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OLFACTORY EFFECT ON LANDSCAPE PREFERENCE

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Abstract

Landscape preference is a result of multi-sensory input. However, the effect of interactions between multi-sensors on it is rarely involved in previous works, especially in olfactory effect on landscape preference. This research project selected three odors (flower of *Osmanthus fragrans* (FO), flower of *Lilium longiflorum* (FL), and sediment on riverbed (SR)) and ten photographs to explore the effect of odor-photograph combinations on landscape preference. The evaluation by undergraduate students demonstrates that, generally speaking, above three odors can increase landscape preference, separately visual beauty or separately olfactory preference keeps a weak influence on olfactory effect on landscape preference. Results of regression analysis suggest that, in a landscape, decreasing "open space" can increase the FO's and FL's effect on landscape preference significantly, while increasing "percentage of area covered by grass" and decreasing "water amount" can enhance the olfactory effect of SR.

Key words: landscape design, landscape preference, olfaction, visual character

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1. Introduction

Landscape preference is a product of the interactions between physical characteristics of landscape and psychological attributes of observers (Molnarova et al., 2012; Tveit, 2009; Vouligny et al., 2009). Landscape is linked to human's multi-sensory perspective (Zube, 1984), which implies that although the eyes are the most important organ for perceiving landscape, and has received the most attention by previous studies (Canas et al., 2009; Junker and Buchecker, 2008; Montero-Parejo et al., 2016; Yao et al., 2012; Zhao et al., 2013), our noses, ears and skin can receive information from the environment. This can be testified by the findings of Benfield et al. (2010) who suggested that man-made sound had a negative influence on environmental assessments. However, these senses have not gained as much consideration.

Odor is a natural feature of many materials, which helps us to understand the peculiarities of a material. Herz (2002) suggested that odor was a strong trigger of attraction or repulsion responses, and might thus influence behavior of human in various contexts. The odor of a material is often linked to impressions from other senses. Based on human's daily-lived experience, a number of studies have reported a strong connection between vision and olfaction in object recognition (Gottfried and Dolan, 2003; Seo et al., 2010; Wada et al., 2012), which implies that a special odor may awake a memory of a lively image of landscape. For example, the odor of green grass may be associated with the scene of a farm.

Therefore, odor is widely used in landscape design, and the traditional Chinese gardens are the outstanding representatives for odor's application. Here some scenes are even typically named with words related to odor, such as "the Hall of Drifting Fragrance" in Humble Administrator's Garden in Suzhou, China. Still, the investigation of olfactory effects on landscape preference is rare in the existing literatures. Landscape character analyses are used broadly in the assessment of visual landscape preference, and understanding the relationships

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between visual characters and landscape preference will benefit landscape planning and management (Arriaza et al., 2004; Bulut and Yilmaz, 2008; Canas et al., 2009; Jaafari et al., 2017; Yao et al., 2012; Zhao et al., 2013). However, the question of which characters playing roles in the olfactory effect on landscape preference has not been involved in previous studies. It is a barrier for integrating the use of odors in landscape designs and management. This research tries to add to the literature and move forward our understanding of olfactory effect on landscape preference. In this research, three materials with distinct odors and ten landscapes (represented by full-color photographs) were selected and evaluated.

Eight visual characters (Table 1) were identified from the ten photographs referring to previous literatures and judged (Arriaza et al., 2004; Bulut and Yilmaz, 2008; Yao et al., 2012). We are aiming to answer the following questions:

1) What are the effects of the three odors on landscape preference assessed by undergraduate students?

2) Which landscape characters are linked closely to the three odors' effects on landscape preference?

3) How do we use these odors in landscape design and management?

2. Materials and methods

2.1. Stimuli

Ten full-color photographs covering natural scenes, rural scenes and urban green spaces (Fig. 1) were used for the experiment. These photographs (with resolution of 2560×1920 pixels) were taken in a clear or less cloudy day, from 10 a.m. to 4 p.m., at eye level, from August to October 2010. The equipment is Olympus digital camera with a 50 mm lens. The three odor materials are flower of *Osmanthus fragrans* (FO), flower of *Lilium longiflorum* (FL) which are used popular as fragrant plants in gardens and they are very easy identified by people with normal olfaction, and the sediment on riverbed (SR) which is often smelled around the water bodies, especially in a drought season, the smell can spread a long distance.

2.2. Respondents

Some studies reported that landscape preference was influenced by the demographic characters of respondents (e.g., Howley et al., 2012; Lindemann-Matthies et al., 2010; Soliva and Hunziker, 2009; Tindall, 2003; van den Berg and Koole, 2006). However, Yao et al. (2012) concluded there was no significant difference between undergraduate students and the public in landscape assessment, and Stamps (1999) suggested that students could substitute for the public in landscape assessment.

A number of 120 undergraduate students from Jiangsu Normal University participated this experiment, 72 males and 48 females. Their mean age was 21.1 years old, and 83 reported to be living in the city while 37 stated they lived in the countryside. They were divided into four groups, 30 students for each group. In addition, five experimenters (four postgraduate students and a teacher from Jiangsu Normal University with normal olfaction) were invited to test the odors' identification and give a preference rating for each odor.

2.3. Evaluation procedures

The trials were conducted in a classroom which is a 55m^2 (9.2m × 6.0m) area in September 2011. In the first step, visual preferences of the ten photographs were evaluated by the first group of students under the condition of the classroom without identified odors. The ten photographs, with the random order, were projected on a white screen (image size: 1.6m × 1.2m) by a projector (Sony VPL-CX80 with resolution of 1024×768 pixels), and they were displayed twice. Initially, all photos were shown quickly, then each photo was displayed for approximately 10 seconds. During this time, the respondents were asked to give an evaluation (writing on a questionnaire) to that photograph according to a five-point scale (1 = not at all preferred, 5 = much preferred) (Garré et al., 2009).

Table 1. Scale of measurement of the visual characters

Visual characters	***Abbreviation***	***Scores***			
		0	***1***	***2***	***3***
Percentage of area covered by woody plants	PCW	0-25%	26-50%	51-75%	76-100%
Percentage of area covered by grass	PCG	0-25%	26-50%	51-75%	76-100%
Vegetation shape	VS	All artificial form	Most artificial form	Man and nature joint form	Natural form
Open space	OS	No open space	Half-open space	Open space	
Water amount	WA	None	A little	More	
Degree of wildness	DW	Most man-made elements	Semi- man-made elements	A little man-made elements	Natural elements
Number of colors	NC	One	Two	Three	Four or more
Color contrast	CC	Weak contrast	Clear contrast	Strong contrast	

Fig. 1. Photographs used for landscape preference assessment

The second step, to include odor in the experiment, all windows of the classroom were closed, then four bundles of fresh flowers of *Osmanthus fragrans* (picked in an urban green park) were set in four corners of the classroom, respectively. These flowers were concealed in four ventilating bags to prevent the respondents and experimenters from seeing them.

As all of the five experimenters who stood in the center of the classroom could scent the odor distinctly (about two minutes after placing flowers), they were asked to leave the room, and the second group of students was invited into the room to evaluate the landscape preferences of the ten photographs with the same method used in the first step. After the evaluation, all windows of the classroom were opened, and the flowers were taken out of the classroom. The five experimenters came into the classroom to scent the odor at the interval of ten minutes. The next trial was conducted when all of the experimenters could not scent the odor of FO. The third and fourth steps, comparing the second step, the differences are odor materials (FO was substituted by the fresh flowers of *Lilium longiflorum* (picked in a greenhouse used for cut-flower) in the third step and sediment on riverbed (dug up in an urban river with moderate water pollution) in the fourth step, respectively) and respondents (the third group students in the third step, the fourth group students in the fourth step), others are done as same as doing in the second step.

During the trial, when the five experimenters could scent an odor distinctly, they were asked to judge the odor preference on a five-point scale (1 = not at all preferred, 5 = much preferred).

2.4. Visual characters judgment

In order to measure the intensity of the visual characters presented in the photographs, a group of eight experts (four teachers and four postgraduates specialized in landscape architecture, coming from Jiangsu Normal University and China University of Mining and Technology) was invited to score the visual characters of the ten photographs according to the scale of measurement shown in Table 1.

2.5. Statistical methods

The preference scores of photographs, odors and odor-photograph combinations took the average of corresponding participants' evaluations, and the scores of each visual character took the average of the eight experts' judgments. Data analysis used SPSS 17.0 software.

Correlation analysis was conducted to explore the relationships between the olfactory preference and olfactory effect on landscape preference. Correlation analysis and regression analysis were used to explore the relationships between the olfactory effect on landscape preference and the visual characters.

3. Results

3.1. Evaluation of odor and landscape photographs

The mean preference scores of three odors are 3.40 (FO), 3.60 (FL), and 1.20 (SR), respectively. Comparing to the separately visual preference scores, all preference scores of ten photographs combined with FO and FL are higher, and the preference scores of nine photographs combined with SR are higher, only one lower. And no matter in alone photograph evaluation or odor-photograph combination evaluation, the photograph 3 takes the highest preference scores, the photograph 6 the lowest scores (Fig. 2).

3.2. Correlations between visual preference, olfactory preference and olfactory effect on landscape preference

The olfactory effect on landscape preference scores is calculated by the following formula (Eq. 1):

$$S_{ij} = N_{ij} - N_i \quad (1)$$

where S_{ij}: effect of the *j*th odor on landscape preference of the *i*th photograph, N_{ij}: preference scores of the *i*th photograph combined with the *j*th odor, N_i: visual preference scores of the *i*th photograph.

The correlations between the visual preferences of the photographs and three odors' effects on landscape preference are analyzed by the method of Spearman. The result shows that no significant correlations could be established between them (for FO, R = 0.225, *Sig.* = 0.532; for FL, R = 0.134, *Sig.* = 0.713; for SR, R = −0.515, *Sig.* = 0.128), which indicates that the visual preference had a weak influence on the olfactory effect on landscape preference. The correlation between olfactory preference and the mean effect on landscape preference of each odor shows that the olfactory preference takes a weak positive correlation with the olfactory effect on landscape preference (R = 0.831, *Sig.* = 0.169).

3.3. Relationships between visual characters and olfactory effect on landscape preference

The correlations between the olfactory effect on landscape preference and the visual characters are shown in Table 2. For FO, its effect on landscape preference increases with increase in "percentage of area covered by woody plants", decreases with increase in "open space". For FL, its effect increases with increase in "percentage of area covered by woody plants", decreases with increase in "open space" and "percentage of area covered by grass", respectively. For SR, its effect increases with increase in "percentage of area covered by grass", decreases with increase in "water amounts". By stepwise multiple linear regression analysis with eight visual characters as independents and three odors' effect on landscape preference as dependent, respectively, the significant predictors are presented in Table 3.

To verify these models, the normality of the residuals, analysis of variance and multi-collinearity were examined. The results indicate that the residuals of the three models (FO, FL, SR) follow a normal distribution (Kolmogorov-Smirnov Z = 0.519, 0.483, 0.525, p = 0.950, 0.974, 0.946, respectively). Variance analysis results reveal a linear correlation between the visual characters and the olfactory effect on landscape preference (F = 14.461, 8.092, 47.195, p = 0.005, 0.022, 0.000, respectively). Menard (1995) reported that a tolerance value of less than 0.2 indicates a multi-collinearity problem. The minimum tolerance value in these models is 0.683. Alternatively, according to the findings of Arriaza et al. (2004), VIF (variance inflation factor) exceeding 10 implies a possible multi-collinearity problem. In these models, the maximum value is 1.464.

Thus there are no multi-collinearity problems in these models. For the olfactory effect of FO and FL on landscape preference, the significantly negative predictor is "open space". For the olfactory effect of SR, the significantly positive predictor is "percentage of area covered by grass", while "water amount" is a negative one.

4. Discussion

4.1. Odor preference and olfactory effect on landscape preference

The results presented here document that people prefer natural flowers fragrance, which is parallel to the findings of Chen et al. (2008) who concluded that natural fragrance from flowers, leaves and rivers were held highly among the respondents, but people's preference for SR is contrary to the results of Chen et al. (2008). The reason may be that the odor of sediments is not equal to the river's odor described by Chen et al. (2008). The polluted river in which we dug the sediments may be another reason.

Although the sediment's odor is some unpleasant (only 1.20 scores on a five-point scale), the odor conveys information of water. Even though no water is visible in a landscape, the smell of sediment could inform respondents a waterscape. Previous studies have concluded that water could be seen as a fascinating visual element enhancing landscape preference (e.g., Kaltenborn and Bjerke, 2002; Laumann et al., 2003; Nasar and Li, 2004; Regan and Horn, 2005; Dramstad et al., 2006). Thus, in spite of the least favor of sediment's odor, the combinations of sediment's odor and the photographs gain higher preference scores than the photographs evaluated separately (Photograph 9 is an exception). That is to say, an unpleasant odor does not appear to reduce the preference people express when asked to rate images.

4.2. Visual associations of an odor and its effect on landscape preference

For human, because of simultaneous work of multi-sensors in perceiving environment, one sensor is commonly linked to another, and interactions occur between them. Engen (1991) reported that odors, especially those associated with emotional events, could trigger powerful memories from the distant past. Zhou et al. (2010) suggested that an odor could modulate the visual perception in adults.

In the present study, the effects of FO and FL on landscape preference are positive to "percentage of area covered by woody plants" (Table 2). The reason may be that the odors of FO and FL are often associated with a visual landscape with dense vegetation. With regard to the effects of SR, the photographs with no or little water and more grass cover can gain greater improvement than the ones with more water (Tables 2 and 3), which can be explicated by the scene associating with SR.

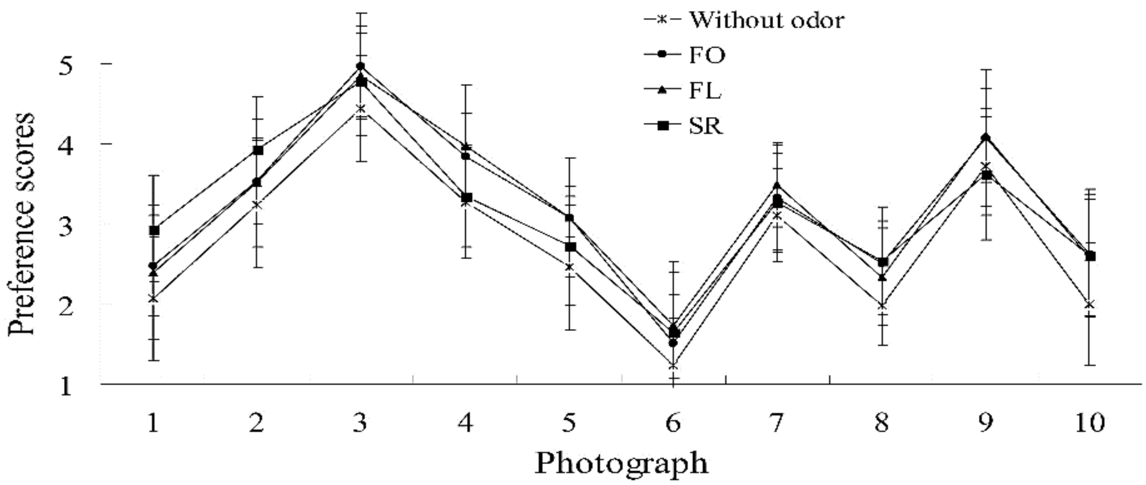

Fig. 2. Mean preference scores of the ten photographs obtained by different odor–photograph combinations

Table 2. Correlations between the visual characters and the olfactory effect on landscape preference

		FO' effect	*FL' effect*	*SR' effect*
PCW	Spearman rho	0.706*	0.657*	-0.171
	Significance	0.022	0.039	0.637
PCG	Spearman rho	-0.561	-0.692*	0.699*
	Significance	0.092	0.027	0.024
VS	Spearman rho	0.078	0.320	-0.358
	Significance	0.830	0.367	0.310
OS	Spearman rho	-0.877**	-0.793**	0.201
	Significance	0.001	0.006	0.577
WA	Spearman rho	-0.196	0.457	-0.944**
	Significance	0.586	0.184	0.000
DW	Spearman rho	-0.325	0.059	-0.285
	Significance	0.359	0.872	0.424
NC	Spearman rho	0.036	-0.163	0.254
	Significance	0.922	0.652	0.479
CC	Spearman rho	0.248	0.068	0.315
	Significance	0.490	0.853	0.376

**Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level*

Table 3. Stepwise multiple linear regression analysis of the influence of the visual characters on the olfactory effect on landscape preference

Dependent (Olfactory effect on landscape preference)	*Independent (Landscape characters)*	*Unstand-ardized Beta*	*Standar-dized Beta*	*t*	*Sig.*	*Collinearity statistics*	
						Tolerance	*VIF*
(FO's effect) (Adjusted R^2=0.599)	(constant)	0.737		9.079	0.000		
	OS	-0.188	-0.802	-3.803	0.005	1.000	1.000
(FL's effect) (Adjusted R^2=0.441)	(constant)	0.680		8.213	0.000		
	OS	-0.143	-0.709	-2.845	0.022	1.000	1.000
(SR's effect) (Adjusted R^2=0.911)	(constant)	0.516		6.658	0.000		
	WA	-0.263	-0.767	-6.382	0.000	0.683	1.464
	PCG	0.084	0.296	2.462	0.043	0.683	1.464

Although SR informs respondents a water image in a landscape, SR's scene is often dry, sludgy or shallow waterscape with a mass of grass growth. In the condition, the waterscape are easily covered by grass or sheltered from seeing by buildings and woods. From the analyses above, we can conclude that, to improve the landscape quality, the olfactory–visual congruency may be better.

This result can also be demonstrated by the findings of Wada et al. (2012) who suggested that even young infants preferred the olfactory–visual congruency of an object based on their own multi-sensory exposure.

4.3. Limitations of this study and future research

As mentioned above, undergraduate students are acceptable as respondents in landscape assessment. However, some studies concluded that undergraduate students were significantly different from general public (Tveit, 2009) and local people (Dramstad et al., 2006) in evaluating aesthetic preference. If the undergraduate students used as respondents in this study are replaced by new respondents such as the public, it may change the results from this research. Therefore, the demographic and social factors of respondents covering a wider demographic range are strongly recommended to be identified and applied in the future study.

The importance of employing a high variety of stimulus materials in an aesthetic assessment is illustrated by the findings of Herzog and Leverich (2003). Van der Jagt et al. (2014), by analyzing the existing literatures, suggested that failing to sample a wide variety of images maybe the reason of inconsistencies between studies related to scenic quality. Although the present experiment tries to include various landscape types, the variety of landscape is still low, and the photographs of a landscape type are very limited. For statistical analysis, more samples are, better the results do. The limited number of photographs will weaken the conclusions of this study. The experiment was performed in Chinese ambiance. However, do the results have a potential to be of relevance also in America or Europe? The present study cannot answer it, because the western people and Chinese may share a great difference in landscape preference for a same landscape (Yu, 1995; Mo et al., 2011). The question is very interesting for further studies.

5. Conclusions and application in landscape design

Respondents are more preferred the odor of FO and FL than that of SR, but, generally speaking, all of the three odors can increase landscape preference scores. The visual preference of a photograph and olfactory preference of a smell had weak influences on the olfactory effect on landscape preference. Still results of regression analysis as exemplified in this paper can help guide landscape design.

Planting the fragrant plants in a closed space is better for improving landscape quality than in an open space; and in an environment with no water but a high grass cover, transferring the information of dry waterscape through the odor of river sediments to the observers can increase its landscape preference ratings significantly.

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