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Effect of an Artificial Sound-Based Index on the Perception of Historical Block Environments

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Abstract: The acoustic environment can influence people's perceptions and experiences and shape the soundscape. The soundscape has a unique role in shaping the cultural identity of a regional culture. Artificial sounds are an essential source of sounds in historical blocks; research has shown the influence of the ratio of perceived artificial sounds to the perceived extent of natural sounds on environmental perception in historical blocks. In order to explore this impact, this study uses the red soundscape index (RSI_n), which represents the ratio of perceived artificial sounds to natural sounds, and constructs a structural equation model to elucidate the relationship between RSI_n, soundscape perception, and sense of place. The results show that: (1) The evaluation of the sense of place is inversely related to the perception of artificial sounds and positively related to the perception of natural sounds. (2) Different artificial sounds have different effects on soundscape perception and the sense of place; the traditional culture soundscape index ($TRSI_n$) has a significant impact on soundscape pleasantness ($\beta = -0.13$, $p < 0.001$) and soundscape quality ($\beta = -0.09$, $p < 0.01$). (3) The human soundscape index ($ARSI_n$) has a significant impact on the sense of place ($\beta = -0.14$, $p < 0.001$). (4) The music soundscape index ($MRSI_n$) has a significant negative impact on soundscape quality ($\beta = -0.13$, $p < 0.05$) and the sense of place ($\beta = -0.12$, $p < 0.05$). Therefore, the different dominant artificial sound sources should be considered and emphasized when designing and optimizing the soundscape of historic districts. The results of this study can serve as design guidelines and supporting data, providing a reference for the optimization and enhancement of the soundscape of historical blocks.

Keywords: red soundscape index (RSI); artificial sound-based index; different dominant artificial sound source; perception of environments; historical block

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1. Introduction

The concept of soundscape was first proposed by the Canadian musician Schafer, who referred to it as the "acoustic environment that is perceived, experienced, or understood by a person or group of people in a particular context" [1]. The soundscape differs from the sound environment because it emphasizes the interaction between humans and sound sources in the background, and the sound environment's perception, understanding, and feedback reconstruction [2]. Different sound sources in this context have varying impacts on subjective human experiences. For example, natural sounds can help reduce stress, restore cognitive states, and enhance feelings of well-being [3,4]. Mechanical sounds, on the other hand, affect hearing and are detrimental to stress recovery, leading to negative emotions and stimulating antisocial behavior [5,6]. Artificial sounds, being more complex, can have both positive and negative effects on the soundscape perception, depending on the environment and the specific sound source [7]. For example, children's playing and shouting are considered harmful sounds [8], while music can improve the acoustic environment and have a positive impact on individuals [9]. However, in urban environments, sound sources do not exist in isolation but are a mixture of artificial, mechanical, and natural sounds. The interaction between these sound sources can lead to isolation and masking effects, and studying each sound source individually may not accurately reflect people's perception of the sound environment [10]. Therefore, it is necessary to discuss the influence of different mixed sound sources on the public's perception and experience.

In this context, scholars have begun to focus on the mixing ratio of different sound sources. Kogan et al. (2018) proposed the green soundscape index (GSI), which represents the ratio of natural sound perception to traffic noise perception. By quantitatively analyzing the interaction between these two types of sound sources, they discussed the relationship between the mixing ratio of these two sound sources and the quality of the sound environment, making groundbreaking contributions to the study of the relationship between different sound source ratios and the soundscape [11]. However, this study only discussed the impact of the mixing of natural sounds and traffic noise on the sound environment, and lacked a discussion of the frequently occurring artificial sounds in urban public spaces. Yang et al. (2022) proposed the red soundscape index (RSI), which represents the ratio of artificial sound perception to other sound perception. They further subdivided the RSI into RSI_n (the ratio of artificial sound perception to natural sound perception) and RSI_t (the ratio of artificial sound perception to mechanical sound perception), and explored the correlation between the RSI and the subjective perception of the soundscape in public spaces dominated by artificial sounds, as well as the application of the RSI to the classification of urban open spaces [12]. However, this study did not discuss the differences in the impact of artificial sounds on the subjective soundscape perception. Artificial sound is significant in historical blocks and plays a crucial role in creating a suitable soundscape [13]. However, research on artificial sounds in historical blocks is still rare.

Historical blocks are a city's most important cultural heritage, embodying the city's developmental history and characteristics [14], and the locality is the core that reflects its characteristics [15]. An iconic sound contains information, triggering a cultural identity that matches with the visual environment, etc. [16]. By leaving a deep impression on people's minds, it directly impacts people's perceptual experience and produces a strong sense of "place" [17]. Therefore, the soundscape of historical blocks has a unique role in shaping the regional cultural personality, and becomes an essential part of the urban cultural landscape. Research on the soundscape of historical blocks has gradually begun to deal with the association between the soundscape and local characteristics and place attachment from the traditional perspectives of audio-visual interaction [18,19], soundscape evaluation and preference [20,21], soundscape protection, and determinants [22,23]. Liu et al., through their study of Jinli Ancient Street, confirmed that there is an influence of the soundscape on visitors' place attachment, which helps to create a sense of place in historical blocks [24]. Zhao et al. explored the influence of the soundscape on place attachment in different types of historic districts [25]. They concluded that the influence of sound source preference on place attachment is related to the type of historic district. However, research on the effect of artificial sound perception on subjective perception has not been sufficiently emphasized. Zinah et al., exploring the effects of reverberation time and source composition on a sense of place, confirmed that reverberation time and source combination can enhance or diminish a sense of place [26]. Therefore, exploring the effects of combining different ratios of artificial and natural sounds on environmental perception is necessary, and a better assessment of this effect needs to be made using the red soundscape index.

Therefore, this research focuses on the effects of an artificial sound-based index (RSI) on the perception of historical block environments in Fuzhou, China. The first part analyzes the relationship between the RSI, soundscape perception, and a sense of place evaluation. Then, it focuses on the effect of different dominant artificial sounds on the $TRSI_n$ (ratio of traditional cultural sound perception to natural sound perception), $ARSI_n$ (ratio of human activity sound perception to natural sound perception), and $MRSI_n$ (ratio of musical sound perception to natural sound perception) on soundscape perception and the sense of place. Finally, the paper proposes optimization suggestions for enhancing the landscape of historical blocks.

2. Materials and Methods

2.1. Study Area

This study was conducted in Fuzhou, located in the southeastern part of China, which has a typical subtropical monsoon climate. Fuzhou is a nationally recognized historical and cultural city with a rich historical heritage in China. Three typical historical blocks, namely, "Three Lanes and Seven Alleys" historical block, "Shangxia Hang" historical block, and "Yantai Hill" historical block, were selected as the study sites (Figure 1). The selected historical blocks showcase Fuzhou's traditional culture and architectural style and have strong representativeness. "Three Lanes and Seven Alleys" (45 hm^2) is one of the largest and most well-preserved historical blocks in China, known as the "living fossil of the urban block system in China" and the "Museum of Ming and Qing Dynasty Architecture in China." "Shangxia Hang" (31.37 hm^2) is a traditional block that blends Fuzhou's architectural and cultural characteristics, featuring a combination of commercial, residential, tourist, and cultural functions. "Yantai Hill" (53.22 hm^2) embodies the history of modern commerce in Fuzhou, which witnessed the city's development and transformation and served as an essential gateway for economic and cultural exchanges with foreign countries in Fujian Province. The entire area and its surroundings have 163 well-preserved historical buildings from the modern and contemporary periods, including numerous foreign consulates, churches, foreign firms, villas, and dozens of traditional Chinese garden-style ancient houses.

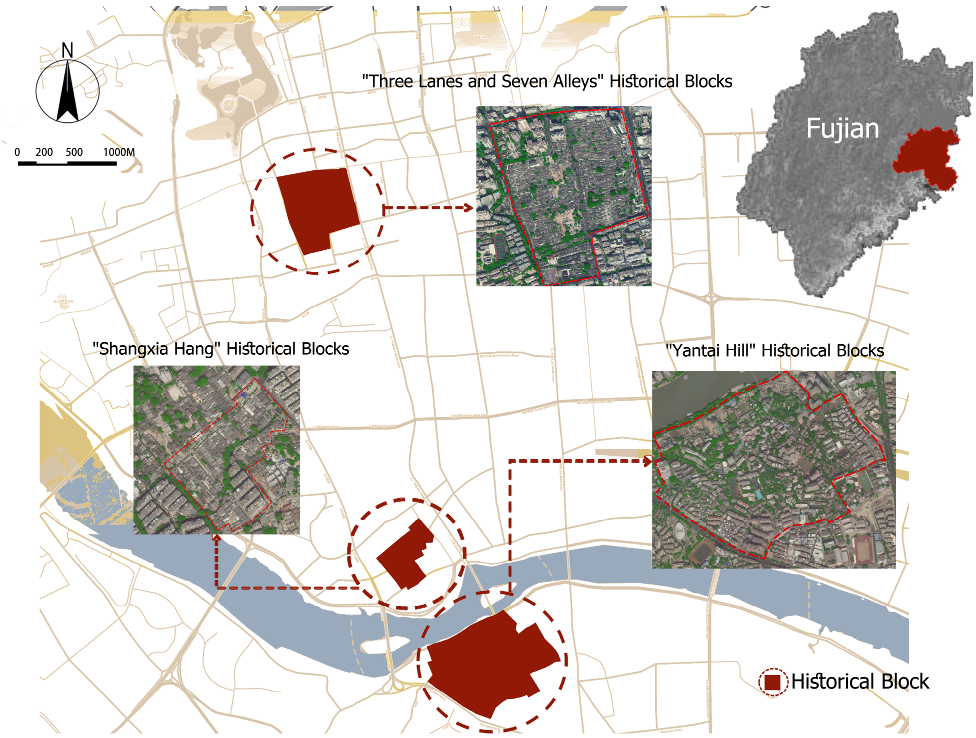

Figure 1. Location of the three historical blocks in Fuzhou, China (Source: Google Earth 2023, author elaboration).

The pilot study conducted at the research sites identified 13 different sound sources, mainly categorized into natural sounds and artificial sounds, as shown in Table 1. Natural sounds refer to sounds generated by non-living and living natural factors, including geophysical sounds and biological sounds. Artificial sounds are caused by human activities, including human sounds, traditional cultural sounds, music, etc. [27]. Therefore, this study discusses the relationship between the RSI_n (the ratio of artificial sound perception level to natural sound perception level) in historical blocks and the perception of soundscape and sense of place.

Table 1. Typical sound sources in historical blocks.

Sound Category	Sound Category Middle Class	Sound Sources	Short Name
Nature sound	Biological sound	Birdsong	BS
	Geophysical sound	Tree rustling	TR
		Water sound	WS
Artificial sound	Human sound	Surrounding speech	SS
		Playing children	PC
		Hawking	HA
		Footsteps	FS
	Traditional cultural sound	Folk activity	FA
		Handcraft making	HM
		Temple music	TM
	Music	Live music	LM
		Shop music	SM
		Broadcasting music	BM

2.2. Questionnaire Design

The questionnaire consisted of four parts, and the basic framework and data collection method were taken from Relevant standards [28].

2.2.1. Basic Information about Participants

The first part of the questionnaire aimed to collect the socio-demographic information about the participants [29–31]. Reference was made to similar studies on urban open space soundscapes. The specific indicators selected for this study included gender (male, female), age (18 years and below, 19–29 years, 30–39 years, 40–49 years, 50–59 years, 60 years and above), educational background (high school and below, undergraduate and above), residency status (resident, tourist), and frequency of visits (first time, 2–3 times, once a month, once a week, multiple times a week).

2.2.2. Perception of Typical Sound Sources

The second part of the questionnaire collected information regarding typical sound source perceptions (Table 1). Interviewees were asked to use a five-point Likert scale to evaluate their perception of the typical sound sources based on their experiences (1—never, 2—occasionally, 3—normal, 4—frequently, 5—very frequently).

2.2.3. Evaluation Indicators for Environmental Perception

1. Selection of Soundscape Perception Indicators

To accurately obtain subjective evaluation information on the soundscape of the historical blocks in Fuzhou, a semantic differential method (SD) was used to create a five-level scale for semantic differential evaluation [32,33].

First, based on existing soundscape research [34–37] and the pre-experiment on the study sites, 18 adjective word pairs (Weak–Strong, Monotonous–Diverse, Constant–Change, Noisy–Quiet, Noisy–Clear, Scattered–Concentrated, Harsh–Soft, Unsafe–Safe, Dislike–Like, Anxiety–Relaxation, Unpleasant–Pleasant, Conflict–Harmony, Uncomfortable–Comfortable, Chaotic–Orderly, Uncharacteristic–Characteristic, Uninteresting–Interesting, Heavy–Light, Artificial–Natural) were determined as the semantic rating items for the perception of the soundscape in the historical block in Fuzhou, scoring on a five-point scale.

2. Perception Dimension of Soundscape

Factor analysis, an important method for extracting soundscape perception dimensions, has been used in many previous studies [38–40]. The present study, through a factor analysis of 18 adjective word pairs, obtained four main factors, from which the perception dimension of the historical blocks soundscape was determined. Dimension 1 accounted for 32.04% of the variance and was related to pleasantness. It mainly included anxiety–relaxation, dislike–like, conflict–harmony, unpleasant–pleasant, uncharacteristic–characteristic, uninteresting–interesting, uncomfortable–comfortable, etc. Dimension 2 accounted for 14.56% of the variance and was related to soundscape quality. It mainly included noisy–clear, chaotic–orderly, scattered–concentrated, etc. Dimension 3 accounted for 11.49% of the conflict and was related to comfort. It primarily included noisy–quiet, harsh–soft, etc. Dimension 4 accounted for 8.30% of the variance and reflected the diversity of sound. It included constant–change and weak–strong (Table 2). These four factors explained 66.38% of the conflict in the sample. The KMO value was 0.93, indicating that the application of factor analysis to this sample was highly practical, and the results were stable.

The explanatory degrees of soundscape pleasantness and soundscape quality are 32.04% and 14.56%, respectively, which are much higher than the other factors and explain most of the variance. It indicates that in the study of soundscape perception in Fuzhou's historical blocks, soundscape pleasantness and soundscape quality determine people's evaluation results to a large extent. Soundscape pleasantness has the highest degree of explanation, indicating that it is the most influential factor for soundscape perception in Fuzhou's historic districts, and this conclusion is consistent with previous studies that have found that the first factor affecting soundscape perception is related to the pleasantness or preference of sound [31,41]. In contrast, soundscape quality is the second factor affecting soundscape perception, which is at variance with previous conclusions that soundscape richness is the second factor affecting soundscape perception. This may be because context influences the selection of semantic word pairs [42], which impacts soundscape perception dimensions. The difference in users' focus in different urban spaces affects their subjective perception [43], and users in historical blocks pay more attention to the soundscape quality. Thus, soundscape quality becomes the second factor affecting soundscape perception. Therefore, the following study further discusses soundscape pleasantness and soundscape quality as the main factors influencing soundscape perception.

Table 2. Soundscape perception dimensions in historical blocks.

Semantic Word Pairs	**Component (Explained Variance, %)**			
	1 (32.04)	**2 (14.56)**	**3 (11.49)**	**4 (8.30)**
Anxiety–Relaxation	0.87			
Dislike–Like	0.88			
Conflict–Harmony	0.88			
Unpleasant–Pleasant	0.89			
Uncharacteristic–Characteristic	0.77			
Uninteresting–Interesting	0.77			
Discomfort–Comfort	0.74			
Noisy–Quiet			0.72	
Harsh–Soft			0.78	
Monotonous–Diverse			0.66	
Artificial–Natural			0.67	
Constant–Change				0.79
Weak–Strong				0.79
Noisy–Clear		0.74		
Chaotic–Orderly		0.82		
Scattered–Concentrated		0.79		
Heavy–Light	0.51	0.55		
Unsafe–Safe	0.64			

3. Selection of environmental perception evaluation indicators

The environmental perception evaluation indicators include soundscape perception and sense of place. Based on the above analysis, soundscape perception evaluation mainly consists of two aspects: soundscape pleasantness and soundscape quality. Among them, the factors with the top three factor loadings are anxiety–relaxation (0.87), dislike–like (0.88), and conflict–harmony (0.88). The three chosen factors loadings for the quality of the sound scenery are noisy–clear (0.74), chaotic–ordered (0.82), and scattered–concentrated (0.79). In the third part of the questionnaire, the leading evaluative indicators for the soundscape perception are anxious–relaxed, dislike–like, conflict–harmony, unpleasant–pleasant, noisy–clear, chaotic–ordered, and dispersed–concentrated. The Likert five-point scale method is used for evaluation.

The sense of place is the subjective feeling of the users in a place and is the relationship between the users and the environment of the place [44]. The place is shaped by the integration of aspects, such as the physical environment and socio-cultural factors [45]. Because the soundscape plays an essential role in promoting people's attachment to and identification with places [46,47], the soundscape is one of the essential sources of information about the sense of place [17]; an incredibly iconic soundscape can quickly form a deep impression on people's minds and create a strong sense of place. Since the characteristics of the soundscape contain so much information, people can produce a sense of cultural identity and visual environment to match [16]. In the fourth part of the questionnaire, the leading evaluative indicators for the "sense of place" are local characteristics, informative, and audio-visual harmony. The Likert five-point scale method is used for evaluation.

2.3. Data Analysis

The survey was conducted in the three historical blocks in Fuzhou from 4–23 November 2021. A total of 37 undergraduate students majoring in urban planning at Fujian Agriculture and Forestry University were divided into six groups to distribute the questionnaires publicly. In order to achieve quality control of the questionnaire, students were thoroughly trained before distributing the survey, including an understanding of the questionnaire's content and the questionnaire filling method, and how to effectively communicate with the interviewees. When the questionnaire was distributed, a small gift, such as a notebook and pen, was provided as a sign of gratitude for completing the survey. The participants were randomly selected at the study sites, and 968 questionnaires were collected, of which 951 were valid, representing a validity rate of 98.24%. The preliminary statistical results of the sample information are presented in Table 3. The number of male (48%) and female (52%) respondents was roughly equal. The percentage of interviewees aged 50 and above (44%) exceeded those of the other age groups. The main educational level was a bachelor's degree and above (64%). In terms of visit frequency, first-time visitors (36%) and visitors who came more than once a week (25%) accounted for a relatively large proportion, with tourists (58%) slightly outnumbering residents (42%).

The data were processed using SPSS 24.0 software. A Pearson correlation analysis examined the relationship between the RSI_n, soundscape perception, and sense of place. In addition, structural equation modeling (SEM) was conducted to describe the relationship between the RSI_n and environmental perception comprehensively. During the SEM process, exploratory and confirmatory factor analysis was performed [48]. Exploratory factor analysis (EFA) extracted the main factors. Then confirmatory factor analysis (CFA) was conducted to validate the factor structure of the RSI_n and environmental perception. Based on the results of the EFA and CFA, an SEM model of the relationship between RSI_n and environmental perception is proposed. The CFA and SEM are analyzed using the AMOS 24.0 software package.

Table 3. Main demographic characteristics of the interviewees.

Demographic Information		Percentage (%)
Gender	Male	48
	Female	52
Age	≤24	13
	25–30	16
	31–40	11
	41–50	16
	51–60	16
	>60	28
Level of education	High school or lower	36
	Bachelor degree or above	64
Visit frequency	For the first time	36
	The second or third time	19
	Once a month	11
	Once a week	9
	Several times a week	25
Place of residence	Resident	42
	Tourist	58

3. Results

3.1. The Relationship between RSI_n and Environmental Perception

The relationship between the RSI_n and environmental perception was examined by dividing the RSI_n into three sub-indices: the perception ratio of traditional sounds to natural sounds ($TRSI_n$), the perception ratio of human activity sounds to natural sounds ($ARSI_n$), and the perception ratio of music sounds to natural sounds ($MRSI_n$). These sub-indices were established as shown in Table 4.

Table 4. Definition of soundscape index.

Indicator	Definition	Formula
RSI_n	Red soundscape index	$\frac{PHS}{PNS}$
$TRSI_n$	Ratio of traditional cultural sound perception to natural sound perception	$\frac{PHIS}{PNS}$
$ARSI_n$	Ratio of human activity sound perception to natural sound perception	$\frac{PAS}{PNS}$
$MRSI_n$	Ratio of musical sound perception to natural sound perception	$\frac{PMS}{PNS}$

Notes: PNS: natural sound perception degree; PHS: artificial sound perception degree; PHIS: the degree of perception of traditional cultural sounds; PAS: the degree of human activity acoustic perception; PMS: music sound perception degree.

The RSI_n, $TRSI_n$, $ARSI_n$, and $MRSI_n$ are all significantly negatively correlated with soundscape perception and sense of place ($p < 0.05$, $p < 0.01$). The strongest correlation is observed between soundscape pleasantness and $TRSI_n$ ($r = -0.20$, $p < 0.01$), while the weakest correlation is observed between soundscape pleasantness and $MRSI_n$ ($r = -0.15$, $p < 0.01$). There are no significant differences in the correlations between soundscape quality and RSI_n, $TRSI_n$, $ARSI_n$, and MRS_{In}. The sense of place is most strongly correlated with $ARSI_n$ ($r = -0.15$, $p < 0.01$), and the weakest correlation is observed with $TRSI_n$ ($r = -0.08$, $p < 0.05$) (Table 5).

Table 5. Correlations between RSI_n and environmental perception.

Indicator	Soundscape Pleasantness	Soundscape Quality	Sense of Place
RSI_n	−0.19 **	−0.12 **	−0.13 **
$TRSI_n$	−0.20 **	−0.11 **	−0.08 *
$ARSI_n$	−0.17 **	−0.10 **	−0.15 **
$MRSI_n$	−0.15 **	−0.12 **	−0.12 **

Notes: ** $p < 0.01$ and * $p < 0.05$.

3.2. RSI and Soundscape Perception Relationship Model

3.2.1. Exploratory Factor Analysis

The results of Bartlett's sphericity test and the KMO value analysis data are significant at 0.000 ($p < 0.001$), indicating that the data passes Bartlett's sphericity test. The KMO value is 0.826 (KMO > 0.70), meaning that the collected data can be subjected to factor analysis.

An EFA exploratory factor analysis was performed to extract the common factors, resulting in four common elements with a total explanatory power of 78.73% (exceeding 50%, indicating good explanatory power). Common factor 1 includes the variables "anxious-relaxed," "dislike-like," "conflict-harmony," and "unpleasant-pleasant," which are summarized as soundscape pleasantness, with an explanatory power of 25.08%. Common factor 2 includes the variables "$TRSI_n$", "$ARSI_n$", and "$MRSI_n$", which are summarized as the RSI_n, with an explanatory power of 18.98%. Common factor 3 includes the variables "informative," "audio-visual harmony," and "local characteristics," which are summarized as the sense of place, with an explanatory power of 17.67%. Common factor 4 includes "noisy-clear," "chaotic-orderly," and "scattered-concentrated," which are summarized as soundscape quality, with an explanatory power of 17.00% (Table 6).

Table 6. Principal factors in the environmental perception and RSI_n that were extracted via EFA.

Semantic Word Pairs	Component (Explained Variance, %)			
	1 (25.08)	2 (18.98)	3 (17.67)	4 (17.00)
Anxiety–Relaxation	0.88			
Dislike–Like	0.89			
Conflict–Harmony	0.87			
Unpleasant–Pleasant	0.87			
Noisy–Clear				0.80
Chaotic–Orderly				0.84
Scattered–Concentrated				0.83
Informative			0.86	
Audio-visual harmony			0.86	
Local characteristics			0.87	
$TRSI_n$		0.87		
$ARSI_n$		0.91		
$MRSI_n$		0.92		

3.2.2. Confirmatory Factor Analysis

The common factors obtained from the EFA are used as latent variables, and the corresponding variables are used as observed variables to establish the measurement model in the structural equation model. A CFA factor analysis is conducted on the measurement model to examine the reliability of the measurement model further. The reliability of the measurement model is analyzed by investigating each measurement model's Cronbach's Alpha coefficient (CA). The Cronbach's Alpha coefficients for the latent variables "pleasantness of the soundscape," "quality of the soundscape," "sense of place," and "RSI" are all greater than 0.7, indicating good data reliability (Table 7). The convergent validity of the data is typically analyzed using factor loadings, average variance extracted (AVE), and composite reliability (CR). Based on the EFA results, a measurement model is established in AMOS to obtain the standardized factor loadings and error variances, and to calculate the AVE and CR values. All the measurement models have CR values greater than 0.5 and AVE values greater than 0.7, which are not lower than the expected values, indicating that the observed variables for each latent variable have high explanatory power and good consistency.

Table 7. Results of CFA for the observed and latent variables.

Observable Variable	Latent Variables	Cronbach's Alpha	Std. Factor Loading	CR	AVE
Soundscape pleasantness	Anxiety–Relaxation Dislike–Like Conflict–Harmony Unpleasant–Pleasant	0.93	0.88 0.89 0.87 0.87	0.93	0.77
Soundscape quality	Noisy–Clear Chaotic–Orderly Scattered–Concentrated	0.81	0.80 0.84 0.83	0.86	0.67
Sense of place	Informative Audio-visual harmony Local characteristics	0.84	0.86 0.86 0.87	0.90	0.75
RSI_n	$TRSI_n$ $ARSI_n$ $MRSI_n$	0.89	0.87 0.92 0.91	0.93	0.81

3.2.3. Conceptual SEM of RSI_n and Environmental Perception

There are significant differences in the impact of various sound sources mixed in different proportions on people's subjective feelings [11,39]. The auditory perception of a place can change significantly in a short period, and even the soundscape at each moment may be different. Over time, a place's frequently occurring and unique soundscape also becomes part of its spirit [49]. The soundscape plays an essential role in promoting people's dependence on and identification with a place [46,47], and is one of the essential sources of information for the sense of place [17]. The conceptual SEM of the RSI_n and the environmental perception of the historical block (referred to as the influence model hereafter) are shown in Figure 2.

The model consists of three main hypotheses (Ha, Hb, and Hc) and six specific hypotheses, as follows.

Ha. *The RSI_n has a significant impact on soundscape perception and the sense of place, with the following specific hypotheses:*

Ha1. *The RSI_n positively influences soundscape pleasantness.*

Ha2. *The RSI_n positively influences soundscape quality.*

Ha3. *The RSI_n positively influences the sense of place.*

Hb. *Soundscape perception has a significant impact on the sense of place, with the following specific hypotheses:*

Hb1. *Soundscape pleasantness positively influences the sense of place.*

Hb2. *Soundscape quality positively influences the sense of place.*

Hc. *Soundscape quality has a significant impact on soundscape pleasantness, with the following specific hypothesis:*

Hc1. *Soundscape quality positively influences soundscape pleasantness.*

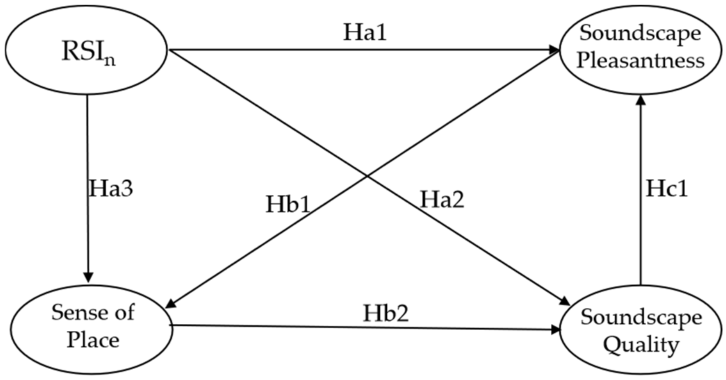

Figure 2. A conceptual SEM of RSI_n and environmental perception.

3.2.4. SEM for RSI_n and Environmental Perception

Based on the above hypotheses, a structural equation model was established to evaluate the model's validity. The fit indices for the model include CMIN/DF, GFI, CFI, and RMSEA. GFI and CFI values greater than 0.9 are considered acceptable [48,50]. The approximate root-mean-square error (RMSEA) measures the approximate fit of the population and is therefore related to the difference caused by the approximation [51]. An RMSEA value of less than 0.08 is considered a proper fit [48,52]. All the fit indices for the model exceeded the recommended values, indicating an acceptable model (Table 8).

Table 8. The values of goodness-of-fit indices for the proposed model.

Model Fit Index	x2/df	GFI	CFI	RMSEA
Obtained values	2.158	0.980	0.991	0.035
Recommended values	<5.00	>0.90	>0.90	<0.08

The standardized path loadings (β) and their statistical significance for the SEM (Model I) in the overall environment, based on the three main hypotheses (Ha, Hb, and Hc) and the four specific hypotheses, were found to be statistically significant (Table 9).

Table 9. Testing results of the hypotheses and standardized path loadings of the SEM.

	Model Fit Index	β	SE	C.R.	*p*-Value
Ha1	RSI_n→soundscape quality	−0.10	0.05	−3.17	0.002
Ha2	RSI_n→soundscape pleasantness	−0.11	0.05	−2.79	0.005
Ha3	RSI_n→sense of place	−0.07	0.05	−1.87	0.062
Hb1	Soundscape pleasantness→sense of place	0.25	0.04	5.53	0.000
Hb2	Soundscape quality→sense of place	0.08	0.05	1.78	0.075
Hc1	Soundscape quality→Soundscape pleasantness	0.52	0.05	13.79	0.000

In the Ha hypothesis, the RSI_n has a significant negative impact on soundscape pleasantness (β = −0.10, $p < 0.01$) and soundscape quality (β = −0.11, $p < 0.01$). In the Hb hypothesis, soundscape pleasantness has a significant positive impact ($p < 0.001$) on the sense of place, with standardized regression coefficients of 0.25. In the Hc hypothesis, soundscape quality significantly impacts soundscape pleasantness (β = 0.48, $p < 0.001$). Among the observed variables of the RSI_n, the factor loadings of $ARSI_n$ (0.91) and $TRSI_n$ (0.88) are significantly higher than that of $MRSI_n$ (0.77), indicating that human sound and traditional cultural sounds have a more significant impact on the RSI_n. In soundscape pleasantness, the observed variables dislike–like (0.89), conflict–harmony (0.86), and unpleasant–pleasant (0.82) have higher factor loadings, indicating a more significant impact on soundscape pleasantness. Regarding the soundscape quality, the factor loading of the latent variable noisy–clear (0.82) is significantly higher than that of the other two latent variables, indicating that it has the most significant impact on sound scenery quality. In terms of the sense of place, the factor loading of the latent variable local characteristics (0.85) is significantly higher than those of audio-visual harmony (0.78) and informative (0.77). Soundscapes with local characters are essential in creating a sense of place (Figure 3).

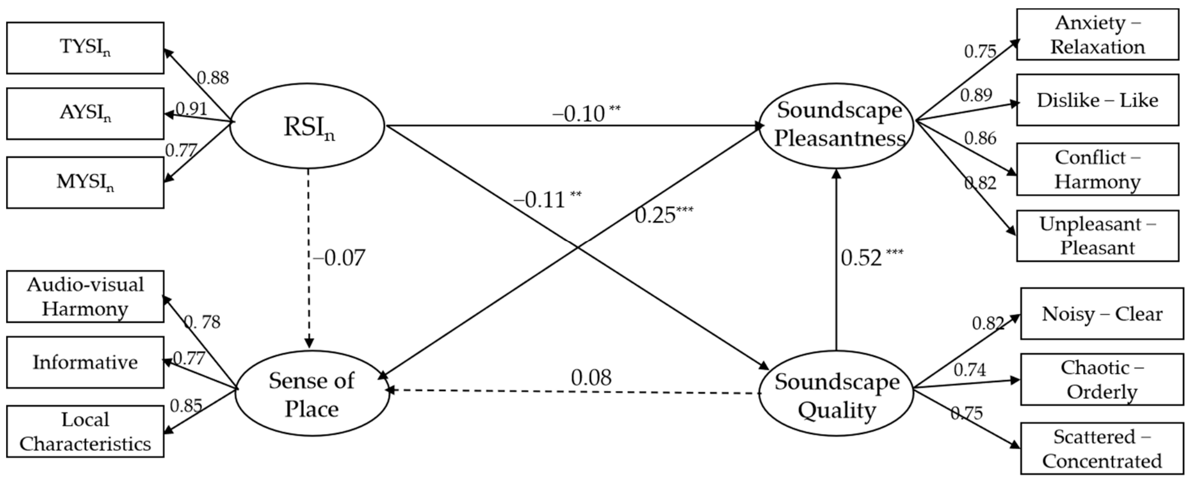

Figure 3. SEM for RSI$_n$ and Environmental Perception (Model I) (** $p < 0.01$, *** $p < 0.001$).

3.2.5. Structural Equation Sub-Model for RSI$_n$ and Environmental Perception based on Different Artificial Sounds

To further understand the impact of the different artificial sound sources on the perception of the soundscape in the historical blocks, the sub-models RSI$_n$, TRSI$_n$, ARSI$_n$, and MRSI$_n$ were constructed, with traditional cultural sound, human activity sound, and music sound as the main factors. The goodness-of-fit indices of these sub-models all exceeded the recommended values, indicating a good fit (Table 10).

Table 10. Testing results of the hypothesis and standardized path loadings of the SEM.

SEM		Model Fit Index	β	SE	C.R.	*p*-Value
Model I$_A$ [1]	Ha1	TRSI$_n$→soundscape quality	−0.13	0.08	−4.23	0.000
	Ha2	TRSI$_n$→soundscape pleasantness	−0.09	0.08	−2.68	0.007
	Ha3	TRSI$_n$→sense of place	−0.02	0.08	−0.46	0.645
	Hb1	Soundscape pleasantness→sense of place	0.25	0.04	5.65	0.000
	Hb2	Soundscape quality→sense of place	0.09	0.05	1.82	0.068
	Hc1	Soundscape quality→Soundscape pleasantness	0.52	0.05	13.73	0.000
Model I$_B$ [2]	Ha1	ARSI$_n$→soundscape quality	−0.05	0.06	−1.35	0.176
	Ha2	ARSI$_n$→soundscape pleasantness	−0.14	0.05	−3.85	0.000
	Ha3	ARSI$_n$→sense of place	−0.06	0.05	−1.95	0.051
	Hb1	Soundscape pleasantness→sense of place	0.25	0.04	5.67	0.000
	Hb2	Soundscape quality→sense of place	0.08	0.05	1.67	0.094
	Hc1	Soundscape quality→Soundscape pleasantness	0.53	0.05	13.74	0.000
Model I$_C$ [3]	Ha1	MRSI$_n$→soundscape quality	−0.08	0.08	−1.83	0.067
	Ha2	MRSI$_n$→soundscape pleasantness	−0.13	0.08	−2.29	0.022
	Ha3	MRSI$_n$→sense of place	−0.12	0.07	−2.48	0.013
	Hb1	Soundscape pleasantness→sense of place	0.24	0.04	5.45	0.000
	Hb2	Soundscape quality→sense of place	0.08	0.05	1.65	0.000
	Hc1	Soundscape quality→Soundscape pleasantness	0.52	0.05	13.67	0.007

[1] x2/df = 2.125, GFI = 0.982, CFI = 0.991, RMSEA = 0.034; [2] x2/df = 2.244, GFI = 0.981, CFI = 0.991, RMSEA = 0.036; [3] x2/df = 2.049, GFI = 0.983, CFI = 0.991, RMSEA = 0.033.

The relationship between the sub-models and Model I is similar, with differences mainly seen in the Ha hypothesis. When traditional cultural sound is the dominant source, the $TRSI_n$ has a significant negative impact on soundscape pleasantness ($\beta = -0.13$, $p < 0.001$) and soundscape quality ($\beta = -0.09$, $p < 0.01$), but does not have a significant impact on the sense of place. Among the traditional cultural sounds, handcraft making (0.91) has a slightly more significant impact on the $TRSI_n$ than traditional folk performance sounds (0.88), while temple music has the most negligible impact (0.68). The observed variables dislike–like (0.87), conflict–harmony (0.86), and unpleasant–pleasant (0.82) have higher factor loadings for soundscape pleasantness. The observed variable chaotic–orderly has the highest factor loading for soundscape quality (0.82), and the observed variable local characteristics has the highest factor loading for the sense of place (0.85) (Figure 4a).

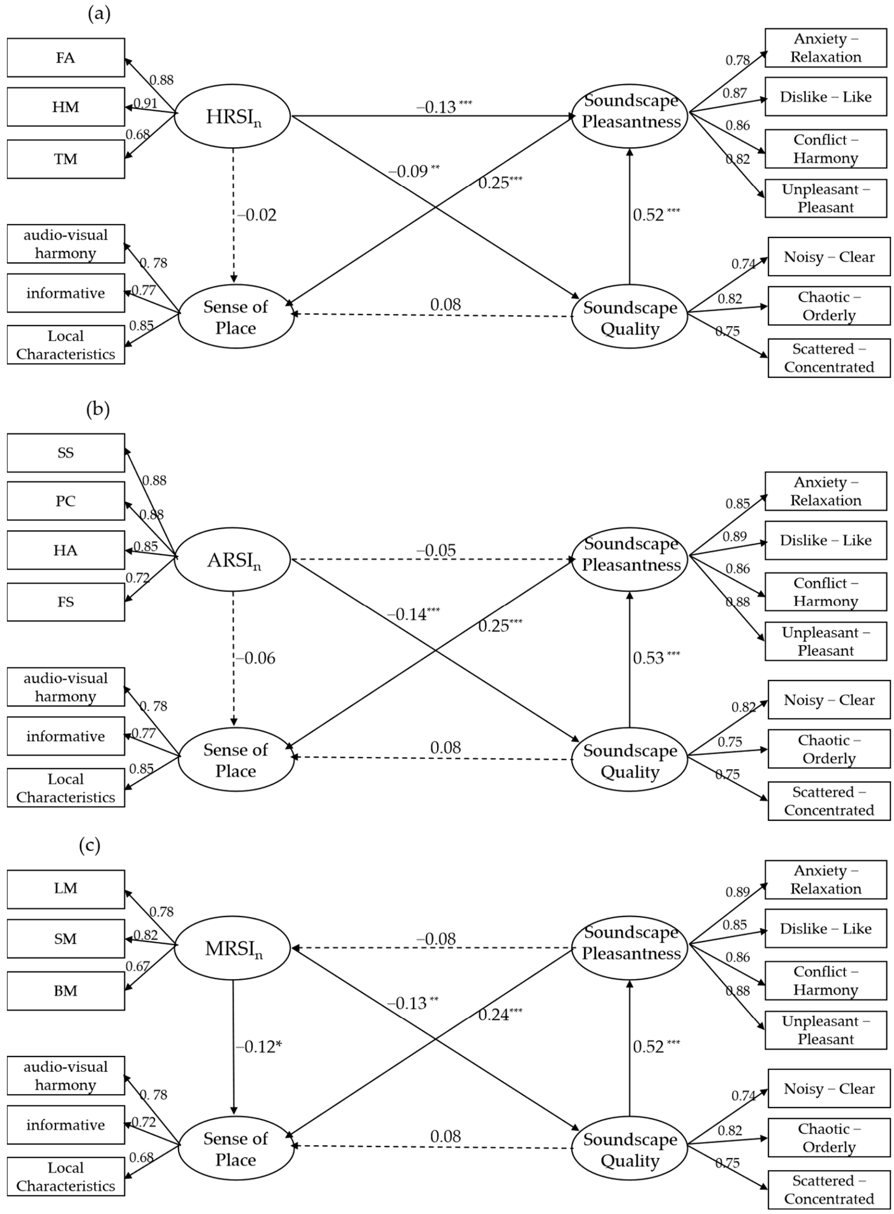

Figure 4. Structural equation sub-model for RSI_n and Environmental Perception. (**a**) Model I_A: Sub-model for $TRSI_n$ and environmental perception, (**b**) Model I_B: Sub-model for $ARSI_n$ and environmental perception, (**c**) Model I_C: Sub-model for $MRSI_n$ and environmental perception. Statistically significant paths are annotated with standardized coefficients (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). Non-significant paths are marked with dashed lines and are not annotated.

When human sound is the dominant source, the $ARSI_n$ significantly negatively impacts soundscape quality ($\beta = -0.14$, $p < 0.01$), but does not significantly impact soundscape pleasantness or the sense of place. Among the human sound sources, playing children (0.88), surrounding speech (0.88), and hawking (0.85) have a more significant impact. The observed variables for soundscape pleasantness have similar factor loadings with no significant differences. The observed variable chaotic–orderly has the highest factor loading for soundscape quality (0.82), and the observed variable local characteristics has the highest factor loading for the sense of place (0.85) (Figure 4b).

When music is the dominant source, the $MRSI_n$ has a significant negative impact on soundscape quality ($\beta = -0.13$, $p < 0.05$) and the sense of place ($\beta = -0.12$, $p < 0.05$), but does not have a significant impact on soundscape pleasantness. Among the music sources, shop music (0.82) and live music (0.78) have the highest factor loadings, while broadcasting music has the lowest factor loading (0.67). The observed variables for soundscape pleasantness have similar factor loadings with no significant differences. The observed variable chaotic–orderly has the highest factor loading for soundscape quality (0.82). For the sense of place, the observed variable audio-visual harmony has the highest factor loading (0.78), while the factor loadings for the observed variables' informative and local characteristics are 0.72 and 0.68, respectively (Figure 4c).

In the Hb hypothesis, all three sub-models for soundscape pleasantness significantly impact the sense of place ($p < 0.001$), with standardized regression coefficients of 0.25, 0.25, and 0.24, respectively. Among the three sub-models, there is no significant difference in the positive impact of soundscape pleasantness on the sense of place, and the impact of soundscape quality on the sense of place is insignificant (Figure 4).

4. Discussion

The RSI_n significantly negatively impacts two dimensions of soundscape perception ($p < 0.01$). Natural sounds positively affect soundscape perception [53]. In historical blocks, the lower the proportion of artificial sounds compared to natural sounds, the higher the evaluation of soundscape perception. Therefore, the evaluation score of soundscape perception in historical blocks can be improved by increasing the proportion of natural sounds. For example, water features can be set up at the main entrances and exits of historical blocks; the frequency of bird songs can also be increased by adding green spaces where various bird species can inhabit [54].

Different artificial sounds also affect the perception of the soundscape in historical blocks. The sub-models (Figure 4) show that the $TRSI_n$ has a significant negative impact on two dimensions of soundscape perception ($p < 0.01$, $p < 0.001$). There is a considerable correlation between traditional cultural sounds and the pleasantness of the soundscape in the historical blocks, which is consistent with the findings of previous studies [27]. With an increased perception frequency of traditional cultural sounds, the participants' pleasantness decreased, contrary to its commonly believed positive influence, which may be because some classic cultural sounds are less prevalent in modern life and fail to evoke emotional resonance. For example, when Min opera is performed, tourists may stop and watch out of curiosity, but quickly leave because they "don't understand" or "are not interested." The visibility of sound sources also has an impact. For example, when hearing handcraft making but not seeing it, participants may only hear a "thud" sound without associating it with the traditional handcrafting process, which affects the users' perception of the local characteristics sound source. Using audio-visual immersive experience devices will be beneficial to interpreting traditional cultural sounds in historical blocks.

The $ARSI_n$ significantly negatively impacts the soundscape quality ($p < 0.001$). Under the condition of an unchanged perception of natural sounds, an increase in the perception of human sounds leads to a decrease in the scores for soundscape quality, which is consistent with the findings of previous research [14]. In historical blocks with a large influx of tourists, sounds with human sources (such as conversations and children playing) are the most commonly perceived sound sources [27]. These sound sources mask pleasant or relaxing sounds and affect the soundscape quality [48]. Human sounds become the primary sound source that influences soundscape quality, so in soundscape optimization design, the perception of human sounds should be reduced.

The $MRSI_n$ significantly negatively impacts the soundscape quality ($p < 0.05$). Under the condition of an unchanged perception of natural sounds, an increase in the perception of music leads to a decrease in the scores for soundscape quality. This finding differs from that of Shu S and Ma H [55], which may be because the performance style and type of music can affect the subjective evaluation of the soundscape; for example, live music is generally liked by people, while broadcasting music needs to consider the impact of music type, melody, and rhythm on subjective evaluations [56,57]. The effect of store music on the $MRSI_n$ (0.82) is greater than that of live music (0.78) and broadcasting music (0.67). Shop music is positively correlated with the impression of "being noisy" and hurts the soundscape quality [27]. The influence of music type and playing form on soundscape evaluation should be considered in soundscape optimization design.

The sub-models show that only the $MRSI_n$ has a direct significant adverse effect on the sense of place, with an increase in the perception frequency of music leading to a decrease in the definition of place scores. Among the three observed variables for the sense of place dimensions, audio-visual harmony (0.78) has the highest factor loading, indicating that it has a more significant impact on the meaning of place than informative (0.72) and local characteristics (0.68). When music is dominant, the degree of harmony between the sound and the surrounding visual environment is an essential factor influencing the sense of place. Visual landscapes will gradually become the spirit or context of a place, and the corresponding auditory experiences will become part of the spirit of the place, enhancing people's sense of place in that space [45]. It is essential to consider the match between the visual landscape and music in the design of the music soundscape, such as playing folk songs or soothing music in private gardens and playing local songs with historical characteristics in historic streets and alleys.

5. Conclusions

Taking "Three Lanes and Seven Alleys", "Shangxia Hang", and "Yantai Hill", three typical historical blocks in Fuzhou as the examples, this study aimed to reveal the relationship between the RSI_n and environmental perception, and to examine differences in the effects of different artificial sound-dominated RSI_ns on environmental perception. The results show that different artificial sounds, when they are the dominant component of the RSI_n, have different effects on the soundscape perception and sense of place. Regarding soundscape perception, the $TRSI_n$ significantly influenced both the soundscape pleasantness and quality dimensions, while the $ARSI_n$ and $MRSI_n$ were the primary sound sources affecting the soundscape quality. Designing soundscapes with visual and auditory consistency can enhance the positive impact of traditional cultural sounds on the soundscape perception. Perceived human activity noise can be reduced to optimize the soundscape quality. The type and performance form of music should be considered based on the demographic characteristics of the users. In terms of the sense of place, only the $MRSI_n$ had a significant effect and, when music was dominant, increasing the audio-visual harmony of the scene helped enhance the sense of place. In addition, mechanical sounds should also be considered in historical blocks. Further research is needed to explore how the variation in the proportion of artificial sounds and mechanical sounds affects the landscape evaluation and overall satisfaction in historical blocks, and to construct models on the effects of changing the perception ratio of artificial sounds to natural sounds and artificial sounds to mechanical sounds on the sense of place evaluation and the overall satisfaction in historical blocks, which would provide more comprehensive supportive data for optimizing the soundscape in historical blocks. In conclusion, the results of this study can serve as design guidelines and supportive data, providing references for optimizing and enhancing the soundscapes of historic and cultural streets.

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