Red Soundscape Index (RSI): An index with the potential to assess soundscape quality

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ABSTRACT

It is not enough to define urban soundscape just using the green soundscape index (GSI), which is the ratio of the perception of natural sounds to the perception of traffic noises. Therefore, in the present study, red soundscape index (RSI), defined as the ratio of perception of natural sounds to perception of human sounds, was introduced. The data for calculating RSI were collected from sound environment measurements and a questionnaire-based survey in seven urban parks in Harbin city, China. The results revealed the following: (1) RSI was correlated with the overall soundscape quality; (2) RSI was correlated with the maximum and minimum instantaneous sound pressure levels and with equivalent sound pressure levels; and (3) The urban sound environment as well as sound quality can be classified by RSI. It was confirmed that RSI could be used as a supplement to GSI in urban soundscape planning.

Keywords: Red soundscape index; Sound perception; Urban sound environment

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1. INTRODUCTION

Urban green space is of great significance for the health of urban residents. Urban green space has a definite impact on human health, independent of the degree of urbanization [1]. In regard to the physical health of the urban residents, the urban green space is associated with longevity and the physical health of the elderly [2]. Urban green space is capable of alleviating air pollution and urban heat island effect, thereby improving the health status of the residents of that region [3]. Urban park is a type of urban green space, which is most commonly used for sports activities by the urban residents, which may in turn reduce the risk and mortality associated with various chronic diseases [4]. In regard to the mental health of the urban residents, urban green space assists the residents in recovering from pressure [5] and regulating their emotions [6]. In regard to the social health of the urban residents, urban green space serves as the most commonly used public space by the residents, which may in turn stimulate the social behaviors of the residents and promote the healthiness of social public relations.

The visual, auditory, and microclimate factors of the urban green space determine the positive significance of this space in the lives of urban residents. Among the afore-stated factors, the auditory factor is the most important one. Noise levels within a city represent one of the factors that exert the greatest impact on the health and the environmental experience of the residents. Urban green space provides effective isolation from noise and a quieter environment. In addition, several sounds from urban green space could directly affect the user’s health and environmental experience, as natural sounds are an intimate part of urban green space. A laboratory study reported that under the condition of exposure to natural sounds, the levels of human skin conductance recovered faster compared to their recovery under the condition of city noise, demonstrating that natural sounds assist humans in recovering from pressure and restoring health[7]. Moreover, natural sounds contribute to human cognitive state , assist in regulating emotions, and improve the sense of pleasure [8]. However, in the urban environment, traffic noise, natural sounds, and human sounds do not appear separately, and there is rather a mixture of all these sounds. Therefore, it is necessary to study the influence of the different ratios of these three types of sounds on the perception and scene experience of the people.

In recent times, attempting to use all means to reduce noise has been the approach followed to improve the urban acoustic environment. This approach is based on the assumption that sound is negative and should be removed from the environment, and that absolute "silence" is the ideal state. However, this approach ignores the positive factors within the acoustic environment. In recent years, an increasing number of scholars have begun studying the soundscape. According to the World Standardization Organization, soundscape is defined as "the acoustic environment perceived, experienced, and understood by individuals or groups". This definition of soundscape affirms the complex role of sound in the environment.

When considering the perspective of soundscape, the impact of the acoustic environment of urban green space on the health and environmental experience of people becomes complex. Soundscape focuses greater attention on the source of the sound and on the people's perception of the different sounds in the environment that constitutes the soundscape [9]. Different sound sources in the environment exert different effects on the health and environmental experience of people. For instance, the natural sounds contribute to the reduction of stress and the recovery of the cognitive state, and are conducive to the enhancement of pleasure [7–8]. Mechanical noise affects the human hearing ability, which is not conducive to recovery from pressure, resulting in bad emotions and stimulating anti-social behaviors [10–12]. Human sounds are further complex, and may produce either positive or negative effects. For instance, children's frolicking would improve the pleasantness and eventfulness of a soundscape [13], while the voices of crying children might increase negative feelings among people [14]. Similarly, music may improve the acoustic environment [15], while it could also mask certain positive natural sounds in the environment, thereby producing adverse effects [16]. As a consequence, the effects of the mixing of natural and human sounds in different proportions on people's experience of the soundscape also becomes complex, as would be discussed ahead in the present report.

In this context, when considering from the perspective of soundscape, it becomes necessary to discuss what proportions of different types of sounds could be mixed to produce a high-quality sound environment. Pablo Kogan et al. explored this issue experimentally in 2018, and presented the GSI, which is the ratio of the perceived degree of natural sound to the perceived degree of traffic noise. The authors indicated that among all the ratios of the various sound source types, GSI is the quantity most relevant to the sound scene quality. The results demonstrated that the higher the value of GSI, the better was the subjective evaluation of the soundscape; similar trends were exhibited by the sound pressure level of the environment, pleasantness of the sound environment, and eventfulness [17].

Within the soundscape, the human sounds are an important sound source that should not be ignored. In the present study, urban green spaces with the dominance of natural sounds and human sounds were selected as survey sites. Questionnaires were developed and used for collecting data on the perception of these two types of sound sources among several respondents at different survey points, and the collected data were used to calculate the Red Soundscape Index (RSI). Furthermore, subjective evaluation of the acoustic environment was investigated and the physical acoustic environment indicators were measured to assess the correlation among the RSI, the subjective evaluation, and the objective physical acoustic indicators.

Using field research and evaluation in seven typical urban parks and pedestrian streets in Harbin, the present study explored the following research questions: (1) what is the correlation between the RSI and the soundscape evaluation?; (2) what is the correlation between the RSI and the physical acoustic environment indicators?; and (3) are there any significant differences among the different urban environments, classified according to the RSI classification of urban environment, in terms of soundscape evaluation and physical acoustic indicators? RSI was expected to be significantly correlated with the overall soundscape assessment, the perceived emotional quality, suitability, recovery, and the physical acoustic environment indicators. If these correlations could be confirmed, RSI could be used as a supplement to the GSI, to predict the quality of urban soundscape through objective sampling and guide the design of the urban acoustic environment.

2. METHODS

2.1 Survey sites

In the present study, the research method reported by Pablo Kogan in 2018 was followed. Seven typical urban parks and pedestrian streets in Harbin, China were selected, within which a total of 23 points were selected as the main survey sites. Questionnaires were developed and used for collecting the required subjective data. The researchers randomly interviewed several visitors at each point in order to assess their perception of the various sound sources and their evaluation of the acoustic environment at that particular point. The survey was conducted on weekends as well as on weekdays in the month of May, when the temperatures ranged from 18 °C to 26 °C. All the respondents were informed regarding the anonymity of the survey, fulfilling their right to know in accordance with the Declaration of Helsinki. A total of 151 valid questionnaires were collected, which included 93 male respondents and 58 female respondents. The age distribution of the respondents was relatively scattered, ranging mainly between 20 and 55 years.

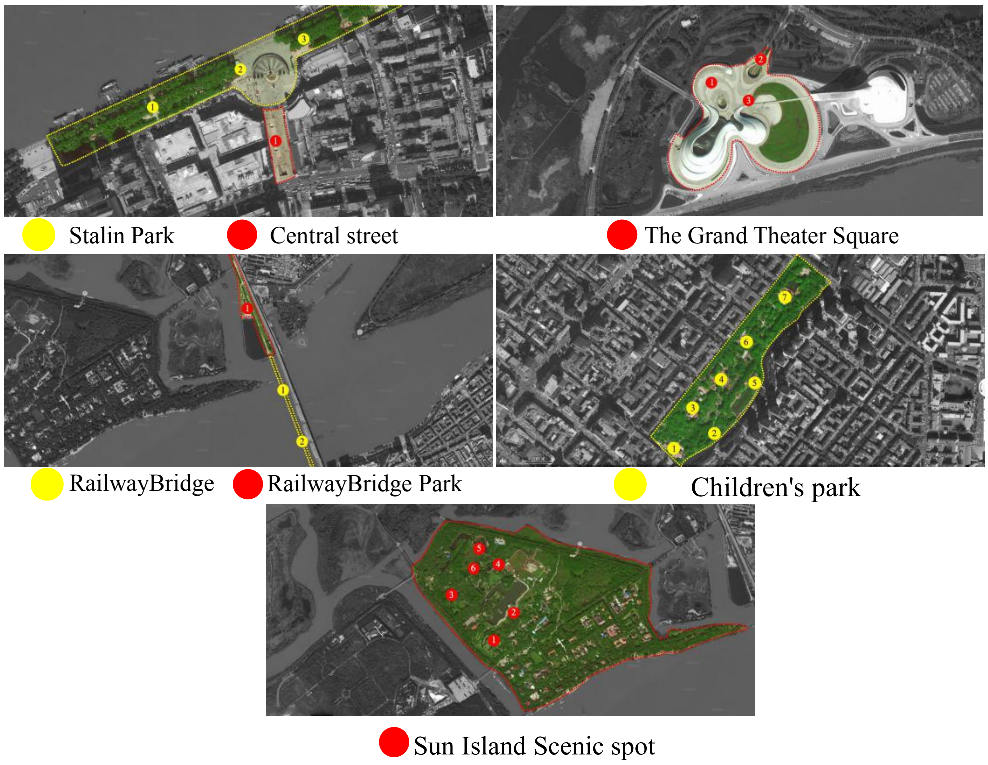

Figure.1: Survey locations in this study

The survey sites included three urban parks, two nature parks, and two pedestrian streets in Harbin. The two urban parks were located in the center of the city, and received a large flow of people. Since the urban parks had a lot of greenery and were far from the main road, the acoustic environment in these parks was less affected by traffic noise. The two nature parks were far away from the city center, received a low inflow of people, and had the dominance of natural scenery. The two pedestrian streets, although being located in the center of the city, did not receive much traffic noise as vehicles were not allowed to pass through these streets, and as such, the influence of traffic noise could be ignored.

As illustrated in Figure 1.**Urban parks**: (1) Children's park. Seven points were selected as survey sites for investigation. In these seven points, human sounds formed the main part and natural sounds formed the auxiliary part of the soundscape. (2) Stalin Park. Three points were selected as survey sites for investigation, with human sounds as the main part and natural sounds as the supplement. (3) The Grand Theater Square. Three points were selected as survey sites for investigation, with human sounds as the main part, supplemented by natural sounds. **Nature Park:** (1) Sun Island Scenic spot. Six points were selected as survey sites for investigation, with natural sounds as the main part and human sounds as the auxiliary part. (2) Railway Bridge Qiaotou Park (north side of the Songhua river). One route and multiple points were surveyed, with natural sounds as the main part and human sounds as the auxiliary part. **Pedestrian street**: (1) Central street (in the vicinity of Songhua river). One points were surveyed, with human sounds as the main part and natural sounds as the auxiliary part. (2) Railway bridge. One route and multiple points were surveyed, with human sounds as the main part and natural sounds as the auxiliary part.

2.2 The questionnaire-based survey

In the first part of the survey, the respondents were inquired regarding their perception of the various local sound sources. Next, following Pablo Kogan's method, the respondents were requested to assess several typical sound sources. The question used while surveying was: "How strong of the following sounds are you able to hear?" The sounds inquired about included the typical human sounds such as the sounds of conversations, footsteps, music, and children playing, and the typical natural sounds such as those of birdsong, wind, running water, and insects. The respondents were requested to provide their assessment on a 7-point scale (0 completely inaudible to 6 completely dominated). Next step involved calculating the value for RSI, which is defined as the ratio of mean value of the natural sounds scores to the mean value of the human sounds scores. In Pablo Kogan's report, the survey sites were divided into three levels according to the obtained GSI value: GSI< 0.9, 0.9 <GSI< 1.1, and GSI> 1.1, representing the sites with perception predominance of traffic noise, the sites with balanced perception, and the sites with perception predominance of natural sounds, respectively.

In the present study, a fitting curve was generated according to individual RSI evaluation and the overall soundscape assessment. According to the change trend observed in the fitting curve, the survey sites were classified into three grades: RSI< 0.8, 0.8 <RSI< 1.2,and RSI> 1.2, representing the sites with perception predominance of human sounds, the sites with balanced perception, and the sites with perception predominance of natural sounds.

The second part of the questionnaire requested the respondents to provide their overall assessment of the acoustic environment of that particular survey site (**The overall soundscape assessment**). The question asked was: "Overall, how would you evaluate the acoustic environment of this site?" The respondents were requested to provide a rating on a 7-point scale (−3 extremely poor feeling to 3 extremely good feeling).

2.3 Sound levels at the sites

At each survey site, a weighted sound level was measured using HS5671A sound level meter. While performing the measurements, a set of sound equivalent acoustic pressure levels was tested every 10 min, with a single set lasting for 30 s. Continuous equivalent sound pressure levels (LAeq), maximum instantaneous sound pressure levels (LAmax), and minimum instantaneous sound pressure levels (LAmin), were recorded, along with L10, L50, and L90.

2.4 Data processing

The valid data were divided into three groups according to the RSI value. In order to compare the differences among the three groups, the overall soundscape assessment (OSA) for the three groups was conducted in pairs using independent sample Mann–Whitney U test. Kruskal–Wallis test was performed to compare the sound pressure levels data of the three groups and to identify any differences in the soundscape evaluation data among the three groups.

3. RESULTS

3.1 The individual evaluation

Correlation analysis was performed on the RSI values obtained from the subjective evaluation and the overall soundscape assessment (OSA) data of all the respondents. Pearson’s correlation analysis was used to analyze the correlation between individual RSI evaluation and the OSA. As visible in Table 1, the RSI value was significantly correlated with the OSA.

In regard to the OSA, the Pearson’s correlation coefficient was 0.199, with significance ($0.000 < P < 0.01$). This indicated that individual RSI evaluation was significantly correlated positively with the OSA, and the OSA tends to increase with increase in RSI evaluation.

Table 1: The results of calculating correlation between RSI and OSA

variables	Parameters	Values
RSI - OSA	Pearson Correlation	0.199**
	Sig.	0.015
	N	149

Taking the RSI value of each respondent's subjective evaluation along the horizontal axis and the OSA value along the vertical axis, a fitting curve could be generated to represent the trend of the change in the individual's OSA value with the corresponding RSI value, as illustrated in Figure 2. It may be observed from the figure that when the RSI value was less than 0.8, the OSA value was relatively low and stable; when the RSI value was between 0.8 and 1.2, the OSA value began to increase with the increase in the RSI value; and when the RSI value was greater than 1.2, the OSA value was relatively high and stable. Therefore, 0.8 and 1.2 were used as the threshold points to classify different urban locations according to RSI.

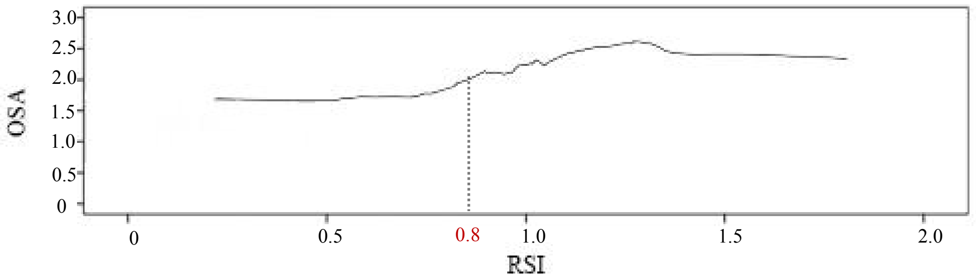

Figure.2: The fitting curve of RSI evaluation of individual interviewees and OSA evaluation of individual interviewees

The mean value of RSI evaluation for the individuals at each survey site was calculated, and each survey site was classified according to its mean RSI value. Among the seven surveyed sites of Children's Park, five were the sites with perception predominance of human sounds and two were the sites with balanced perception. All the surveyed sites of Stalin Park and Grand Theatre square were the sites with perception predominance of human sounds. Among the six surveyed sites of Sun Island Scenic Spot, two were the sites with balanced perception, one was the site with perception predominance of human sounds, and three were the sites with perception predominance of natural sounds. The railway Bridge Park was the site with perception predominance of natural sounds, while the Railway bridge and Central Avenue were the sites with perception predominance of human sounds. The OSA and the environmental sound levels were compared among the three groups classified according to the RSI-based grouping of the urban environment, and the results revealed significant differences.

3.2 Overall soundscape assessment

Table2: Descriptive statistics of OAS from the three groups

Classifications of study sites	N	OSA	
		Mean	SD
Perception predominance of human sounds	72	1.58	1.148
Balanced perception	31	1.90	1.446
Perception predominance of natural sounds	46	2.50	0.691

As explained earlier, the surveyed sites were divided into three levels according to the RSI evaluation mean of the samples: 0–0.8, 0.8–1.2, and above 1.2, representing the sites with perception predominance of human sounds, sites with balanced perception, and sites with perception predominance of natural sounds, respectively.

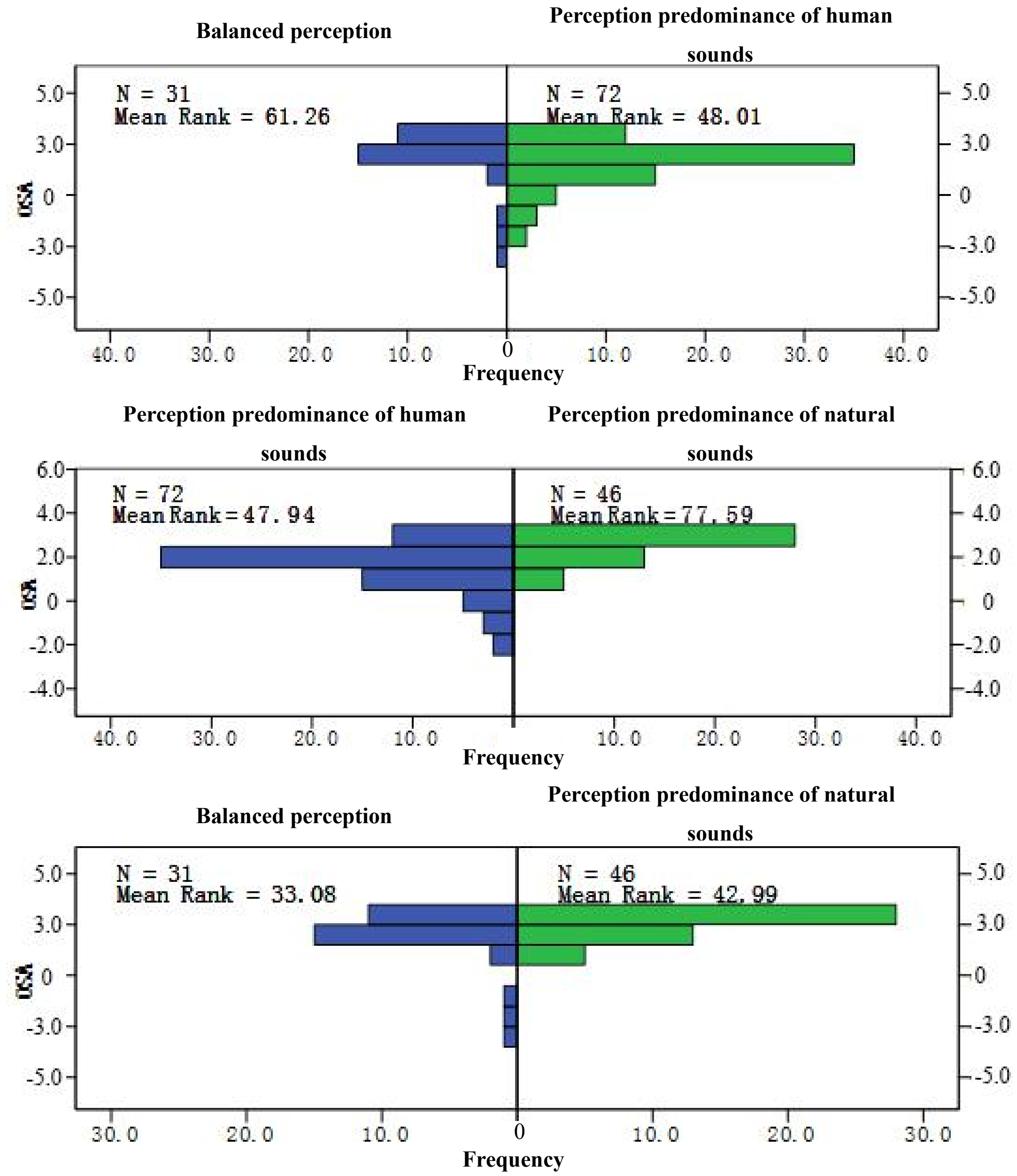

Figure.3:Score distribution obtained for the variables considered of the overall soundscape assessments corresponding to the three groups

The Descriptive data of the OSA are presented in Table 2. Independent sample Mann-Whitney U test was performed on the three groups of OSA data, in pairs, as illustrated in Figure 3. The following results were obtained: (1) The mean rank of the scores of the sites with balanced perception was 61.26, while that of the sites with perception predominance of human sounds was 48.01. The test results revealed significant differences (P=0.027< 0.05). This indicated that the overall soundscape assessment of the sites with balanced perception was superior to that of the sites with perception predominance of human sounds. (2) The mean rank of the scores of the sites with perception predominance of human sounds was 47.94, while that of the sites with perception predominance of natural sounds was 77.59. The test results revealed significant differences (P=0.000< 0.01). This indicated that the overall soundscape assessment of the sites with perception predominance of natural sounds was superior to that of the sites with perception predominance of human sounds. (3) The mean rank of the scores of the sites with balanced perception was 33.08, while that of the sites with perception predominance of natural sounds was 42.99, with significant differences (P=0.035< 0.05). This indicated that the overall soundscape assessment of the sites with perception predominance of natural sounds was superior to that of the sites with balanced perception.

The higher the proportion of natural sounds in the urban environment, the higher was the OSA of the sound environment by the residents. The higher the proportion of human sounds, the lower was the OSA of the sound environment by the residents. Therefore, in order to improve the overall quality of the urban sound environment, the proportion of natural sounds must be increased as far as possible. For instance, the green area in the city could be increased, and water fountains and various other natural landscape settings could be introduced.

3.3 Sound levels in the environment

Basic sound levels data for the study sites are presented in Table 3. The LAeq, LAmax, LAmin, L90, L50, and L10 of the three groups determined using non-parametric tests. As presented in Figure 4 and Table 4, irrespective of the values of LAeq, LAmax, LAmin, L90, L50, and L10, there were significant differences among the three groups, and the sound pressure levels of the sites with perception predominance of human sounds were the highest, followed by those of the sites with balanced perception and the sites with perception predominance of natural sounds, respectively.

Table3: Descriptive statistics of Sounds pressure levels of the three groups

Classifications of study sites	N	LAeq		LAmax		LAmin	
		Mean	SD	Mean	SD	Mean	SD
Perception predominance of human sounds	43	62.89	5.982	71.14	6.235	55.89	7.455
Balanced perception	36	55.15	4.733	60.97	4.603	51.20	6.007
Perception predominance of natural sounds	37	50.24	4.935	54.90	4.413	46.36	6.441

Classifications of study sites	N	L_{10}		L_{50}		L_{90}	
		Mean	SD	Mean	SD	Mean	SD
Perception predominance of human sounds	43	66.16	6.167	61.21	6.686	56.47	7.266
Balanced perception	36	57.18	4.893	54.18	5.314	52.06	5.858
Perception predominance of natural sounds	37	51.72	4.861	49.01	5.625	47.34	6.137

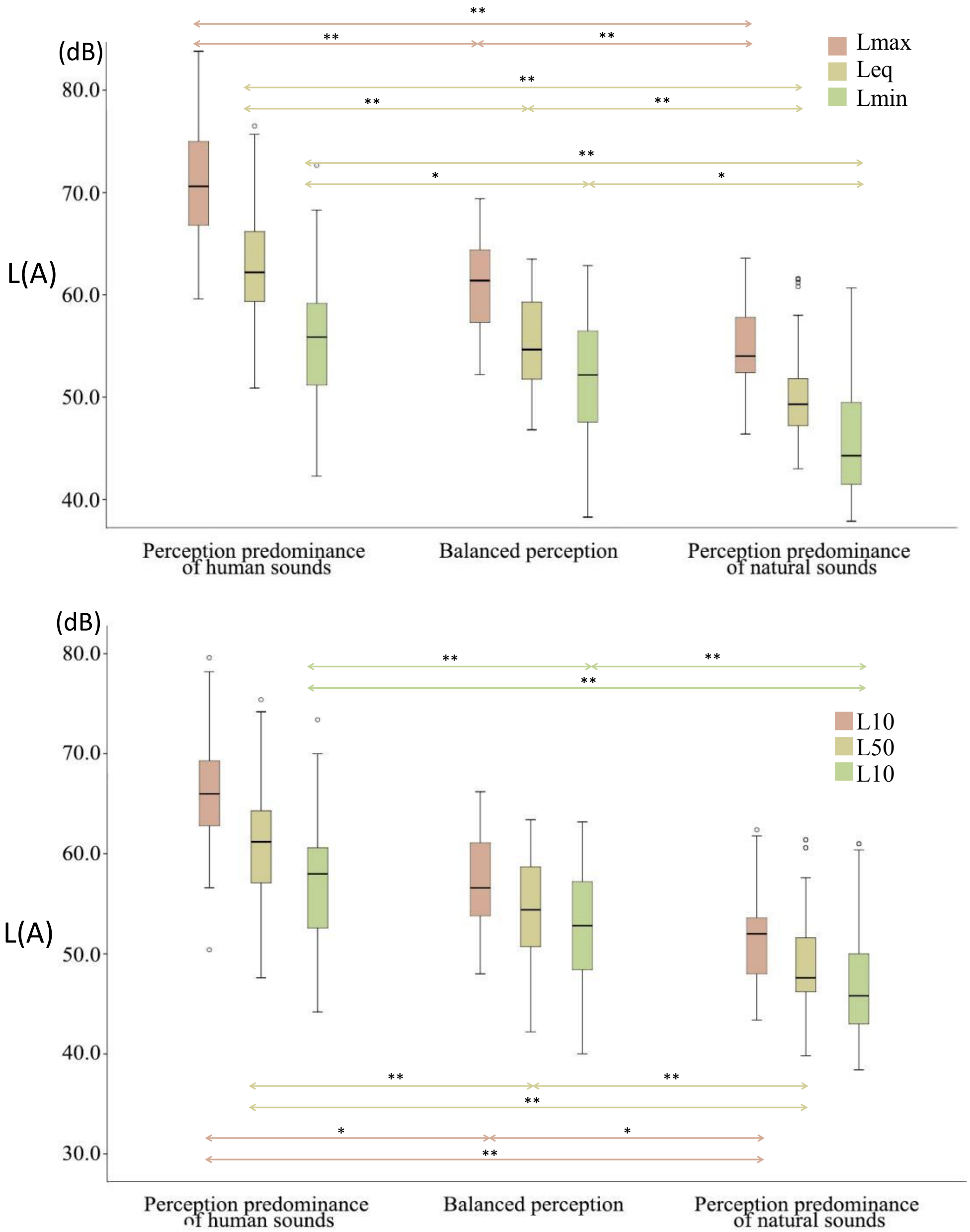

Figure.4: Mean values and standard deviations obtained for the variables considered of the physical acoustic environment indicators *corresponding to the three groups*

The higher the proportion of natural sound in urban environment usually means the lower the environmental sound level, and the higher the proportion of human sounds means the higher the environmental sound level. Urban residents tend to live in quieter areas, so increasing the proportion of natural sounds is an important and effective means.

Table4: Differences of sound pressure levels among the three groups

Groups of Kruskal-Wallis test	LAeq		LAmax		LAmin	
	Sig.	Adj.Sig.	Sig.	Adj.Sig.	Sig.	Adj.Sig.
Balanced perception - Perception predominance of human sounds	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01	0.014<0.01	0.042<0.05
Perception predominance of natural sounds - Perception predominance of human sounds	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01
Balanced perception - Perception predominance of natural sounds	0.002<0.01	0.006<0.01	0.001<0.01	0.002<0.01	0.004<0.05	0.013<0.05
Groups of Kruskal-Wallis test	L_{10}		L_{50}		L_{90}	
	Sig.	Adj.Sig.	Sig.	Adj.Sig.	Sig.	Adj.Sig.
Balanced perception - Perception predominance of human sounds	0.005<0.01	0.014<0.05	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01
Perception predominance of natural sounds - Perception predominance of human sounds	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01	0.000<0.01
Balanced perception - Perception predominance of natural sounds	0.004<0.01	0.013<0.05	0.003<0.01	0.008<0.01	0.001<0.01	0.004<0.01

4. CONCLUSIONS

Although several studies have confirmed the positive impacts of natural sounds on soundscape and the positive or negative effects of certain human sounds on the soundscape, no studies have to date confirmed the effects of a mixture of natural sounds and human sounds on the soundscape. The results revealed a significant positive correlation between individual RSI evaluation and the soundscape evaluation, i.e. the more natural sounds the individuals perceived, the less they perceived the human sounds, and the higher was the soundscape evaluation. This could form the basis for urban environment design. The design of a pleasant and quiet environment for the urban residents would involve more natural sounds and lesser human sounds.

In addition, the present study utilized RSI to categorize the urban environment into three groups. The higher the RSI of the urban environment, the higher would be the people's assessment of its acoustic environment. Higher proportion of natural sounds in the urban environment would usually imply lower environmental sound level, while a higher proportion of human sounds would imply higher environmental sound level. In other words, the higher the RSI of the urban environment, the quieter is the acoustic environment. It is possible to use RSI to classify different urban environments and predict the soundscape quality of any urban environment.

5. ACKNOWLEAGEMENTS

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