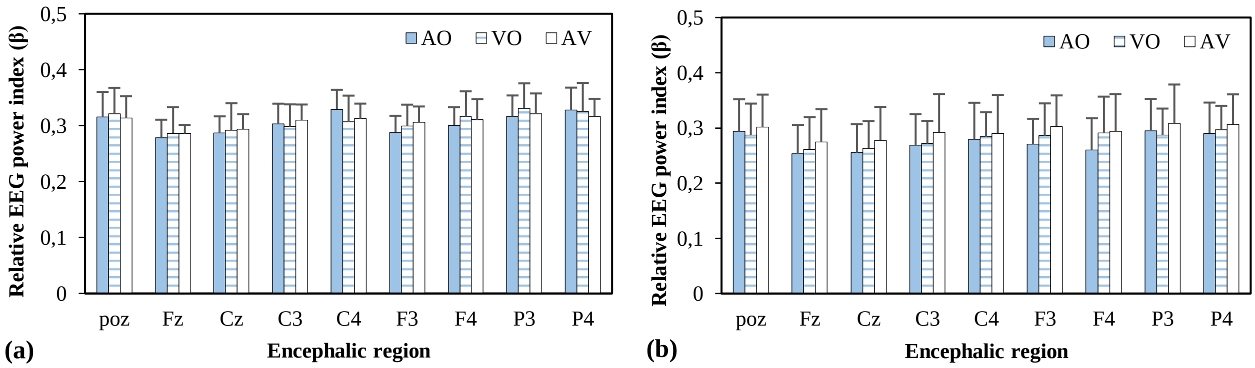


Figure 3. EEG power change of β wave in different encephalic regions electrode placement for 3 audio and visual conditions, (a) in Low-comfort environment, (b) in High-comfort environment.

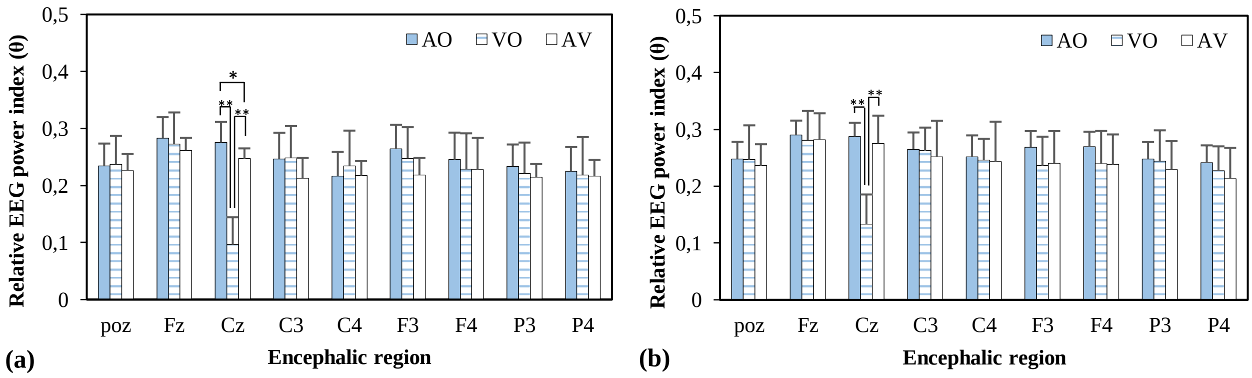


Figure 4. EEG power change of θ wave in different encephalic regions electrode placement for 3 audio and visual conditions, (a) in Low-comfort environment, (b) in High-comfort environment.

4. Conclusion

This paper investigated the soundscape in typical mountainous urban park, through the on-site soundwalk method including the acoustic measurement, subjective evaluation, and EEG experiment. As result, for α wave, the EEG power of audio-only condition in the high-comfort environment was significantly higher than the low-comfort environment as well. For β wave, the relative EEG power index were negatively related to the sound and visual comfort degrees. EEG power change of the temporal lobe zone of β wave were more notable than the other encephalic regions. Furthermore, the relative EEG power index of θ wave were positively related to the sound and visual comfort degrees. The centre zone (CZ), Fz, F3 and F4 of θ wave could be considered as the evaluating indicator of EEG emotion change in different comfort degrees environment.

Acknowledge

This research is grateful for the National Natural Science Foundation of China (51308562), the State Key Laboratory of Subtropical Building Science Open Foundation (2015ZB15), and the Chongqing University Postgraduates' Innovation Project.

REFERENCES

1 Ulrich, R. S. View through a Window May Influence Recovery from Surgery, *Science*, **224** (4647), 420-421, (1984).
2 Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A. and Zelson, M. Stress Recovery during Exposure to Natural and Urban Environments, *Journal of Environmental Psychology*, **11** (3), 201-230, (1991).
3 Chang, C. Y., Hammitt, W. E., Chen, P. K., Machnik, L. and Su, W. C. Psychophysiological responses and restorative values of natural environments in Taiwan, *Landscape and Urban Planning*, **85** (2), 79-84, (2008).
4 Kabuto, M., Kageyama, T. and Nitta, H. EEG power spectrum changes due to listening to pleasant music and their relation to relaxation effects, *Nihon eiseigaku zasshi. Japanese journal of hygiene*, **48** (4), 807-18, (1993).
5 Bradley, M. M. and Lang, P. J. Affective reactions to acoustic stimuli, *Psychophysiology*, **37** (2), 204-215, (2000).
6 Liu, J., Kang, J., Behm, H. and Luo, T. Effects of landscape on soundscape perception: Soundwalks in city parks, *Landscape and Urban Planning*, **123**, 30-40, (2014).
7 Evensen, K. H., Raanaas, R. K. and Fyhri, A. Soundscape and perceived suitability for recreation in an urban designated quiet zone, *Urban Forestry & Urban Greening*, **20**, 243-248, (2016).
8 Ruotolo, F., Maffei, L., Di Gabriele, M., Iachini, T., Masullo, M., Ruggiero, G. and Senese, V. P. Immersive virtual reality and environmental noise assessment: An innovative audio-visual approach, *Environmental Impact Assessment Review*, **41**, 10-20, (2013).
9 Watts, G. R. and Pheasant, R. J. Factors affecting tranquillity in the countryside, *Applied Acoustics*, **74** (9), 1094-1103, (2013).