

Correlation between soundscape and sense of culture in historic public space

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ABSTRACT

Soundscapes, as part of cultural heritage, have attracted attention for their role in crafting atmospheres and fostering a sense of place. It is still unclear how soundscapes and the sense of culture interlink within historic public spaces. This research explores how soundscape elements influence the sense of culture in historic towns. Twenty-five typical railway-type historic public spaces in northern China are selected as examples. We restored the field situation in the laboratory. Through correlation analysis in SPSS, we analyzed the relationships between soundscape elements (encompassing objective environmental attributes and subjective perception) and cultural senses. The result shows: 1) Natural sounds, people sounds, and cultural activities sounds like music/shows significantly influence the sense of culture in historical spaces along the Chinese Eastern Railway (CER). 2) Calm and stable sound environments contribute to creating a cultural atmosphere. 3) Pleasure and eventful sounds strengthen people's connection to culture. 4) Enclosed spaces, pedestrian-friendly environments, and bustling crowds enhance the cultural ambience. 5) Visual perception correlates more strongly with the sense of culture than auditory evaluation. This research provides valuable insights for enhancing cultural senses in historic towns through soundscape design.

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1. Introduction

Soundscapes, like architecture, customs, and attire, signify the characteristics of a regional community. Cultural sounds can represent social, spiritual, historical, national and cultural memories of a specific place and society[1]. For instance, the Izmir anthem holds great importance for Turkish citizens as it symbolizes the collapse of the Ottoman Empire and the establishment of the Turkish Republic[2]. Similarly, church bells and military communications reveal social interactions in Castilian cities during the 15th and 16th centuries [3]. Studies have shown that soundscapes embody both natural and religious cultures. For example, Zheng examined the geological, ecological, and artificial sounds in three typical historical spaces in China, revealing the historical narratives and philosophical ideas, indicating the inseparable connection between soundscapes and culture, history, philosophy, religion, and natural background[4].

While there is limited literature on how soundscapes in heritage sites affect cultural perception, it has been shown that cultural perception can influence soundscape perception. For instance, Jordan (2019) found that participants' understanding of historical relics' value could influence their interpretation of typical soundscapes, demonstrating the impact of cultural perception on soundscape perception. Furthermore, research has demonstrated that soundscapes can influence perceptions of place, social, and natural cultures in buildings, landscape environments, and city centers. For example, in terms of landscape culture, experiments have shown that sound affects people's visual observation patterns of rural landscapes[6]. Regarding social culture, experiments exploring language diversity in Amsterdam's urban areas and its impact on spatial and social diversity experiences have been conducted [7]. In terms of architectural culture, computer simulations and on-site sound pressure level measurements have shown how acoustic indicators, including reverberation time (RT) and speech transmission index (STI), affect individuals' responses to the physical environment of mosques [8].

In conclusion, soundscapes embody various cultural values, including social, spiritual, and historical aspects[9]. However, there still needs to be more systematic exploration into the correlation between soundscape elements and sense of culture in heritage sites. How to design soundscapes to highlight the perceptibility of these cultures remains uncertain. Therefore, this study aims to investigate whether and to what extent soundscape elements affect the sense of culture.

2. Methodology

It has been established that soundscape can influence the sense of place in heritage sites. However, it is unclear whether the "sense of culture," a concept related to the sense of place, is affected by specific elements in the soundscape. In this study, we divided these elements into four categories: acoustic environment, soundscape perception (SSID), visual characteristics, and visual perception, which include both subjective and objective dimensions of visual and auditory. We hypothesized that specific indicators within these categories would influence the

sense of culture (Fig.1). Using bivariate Pearson correlation analysis in SPSS, we identified the soundscape elements that may significantly affect the sense of culture.

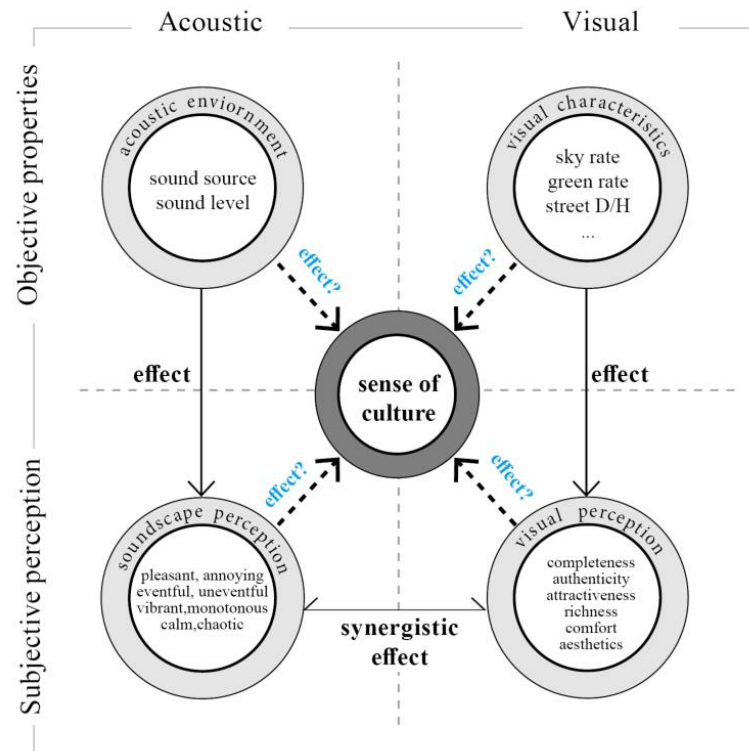


Fig.1 Hypothesis of the relationship among soundscape elements and sense of culture

2.1. Sites and cases

The cases are in Heilongjiang Province, northern China. Here lies the Chinese Eastern Railway (CER), a historic railway connecting the continents of Asia and Europe. Many towns along its route owe their establishment and development to this railway, constructed by the same group of builders during the same period. These towns share a common cultural background and architectural style, reflecting their origins. Hence, we visited three cities and towns along this railway line and selected 25 historically public spaces (Fig. 2). These spaces possess variations in visual and auditory characteristics as well as cultural activities.

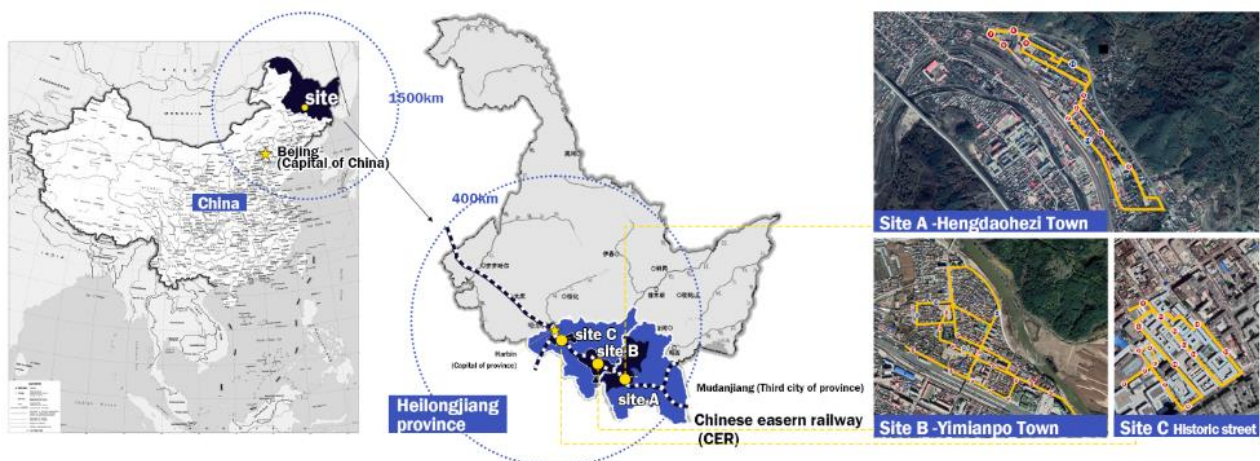


Fig.2 Sites and cases

2.2. Data collection

Firstly, we utilized a 360-degree camera to record the site and measured the sound environment with a sound level meter for later lab calibration. Each case (public space) was captured for 3 minutes, and after data cleaning (removing wind sounds, equipment crashes, researcher talking, etc.), a 30-second audio-visual segment was selected for each case. Subsequently, we reproduced the scenes using VR and headphones. 42 participants were recruited to complete questionnaires after watching each video segment. The questionnaire focused on subjective perceptions, covering aspects of 'sense of culture', visual perception, and soundscape perception. Objective features of the acoustic and visual environments were derived from fieldwork data analysis.

It is worth noting that the 'sense of culture' indices were derived from previous research using Grounded Theory (not yet published, so cannot be quoted). We interviewed 22 individuals associated with the cases, summarizing their perceptions of the cultural atmosphere in historical spaces. Through semantic differential analysis and principal component analysis, we reduced over 20 factors into three dimensions: Dimension 1 - placeness, Dimension 2 - sense of place, and Dimension 3 - spirit of place. These dimensions correspond to whether the physical space holds historical significance and whether its atmosphere fosters empathy or emotional attachment. As well as whether people can genuinely comprehend and engage with the cultural atmosphere, including acknowledging cultural values and the quality and inclusivity of cultural activities.

2.3. Data preprocessing

(1) Sound sources

We predicted the occurrence probability of 527 types of AE in each audio segment (Fig. 3). Subsequently, relevant sound source labels related to the indicators in Table 1 are selected to form a description of the sound sources in the scene (Fig. 4). Each type of sound source is assigned a specific occurrence probability value, which will be used for subsequent correlation analysis.

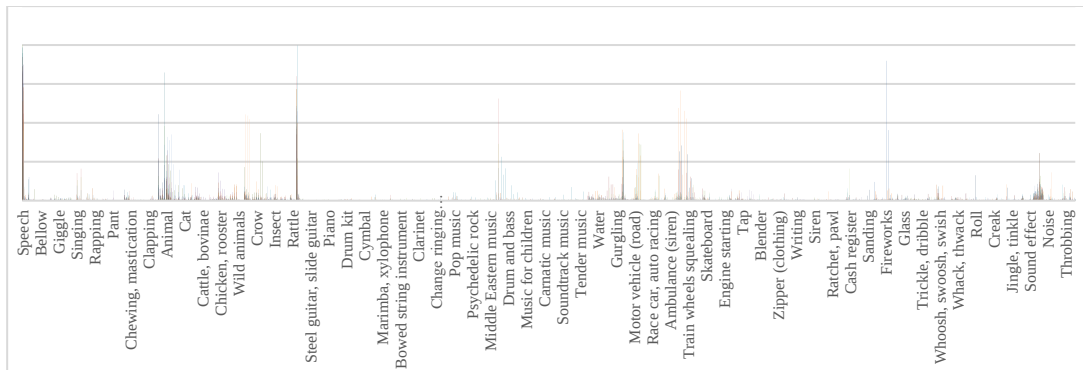


Fig.3 Deep learning-based sound source labelling results



Fig.4 Specific case's sound source characteristic

(2) Visual characteristics

Semantic segmentation of visual images using deep learning fully convolutional networks (FCNs) contributes to our understanding of the complex elements in built environments in street scenes. The ADE_20K database trained by the MIT CSAIL Computer Vision Group allows semantic segmentation of 150 street-image labels. It can provide a sufficient diversity of objects and proportions of the image area, aiming to offer more refined and differentiated results for the experimental outcomes. We also can visualize the visual elements segmentation in GIS, as shown in Fig 5.



Fig.5 Semantic segmentation of 360 street image (use case 1 as an example)

Therefore, the visual indexes like sky view factor, green visibility, pedestrian index, road visibility, building visibility, enclosure index and crowd density can be calculated.

3. Results

3.1 Correlation between sound sources and the sense of culture

From the results in the table1, the following can be obtained:

(1) A total of 35 sound sources factors' correlations with the intrinsic dimension of sense of culture showed significance at the level of 0.01; a total of 3 sound sources factors' correlations with the intrinsic dimension of sense of culture showed significance at the level of 0.05.

(2) From the perspective of the sound sources category, natural sounds are generally negatively correlated with sense of culture, while people sound are positively correlated. However, the impacts of traffic sounds and cultural activity sounds vary depending on the specific source.

(3) Specifically, in natural sounds, the effects of water and wind sounds are relatively pronounced, particularly in the sense of place aspect (dimension 2), where continuous rainy and windy weather may diminish emotional connections to a place, such as reducing dependence and attachment. Among people, speech has the strongest positive effect on the sense of culture, particularly in dimensions 2 and 3. In traffic sounds, the mechanical sounds of vehicles such as trucks and cars, as well as horn honking, notably negatively impact the sense of place and spirit of space. However, railway sounds show a weak positive correlation with the spirit of place, likely due to the cases being in railway-type historic towns, where train sounds evoke urban memories for residents, thus influencing cultural connotations differently from truck noise. However, due to the limited number of samples with train sounds, their contribution to cultural perception may be underestimated in this analysis, and future research will supplement samples with railway culture/sounds. Regarding cultural activity sounds, a specific analysis of music and fireworks reveals a strong positive correlation between music and cultural perception. In contrast, fireworks sound exhibits a weak negative correlation, possibly because people perceive fireworks as noise.

Table 1. Correlation results between sound sources and the sense of culture

Sound sources		Theoretical Dimensions and calculated result of 'sense of culture'			
		Dimension1: Placeness	Dimension2: Sense of place	Dimension3: Spirit of Place	Sense of culture
Natural sounds	total value	-.202**	-.098**	-.175**	-.184**
	Wind	-.103**	-.189**	-.166**	-.179**
	Water	-.162**	-.209**	-.192**	-.219**
	Animals	-.161**	-0.01	-.110**	-.108**
People sounds	total value	.116**	.219**	.212**	.214**
	Footsteps	.151**	.160**	.143**	.176**
	Talking	.147**	.246**	.236**	.246**
	Children	0.018	.096**	.097**	.083**
	Laughing	0.057	.171**	.166**	.155**
Mechanical sounds	total value	-0.031	-.166**	-.111**	-.121**
	Vehicles	-.076*	-.202**	-.195**	-.186**
	Railway	0.04	-0.053	0.024	0.004
Cultural activity sounds	total value	.215**	.202**	.261**	.264**
	Music and show	.245**	.233**	.322**	.312**
	Framework	-.069*	-.072*	-.143**	-.111**

Note: ** p < 0.01, * p < 0.05.

3.2 Correlation between sound level and the sense of culture

A total of 27 sound level factors' correlations with the intrinsic dimension of sense of culture showed significance at the level of 0.01; a total of 3 sound level factors' correlations with the intrinsic dimension of sense of culture showed significance at the level of 0.05.

Table 2. Correlation results between sound level and the sense of culture

Sound Level	Theoretical Dimensions and calculated result of 'sense of culture'			
	Dimmensin1: Placeness	Dimmensin2: Sense of place	Dimmensin3: Spirit of Place	calculated result Sense of culture
LAeq (TH) [dB]	-0.01	.082**	.145**	.087**
LApeak (TH) [dB]	-.164**	-.145**	-.166**	-.185**
LAFmax (TH) [dB]	-0.06	0.051	.101**	0.038
LAFmin (TH) [dB]	.071*	.115**	.158**	.135**
LCeq (TH) [dB]	.161**	.209**	.234**	.236**
LCpeak (TH) [dB]	-.199**	-.129**	-.115**	-.171**
LCFmax (TH) [dB]	-.135**	-.076*	-0.029	-.091**
LCFmin (TH) [dB]	-.125**	-0.019	0.031	-0.042
LAeq Ln L10 [dB]	-0.042	-0.001	.069*	0.012
LAeq Ln L50 [dB]	0.052	.136**	.221**	.161**
LAeq Ln L90 [dB]	.107**	.206**	.253**	.222**
LC-LA	.222**	.229**	.225**	.262**
L10-L90	-.146**	-.198**	-.170**	-.200**

Note: ** p < 0.01, * p < 0.05.

From the sound level category, the equivalent C-weighted sound level exhibits a robust positive correlation with every cultural perception dimension. Conversely, both LApeak and LCpeak demonstrate relatively negative associations across various dimensions of cultural perception, suggesting that excessively high transient sound levels may cause adverse spatial perceptions. Furthermore, L50 and L90 display significant positive correlations with the

cultural perception dimension, particularly in aspects closely intertwined with social activities, like the sense and spirit of place. This underscores the influence of medium to low sound levels on the sense of culture throughout the event duration.

Through calculations, 'LC-LA' shows positive correlations with various dimensions of sense of culture, indicating that larger disparities between low-frequency (LC) and high-frequency (LA) sound levels result in more positive perceptions. Conversely, the 'L10 - L90' displays negative correlations with sense of place, indicating that reduced sound fluctuations contribute to heightened perceptions positivity. This positive association may be attributed to the stability, comfort, and natural of the sound environment.

3.3 Correlation between SSID perception and the sense of culture

From the results in the table 3, the following can be obtained:

(1) A total of 22 SSID correlations with the intrinsic dimension of sense of culture showed significance at the level of 0.01; a total of 1 sound level factors' correlations with the intrinsic dimension of sense of culture showed significance at the level of 0.05.

(2) Pleasant, vibrant, and eventful sounds exhibit strong positive correlations to cultural dimensions, especially regarding the sense of place. These kinds of sounds enhance people's identification with and emotional connection to culture. Conversely, non-eventful and monotonous sounds are negatively correlated with cultural perception. In terms of correlation values, pleasant sounds have the most significant positive impact on cultural scores, while monotonous sounds have the greatest negative impact.

Table 3 Correlation results between SSID and the sense of culture

SSID	Theoretical Dimensions and calculated result of 'sense of culture'			
	Dimmensin1: Placeness	Dimmensin2: Sense of place	Dimmensin3: Spirit of Place	calculated result Sense of culture
Pleasant	.354**	.491**	.337**	.459**
Chaotic	-.154**	-.186**	-.147**	-.189**
Vibrant	.304**	.424**	.287**	.395**
eventful	.410**	.452**	.358**	.473**
Calm	.078*	.125**	0.029	.089**
Annoying	-.188**	-.234**	-.178**	-.233**
uneventful	-.284**	-.317**	-.327**	-.361**
Monotonous	-.270**	-.343**	-.334**	-.369**

Note: ** $p < 0.01$, * $p < 0.05$.

3.4 Correlation between visual index and the sense of culture

From the results in the table 4, the following can be obtained:

(1) A total of 11 visual indexes correlation with the intrinsic dimension of sense of culture showed significance at the level of 0.01; a total of 3 factors' correlations with the intrinsic dimension of sense of culture showed significance at the level of 0.05.

(2) In terms of placeness, the sky rate and road visibility exhibit a negative correlation, suggesting that closer spaces are more conducive to cultural perception. Regarding the sense of place, pedestrian index, crowd density, and pedestrian activity demonstrate a positive influence, indicating that pedestrian-friendly environments and bustling crowds enhance people's emotional attachments. The spirit of culture shows a similar pattern to the sense of place, although the sky rate has a more pronounced negative impact on the spirit.

Table 4. Correlation results between visual index and the sense of culture

Visual index	Theoretical Dimensions and calculated result of 'sense of culture'			
	Dimmensen1: Placeness	Dimmensen2: Sense of place	Dimmensen3: Spirit of Place	calculated result Sense of culture
Sky View Factor	-.118**	-0.026	-.075*	-.080**
Green View Index	0.03	0	-0.012	0.007
Pedestrian Index	.124**	.159**	.122**	.151**
Road Visibility	-.087**	-.135**	-0.056	-.104**
Building Visibility	.063*	0.056	0.033	0.057
Enclosure Index	.135**	.085**	.075*	.109**
Crowd Density	.189**	.229**	.185**	.224**

Note: ** p < 0.01, * p < 0.05.

3.5 Correlation between visual perceptions and the sense of culture

From the results in the table5, the following can be obtained:

(1) All visual perception indexes correlated with the intrinsic dimension of sense of culture showed significance at the level of 0.01, which number 18.

(2) Overall, attractiveness has the most significant impact on the sense of culture, particularly in the dimension of cultural emotion, among different visual perception indicators. In contrast, completeness has a relatively smaller impact, primarily influencing placeness with lower effects on the other two dimensions. Nonetheless, even with this difference, its correlation with the sense of culture remains high at 0.534.

(3) Subjective visual perception is strongly associated with cultural perception. Interviewees may find it challenging to differentiate between subjective visual indicators and evaluation criteria for cultural perception since both involve cognitive processes and consciousness mediated by the brain. Furthermore, compared with auditory subjective evaluation, visual perception has a higher correlation.

Table 5. Correlation results between SSID and the sense of culture

Visual perception	Theoretical Dimensions and calculated result of 'sense of culture'			
	Dimmensen1: Placeness	Dimmensen2: Sense of place	Dimmensen3: Spirit of Place	calculated result Sense of culture
Completeness	.511**	.461**	.407**	.534**
Authenticity	.451**	.465**	.489**	.546**
Attractiveness	.627**	.674**	.610**	.742**
Richness	.525**	.635**	.543**	.662**
Comfort	.511**	.551**	.433**	.580**
Aesthetics	.633**	.624**	.570**	.709**

Note: ** p < 0.01, * p < 0.05.

4. Discussion and conclusion

This study explored how visual and auditory elements in soundscapes relate to the perception of the sense of culture. The findings showed: 1) Natural sounds, people sound, and cultural activities sounds like music/shows significantly influence the sense of culture in historical spaces along the Chinese Eastern Railway (CER). 2) Calm and stable sound environments contribute to creating a cultural atmosphere. 3) Pleasure and eventful sounds strengthen people's connection to culture. 4) Enclosed spaces, pedestrian-friendly environments, and bustling crowds enhance the cultural ambience. 5) Visual perception has a stronger correlation with sense of culture compared to auditory evaluation.

It is worth discussing that cultural connotations vary greatly based on regional and background differences, so whether the conclusions of this study apply to other types of

historical towns requires validation with a large number of cases. This study contributes to creating a workflow for urban designers to pay attention to specific soundscape elements when preserving historical spaces, thereby fostering a stronger sense of place and emotional attachment among people.

This study is foundational work on how audiovisual interaction in soundscapes affects the sense of culture. Based on this study, future research will expand the cases, introduce control experiments, and establish structural equation models (SEM) to investigate the mechanisms. The entire work contributes to regenerating cultural spaces by modulating soundscape elements.

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