Effects of soundscape on rural landscape perception: *Landscape visual aesthetic quality and landscape tranquillity of rural landscapes in China*

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Summary

The present study analyses the effects of soundscape on rural landscape perception, including landscape visual aesthetic quality (VAQ) and landscape tranquillity, based on audiovisual information collected in rural villages in China using the methods of audiovisual experiment and eye-tracking test. First, the results showed significant correlations between the two landscape perceptions, both with and without sound stimuli. Second, the landscape perceptions 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 evaluations of landscape perceptions could be enhanced by sound stimuli, including natural or artificial soundscape and for both positive and negative landscapes. Third, bare ground, green plants, mountains, and the sky were found to be significant landscape elements that influence landscape perceptions with sound stimuli, and in particular, the evaluations could be substantially decreased by certain disturbing elements together with artificial sounds.

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1. Introduction

An increasing number of people visit their local countryside [1-2] because these rural areas can be considered restorative or tranquil environments, providing relief from cognitive overload and reducing stress, where man-made noise is at a low level and the dominance of natural sounds promotes rural landscape tranquillity, and the visual sense of tranquillity is also significant due to the appearance of natural features, such as vegetation, water, and geological features [3]. However, the audiovisual environment on a rural landscape atmosphere can also negatively influence landscape perception. For example, tranquillity is found to be determined by the presence or absence of development and traffic and to be depressed by the presence of litter, people and vehicles as well as poor visual quality of rough and sometimes muddy ground caused by parked vehicles [3-5].

In addition to landscape tranquillity, visual aesthetic quality (VAQ) is often considered to be in the public interest, which is a resource that is valuable for maintaining good psychic health and the tourism potential of a landscape [6-7]. Perception-based assessment usually depends on the VAQ of the assessed landscapes and the landscape type as well as whether the evaluated landscapes meet idealized mental images using choices, rankings or ratings (usually represented by photographs) provided by samples of human viewers [8-9].

While the above studies are mainly focused on landscape perception, few studies have examined the effects of different soundscapes on such perceptions for rural landscapes in China. The aim of this study is therefore to examine the effects of soundscape on landscape VAQ and landscape tranquillity, considering the landscape contents of a distant view, farmland, waterscape, road, and courtyard in rural landscapes in China, which is a rapidly developing country with rapidly changing landscapes. This research was conducted using both audiovisual experiment and eye-tracking test based on landscape field images and sounds collected from typical villages in China.

2. Methodology

2.1.Case study area

Since entering the new century, China has experienced a leapfrogging development in urbanization, with an urbanization rate of 1.2% per year, and rural landscapes in China are simultaneously undergoing ever- advancing changes[10-11]. Rural settlements in China are complex, regarding earth landscape as a background, with the core of a settlement's landscape characteristic between an urban landscape and natural landscape [12]. Therefore, the rural landscapes in China, combined with natural and artificial landscape elements, were considered in this study. In traditional rural settlements located in three typical provinces, Heilongjiang, Ji Lin, and Liaoning, 25 typical rural landscapes were selected [9,11-13], focusing on 5 landscape types: a distant view, farmland, waterscape, road, and courtyard, with 5 images from each type.

2.2.Images

Photographs, which can be valid surrogates for actual landscape judgments [14-15], were chosen for use in this study. To reproduce a more realistic visual landscape, the photographs were taken in a 3D format [16]. They were taken at eye-level, at a height of approximately 1.5 m above the ground, with typical angles and panoramic colour for landscape pictures [17]. All the images were taken in the late spring and summer of 2014, on clear days, by avoiding telephoto shots [18].

The selected five images in each landscape type were ordered (from Group I to Group V) according to the percentage of certain landscape elements that occupied each scene. For distant view, farmland and road landscapes, they were ordered according to the percentage of man-made objects, from the least to the most, whereas the five images of waterscapes and courtyard landscapes were ordered according to the percentage of water and courtyard sizes, from the largest to the smallest. In Table I the images ordered the first (Group I) and the fifth (Group V) are presented, which were also used in the audiovisual experiment.

2.3.Sound signals

During field surveys in villages, a series of typical sounds that were frequently heard were recorded, with two types of sounds for each landscape type, one natural or musical sound and the other artificial sound. The recorded sounds included bird twittering (A) and highway traffic (B) sounds for the distant view, cricket chirping (C) and tractor working (D) sounds for farmland, water flowing (E) and hawker selling (F) sounds for waterscape, music (G) and road traffic (H) sounds for roads, and cock crowing (I) and repairing house (J) sounds for courtyards.

Table I. Images of five rural landscape types.

	Group I	Group V
Distant view Image ID/ Buildings and artificial facilities (%)	 D1/ 0.84	 D5/ 32.58
Farmland Image ID/ Buildings (%)	 F1/ 0	 F5/ 18.54
Waterscape Image ID/ Water (%)	 W1/ 40.70	 W5/ 3.37
Road Image ID/ Road and moving vehicles (%)	 R1/ 6.18	 R5/ 26.40
Courtyard Image ID/ Courtyard (%)	 C1/ 52.25	 C5/ 25.84

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 ground, and more than 3.5 m away from any other reflectors when the wind speed was less than 5 m/s [19]. 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 all were adjusted to 50 dBA because the mean SPL of the field measurements was approximately at this level.

2.4.Subjects and experimental settings

The young people with high auditory sensitivity were selected as subjects [20-21]: randomly selected students from Harbin Institute of Technology. A sample size of 20 was used according to previous studies of acoustic experiments [22] and landscape visual evaluation [8], including ten males and ten females.

The experiments were conducted in an enclosed recording studio. For the audiovisual experience, polarized 3D glasses and Sennheiser RS 170

headphones were used. The effects of 3D images were adjusted using Stereo Photo Maker software, and the sound signals were calibrated using a dummy head and 01 dB software and were edited using Cooledit software. Tobii T60XL software was used for the eye-tracking test by recording the heat maps during eye movement.

2.5. Evaluation indicators

For the landscape VAQ, "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. Therefore, the two terms were chosen to represent the two ends of a VAQ [7]. They were thus expressed on a seven-point Liket scale: -3, very ugly; -2, ugly; -1, moderate ugly; 0, medium; +1, moderate beautiful; +2, beautiful; and +3, very beautiful. Correspondingly, "tranquil" and "noisy" were used to indicate the landscape tranquillity evaluation [3, 23]: -3, very noisy; -2, noisy; -1, moderate noisy; 0, medium; +1, moderate tranquil; +2, tranquil; and +3, very tranqui.

2.6. Experimental procedure

The perception without sound stimuli was conducted first. The subjects were asked to observe the 25 3D images in a random order, at a position of 1 m away from the monitor. Meanwhile, the evaluation for landscape VAQ was made. Then, the images were presented randomly again, and landscape tranquillity was evaluated.

Then, the audiovisual experiment was conducted. The subjects were asked to experience audiovisual clips with two sound signals (natural or musical sound, and artificial sound, respectively) coupled to each image (as shown in Table 1) in random order, with each audiovisual clip lasting 10 second, followed by a five-second break [17] between every two images. Meanwhile landscape VAQ evaluation was made. The audiovisual clips were also presented again in the same way, and the landscape tranquillity was evaluated.

Next, the eye-tracking test was conducted. After becoming familiarised with the Tobii T60XL software, the 20 eligible subjects, who had been tested personal eye flexibility, were asked to experience the audiovisual clips as the audiovisual experiment in random order, with the question of "whether your perception for the landscape is beautiful or ugly." Then, the clips were experienced again randomly, with the question of "whether your perception for the landscape is tranquil or noisy."

3. Results

Before presenting the specific effects of soundscape, the relationship between the two landscape perceptions is examined through Pearson correlation analysis. The results show landscape VAQ and tranquillity have significant correlations with each other ($0.406< r <0.814$, $p<0.01$), with and without sound stimuli, and the differences only exist in courtyard landscapes in which insignificant correlations ($p>0.05$) are observed either with or without sound stimuli.

3.1. 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. For positive landscapes under the effects of natural or musical soundscape, the score fluctuated between 0.00 and 1.80, whereas with the artificial sounds, the evaluation score decreased to -1.25 to 0.95. In particular, for the positive landscape of waterscapes in Figure 2c, the evaluation score was considerably decreased (by 3.05), with a judgment of close to "beautiful" dropping to lower than "moderately ugly," under the effects of artificial soundscape. For negative landscapes, the evaluation scores are generally lower than for positive landscapes, although the evaluations were also decreased by the artificial soundscape. Interestingly, Figure 2e shows that artificial soundscape increases the evaluation score with the natural sound, as well as the score without sound stimuli. This is possibly due to the matching phenomenon of audiovisual environment [24], where the untidy courtyard scene moderated the uncomfortable audio perception of the artificial sound (repairing house sound).

As an overall result in Fig. 3f, it can be seen that the natural or musical soundscape increases the evaluation scores of distant view, farmland, waterscapes and road landscapes by 1.06, on average, compared to those with the artificial sounds. In general, the mean score of positive landscapes is increased by 1.24, whereas that of negative landscapes is increased only by 0.46.

3.2. Effects of soundscape on landscape tranquillity

In Figure 3, the evaluation scores of landscape tranquillity influenced by different soundscapes are compared. Fig. 3a to 3e show that the natural or musical soundscape substantially increases the evaluation score of positive landscape of each

landscape type by between 1.25 and 3.45 from the score with artificial sounds. In particular, for farmland, waterscapes and courtyards, the evaluation scores with natural sounds are even higher than those without sound stimuli. Thus more tranquillity 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 and 3.05, and the evaluations with natural or musical sounds are always higher than those without sound stimuli in each landscape type, by 1.39 on average. Figure 3a even shows that the evaluation for negative landscape is high by 0.20 with artificial sound than that without. This result is similar to that in Fig. 2a, as the VAQ score of negative landscape for distant view is also increased by the artificial soundscape. In other words, for certain negative rural landscapes, soundscape with either natural or artificial sound can increase the landscape perception compared to that without sound stimuli.

In general, Fig. 3f shows that the evaluation scores with natural or musical sounds are higher than those with artificial sounds by an average of 2.41. The evaluations influenced by the natural or musical soundscape are higher by 2.58 and 2.24 and are evaluated as close to "tranquil" and "moderately tranquil" for positive and negative landscapes, respectively.

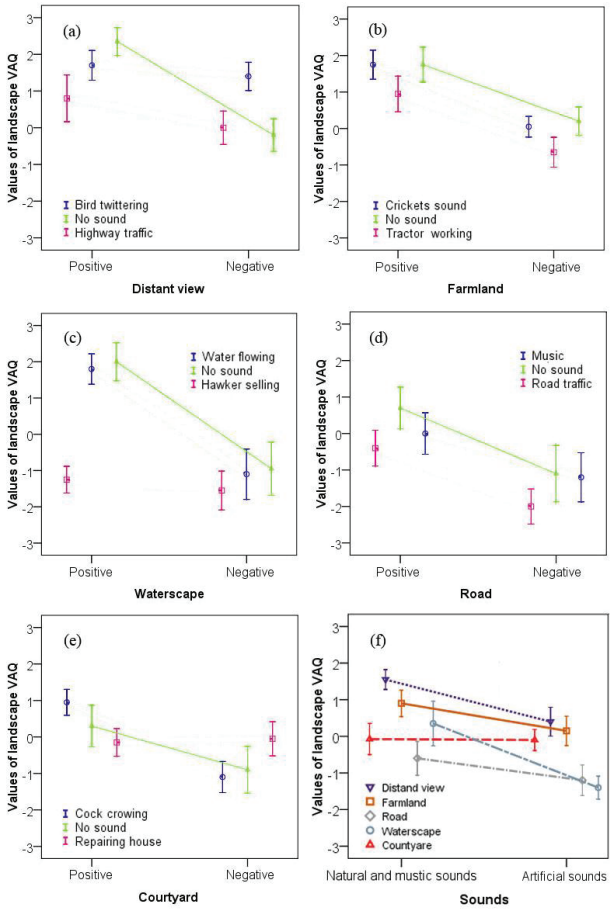

Figure 1. Landscape VAQ evaluation scores of positive and negative landscapes with 95% confidence intervals of the mean scores for distant view (a), farmland (b), waterscapes (c), roads (d), courtyards (e) as well as the mean scores for corresponding landscape types (f) under the effect of different soundscapes. In (a)-(e) the results without sound stimuli are also shown.

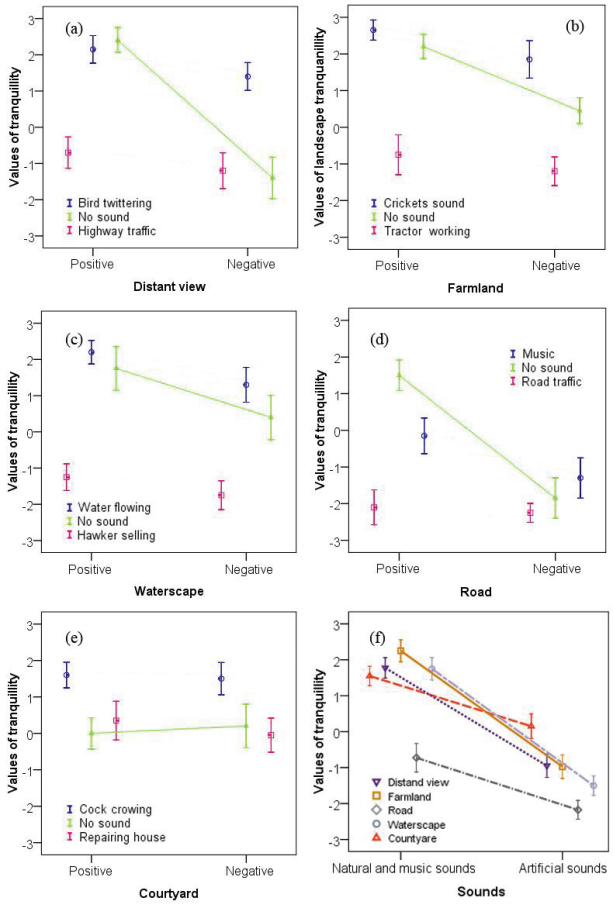

Figure 2. Landscape tranquillity evaluation scores of positive and negative landscapes with 95% confidence intervals of the mean scores for distant view (a), farmland (b), waterscapes (c), roads (d), courtyards (e) as well as the mean scores for corresponding landscape types (f) under the effect of different soundscapes. In (a)-(e) the results without sound stimuli are also shown.

3.3. Effects of landscape elements on landscape perceptions with sound stimuli

Based on the method in Section 2.1, the percentage of landscape elements in each of the ten scenes

were categorized as water, green plants, bare ground (including moving vehicles, people, etc., on bare ground), buildings and man-made facilities, mountain, and sky. Then, stepwise regression was conducted by defining the landscape evaluation scores as dependent variables and the six components of landscape elements as independent variables. From the results in Table II it can be seen that bare ground, green plants, mountains, and the sky are significantly effectvie landscape element for landscape perceptions.

Table II. Results of the stepwise multiple linear regression analysis for the landscape VAQ and landscape tranquillity.

		Coefficients	Std. Error	t	Significance
Landscape VAQ	Bare ground	-.090	.009	-9.802	.000**
	Green plants	.013	.006	2.291	.022*
	Mountain	.016	.008	2.011	.045*
Landscape tranquillity	Bare ground	-.066	.013	-4.945	.000**
	Sky	-.028	.007	-3.822	.000**
	Mountain	-.031	.011	-2.860	.004**

** $p < 0.01$
* $p < 0.05$

The landscape elements with significant influence on landscape evaluations are further examined. Generally, the evaluations can well follow the trend with increasing or decreasing percentage of the corresponding landscape element as suggested in regression coefficients in Table II, but the substantial change was caused by Image W5 in landscape VAQ, and Image R5 in landscape tranquillity, which both significantly decrease the evaluations. Correspondingly, the heat map analyses for the images during landscape perceptions are shown in Figures 3 and 4.

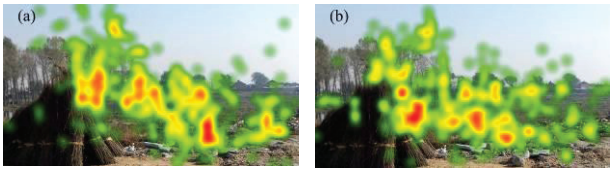

Figure 3. Heat map analyses for the landscape VAQ of W5 influenced by natural soundscape (a) and artificial soundscape (b), where red indicates the highest number of fixations and the longest time, whereas green indicates the least, with varying levels in between.

Regarding the red areas, which recorded the highest number and the longest time fixations during eye movement, it can be observed in Figure 3a and 3b that the visual fixations are mostly focused on such disturbing elements, such as rubbishes and hay bales on the bare ground, which may result in low landscape VAQ scores for W5.

Figure 4. Heat map analyses for the landscape tranquillity of R5 influenced by musical soundscape(a) and artificial soundscape (b).

In Figure 4, the fixations with different sounds are both gathered on moving vehicles in Figure 4a and 4b. Therefore, the low tranquillity perception may be due to the disturbing elements together with the road traffic sounds. This audiovisual environment may, in turn, accentuate the negative effect of road traffic sounds on the perception of landscape tranquillity.

4. Conclusions

Based on audiovisual experiment on rural landscape perceptions, this study revealed that *landscape VAQ* and *landscape tranquillity* of a distant view, farmland, waterscape, and road presented significant correlations with each other, either with or without sound stimuli. The study also demonstrated the effects of different soundscapes on the landscape perceptions in terms of positive and negative landscapes.

Landscape VAQ of positive landscapes were affected more by soundscape, with a higher mean difference value (1.24) between the scores influenced by the natural or musical soundscape and artificial soundscape. This value is only less than one evaluation scale (0.46) for negative landscapes. In terms of *Landscape Tranquillity*, however, the effects of soundscape are high for both positive and negative landscapes, as the natural soundscape considerably increased the scores with artificial sounds more than two evaluation scales (2.58 for positive landscapes, 2.24 for negative landscapes); particularly for farmland, waterscapes and courtyards, the evaluation scores were even higher with natural sounds than without and were perceived as close to "very tranquil", higher than "moderate tranquil" and close to "moderate tranquil", respectively.

In addition, bare ground, green plants, mountains, and the sky were significantly effective landscape elements in the landscape perceptions with sound

stimuli, and certain disturbing elements together with artificial sounds could greatly reduce the landscape perceptions.

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References

[1] J. N. Zhu: Urban lakeside landscape design- The significance of creating wild landscape in urban parks. Proc. The International Exchange Congress of Landscape Architecture 2007, Wuxi. (in Chinese).

[2] Natural England: Monitor of engagement with the naturalenvironment. http://www. naturalengland. org. uk/ ourwork/ research/ mene. aspx.

[3] G. R. Watts, R. J. Pheasant: Factors affecting tranquillity in the countryside. Applied Acoustics 2013; 74, 1094-1103.

[4] K. C. Lam, A. L. Brown, L. Marafa, K. C. Chau: Human preference for countryside soundscapes. Acta Acustica united with Acustica 2010; 96, 463-471.

[5] G. R. Watts, R. J. Pheasant, K. V. Horoshenkov: Validation of tranquillity rating method. Proc. The Institute of Acoustics and Belgium Acoustical Society: noise in the built environment 2010, Ghent.

[6] O. Kurdoglu, B. C. Kurdoglu: Determining recreational, scenic, and historicale cultural potentials of landscape features along a segment of the ancient Silk Road using factor analysing. Journal of Environmental Monitoring 2010; 170 (1-4), 99-116.

[7] O. Kalivoda, J. Vojar, Z. Skrivanová, D. Zahradník: Consensus in landscape preference judgments: Three effects of landscape visual aesthetic quality and respondents' characteristics. Journal of Environmental Management 2014; 137, 36-44.

[8] T. C. Daniel: Whither scenic beauty? Visual landscape quality assessment in the 21st century. Landscape and Urban Planning 2001; 54, 267-281.

[9] A. Ode, G. Fry, M. S. Tveit, P. Messager, D. Miller: Indicators of perceived naturalness as drivers of landscape preference. Journal of Environmental Management 2009; 90 (1), 375-383.

[10]W. Y. Niu: New urbanization in China. Science Press, Beijing, 2009. (in Chinese).

[11]X. Q. Zhou: Study on the change of rural landscape in urbanization process: A case study of southern Jiangsu province. PhD Thesis, Nanjing Normal University, Nanjing, 2006. (in Chinese).

[12]B. Y. Liu, Y. C. Wang: Theoretical base and evaluating indicator system of rural landscape assessment in China. Chinese Landscape Architecture 2002; 5, 76. (in Chinese).

[13]E. Strumse: Environmental attributes and the prediction of visual preferences for agrarian landscapes in Western Norway. Journal of Environmental Psychology 1994; 14 (4), 293-303.

[14]F. J. Palmer, R. E. Hoffman: Rating reliability and representation validity in scenic landscape assessment. Landscape and Urban Planning 2001; 54, 149-161.

[15]E. Rogge, F. Nevens, H. Gulinck: Perception of rural landscapes in Flankers: Looking beyond aesthetics. Landscape and Urban Planning 2007; 82, 159-174.

[16]J. S. Berry, D. A. T. Roberts, N. S. Holliman: 3D sound and 3D image interactions: a review of audio-visual depth perception. Proc. The international society for optical engineering 2014, San Francisco.

[17]R. J. Pheasant, M. N. Fisher, G. R. Watt, D. J. Whitaker, K. V. Horoshenkov: The importance of auditory-visual interaction in the construction of 'tranquil space'. Journal of Environmental Psychology 2010; 30, 501-509.

[18]Y. Natori, R. Chenoweth: Differences in rural landscape perceptions and preferences between farmers and naturalists. Journal of Environmental Psychology 2008; 28, 250-267.

[19]State Standard of the People's Republic of China (GB 3096-2008). Environment quality standard for noise. China Environmental Science Press, Beijing, 2008. (in Chinese).

[20]N. D. Weinstein: Individual differences in reactions to noise: a longitudinal study in a college dormitory. Journal of Applied Psychology 1978; 63, 458-466.

[21]S. M. Taylor: A path model of aircraft noise annoyance. Journal of Sound and Vibration 1984; 96, 243-260.

[22]J. Kang: Urban Sound Environment. Taylor and Francis, London, 2004.

[23]G. R. Watts, R. J. Pheasant: Identifying tranquil environments and quantifying impacts. Applied Acoustics 2015; 89, 122-127.

[24] X. Ren, J. Kang, X. G. Liu: An experimental study on the subjective evaluation of traffic sounds under the visual impact of ecological waterscape. Acta Acustica 2015. (accepted) (in Chinese).