Effects of soundscape on rural landscape evaluations

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Abstract: The present study analyses the effects of soundscape on rural landscape evaluations, including landscape visual aesthetic quality (VAQ), landscape tranquility and landscape preference, based on audiovisual information collected in typical rural villages using the methods of an audiovisual experiment and eye-tracking test. First, the results showed the landscape evaluations influenced by different soundscapes are significantly different. Generally, the evaluation scores with natural or musical sounds were higher, and for positive landscapes, the difference among different sounds is greater than that for negative landscapes. Moreover, the landscape evaluations could be enhanced by sound stimuli, including natural or artificial soundscapes and for both positive and negative landscapes. Third, soundscapes can also modulate the effects of landscape elements on landscape evaluations. No-vegetation ground, vegetation, mountains, the sky, and water were found to be significant landscape elements that influence landscape evaluations with sound stimuli, and in particular, the landscape evaluations could be substantially decreased by particular disturbing elements together with artificial sounds.

Keywords: Soundscape; rural landscape; sound; landscape VAQ; landscape tranquility; landscape preference; landscape element

1. Introduction

In recent years, the number of people visiting their local countryside has been increasing. One of the major reasons is that the rural soundscape is considered a more restorative and tranquil environment, providing relief from cognitive overload and reducing the stress of everyday life, as man-made noise is at a low level, while the dominance of natural sounds promotes the rural landscape's sense of tranquility (Lam et al., 2010; Pheasant et al., 2010; Watts and Pheasant, 2013; Watts and Pheasant, 2015a; Watts and Pheasant, 2015b; Filipan et al., 2017). Aside from tranquility, most previous studies on rural areas have focused on visual aspects, without considering non-visual cues (Arriaza et al., 2004). The assessment has been carried out with respect to certain assumptions or design criteria that are relevant to visual landscape quality. Some perception-based studies found that vegetation, water, well-preserved man-made elements, and traditional, rather than more uniform, modern farming landscapes have been found to improve the aesthetic assessments of rural landscapes considerably (Vos and Meekes, 1999; Dramstad et al., 2006; Howley, 2011). Within rural settlements, traditional architecture (Kalivoda et al., 2010) and family houses (Sullivan, 1994) are appreciated. Moreover, certain landscape elements, such as the presence of woodlots, plants, water, and mountains are found to be preferred, while abandoned farmlands and landscapes crossed by rural roads produce negative perceptions (Arriaza et al., 2004; Benjamin, 2007; Howley, 2011). Lower preference is also given to the landscapes with wires, automobiles, and other disturbing elements (Stamps, 1994).

The existing studies indicate that the rural soundscape is not statistically related to common

acoustical and psychoacoustical metrics, but has higher correlations with the absence or presence of wanted and unwanted sounds (Lam et al., 2010). Along the urban–rural gradient, landscape preference is affected much more by soundscape perception than visual landscape perception (Gan et al., 2013). During the evaluation of rural landscapes, the visual attention areas were significantly influenced by the soundscape from those without sound stimuli (Ren and Kang, 2015a). However, few previous studies have investigated auditory perception in the environmental assessment of rural areas.

In the above studies, the evaluations of rural landscapes can be approached in different ways, using evaluation indexes including the visual aesthetic quality (VAQ), landscape tranquility, or landscape preference. While the importance of the effects of different soundscapes on the evaluation of rural landscapes has been suggested and incorporating the valuable perspectives that have evolved in environmental assessment directly into the project design has been encouraged (Botteldooren et al., 2006; Brown and McDonald, 1995; Wang and Bao, 2007; Lee et al., 2014; Oberman et al., 2016), there is still a lack of systematic studies in this respect.

The aim of this study is, therefore, to examine in greater depth the effects of soundscapes on rural landscape evaluations in terms of landscape VAQ, landscape tranquility, and landscape preference indicators. This study also aims to identify the specific contribution of a soundscape to the rural landscape with different landscape characteristics for effective environmental assessment, soundscape conservation, and landscape design. The research was conducted using both audiovisual experiments and eye-tracking tests based on landscape field images and sounds collected from typical villages in China. A range of rural landscape types are considered, including distant views, farmlands, waterscapes, roads, and family houses.

2. Methodology

2.1 Study area

Traditional villages in China were chosen as the study area for field surveys in terms of visualization and auralization, covering typical villages in Heilongjiang, Jilin, and Liaoning provinces, located in the northeast plain, the largest of China's plains, between the greater and lesser Hinggan ranges and the Changbai ranges. The study was not intended to examine the rural landscapes of specific sites; rather, typical actual rural areas centered by human settlements are used, with natural landscapes as a background (Wang and Liu, 2003). The villages are rather dispersed in this area, and the rural landscapes in the villages contain elements of irregular farmlands, waters, and mountains. The rural family houses are usually distant from the courtyards, and some are surrounded by farmlands (Wang and Liu, 2003; Wang, 2003; Shen, 2010).

In this study, rural landscapes including natural and man-made elements were considered. The selection is based on three aspects: typical types of rural landscape (Xie et al., 2003; Xie, 2004), landscape visual attributes, such as openness (Strumse, 1994), naturalness (Ode et al., 2009), and possession of traditional architecture (Kalivoda et al., 2010) and rural characteristics. Consequently, five landscape types were considered: distant views, farmlands, waterscapes, roads, and family houses.

2.2 Images

Perception-based evaluation studies, to a large extent, have used landscape photographs as

valid landscape surrogates for actual landscape judgments (Shuttleworth, 1980; Kaltenborn and Bjerke, 2002), although it could be argued that photographs, as a mechanism to ascertain visual preferences, limit generalizability into real-world settings. Nevertheless, a variety of studies have pointed out that carefully selecting landscape scenes for evaluation by the general public yields valid and reliable results, which are also widely used for rural landscape evaluation (Arriaza et al., 2004; Benjamin et al., 2007; Ramírez et al., 2011; Howley, 2011; Yao et al. 2012; Watts and Pheasant, 2013; Cloquell-Ballester et al., 2012; Jiang et al. 2015). To reproduce a more realistic visual landscape, in this study, the photographs were taken in a 3D format (Lindquist et al., 2016) using a Fuji 3D W3 camera. These stereoscopic images were taken at eye-level, at a height of approximately 1.5 m above the ground, with typical angles and panoramic color for landscape photographs (Rogge et al., 2007; Pheasant et al., 2010). To reduce seasonality bias, all of the images were taken in approximately the same season, in the late spring and summer, and on clear days to control for lighting conditions and avoid telephoto shots (Buhyoff and Wellman, 1979; Natori and Chenoweth, 2008).

There are many indicators of landscape visual character (Ode et al., 2009), in which the percentage of natural or contextual features in the scene was found to be of significance for the evaluations of the landscape VAQ, tranquility, and preference (Arriaza et al., 2004; Watts and Pheasant, 2013; Rogge et al., 2007; Ramírez et al., 2011; Yao et al., 2012). For this reason, five images of each landscape type were selected and ordered according to the coverage of contextual features, including natural or artificial elements in the landscape, as shown in Table 1. This was done to eliminate the effects of the proximity of attributes on the evaluation, and to ensure the diversity of scenes in each landscape type.

2.3 Sound signals

During field surveys in villages, a series of typical sounds heard frequently were recorded, with two types of sound for each landscape type, one natural or musical, and the other artificial. According to previous studies (Murphy et al., 2009; Lam et al., 2010; Ren et al., 2015), these were possibly wanted and unwanted sounds, respectively. The recorded sounds included birdsong (A) and highway traffic sounds (B) for the distant view, crickets chirping (C) and tractor sounds (D) for farmlands, water flowing (E) and hawker selling sounds (F) for waterscapes, music (G) and road traffic sounds (H) for roads, and rooster crowing (I) and house repair sounds (J) for family houses.

The sound recordings were made using a FOSTEX FR-2LE high-fidelity audio recorder. The highway traffic and country road traffic sounds were recorded 1 m away from the road edge, 1.5 m away from the ground, and more than 3.5 m away from any other reflectors with wind speeds was less than 5 m/s (GB 3096-2008, 2008). The other sounds were made at positions close to the sound sources, with no other sounds interfering. The ten recorded sounds (A–J) were edited as ten sound signals, respectively, and were all adjusted to 50 dBA. The sound level was selected for the audio data for two reasons: (1) with a lower noise level, the mean SPL of the field measurements in relatively quiet rural environments was approximately at this level, with the sound identifiable, and (2) this study was focused on the types of sound, rather than the sound level (Hong and Jeon, 2013; Hao et al., 2016), and an acceptable and identical level can make the sound sources comparable.

2.4 Subjects and experimental settings

Previous studies (Weinstein, 1978; Taylor, 1984; Ma, 2004; Yang and Kang, 2005; Lavia et al., 2016) suggested that there are no significant differences in the subjective evaluation of sound levels among different age groups, while the audio sensitivity of adults could decrease gradually with the increase of age. Therefore, young people with high auditory sensitivity were selected as the subjects for the evaluation experiments. The subjects (urban dwellers) were randomly sampled students from Harbin, including ten males and ten females. A sample size of 20 was used according to acoustic experiments (Kang, 2004; Hong and Jeon, 2013), visual landscape evaluation (Daniel, 2001; Cloquell-Ballester et al., 2012), and eye tracking tests (Dupont et al., 2014; Hessels et al., 2016; Ren and Kang, 2015b).

The experiments were conducted in a virtual reality laboratory. For the visual-only evaluation, polarized 3D glasses and 3D display were used. The effects of the 3D images were adjusted using Stereo Photo Maker software. For the audiovisual experience, Sennheiser RS 170 headphones and Tobii T60XL were used. The sound signals were calibrated using a dummy head and 01 dB software, and were edited using Cooledit software.

2.5 Evaluation indicators

For the landscape VAQ evaluation, “ugly” and “beautiful” were thought to be the primary and prototypical descriptive dimensions used to address the aesthetics, and were expected to be influenced by the subjects. In this study, two terms, leading to a judgment within the basic categories of artistic aesthetics, were chosen to represent the two ends of a VAQ evaluation, and they were thus expressed on a seven-point Likert scale (Stich, 2005; Jacobsen et al., 2004; Val et al., 2006; Kalivoda et al., 2010), valued from -3 to +3, encompassing extreme values of “very ugly” and “very beautiful”, namely: -3, very ugly; -2, ugly; -1, somewhat ugly; 0, neither ugly nor beautiful; +1, somewhat beautiful; +2, beautiful; and +3, very beautiful. Correspondingly, landscape tranquility evaluation was also carried out with a seven-point scale from -3 to +3 (Mace et al., 2012; Watts and Pheasant, 2015a; Watts and Pheasant, 2015b). In terms of landscape preference, corresponding to previous studies (Rogge et al., 2007; Natori and Chenoweth, 2008; Soini et al., 2012; Meng et al., 2017), a five-point Likert scale was used to clarify judgments, with descriptions of “like” and “dislike”: 1, really dislike; 2, dislike; 3, neither like nor dislike; 4, like; and 5, really like. The evaluation indicators in the questionnaire and the instruction were all administered in the subjects’ familiar language, Chinese, to speed up the processing of audiovisual perception (Navarra et al., 2010).

2.6 Experimental procedure

In the experiment, the landscape evaluations were recorded according to the audiovisual clips. In previous studies, 30–32-s durations were used for audio only, video only, and combined audiovisual data, and 16 s were used for the remaining stationary clips (Pheasant et al., 2010; Watts and Pheasant, 2015a; Watts and Pheasant, 2015b); the short 8-s duration for sounds tended to repeat, and a 6-s duration for single sounds was also used (Bradley and Lang, 2000; Hall et al., 2013). In this study, the visual images were stationary scenes, and the audio signals were all dominantly single sounds, which were easy to identify. Hence, each clip was relatively short, edited to a duration of 10 s.

The experiments consisted of two parts, as given in Table 2. The first was the visual-only condition. The subjects were instructed to imagine being present in the landscapes shown by the

3D screen and were asked to observe the 25 3D images (as shown in Table 1) in a random order, at a position of 1 m away from the display. Meanwhile, the evaluation for landscape VAQ was made with the instruction, “Please evaluate the landscape presented on the screen according to aesthetic quality on the questionnaire.” Then, the subjects were asked to view the scenes randomly again in the same way, and a landscape tranquility evaluation was made. The following instruction was used: “Please evaluate the landscape presented on the screen according to tranquility on the questionnaire.” Afterward, the subjects were asked to rank the 5 landscapes (photo scenes) of each landscape type purely on the basis of preference from “really like” to “really dislike” (ranked position from 1st to 5th) based on high-quality (150 mm × 300 mm) photographic prints. The second part was the combined audiovisual condition. After becoming familiar with the Tobii T60XL, the subjects were tested for personal eye flexibility. Then, the qualified subjects (all 20) were asked to experience the audiovisual clips, where each image was coupled with two sound signals (natural or musical sound, and artificial sound) (as shown in Table 1 with dotted lines) in a random order, followed by a five-second break (Pheasant et al., 2010) between every image. Meanwhile, the landscape VAQ evaluation was made. The audiovisual clips were also presented again randomly in the same way, and the landscape tranquility was evaluated. During this part, the eye test was made automatically. At the end, the subjects with impressions during the audiovisual experiment were also asked to judge the preference on a landscape preference scale based on photographic prints (high-quality, 150 mm × 300 mm) with corresponding names of sound sources. The landscape evaluations were emphasized as a perception for scenery, from the perspective of visitor, and not for a dwelling.

3. Results

According to the results of visual-only and audiovisual experiments, this section presents the effects of soundscape on landscape VAQ, tranquility, and preference in terms of positive and negative landscapes considering five rural landscape types. Before processing the data sets, the inter-rater reliability and intra-group reliability of the 20 subjects in each evaluation dimension were calculated, showing an inter-rater reliability of 0.87–0.93 (Cronbach’s alpha) and intra-group reliability of 0.76–0.91 (intra-class correlation for average measures), which are consistent with the requirements (>0.70) and hence can be used with confidence (Rogge et al., 2007; Liu et al., 2013).

3.1 Rural landscape evaluations without sound stimuli

The landscape VAQ and tranquility without sound stimuli are presented first in Table 3, considering five landscape types. It can be seen that the evaluations vary considerably, from higher than “somewhat beautiful” (mean value = 1.02) to close to “somewhat ugly” (-0.52) in VAQ, and from the highest score (1.42) evaluated as higher than “somewhat tranquil” to the score (-0.31) evaluated as lower than “neither tranquil nor non-tranquil” in landscape tranquility. Similarly, the farmland and road landscapes are found at the two ends of the evaluations. To identify the significant influence of landscape diversity, the evaluation variance is examined through one-way analysis. The results show that there are significant differences among the five landscape types ($p = 0.000 < 0.01$) for both VAQ and tranquility.

Correspondingly, the results of landscape preference with the calculated percentage of the ranked position by the subjects are presented in Fig. 1. It can be seen that although the ranked

positions were occupied differently between subjects, D1, F1, W1, R1 and C1 (Group I) were mostly perceived as “really like,” with landscape preferences of 48%, 44%, 52%, 76%, and 52% for the first ranked positions, respectively. In contrast, the images in Group V containing the highest percentages of man-made elements were always ranked last, with fifth positions of 68% (D5) for distant view, 64% (W5) for waterscapes, 64% (R5) for roads and up to 80% (C5) for family houses. Furthermore, the 25 scenes were also scored according to their ranked positions, with a value of 5 being attributed to the first ranked position and decreasing values awarded to the remaining 4 positions. The results of landscape preferences based on the ranked positions were analyzed in Table 4. It can be seen that with the highest score of 4.29 for the landscapes in Group I and the lowest score of 1.71 for the landscapes in Group V, the standard deviations of the evaluations in the two groups (0.25 and 0.44) are low. In terms of the evaluation variance, a significant difference was observed ($p = 0.000 < 0.01$) among the five landscape groups. These suggest that the subjects’ preferences were relatively consistent in the ten scenes of Group I and V with the approximate judgement of “like” and “dislike,” respectively. Therefore, Group I (D1, F1, W1, R1, C1) and Group V (D5, F5, W5, R5, C5) (as shown in Table 1 with dotted lines) are selected to present the two ends of the spectrum for landscapes in this study: positive landscapes and negative landscapes.

3.2 Effects of soundscape on landscape VAQ

Figure 2 shows the evaluation scores in landscape VAQ under the effects of different soundscapes for each landscape type. The scores of positive and negative landscapes without sound stimuli are also shown. For positive landscapes, under the effects of natural or musical soundscapes, such as birdsong, crickets chirping, water flowing, rooster crowing, and music, respectively, the landscape VAQ score fluctuated between 0.00 and 1.80, whereas with the artificial sounds of highway traffic, tractors working, hawkers selling, house repair, and road traffic, the evaluation score decreased to -1.25–0.95. In particular, for the positive landscape of waterscapes in Fig. 2c, the evaluation score was considerably decreased (by 3.05), with a judgment of close to “beautiful” dropping to lower than “somewhat ugly,” under the effects of the artificial soundscape. Generally speaking, the landscape VAQ scores for negative landscapes are lower than those for positive landscapes. The evaluations for negative landscapes decreased from 1.40, 0.05, -1.20, and -1.1 for distant view, farmlands, roads, and waterscapes, respectively, with natural or musical sounds, to 0.00, -0.65, -2.00 and -1.55, respectively, with the artificial soundscape. However, the artificial soundscape can also increase the evaluation of negative landscapes as a natural or musical soundscape does. Figure 2(e) shows that the score for the negative family houses landscape is increased to -0.05 with the artificial sound from that with the natural sound (-1.1), which is even higher than that without sound stimuli. This is possibly due to the matching phenomenon of audiovisual information (Ren and Kang, 2015b), where the untidy family houses scene moderated the uncomfortable audio perception of the artificial sound (house repair sound).

As an overall result, Fig. 2(f) compares the evaluations influenced by the two types of soundscapes. The results show that the natural or musical soundscape increases the evaluation scores of distant views, farmlands, waterscapes, and road landscapes by 1.06, on average, compared to those with the artificial sounds. To examine whether the soundscape has a significant effect on landscape evaluation, the significance levels between the evaluation scores

influenced by the two types of soundscapes for positive and negative landscapes are analyzed using a t-test of paired samples. The results show that there is a significant difference, and the significance level for positive landscapes ($p = 0.000$) is stronger than that for negative landscapes ($p = 0.020$). This indicates that the VAQ evaluations for positive landscapes are more likely to be influenced by the different soundscapes. In general, under the effects of the natural or musical soundscape, compared to the artificial soundscape, the mean score of the positive landscapes is increased by 1.24, whereas that of the negative landscapes is increased only by 0.46.

3.3 Effects of soundscape on landscape tranquility

In Fig. 3, the evaluation scores of landscape tranquility under the effects of different soundscapes are compared. From Fig. 3(a) to 3(e), it can be seen that the natural or musical soundscape substantially increases the evaluation score of positive landscapes of each landscape type by between 1.25 and 3.45 from the scores with artificial sounds. In particular, for farmlands, waterscapes, and family houses, the evaluation scores with natural sounds are even higher than those without sound stimuli, and are perceived to be close to “very tranquil” (2.65), higher than “somewhat tranquil” (2.2), and close to “somewhat tranquil” (1.6), respectively. Thus more tranquility is perceived for these positive landscapes with natural sounds than without. Similarly, for the negative landscapes of each landscape type, the score is also substantially increased by the natural or musical soundscape by between 0.95, for road landscapes in Fig. 3(d), and 3.05, for farmlands in Fig. 3(b) and waterscapes in Fig. 3(c). Further, the landscape tranquility evaluations for negative landscapes with natural or musical sounds are observed to be higher than those without sound stimuli in each landscape type, by 1.39, on average. Figure 3(a) even shows that the artificial soundscape also increases the evaluation for negative distant-view landscapes by 0.20 compared to that without sound stimuli. This result is similar to that in Fig. 2(a), as the VAQ score of the negative landscape for distant view is also increased by the artificial soundscape. Interestingly, this phenomenon is also seen in Fig. 3(e) for the positive landscape of family houses. In other words, for certain rural landscapes, a soundscape with either natural or artificial sound can increase the landscape evaluation compared to that without any sound stimuli.

In general, Fig. 3(f) shows that the evaluation scores with natural or musical sounds are higher than those with artificial sounds by an average of 2.41. The difference between the scores influenced by the two types of soundscapes are examined to be significant for both positive and negative landscapes ($p = 0.000$) based on t-tests of paired samples. In comparing the evaluation scores with the artificial sounds, the evaluations influenced by the natural or musical soundscape are higher by 2.58 and 2.24, evaluated as close to “tranquil” and “somewhat tranquil” for positive and negative landscapes, respectively.

3.4 Effects of soundscape on landscape preference

In Fig. 4, the evaluations of landscape preference influenced by the natural or musical and artificial soundscape are shown. From Fig. 4(a)–4(e), it can be seen that for positive landscapes, the natural or musical soundscape considerably increases the evaluation scores of each landscape type with artificial sounds; the scores increased from 2.4 (higher than “dislike”) to 4.51 (close to “really like”), on average, and the scores with the natural sounds for distant view, farmland, waterscapes, and family houses are also evaluated higher than those without by 0.50. However,

for road landscapes, as shown in Fig. 4(d), neither the musical nor road traffic soundscape can increase the score beyond that without sound stimuli. Correspondingly, for the negative landscapes, the evaluation scores are also substantially increased by the natural or musical soundscape; the scores were 2.07 (“dislike”) with artificial sounds, and 3.36 (higher than “neither like nor dislike”) with natural or musical sounds, on average. Interestingly, similar to the results in Fig. 2(a) and Fig. 3(a), in Fig. 4(a), (d), and (e), the soundscape with different artificial sounds increased the evaluation scores without sound stimuli for negative landscapes by 0.64 on average. Therefore, the negative landscapes are better with sound stimuli than without.

In summary, Fig. 4(f) shows that for each landscape type, the evaluation scores with natural or musical sounds are higher than those with artificial sounds (by 1.70; the judgment changes from “dislike” to “like”). Similarly, to landscape VAQ and tranquility, a significant difference ($p = 0.000$) is observed in the landscape preference evaluation between the two types of soundscapes for both positive and negative landscapes. Under the effects of the natural or musical soundscape, the positive landscapes increased more than the negative landscapes. The evaluation scores are increased from a judgment of “dislike” (2.07–2.40) with the artificial sounds, to close to “really like” (4.51) and to higher than “neither like nor dislike” (3.36), for positive and negative landscapes, respectively, by the natural or musical soundscape.

3.5 Effects of landscape elements on landscape evaluations

The above results reveal that the evaluations of landscape VAQ, tranquility, and preference for rural landscapes are significantly influenced by soundscapes in terms of the difference between evaluations with and without sound stimuli, and evaluations with different sounds, for both positive and negative landscapes. However, the evaluations may also be related with visual landscape elements, as shown in the analyses in Section 3.1 and the results in a number of previous studies (Arriaza et al., 2004; Benjamin, 2007; Ramírez et al., 2011; Yao et al., 2012; Kalivoda et al., 2014) on landscape evaluations without sound stimuli. In this section, the contribution of landscape characteristics with various landscape elements to landscape evaluations with and without sound stimuli are both examined through stepwise linear regression analysis.

Based on the method in Section 2.2, the landscape elements in each of the ten scenes were categorized as water, vegetation, no-vegetation ground (including moving vehicles, people, etc., on roads, and bare ground without vegetation cover), buildings and facilities, mountain, and sky. The stepwise regression was therefore conducted by defining the landscape evaluation scores as dependent variables, and the six components with different percentages of coverage as independent variables. Tables 5 and 6 show the results of stepwise regression for the three evaluations with and without sound stimuli, respectively. It can be seen that each landscape indicator could be explained by different predictors. Generally speaking, for the evaluation indicators, five key landscape elements (no-vegetation ground, vegetation, mountains, the sky, and water) are examined with sound stimuli, showing less values than those without sound stimuli (no-vegetation ground, buildings and facilities, vegetation, mountains, the sky, and water). It is therefore possible to assert that sound attracts more attention in audiovisual condition, when landscape elements are generally not effective. However, compared with the visual-only condition, it is interesting to note that the negative effect of no-vegetation ground, which is the most significant landscape element for each of the evaluation indicators, is enhanced by

soundscapes, for the combined audiovisual condition. In other words, with the increase of no-vegetation ground, the landscapes may be less appreciated in terms of landscape VAQ, tranquility, or landscape preference with sound stimuli. On the other hand, for landscape VAQ evaluation, the effects of natural elements (vegetation and mountain) are observed to be clearly greater in a positive way, whereas for landscape tranquility and landscape preference evaluations, the positive effects of natural elements (i.e. vegetation and water) are decreased with sound stimuli. These results suggest that soundscape can modulate the effects of landscape elements on landscape evaluations. In particular, no-vegetation ground is the significant negative landscape element that influences the landscape evaluations with sound stimuli.

3.6 Influence of special landscape elements based on the eye-tracking test

Eye-tracking provides an objective way to measure people's observation of landscapes, and it is also a powerful tool for analyzing people's observation of landscapes when represented by photographs (Berto et al., 2008; Guerard et al., 2009; Muller et al., 2012; Patalano et al., 2010; Dupont et al., 2014). In this section, the evaluation scores influenced by landscape elements are further examined, while the relative results of eye-tracking tests are reported to determine the special landscape elements which may break the effects of landscape elements shown in Table 5.

According to the results in Table 5, Fig. 5 presents the landscape VAQ evaluation influenced by its predictor, i.e., percentage of no-vegetation ground, vegetation, and mountains, respectively. It can be seen that the evaluations in Fig. 5(b) with vegetation are not always in the trend, as they fluctuate considerably from 17% to 20%, corresponding to Images W5 and R5, respectively. Similarly, in Fig. 5(c), the trend markedly fluctuated by R5, with a mountain percentage of 30%. Correspondingly, the heat map analyses (showing the centers of attention) for W5 and R5 during landscape VAQ evaluation with sound stimuli are shown in Fig. 6. Regarding the red areas, which recorded the attention areas with the most visual fixations during eye movement, it can be observed in Fig. 6(a) and (b) that the attention area with visual fixations are mostly focused on the disturbing elements, such as rubbish and hay bales on the no-vegetation ground, which may result in low landscape VAQ scores for W5, whereas for R5, compared to the musical soundscape in Fig. 6(c), the road traffic soundscape in Fig. 6(d) is likely to cause visual fixations to be gathered more on sound sources (Ren and Kang, 2015b). This audiovisual information may, in turn, accentuate the negative effect of road traffic sounds on the landscape VAQ evaluation.

Simultaneously, the landscape tranquility evaluation scores influenced by the effective landscape elements are examined. Figure 7 shows the evaluation scores influenced by the percentage of no-vegetation ground, sky, and mountains, respectively. Similar to the landscape VAQ, the trends showed in regression analyses are substantially decreased in Fig. 7(b) and (c), corresponding to Images R1 and R5, respectively. Considering visual attention in tranquility evaluation using eye tracking test, although the results are different with different sounds, certain landscape elements in the road landscapes are observed consistently, as can be seen in Fig. 8, where the visual fixations are consistently focused on the people in Fig. 8(a) and (b). For Image R5, Fig. 8(c) and (d) show that the fixations with different sounds are both gathered on moving vehicles. This indicates that the low tranquility evaluations may be higher due to the disturbing elements (on the no-vegetation ground) together with the road traffic sounds, rather than other landscape elements, e.g., the sky, mountains, as presented in Table 5.

Compared with landscape VAQ evaluation, the special landscape elements related to

human-involved sound sources are more effective in the landscape tranquility evaluation, and they tend to attract a more concentrated area, suggested in an additional eye-tracking test using the 25 images (as shown in Table 1), as can be seen in Table 7, where the attention areas with fixations are much more towards people and man-made elements without sound stimuli, while for certain landscape type, the special landscape elements are always focused either for landscape VAQ or for landscape tranquility with different sounds, as can be seen in the above heat maps of Image R5. Similar results are also obtained in the corresponding recorded data of eye tracking, including the number of fixation, the fixation duration, the number of gaze points, the Strict Average Gaze Point X (Active Display Coordinate Millimeters) and the Strict Average Gaze Point Y (ADCSmm). More specifically, Table 8 shows the results of paired samples t-tests of the database. The differences in fixations and gaze points suggest that compared with landscape tranquility the visual attention is easier to extract, with shorter fixation duration, less searching, and thus less fixations and gaze points, when the landscape indicator is VAQ. Considering the different results relating to different sounds, previous studies suggest that natural sounds can promote diversification to a certain extent and create larger attention areas on natural landscape elements for tranquility evaluations (Ren and Kang, 2015b; Ren and Kang, 2016), while the results in Table 8, which may be a supplement, shows that musical soundscape can direct more observation, extraction and interpretation of the landscape, with more fixations and longer duration than those influenced by road traffic soundscape. However, no significant difference is observed between the paired results of the Strict Average coordinates of the gaze points. This indicates again that the interest-elements for road landscapes are relatively fixed (as human-involved sound sources, i.e. moving vehicles, people, etc). Therefore, the audiovisual environment should be taken into account for particular elements in landscape and soundscape assessments.

4. Discussion

In terms of visual stimuli, landscape evaluation surveys are often preferred to photograph-based surveys in landscape VAQ, landscape tranquility, and landscape preference studies (Arriaza et al, 2004; Watts and Pheasant, 2013; Howley, 2011) because they provide a more direct way of presenting landscapes to the perceivers, with all their senses used in the evaluation. Rural photographic stimuli were used in this study for the following reasons. Photograph-based evaluations have the advantage of having better control over the experience of viewing the landscapes and of involving larger samples landscapes (Shuttleworth, 1980). The rural environment is of simple landscape construction, comprehensive landscape elements, and identifiable sound sources, which contribute to explore the effect of soundscapes on landscape evaluations. Moreover, the purpose of this study has not been to perceive any particular landscape, but to identify the general way of different soundscapes related to landscape evaluation indicators. Thus, the specific region of rural landscapes is of minor influence (Natori and Chenoweth, 2008).

In terms of experimental study, most of audiovisual studies were conducted in laboratory settings with various combinations of sounds and vision. Corresponding to the previous studies, a limited number of visual images were applied in this study because the study focused mainly on the rural landscape characteristics and landscape perception (i.e. positive or negative). In addition, the images used in this study were representative of the landscape attitudes of openness,

naturalness, and traditional characteristics. Therefore, the findings would be beneficial for environment assessment, especially in the aspects of rural soundscape and landscape design in a wider context. However, it must be noted that multiple rural landscape values exist (aside from rural tourism, etc.), and participants in this study were asked to evaluate the various landscape images from the perspective of a visitor from urban areas, focusing purely on scenery. Thus, additional experimental studies with greater variation, including rural dwellers, landscape designers, on-site audiovisual materials, etc., would be useful in the future.

5. Conclusions

Based on audiovisual experiments, this study analyzed the effects of different soundscapes on landscape evaluations including landscape VAQ, landscape tranquility and landscape preference of rural landscapes, in terms of positive and negative landscapes.

In terms of both positive and negative landscapes, the landscape evaluations were significantly influenced by the sound source types. Generally speaking, the evaluations are higher with natural or musical sounds than with artificial sounds and without sound stimuli. On the other hand, for certain landscape types, the evaluations with artificial sounds are also higher than those without sound stimuli. More specifically, landscape VAQ evaluations of positive landscapes were affected more by soundscape, as the evaluations with natural or musical sounds are higher by 1.24 than those with artificial sounds. This difference is only less than one evaluation scale (0.46) for negative landscapes. In terms of landscape tranquility, however, the effects of the soundscape are relatively high for both positive and negative landscapes, as the natural soundscape considerably increased the scores with artificial sounds by more than two evaluation scales (2.58 for positive landscapes, 2.25 for negative landscapes); particularly for farmland, waterscapes, and family houses, the evaluation scores were even higher with natural sounds than without, and were perceived as close to “very tranquil”, higher than “somewhat tranquil,” and close to “somewhat tranquil”, respectively. In terms of landscape preference, the natural or musical soundscape similarly increased the evaluation scores of positive landscapes more, with a judgment of “dislike” (2.07–2.40) with artificial sounds changed to close to “really like” (4.51) and higher than “neither like nor dislike” (3.36) for positive and negative landscapes, respectively. For the distant view, farmlands, and waterscapes, the evaluations were also higher with natural sounds than without. Furthermore, higher preferences were perceived for the negative landscapes of distant view, roads, and family houses with artificial sounds than without.

Soundscapes can also modulate the effects of landscape elements on landscape evaluations. Generally speaking, no-vegetation ground, vegetation, mountains, the sky, and water were significantly effective landscape elements with sound stimuli, but the evaluations could be greatly reduced by particular disturbing elements together with artificial sounds, based on the eye-tracking test.

Acknowledgements

We thank the reviewers for their constructive comments which greatly helped improving the paper. The research was supported by the Natural Science Foundation of China (51741803, 51778100), Chinese Fundamental Research Funds for the Central Universities (DUT17RC(3)018) and the Social Science Association Fund of Liaoning Province (2018slktyb-023).

References

- Arriaza, M., Cañas-Ortega, J. F., Cañas-Madueño, J. A., Ruiz-Aviles, P., 2004. Assessing the visual quality of rural landscapes. *Landscape and Urban Planning*. 69 (1), 115-125.
- Brown, A. L., McDonald, G. T., 1995. From Environmental Impact Assessment to environmental design and planning. *Australian Journal of Environmental Management*. 2(2), 65-77.
- Buhyoff, G. J., Wellman, J. D., 1979. Seasonality bias in landscape preference research. *Leisure Science*. 2, 181-190.
- Botteldooren, D., De Coensel, B., De Muer, T., 2006. The temporal structure of urban soundscapes. *Journal of Sound and Vibration*. 292, 105-23.
- Bradley, M. M., Lang, P. J., 2000. Affective reactions to acoustic stimuli. *Psychophysiology*. 37, 204-215.
- Benjamin, K., Bouchard, A., Domon, G., 2007. Abandoned farmlands as components of rural landscapes: An analysis of perceptions and representations. *Landscape and Urban Planning*. 83, 228-244.
- Berto, R., Massaccesi, S., Pasini, M., 2008. Do eye movements measured across high and low fascination photographs differ? Addressing Kaplan's fascination hypothesis. *Journal of Environmental Psychology*. 28, 185-191.
- Cloquell-Ballester, V. A., Torres-Sibille, A. C., Cloquell-Ballester V. A., Santamarina-Siurana M.C., 2012. Human alteration of the rural landscape: Variations in visual perception. *Environmental Impact Assessment Review*. 32, 50-60.
- Daniel, T. C., 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. *Landscape and Urban Planning*. 54, 267-281.
- Dramstad, W. E., Tveit, M. S., Fjellstad, W. J., Fry, G. L. A., 2006. Relationship between visual landscape preferences and map-based indicators of landscape structure. *Landscape and Urban Planning*. 78 (4), 465-474.
- Dupont, L., Antrop, M., Eetvelde, V. V., 2014. Eye-tracking Analysis in Landscape Perception Research: Influence of Photograph Properties and Landscape Characteristics. *Landscape Research*. 39 (4), 417-432.
- Filipan, K., Boes, M., De Coensel, B., Lavandier, C., Delaitre, P., Domitrovic, H., Botteldooren, D., 2017. The personal viewpoint on the meaning of tranquility affects the appraisal of the urban park soundscape. *Applied Sciences*. 7, 91.
- Gan, Y. H., Luo, T., Zhang, T. H., Zhang, T., Qiu, Q. Y., 2013. Changes of visual and acoustic landscape along urban-rural gradients and their influence on landscape evaluation, *Environmental Science & Technology*. 36, 347-354. (in Chinese).
- Guerard, K., Tremblay, S., Saint-Aubin, J., 2009. The processing of spatial information in short-term memory: Insights from eye tracking the path length effect. *Acta Psychologica*. 132, 136-144.
- Hall, D. A., Irwin, A., Edmondson- Jones, M., Phillips, S., Poxon, J. E.W., 2013. An exploratory evaluation of perceptual, psyceptual, psychoacoustic and acoustical properies of urban soundscapes. *Applied Acoustics*. 74, 248-254.
- Hessels, R. S., Kemner, C., Boomen, C. V. D., Hooge, I. T. C., 2016. The area-of-interest problem in eyetracking research: A noise-robust solution for face and sparse stimuli. *Behavior Research Methods*. 48 (4), 1694-1712.
- Hong, J. Y., Jeon, J. Y., 2013. Designing sound and visual components for enhancement of urban

- 511 soundscapes. *Journal of the Acoustical Society of America*. 134 (3), 2026-2036.
- 512 Hao, Y ., Kang, J. Wörtche, H., 2016. Assessment of the masking effects of birdsong on the road
- 513 traffic noise environment. *The Journal of the Acoustical Society of America*. 138(5):
- 514 3019-3022.
- 515 Howley, P., 2011. Landscape aesthetics: Assessing the general publics' preferences towards rural
- 516 landscapes. *Ecological Economics*. 72, 161-169.
- 517 Jacobsen, T., Buchta, K., Köhler, M., Schröger, E., 2004. The primacy of beauty in judging the
- 518 aesthetics of objects. *Psychological Reports*. 94 (3c), 1253-1260.
- 519 Jiang, L., Kang, J., Schroth, O., 2015. Prediction of the visual impact of motorways using GIS.
- 520 *Environmental Impact Assessment Review*. 55, 59-73.
- 521 Kalivoda, O., Skrivanová, Z., Drábková, A., 2010. Aesthetical preferences of landscape in
- 522 protected area Český kras. In: Bejcek, V., Fernández, E., Jílek, F., Libra, M., Marusák, R.,
- 523 Sedmíková, M., Zagata, L. (Eds.), *UCOLIS 2010- University Conference in Life Sciences -*
- 524 *Proceedings. Czech University of Life Sciences Prague, Prague*, 195- 202.
- 525 Kalivoda, O., Vojar, J., Skrivanová, Z., Zahradník, D., 2014. Consensus in landscape preference
- 526 judgments: Three effects of landscape visual aesthetic quality and respondents'
- 527 characteristics. *Journal of Environmental Management*. 137, 36-44.
- 528 Kaltenborn, B. P., Bjerke, T., 2002. Associations between environmental value orientations and
- 529 landscape preferences. *Landscape and Urban Planning*. 59, 1-11.
- 530 Kang, J., 2004. *Urban Sound Environment*. London: Taylor and Francis.
- 531 Lam, K. C., Brown, A. L., Marafa, L., Chau, K. C., 2010. Human preference for countryside
- 532 soundscapes. *Acta Acustica united with Acustica*. 96, 463-71.
- 533 Lee, P. J., Hong, J. Y., Jeon, J. Y., 2014. Assessment of rural soundscapes with high-speed train
- 534 noise. *Science of the Total Environment*. 482-483, 432-9.
- 535 Liu, J., Kang, J., Luo, T., Behm, H., 2013. Landscape effects on soundscape experience in city
- 536 parks. *Science of the Total Environment*. 454, 474–481.
- 537 Lindquist, M., Lange, E., Kang, J., 2016. From 3D landscape visualization to environmental
- 538 simulation: The contribution of sound to the perception of virtual environments. *Landscape*
- 539 *and Urban Planning*. 148, 216-231.
- 540 Lavia, L., Dixon, M., Witchel, H. J., Goldsmith, M., 2016. *Applied Soundscape Practices*. In
- 541 *Soundscape and the Built Environment*, edited by J. Kang and B. Schulte-Fortkamp.
- 542 London: CRC Press.
- 543 Mace, B. L., Corser, G. C., Zitting, L., Denison, J., 2012. Effects of overflights on the national
- 544 park experience. *Journal of Environmental Psychology*. 35, 30-39.
- 545 Ma, D. Y., 2004. *Theoretical foundation of modern acoustic*. Beijing: Science Press. (in Chinese).
- 546 Meng, Q., Zhang, S. L., Kang, J., 2017. Effects of typical dining styles on conversation
- 547 behaviours and acoustic perception in restaurants in China. *Building and Environment*. 121,
- 548 148-157.
- 549 Murphy, E., King, E. A., Rice, H. J., 2009. Estimating human exposure to transport noise in
- 550 central Dublin, Ireland. *Environment International*. 35, 298-302.
- 551 Muller, M. G., Kappas, A., Olk, B., 2012. Perceiving press photography: A new integrative model,
- 552 combining iconology with psychophysiological and eye-tracking methods. *Visual*
- 553 *Communication*. 11, 307-328.
- 554 Natori, Y., Chenoweth, R., 2008. Differences in rural landscape perceptions and preferences

- 555 between farmers and naturalists. *Journal of Environmental Psychology*. 28, 250-267.
- 556 Navarra, J., Alsius, A., Velasco, I., Soto-Faraco, S., Spence, C., 2010. Perception of audiovisual
- 557 speech synchrony for native and non-native language. *Brain Research*. 1323, 84-93.
- 558 Oberman, T., Bojanić, Obad, Scitaroci, B., Jambrošić, K., 2016. Post-hoc analysis of two
- 559 temporary acoustic shelters in London. In: *Proceedings of Inter-Noise 2016*, Hamburg,
- 560 Germany. 4760-4769.
- 561 Ode, A., Fry, G., Tveit, M. S., Messenger, P., Miller, D., 2009. Indicators of perceived naturalness
- 562 as drivers of landscape preference. *Journal of Environmental Management*. 90 (1), 375-383.
- 563 Patalano, A. L., Juhasz, B. J., Dicke, J., 2010. The relationship between indecisiveness and eye
- 564 movement patterns in a decision making informational search task. *Journal of Behavioral*
- 565 *Decision Making*. 23, 353-368.
- 566 Pheasant, R. J., Fisher, M. N., Watt, G. R., Whitaker, D. J., Horoshenkov, K. V., 2010. The
- 567 importance of auditory-visual interaction in the construction of ‘tranquil space’. *Journal of*
- 568 *Environmental Psychology*. 30, 501-509.
- 569 Ramírez, Á., Ayuga-Téllez, E., Gallego, E., Fuentes, J. M., García, A. I., 2011. A simplified
- 570 model to assess landscape quality from rural roads in Spain. *Agriculture,*
- 571 *Ecosystems and Environment*. 142, 205- 212.
- 572 Rogge, E., Nevens, F., Gulinck, H., 2007. Perception of rural landscapes in Flanders: Looking
- 573 beyond aesthetics. *Landscape and Urban Planning*. 82, 159-174.
- 574 Ren, X., Kang, J., Liu, X. G., 2015. An experimental study on the subjective evaluation of traffic
- 575 sounds under the visual impact of ecological waterscape. *Acta Acustica*. 40, 361-369. (in
- 576 Chinese).
- 577 Ren, X., Kang, J., 2015a. Effects of visual landscape factors of ecological waterscape on acoustic
- 578 comfort. *Applied Acoustics*, 96, 171-179.
- 579 Ren, X., Kang, J., 2015b. Interactions between landscape elements and tranquility evaluation
- 580 based on eye tracking experiments. *The Journal of the Acoustical Society of America*.
- 581 138(5): 3019-3022.
- 582 Ren, X., Kang, J., 2016. Interaction of audiovisual evaluation for wetland landscapes from the
- 583 perspective of soundscape. *Architectural Journal*. Academic issue 15, 7-11. (in Chinese).
- 584 Shen, Z. X., 2010. The research and construction of ecological landscape system in the northeast
- 585 villages. Thesis for Master degree of Northwest A & F university. Shan Xi.
- 586 Soini, K., Vaarala, H., Pouta, E., 2012. Residents’ sense of place and landscape perceptions at the
- 587 rural-urban interface. *Landscape and Urban Planning*. 104, 124-134.
- 588 Stamps, A. E., 1994. A study in scale and character: contextual effects on environmental
- 589 preferences. *Journal of Environmental Management*. 42, 223-245.
- 590 Stich, Ch, 2005. Development of scales for aesthetic research. Dissertation. Online.
- 591 http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000001553(accessed
- 592 09.09.13).
- 593 State Standard of the People’s Republic of China (GB 3096-2008). Environment quality standard
- 594 for noise. Beijing: China Environmental Science Press; 2008. (in Chinese).
- 595 Strumse, E., 1994. Environmental attributes and the prediction of visual preferences for agrarian
- 596 landscapes in Western Norway. *Journal of Environmental Psychology*. 14 (4), 293-303.
- 597 Shuttleworth, S. (1980). The use of photographs as an environment presentation medium in
- 598 landscape studies. *Journal of Environmental Management*, 11, 61-76.

- 599 Sullivan, W. C., 1994. Perceptions of the rural-urban fringe: citizen preferences for natural and
600 developed settings. *Landscape and Urban Planning*. 29, 85-101.
- 601 Taylor, S. M., 1984. A path model of aircraft noise annoyance. *Journal of Sound and Vibration*.
602 96, 243-60.
- 603 Vos, W., Meekes, H., 1999. Trends in European cultural landscape development: perspectives for
604 a sustainable future. *Landscape and Urban Planning*. 46(1), 3-14.
- 605 Val, G. D. L. F. D., Atauri, J. A., Lucio, J. V., 2006. Relationship between landscape visual
606 attributes and spatial pattern indices: A test study in Mediterranean-climate landscapes.
607 *Landscape and Urban Planning*. 77, 393-407.
- 608 Wang, Y., Bao, Z. Y., 2007. The application of soundscape in landscape design. *Huazhong*
609 *Architecture*, 25,150-2. (in Chinese).
- 610 Wang, Y. C., Liu, B. Y., 2003. Discussions on rural landscape and rural landscape planning in
611 China. *Chinese Landscape Architecture*. 5, 76-79. (in Chinese).
- 612 Wang, Y. C., 2003. Planning and design for modern rural landscape tourism. Qingdao: Qingdao
613 press. (in Chinese).
- 614 Weinstein, N. D., 1978. Individual differences in reactions to noise: a longitudinal study in a
615 college dormitory. *Journal of Applied Psychology*. 63, 458-66.
- 616 Watts, G. R., Pheasant, R. J., 2013. Factors affecting tranquillity in the countryside. *Applied*
617 *Acoustics*. 74, 1094-1103.
- 618 Watts, G. R., Pheasant, R. J., 2015a. Identifying tranquil environments and quantifying impacts.
619 *Applied Acoustics*. 89, 122-7.
- 620 Watts, G. R., Pheasant, R. J., 2015b. Tranquillity in the Scottish Highlands and Dartmoor
621 National Park-The importance of soundscapes and emotional factors. *Applied Acoustics*. 89,
622 297-305.
- 623 Xie, H. L., 2004. Preliminary researches on the functional evaluation of rural landscape. *Acta*
624 *Ecologica Sinica*. 24(9), 1991. (in Chinese).
- 625 Xie, H. L., Liu, L. M., Xu, W., 2003. Research on the esthetic evaluation of rural landscape.
626 *Economic Geography*. 23(3), 423-424. (in Chinese).
- 627 Yao, Y. M., Zhu, X. D., Xu, Y. B., Yang, H. Y., Wu, X., Li, Y. F., Zhang Y. F., 2012. Assessing the
628 visual quality of green landscaping in rural residential areas: the case of Changzhou, China.
629 *Environmental Monitoring and Assessment*. 184, 951-967.
- 630 Yang, W., Kang, J., 2005. Acoustic comfort evaluation in urban open public spaces. *Applied*
631 *Acoustics*. 66, 211-229.

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Table 1. Rural landscape images of five landscape types. The images for distant view, farmland, and road landscapes were ordered according to the coverage of man-made elements, from the least to the most, whereas the five images of water and family house landscapes were ordered according to the coverage of water and courtyard, from the largest to the smallest, where the images with dotted lines are also used in the audiovisual evaluation experiment.

Rural landscape types	Ordered position for each landscape				
	Group I	Group II	Group III	Group IV	Group V
<u>Distant view</u> Image ID/ Man-made elements (%)	D1/0.84	D2/1.87	D3/6.91	D4/9.55	D5/32.58
<u>Farmland</u> Image ID/ Family houses (%)	F1/0	F2/0.21	F3/4.38	F4/5.62	F5/18.54
<u>Waterscape</u> Image ID/ Water (%)	W1/40.70	W2/29.78	W3/28.65	W4/26.40	W5/3.37
<u>Road</u> Image ID/ Road and moving vehicles (%)	R1/6.18	R2/8.43	R3/11.80	R4/16.85	R5/26.40
<u>Family houses</u> Image ID/ Courtyard (%)	C1/52.25	C2/42.70	C3/37.64	C4/26.70	C5/25.84

Table 2. Experimental procedure with audio-visual clips

	Evaluations	Image ID	Sound signals
1)Visual-only condition	Landscape VAQ	D1~D5, F1~F5, W1~W5, R1~R5, C1~C5	None
	Landscape tranquility		
	Landscape preference		
2)Audio-visual condition	Landscape VAQ (& eye tracking)	D1/ D5	A/B
		F1/ F5	C/D
	Landscape tranquility	W1/ W5	E/F
	(& eye tracking)	R1/ R5	G/H
	Landscape preference	C1/ C5	I/J

Table 3. Landscape VAQ and landscape tranquility evaluation scores considering five landscape types without sound stimuli.

	Rural Landscape types	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
				Lower	Upper		
Landscape VAQ	Distant view	1.02	1.24	0.77	1.27	-3	3
	Farmland	1.01	1.04	0.80	1.22	-1	3
	Waterscape	0.84	1.62	0.52	1.16	-3	3
	Road	-0.52	1.40	-0.80	-0.24	-3	2
	Family house	0.36	1.34	0.09	0.63	-3	3
Landscape tranquility	Distant view	0.37	1.84	0.00	0.74	-3	3
	Farmland	1.42	1.15	1.19	1.65	-1	3
	Waterscape	1.13	1.27	0.88	1.38	-2	3
	Road	-0.31	1.70	-0.65	0.03	-3	3
	Family house	0.50	1.19	0.26	0.74	-2	3

Table 4. Landscape preference evaluation scores considering five groups without sound stimuli.

	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum (Image ID)	Maximum (Image ID)
			Lower	Upper		
Group I	4.29	2.25	4.01	4.57	4.12 (F1)	4.68 (R1)
Group II	3.45	0.75	2.52	4.38	2.36 (W2)	4.12 (F2)
Group III	2.62	0.52	1.98	3.27	1.80 (F3)	3.08 (C3)
Group IV	2.86	0.69	2.01	3.72	2.16 (R4)	3.80 (W4)
Group V	1.71	0.44	1.16	2.26	1.24 (C5)	2.44 (F5)

Table 5. Stepwise regression analysis for the evaluation scores of landscape VAQ, landscape tranquility and landscape preference with sound stimuli.

	Predictor	Standardized Beta Coefficients	t	Significance
Landscape VAQ $R^2=28\%$; $R^2(\text{adj})=27\%$	No-vegetation ground	-0.52	-9.80	.000**
	Vegetation	0.11	2.29	.022*
	Mountain	0.10	2.01	.045*
Landscape tranquility $R^2=11\%$; $R^2(\text{adj})=10\%$	No-vegetation ground	-0.32	-4.95	.000**
	Sky	-0.24	-3.82	.000**
	Mountain	-0.16	-2.86	.004**
Landscape preference $R^2=16\%$; $R^2(\text{adj})=15\%$	No-vegetation ground	-0.41	-6.87	.000**
	Mountain	0.19	3.54	.000**
	Water	0.10	1.99	.048*

**The correlation between landscape evaluation and landscape element is significant at the 0.01 level.

*The correlation between landscape evaluation and landscape element is significant at the 0.05 level.

Table 6. Stepwise regression analysis for the evaluation scores of landscape VAQ, landscape tranquility and landscape preference without sound stimuli.

	Predictor	Standardized Beta Coefficients	t	Significance
Landscape VAQ $R^2=45\%$; $R^2(\text{adj})=44\%$	No-vegetation ground	-0.42	-5.46	.000**
	Buildings and facilities	-0.53	-7.15	.000**
	Sky	-0.24	-3.20	.002**
	Mountain	-0.22	-2.65	.009**
Landscape tranquility $R^2=42\%$; $R^2(\text{adj})=41\%$	Vegetation	0.30	3.84	.000**
	Water	0.29	4.15	.000**
	Mountain	-0.33	-5.14	.000**
	Building and facilities	-0.23	-2.56	.011**
Landscape preference $R^2=92\%$; $R^2(\text{adj})=90\%$	Vegetation	0.93	8.78	.000**
	Water	0.41	4.04	.005**

**The correlation between landscape evaluation and landscape element is significant at the 0.01 level.

Table 7. Heat map analyses for landscape VAQ and landscape tranquility evaluations without sound stimuli, where the results for Image W1~W5 were presented as an example.

Image ID	W1	W2	W3	W4	W5
Landscape VAQ
Landscape tranquility

Table 8. Paired samples t-tests for the eye-tracking data, where the results between landscape VAQ and landscape tranquility evaluations with sound stimuli, and the results between musical and road traffic soundscapes for Image R5 are presented, respectively.

	Landscape VAQ –Landscape tranquility evaluations						The evaluations influenced by musical soundscape – road traffic soundscape					
	Mean	Std.Deviation	Std.Error Mean	95% confidence Interval of the Difference		Significance	Mean	Std.Deviation	Std.Error Mean	95% confidence Interval of the Difference		Significance
				Lower	Upper					Lower	Upper	
Total fixations	-1.35	8.81	1.39	-4.17	1.47	0.34	2.55	9.00	1.42	-0.33	5.43	0.08
Fixation duration	-73.41	687.23	108.66	-293.19	146.38	0.50	15.31	686.16	108.49	-204.13	234.76	0.89
The number of gaze points	-0.43	3.63	0.57	-1.59	0.74	0.46	0.38	4.02	0.64	-0.91	1.66	0.56
The Strict Average Gaze Point X	2.96	21.17	3.35	-3.81	9.73	0.38	-2.14	22.60	3.57	-9.37	5.08	0.55
The Strict Average Gaze Point Y	3.30	17.55	2.77	-2.31	8.91	0.24	-3.53	17.42	2.75	-9.09	2.05	0.21

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Fig. 1. Percentages of landscape preference evaluation ranked positions by subjects without sound stimuli for the five landscape types of distant views, farmlands, waterscapes, roads and family houses.

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Fig. 5. Landscape VAQ evaluation scores influenced by the percentage of landscape elements, including no-vegetation ground (a), vegetation (b), and mountains (c), occupied in the scene, where the percentage of each landscape element is presented from the least to most and the image ID corresponds to the greatest fluctuant point.

Fig. 6. Heat map analyses for the landscape VAQ evaluations of Image W5 and R5, including the evaluation of W5 influenced by the water flowing soundscape (a) and hawker selling soundscape (b), and the evaluation of R5 influenced by the musical soundscape (c) and road traffic soundscape (d), where red indicates the highest number of fixations and the longest time, whereas green indicates the least, with varying levels in between.

Fig. 7. Landscape tranquillity evaluation scores influenced by the percentage of landscape elements, including no-vegetation ground (a), the sky (b), and mountains (c), occupied in the scene, where the percentage of landscape element is presented from the least to the most, and the image ID corresponds to the greatest fluctuant point.

Fig. 8. Heat map analyses for landscape tranquillity evaluations of Image R1 and R5, including the evaluation of R1 influenced by the musical soundscape (a) and road traffic soundscape (b), and the evaluation of R5 influenced by the musical soundscape (c) and road traffic soundscape (d), where the instruction for the heat map is the same as that in Fig. 7.

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Fig. 4. Landscape preference evaluation scores of positive and negative landscapes with 95% confidence intervals of the mean scores for distant views (a), farmlands (b), waterscapes (c), roads (d), family houses (e) as well as the mean scores for corresponding landscape types (f) under the effect of natural or musical soundscape and artificial soundscape. In (a)-(e) the results without sound stimuli (visual - only evaluation) are also shown.

Fig. 5. Landscape VAQ evaluation scores influenced by the percentage of landscape elements, including no-vegetation ground (a), vegetation (b), and mountains (c), occupied in the scene, where the percentage of each landscape element is presented from the least to most and the image ID corresponds to the greatest fluctuant point.

Fig. 6. Heat map analyses for the landscape VAQ evaluations of Image W5 and R5, including the evaluation of W5 influenced by the water flowing soundscape (a) and hawker selling soundscape (b), and the evaluation of R5 influenced by the musical soundscape (c) and road traffic soundscape (d), where red indicates the highest number of fixations and the longest time, whereas green indicates the least, with varying levels in between.

Fig. 7. Landscape tranquility evaluation scores influenced by the percentage of landscape elements, including no-vegetation ground (a), the sky (b), and mountains (c), occupied in the scene, where the percentage of landscape element is presented from the least to the most, and the image ID corresponds to the greatest fluctuant point.

Fig. 8. Heat map analyses for landscape tranquility evaluations of Image R1 and R5, including the evaluation of R1 influenced by the musical soundscape (a) and road traffic soundscape (b), and the evaluation of R5 influenced by the musical soundscape (c) and road traffic soundscape (d), where the instruction for the heat map is the same as that in Fig. 7.