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A good sound in the right place: Exploring the effects of auditory-visual combinations on aesthetic preference

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A R T I C L E I N F O

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A B S T R A C T

Although research on the effect of soundscape on preference has been growing rapidly in recent years, a detailed understanding of the aesthetic quality of interactions between key characteristics of the visual landscape and soundscape is poorly known. In order to explore the effects of auditory-visual combinations on aesthetic preference we conducted an experiment involving eight videos of urban green spaces in Xuzhou, eastern China were merged with five natural sounds (birdsongs of single and multiple species, wind sounds, a frog croak and running water sounds). The aesthetic preferences of these combined sounds and videos, as well as silent videos were evaluated by 379 college students using a seven-point Likert scale. The results suggested that: (1) generally speaking, birdsongs of a single or multiple species, wind sounds and running water sounds enhanced aesthetic enjoyment, while a frog croak decreased it; (2) introducing birdsongs and wind sounds to a place with diverse types of vegetation, and introducing running water sounds to a landscape possessing undulating topography and few aquatic plants were the effective ways to increase the effect of soundscape on aesthetic quality; (3) in general, if the visual association of a soundscape was congruent with the existing visual landscape, the combination was more likely to improving the aesthetic experience. These results provide valuable guidance and reference for urban planners, managers and landscape architects.

1. Introduction

Urban green spaces tend to be the most common places where residents are able to connect with nature and undertake various outdoor activities. These green spaces are defined as being both public and private open spaces in urban areas that are covered by vegetation (Haq, 2011). Such environments are considered to have a multitude of benefits for citizens, which include promotion of mental restoration and reducing health risk (Morita et al., 2007; Park et al., 2011; Wood et al., 2017), aspiring to the psychological needs of individuals and the sustainability requirements of a society (Chiesura, 2004), whilst also enhancing social contact (Kuo et al., 1998; Maas et al., 2006). In addition, the green spaces provide an enhanced opportunity for people to experience desirable and comforting sounds that can reduce negative noise pollution (Fang and Ling, 2003).

The significance of the urban green space is evidently important to wellbeing. However, the retention of such spaces and an ambition to develop further faces an array of on-going challenges. These include the availability of land, diverse and challenging financial constraints and other economic difficulties especially in densely populated regions. For example, it is becoming increasingly difficult to increase the amount of green spaces in crowded downtown areas. The focus therefore is often directed to a need to maximise the benefits of existing green spaces and to continually aim to improve their quality and ability to adequately respond to the wellbeing of citizens.

The quality of green spaces includes many aspects, with overall aesthetic quality being a central feature. A beautiful green space naturally invites residents to access it and in doing so can be beneficial to both their physical and psychological health (Velarde et al., 2007; Kurdoglu and Kurdoglu, 2010). A beautiful landscape can also be seen to increase the tourism potential of a city (Ewald, 2001). Additionally, aesthetic quality is linked to an ecological quality (Zhao et al., 2017a). Junker and Buchecker (2008) suggested that ecological project proposals in a city might fail due to its damage to the aesthetic quality of a landscape, which was likely to lose public support. As a result, aesthetic quality is considered as important as resources such as water, soil, mines and fossil fuels (Kane, 1981), and is a central issue of landscape design and management (Wang et al., 2016).

A literature review of studies associated to the landscape preference and aesthetic quality of visual perception conducted by Burton (2011)

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revealed that, in general, favoured landscapes were: natural, verdant, forested, traditionally cultural, half-open, and contain water, especially in landscapes containing strong, but not exclusively, natural components and where there is a variety in form. In contrast the landscapes that people did not subscribe to as positively include: urban or built, enclosed, industrial agricultural, or generally absent of natural elements. However, a visitor perceives landscape not merely as an isolated visual experience but rather as a multisensory encounter that embraces the visual, auditory, tactile and olfactory (Porteous, 1982; Schwarz, 2013), and it is the interactions between these senses which generates the essential influence on perception. For example, Pheasant et al. (2008) demonstrated the importance of visual stimuli in providing auditory context to a sound environment, and they further specified that perceived tranquility was not only linked to the maximum sound pressure level, but also the percentage of natural features that were presented at a particular location. In recent years, the combination of visual landscape and soundscape for improving the aesthetic experience of visitors has attracted extensive attention from academic research (e.g. Carles et al., 1999; Benfield et al., 2010; Lindquist et al., 2016; Liu et al., 2014; Ren and Kang, 2015). Liu et al. (2017) indicated that green spaces with a better soundscape quality could be more popular for the public. Furthermore Gan et al. (2013) suggested that landscape preference was affected much more by soundscape perception than visual perception.

Human's perception for soundscape is influenced by the features in the environment (Song et al., 2018). Liu et al. (2014) suggested that the aesthetic quality of a visual landscape could affect the overall soundscape perception to a large extent. Despite the fact that much literature explores the aesthetic preference of a combination of sound and setting, the classification of settings is very coarse, such as natural settings and urban (artificial) settings (Hedblom et al., 2014; Ren and Kang, 2015), and settings with low and high scenic quality (Benfield et al., 2010), only limited literature explores the aesthetic effect of fine-scaled interaction between a visual landscape and a soundscape (Carles et al., 1999; Liu et al., 2014; Ren and Kang, 2015; Viollon et al., 2002). For example, Liu et al. (2014) suggested that a percentage of buildings, vegetation and sky in panoramic views were effective landscape elements influencing soundscape perception.

The limited number of case studies fails to provide a systematic understanding on this issue, which perhaps does not provide a cohesive guideline for practical design. Thus it is necessary to generate more detailed information to truly understand which characteristic of landscape can connect most effectively with which specific sounds to continually improve aesthetic quality.

2. Aims and overall framework of the study

The main purpose of the present paper is to find reliable evidence to inform landscape architects how to use soundscape to improve the aesthetic quality of urban green spaces. To reach this goal we established quantitative models to describe the relationships between the subject's judgments on preferences of auditory-visual combinations and specific objective attributes of a landscape (Real et al., 2000; Daniel, 2001). The following research questions guided this study:

(1) Among the five natural sounds, which sound, in general, is better for improving the aesthetic quality of urban green spaces? This will help us to find good sounds.
(2) Which kind of sound combining what features a landscape possesses can produce a higher preference rating? This can inform the right place for a sound.

3. Methods

3.1. Visual landscape

In a real landscape, it is very difficult to control the background sounds. A video, compared to a photograph, is much closer to the experience of users in a real world. Thus, videos were used to represent visual landscapes. Eight sample sites of urban green spaces in Xuzhou, eastern China were selected to represent the diversity of visual landscapes. In each site, a video was taken at an eye-level that was approximately 1.55 m above the ground and where the atmospheric lighting conditions were regulated for example a clear day. The activities were conducted between 9am to 5 pm. To reduce seasonality bias, all the videos were taken in approximately the same season, in the late summer of 2017. The video camera was positioned horizontally to capture the principal characteristics of a scene, and was held sideways to target the green spaces beside a path to avoid the path factor and possible pedestrians in the videos. In the process of shooting, the same photographer, along the path normally used by visitors, moved at a normal walking speed and kept the camera stable to avoid jitter. After recording the video, several photographs were taken immediately using the same angle by the same photographer using an approach where an image was taken every few steps on the same path. There were purposefully overlaps between the scenes in any two adjacent photographs. In order to eliminate the effect of video length, the eight videos were clipped to a uniform length (85 s). Correspondingly, the photographs taken on a particular site were combined into a picture to represent the landscape in the clipped video as precisely as possible. Two examples of the pictures are shown in Fig. 1.

3.2. Soundscapes

Previous works suggested that natural sounds were positive for promoting the aesthetic experience of visitors (Benfield et al., 2010; Yang and Kang, 2005; Carles et al., 1999), which implies that natural sounds have the potential to be used in urban green spaces for

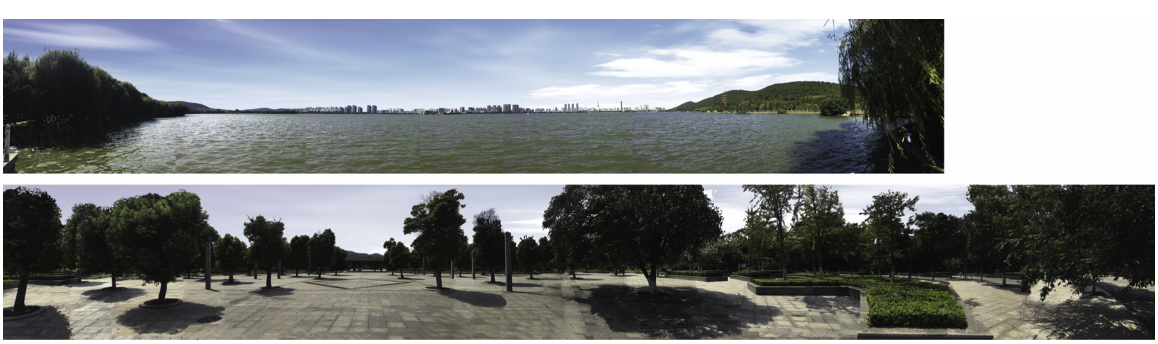

Fig. 1. Two sample pictures which represent the highest (top) and lowest (bottom) aesthetic quality under the salient conditions. The different lengths of the pictures are due to a slight difference in the walking speed of the photographer in different sites when the videos were photographed, and the different curvature of the path which the photographer goes along: bigger curvature leading to less landscape content in the clipped video and combined picture).

improving their aesthetic quality. Therefore, five natural sounds (birdsongs of single species, birdsongs of multiple species, wind sounds, a frog croak and running water sounds) were selected for our trials. These materials were downloaded from the Internet according to the criteria of clarity and high quality based on the authors' perception but with several versions, respectively. Three postgraduate students with normal hearing were invited to evaluate which version was the best to represent the corresponding sound, and the best versions were used.

The pairing of five sounds and eight videos was combined using Adobe Premiere software and resulted in 40 (8×5) sound-video combinations. These combinations were divided into five groups (A-E) according to the criterion of unrepeated videos within each group and one sound appearing no more than twice in a group. The eight silent videos were regarded as the sixth group (F).

3.3. Measurement of landscape preference of respondents

The aesthetic preferences of five groups (A-E) of sound-video combinations and the sixth group (F) of silent videos were assessed using a seven-point scale ranging from 1 (the scene is not at all beautiful) to 7 (the scene is very beautiful) in the manner suggested by Hands and Brown (2002). The mean score of all valid assessments was the preference rank of a stimulus.

Undergraduate students with self-reported normal eyesight and hearing, from a wide discipline background within China University of Mining and Technology (CUMT) were used as respondents for increasing efficiency and reducing costs.

We conducted the surveys in a classroom which could accommodate a maximum of 80 people in April 2018. The eight videos within a group were played on a 1.6×1.2 m white screen in a random order by a projector. Before the survey the participants were told: "imagine you are in the projected scene, please select a scale of preference according to your perception". After playing a video, the respondents had 15 s to evaluate their preference scale for the video. The respondents were encouraged to use the entire range of the rating scale.

HIVI (VA6-0S0) loud speakers were located in the four corners of the classroom. The sounds were produced by a computer and transmitted to the four speakers by data lines to create the atmosphere of surrounded sound in the classroom. The volumes of the five sounds attached the various videos were regulated to ensure that they could be heard comfortably and clearly from anywhere in the classroom by the five postgraduates with normal hearing prior to the survey being conducted to the undergraduate sample. The five postgraduates did not therefore participate in the actual preference surveys. The other five groups' presentations were followed one after another and were evaluated by different students to avoid a participant seeing the same video twice or more. The only difference in group F (the silent group) to the other groups was the obvious exclusion of sound. The number of respondents for A-F groups was (A) 68: male 30, 67 valid questionnaires; (B) 56: male 31, 49 valid; (C) 69: male 33, 63 valid; (D) 55: male 29, 52 valid; (E) 72: male 39, 65 valid; and (F) 59: male 32, 54 valid. The invalid questionnaires included two or more choices for preference scale or were uncompleted questionnaires.

3.4. Landscape characteristics evaluation

Fifteen landscape characteristics, which represented the main features of the landscapes studied in this research, were selected by analyzing the characteristics of these landscapes and referring to previous literature (Arriaza et al., 2004; Wang et al., 2016; Zhao et al., 2016) (see Table 1).

Five landscape architects (one teacher and four postgraduates majoring in landscape architecture from CUMT) were invited to evaluate the landscape characteristics. In an office room ($3.3\,m \times 4.2\,m = 13.86 m^2$) the eight combined pictures were independently projected onto a white wall in a non-bias order. The width of each picture on the wall is constant (about 0.6 m). The panel was asked to evaluate the 16 landscape characteristics of each picture according to the scales shown in Table 1. The next picture was not presented until all members of the panel had completed the landscape characteristic survey for a picture. The interclass reliability (Cronbach's Alpha was from 0.719 to 0.833) of landscape characteristics scores across the panel could be used with confidence according to the findings of Landis and Koch (1977) who indicated that if the Cronbach's Alpha was > 0.701, it was good. Thus, the average score of the panel was used as the score for each picture of a particular landscape characteristic.

3.5. Data analysis

The eight videos with the same sound were regrouped. At first, the interclass reliability of preference scores was tested using SPSS 17.0 software, and one-way ANOVA was conducted to explore the significance of the effect of each sound on preference. Then, correlation analysis and stepwise multiple linear regression analysis were performed to explore the driving force of landscape characteristics on the effect of soundscape on the aesthetic preference.

4. Results

4.1. Reliability

The interclass reliabilities of preference scores of A-F groups were calculated, respectively. Cronbach's Alpha was 0.739 (birdsongs of single species), 0.772 (birdsongs of multiple species), 0.692 (wind sounds), 0.764 (a frog croak), 0.719 (running water sounds), and 0.817 (silence). In general, the results showed acceptable internal reliabilities of aesthetic preference score for all groups.

4.2. Overall evaluation of aesthetic preference

The aesthetic preferences of auditory-visual combinations and silent videos were presented in Fig. 2. Based on the average scores, four of the five sounds (average score of birdsongs of single species = 5.653, birdsongs of multiple species = 5.980, wind sounds = 5.456, and running water sounds = 5.386) increased the preference of silent landscapes (average score of silence = 5.228), while a frog croak (average score = 4.720) decreased the preference. The one-way ANOVA showed that there was a closely significant difference of preference among the six groups ($F = 2.237$; $p = 0.068$), which implied that soundscape was a non-negligible factor for affecting the preference of landscapes. In addition, the different changes of preference scores of various landscapes with the same sound suggested that the effect of a sound on preference was dependent on visual landscape features.

4.3. Effects of auditory-visual combinations on aesthetic preference

A sound's effect on aesthetic preference was defined as the changes in preference caused by introducing a sound to a silent landscape. In this study, the effects of the five sounds on aesthetic preference were calculated using the following formula.

$$S_{ij} = N_{ij} - N_i$$

Where, S_{ij}: mean effect of jth sound on aesthetic preference of ith video; N_{ij}: mean aesthetic preference of ith video with jth sound within the respondents; and N_i: mean aesthetic preference of ith video without sound within the respondents.

The correlation analysis of landscape characteristics and the effects of the five sounds on preference indicated that the effects of birdsongs of single or multiple species on the aesthetic preference increased with type of land vegetation (Table 2). The effect of wind sounds increased with higher coverage of land vegetation and mixed land vegetation. The

Table 1
Measurement scale of landscape characteristics.

Landscape characteristics	Abbreviation	Scores
Number of landscape elements*	NLE	Only one = 0; two = 1; three = 2; four = 3
View scale	VS	Closed space = 0; slightly open space = 1; semi-open space = 2; open space = 3
Number of colors	NC	Only one = 0; two = 1; three = 2; four or more = 3
Percentage of land covered by vegetation	PLCV	No vegetation = 0; < 35% = 1; 36–70% = 2; 71–100% = 3
Type of land vegetation	TLV	No vegetation = 0; Grasses or(and) shrubs = 1; only trees or tree with grass = 2; mixed vegetation = 3
Configuration of land vegetation	CLV	No vegetation = 0; orderly configuration = 1; semi-natural configuration = 2; natural configuration = 3
Growth status of vegetation	GSV	No vegetation = 0; bad = 1; moderate = 2; good = 3
Perceived diversity of vegetation	PDV	No vegetation or single = 0; low = 1; moderate = 2; high = 3
Percentage of land covered by water	PLCW	No water = 0; < 35% = 1; 36–70% = 2; 71–100% = 3
Visual naturalness of water	VNW	No water = 0; orderly form = 1; semi-natural form = 2; natural form = 3
Accessibility of water	AW	No water = 0; difficult to access = 1; neutral to access = 2; easy to access = 3
Quality of water	QW	No water = 0; bad = 1; moderate = 2; good = 3
Aquatic plants on water	APW	No water or no aquatic plants = 0; a few = 1; more = 2; almost full cover = 3
Man-made elements	MME	None = 0; very little = 1; somewhat = 2; much = 3
Type of topography	TT	Almost flat = 0; Slightly undulating = 1; Much more undulating = 2, violently undulating = 3

* Landscape elements were divided into four categories: building, topographical variation, water body, and plants by referring the manner suggested by Zhao et al. (2013).

effect of a frog croak decreased with undulating topography, but the effect of flowing water sounds increased with undulating topography.

The correlation analysis just illustrates the relationship between the aesthetic preferences of sounds and individual landscape characteristic. It does not consider the multi-collinearity among the landscape characteristics. Multivariate regression analysis can solve this issue (Zhao et al., 2017b). The stepwise multiple linear regression analysis showed that type of land vegetation was the reliable predictor for the effects of two types of birdsongs and wind sounds on aesthetic preference; type of topography and aquatic plants on water were the two predictors for the effect of running water sounds (Table 3). No predicator was found for the effect of a frog croak.

5. Discussion

5.1. Influence of individual sound feature on perceived aesthetic quality

Although many previous works suggest that natural sounds can improve aesthetic quality (Ge et al., 2013; Kang and Zhang, 2010; Pilcher et al., 2009; Ren et al., 2018), the present study can only partially support them. It indicates that the different natural sounds have different impacts on perceived aesthetic quality. Comparatively, birdsongs of single or multiple species are much better than other three sounds used in the present study. This result replicates the findings of two previous studies, which indicate that the presence of birds is identified as important components of biodiversity (Fuller et al., 2007; Luck et al., 2011), especially for the presence of multiple bird species. High biodiversity environment has been evidenced to possess higher aesthetic quality (Gobster et al., 2007; Junge et al., 2015; Jiang et al., 2015; Folmer et al., 2016; Southon et al., 2017). However, a frog croak decreases aesthetic quality, which is possibly explained by three aspects. Firstly, a frog croak indicates a swamp-like environment. Despite the higher ecological functions of this environment, it is somewhat dangerous for human being. For example, a person accessing this environment may be trapped in mud, and some detrimental animals such as mosquitoes, leeches or snakes might hide in it. Secondly, a frog croak is so similar to a toad croak that the laymen can not identify them. Most people do not like toads and look on them as a threat because toads are poisonous. Thirdly, the frog croak that was used for this study is clear and intense, which implies that the listener is very close to frogs, intensifying the feeling of insecurity. Overall, a frog croak may imply an unsafe environment which indicates a lower preference rating (Appleton, 1975; Andrews and Gatersleben, 2010; Herzog and Kutzli, 2002).

The wind sounds make a moderate contribution to improving aesthetic quality. These results can be possibly explained by the fact that wind can blow off air pollutants, improving air quality. This is very important for urban areas in China where severe air pollution is common (Xie et al., 2018). Furthermore, wind can also promote the pollination of anemophilous plants, thereby increasing the food supply of the environment and, in turn improving landscape preference according to the habitat theory (Appleton, 1975).

The running water sounds also make a moderate improvement to landscape quality, because water is the essential source of all life in the world. Yamashita (2002) suggests that the landscape containing water is considered to be “peaceful”, “traditional”, “worth-preserving” and “preferable”.

5.2. Effect of soundscape on preference in relation to the features of visual landscape

This study suggests that different sounds have different influences on landscape preference. Correspondingly, we can say that one sound is better than others. However, a good sound also depends on the visual

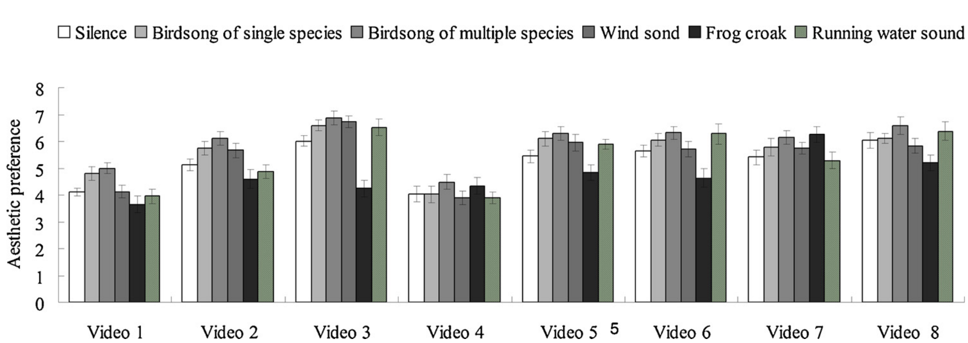

Fig. 2. Mean preference scores (± standard error) within respondents for 8 videos with sounds or silence.

Table 2
Correlations between the effects of five sounds on aesthetic preference and landscape characteristics (Spearman).

		NLE	VS	NC	PLCV	TLV	CLV	GSV	PDV	PLCW	VNW	AW	QW	APW	MME	TT
Effect of birdsongs of single species	Coefficient	−0.506	−0.473	−0.349	0.482	0.803*	−0.277	0.051	0.258	−0.514	−0.514	−0.504	−0.514	−0.483	0.000	−0.121
	Sig. (2-tailed)	0.201	0.237	0.396	0.227	0.016	0.506	0.904	0.538	0.192	0.192	0.203	0.192	0.225	1.000	0.775
Effect of birdsongs of multiple species	Coefficient	−0.349	−0.509	−0.133	0.398	0.840**	−0.374	0.217	0.295	−0.405	−0.405	−0.378	−0.405	−0.343	0.136	−0.230
	Sig. (2-tailed)	0.396	0.197	0.754	0.329	0.009	0.362	0.606	0.479	0.319	0.319	0.356	0.319	0.406	0.747	0.583
Effect of winds sound	Coefficient	−0.530	−0.800*	−0.554	0.807*	0.927**	−0.108	0.587	0.602	−0.436	−0.436	−0.378	−0.436	−0.312	0.027	0.158
	Sig. (2-tailed)	0.177	0.017	0.154	0.015	0.001	0.798	0.126	0.115	0.280	0.280	0.356	0.280	0.452	0.949	0.709
Effect of a frog croak	Coefficient	0.578	−0.061	0.542	−0.590	−0.198	−0.458	−0.281	0.123	0.171	0.171	0.252	0.171	0.327	−0.027	−0.764*
	Sig. (2-tailed)	0.133	0.887	0.165	0.123	0.639	0.254	0.500	0.772	0.685	0.685	0.547	0.685	0.429	0.949	0.027
Effect of running water sounds	Coefficient	−0.506	−0.158	−0.566	0.639	−0.025	0.651	0.153	0.049	0.016	0.016	0.000	0.016	−0.016	−0.464	0.861**
	Sig. (2-tailed)	0.201	0.709	0.143	0.088	0.954	0.081	0.717	0.908	0.971	0.971	1.000	0.971	0.971	0.247	0.006
NLE	Coefficient		0.239	0.909**	−0.780*	−0.463	0.201	0.071	0.205	0.773*	0.773*	0.765*	0.773*	0.741*	−0.014	−0.252
	Sig. (2-tailed)	.	0.568	0.002	0.022	0.248	0.633	0.867	0.626	0.024	0.024	0.027	0.024	0.035	0.974	0.548
VS	Coefficient			0.239	−0.663	−0.774*	−0.086	−0.533	−0.844**	0.040	0.040	−0.064	0.040	−0.167	0.486	−0.142
	Sig. (2-tailed)			0.568	0.073	0.024	0.840	0.174	0.008	0.926	0.926	0.880	0.926	0.693	0.222	0.737
NC	Coefficient				−0.750*	−0.431	0.195	−0.090	0.081	0.773*	0.773*	0.765*	0.773*	0.741*	−0.138	−0.245
	Sig. (2-tailed)				0.032	0.286	0.643	0.831	0.849	0.024	0.024	0.027	0.024	0.035	0.744	0.558
PLCV	Coefficient					0.669	0.226	0.317	0.342	−0.426	−0.426	−0.383	−0.426	−0.331	−0.248	0.571
	Sig. (2-tailed)					0.070	0.591	0.445	0.407	0.293	0.293	0.350	0.293	0.423	0.553	0.140
TLV	Coefficient						−0.225	0.523	0.611	−0.437	−0.437	−0.392	−0.437	−0.340	0.028	−0.025
	Sig. (2-tailed)						0.592	0.183	0.107	0.279	0.279	0.337	0.279	0.410	0.947	0.953
CLV	Coefficient							0.246	0.267	0.663	0.663	0.638	0.663	0.599	−.538	0.883**
	Sig. (2-tailed)							0.558	0.522	0.073	0.073	0.089	0.073	0.116	0.169	0.004
GSV	Coefficient								0.757*	0.268	0.268	0.270	0.268	0.268	−0.102	0.273
	Sig. (2-tailed)								0.030	0.522	0.522	0.517	0.522	0.522	0.809	0.513
PDV	Coefficient									0.321	0.321	0.390	0.321	0.450	−0.394	0.144
	Sig. (2-tailed)									0.438	0.438	0.340	0.438	0.263	0.334	0.734
PLCW	Coefficient										1.000**	0.990**	1.000**	0.959**	−0.518	0.286
	Sig. (2-tailed)										.	0.000	.	0.000	0.189	0.493
VNW	Coefficient											0.990**	1.000**	0.959**	−0.518	0.286
	Sig. (2-tailed)										.	0.000	.	0.000	0.189	0.493
AW	Coefficient												0.990**	0.990**	−0.577	0.257
	Sig. (2-tailed)												0.000	0.000	0.134	0.540
QW	Coefficient													0.959**	−0.518	0.286
	Sig. (2-tailed)													0.000	0.189	0.493
APW	Coefficient														−0.625	0.222
	Sig. (2-tailed)														0.098	0.597
MME	Coefficient															−0.417
	Sig. (2-tailed)															0.304

NLE: Number of landscape elements; VS: view scale; NC: number of colors; PLCV: percentage of land covered by vegetation; TLV: type of land vegetation; CLV: configuration of land vegetation; GSV: growth status of vegetation; PLCW: percentage of land covered by water; VNW: visual naturalness of water; AW: accessibility of water; APW: aquatic plants on water; MME: man-made elements; TT: type of topography.

* Significance at the 0.05 level.

** Significance at the 0.01 level.

Table 3
Significant predictors for the effects of five sounds on aesthetic preference, respectively, emerging from stepwise multiple linear regression analysis.

Dependent	Independent	Unstandardized Beta	Standardized Beta	T	Significance	Collinearity statistics	
						Tolerance	VIF
Effect of birdsongs of single species (*R^2 = 0.821; adjusted R^2 = 0.791*)	(constant)	−1.982		−4.304	0.005		
	Type of land vegetation	0.653	0.906	5.237	0.002	1.000	1.000
Effect of birdsongs of multiple species (*R^2 = 0.863; adjusted R^2 = 0.840*)	(constant)	−0.988		−3.475	0.013		
	Type of land vegetation	0.474	0.929	6.145	0.001	1.000	1.000
Effect of wind sounds (*R^2 = 0.800; adjusted R^2 = 0.767*)	(constant)	−2.916		−4.524	0.004		
	Type of land vegetation	0.856	0.894	4.899	0.003	1.000	1.000
Effect of running water sounds (*R^2 = 0.905; adjusted R^2 = 0.867*)	(constant)	−1.419		−5.110	0.004		
	Type of topography	0.753	1.005	6.851	0.001	0.886	1.129
	Aquatic plants on water	−0.313	−0.442	−3.014	0.030	0.886	1.129

features of an existing landscape (Fig. 2). Even a good sound can decrease aesthetic quality when it is introduced to the wrong place. For example, despite the general improvement for the aesthetic quality of urban green spaces, the birdsongs of single species slightly decreases the preference rating of video 4, which reminds us to pay careful attention not only to soundscape, but also in selecting an appropriate environment for the soundscape. The environment containing mixed vegetation (grasses, bushes, trees and climbing plants being together) is the appropriate visual landscape for the birdsongs and wind sounds. The mixed vegetation implies a high diversity of plant species, which provide various environments and plentiful food for bird survival.

Wind itself can not make a sound. It must interact with other objects for a sound. In urban green spaces the vegetation is the most common object, the mixed vegetation is much more likely to promote wind sounds. The sounds of running water imply the presence of flowing water in a landscape. In a natural condition, changeable terrain is the basis for producing flowing water, and running water often contains less aquatic plants than still water, since most aquatic plants can not tolerate fast running water. For example, the lotus, a very popular aquatic plant in urban green spaces, in eastern China, prefers to grow in still water rather than running water. Therefore, topography being a positive and aquatic plant, a negative predicator, for the effect of running water sounds on preference can make sense. These results are generally in line with the findings of Liu et al. (2017) who conclude that visual landscape containing elements that can produce natural sounds or minimize the opportunities to perceive the negative sounds would attract people with beautiful scenery.

From the experience of daily life or/and heredity, our hearing and vision are closely connected. Soundscape had a visual association, and visual landscape has an auditory association. When hearing a sound, listeners may be made aware of the presence of specific elements in the environment, and vice versa, which is similar with the concept of sound-expectation proposed by Ren and Kang (2016) who indicate that sound-expectation refers to the expectation of hearing particular sounds when facing the landscape, in particular sounds which are in harmony with the visual landscape. The results of the present study seem to claim that when the visual association of soundscape is consistent with existing visual landscape or the auditory association of visual landscape is consistent with the soundscape, the auditory-visual combinations will produce a higher preference rating. A similar result has also been found by a recent study (Lindquist et al., 2016) which concludes that sounds and visuals that are congruent receive a higher realism and preference rating, while the more incongruent the combination is, the lower the corresponding ratings.

5.3. Application for soundscape design

Soundscape planning emerges as a multidisciplinary way of thinking through the interweaving of landscape, sound, and experience (Prior, 2017). Similarly, soundscape design takes sounds, listeners and environment together to create a beautiful overall perception of the landscape (Song et al., 2018). The concept of Proposed Acoustic Environment developed by Brown and Muhar (2004) also indicates that the information content of a sound depends on a particular place and context.

For the practical design, there are two strategies: defensive strategy which aims to eliminate or control unwanted sounds, and offensive strategy which attempts to maintain, enhance or introduce wanted sounds to the appropriate environment (Cerwén, 2017). However, identifying wanted or unwanted sounds must be dependent on existing visual landscape. If we introduce a good sound to the wrong place, the sound may be unwanted. Therefore, this study indicates that understanding sounds' association with vision is the premise of soundscape design. After that, the aesthetic quality of a landscape can be improved by creating some factors to produce wanted sounds. For example, according to the results of this study, we can create habitats such as access to water, food and sheltering vegetation to attract birds (Forman, 2014) in the landscape possessing diverse types of vegetation; set up some wind sounding devices or choose species like poplar, bamboo and winter beech in the place with mixed vegetation, and build flowing waterscape to produce water sounds in the landscape with undulating terrain and less aquatic plants. Speakers are increasingly being used to emit the appropriate sounds in a specific environment to enhance the aesthetic experience of visitors (Cerwén, 2017). Alternatively, we can create a proper visual landscape according to the sound of the site. For example, planting mixed vegetation in a windy position (e.g. open fields, mounds and wind tunnels) is better to improve its landscape quality.

5.4. Limitations and future research

The undergraduate respondents used in our study are relatively demographically homogeneous. Although some researchers suggest that there is no significant difference in landscape preferences between undergraduate students and the general public (Yao et al., 2012), other works indicate that cultural background (Yu, 1995), education level (Molnarova et al., 2012; Svobodova et al., 2015; Wang and Zhao, 2017), gender (Lindemann-Matthies et al., 2010; Wang and Zhao, 2017), age (Yamashita, 2002; van den Berg and Koole, 2006), expertise (Strumse, 1996; Vouligny et al., 2009) and living environment (Van den Berg and Velk, 1998; Yu, 1995) have a significant influence on preference assessment. Soundscape preference is also closely related to the demographics (Liu et al., 2017; Ratcliffe et al., 2013). Strumse (1996) thus suggests that demographic group differences in landscape evaluation should not be neglected. Therefore, the research, which uses respondents from a wider demographic range, is needed for increasing the generalizability of the results.

Secondly, sound level has an essential effect on people's soundscape experience, and the soundscape experience has a threshold of sound level (Kang, 2011; Zhang et al., 2016). Examining the effects of sound level on aesthetic quality or exploring the threshold of sound level is never the aim of this study. Therefore, a study which includes the effect of sound level, especially for finding the threshold of sound level, is recommended in the future.

Thirdly, a real place commonly contains several sounds simultaneously such as nature sounds, sounds associated to human activities and mechanical sounds (Jeon and Hong, 2015). There are complex interactions between them, which is called auditory masking by Cerwén (2017). Auditory masking will cause a comprehensive influence on people's landscape experience. However, this study only considers the effect of isolated sound on landscape preference, weakening the practical values of our results. What is the effect of multiple sounds that are layered and coexist in one particular situation on the aesthetic preference? This is a difficult but interesting question to be answered in a future study.

At last, the videos and photographs used in this study are taken sideways to focus on the roadside greenery. However, it is unlikely that visitors are able to continually observe the roadside landscape when they are walking and therefore the imagery presented to the selected participants for evaluation are potentially different to the actual landscapes that might be experienced by a visitor, which could also influence the findings. The approach though is considered to be beneficial since it can focus on the specific elements being studied and intentionally avoids the distraction of any non-research features as far as is reasonably possible.

6. Conclusions

This study explores the effects of five natural sounds on landscape preference and the relationships between these effects and 16 visual landscape characteristics. The main results include that, in general, two types of birdsongs, wind sounds and running water sounds improve the aesthetic preference, but a frog croak decreases it. Introducing birdsongs and wind sounds to a place with diverse vegetation, and adding flowing water sounds to an environment possessing undulating terrain, with less aquatic plants, are the efficient ways to increase the effect of soundscape on aesthetic quality. Therefore, not only soundscape features but also the congruence of soundscape and visual landscape has an essential influence on preference. We can tentatively conclude that the matching degree of the visual association of soundscape and existing visual landscape is a key for soundscape design, which provides a valuable clue for urban planners, managers and landscape architects.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ufug.2019.05.018.

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