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SOUNDSCAPE ATTRIBUTES FOR THE ASSESSMENT OF THE ACOUSTICAL ENVIRONMENT IN APARTMENTS

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ABSTRACT

This study investigated the soundscape attributes of apartment acoustic environments consisting of residential noise and combined sounds with intervening natural sounds. The sound sources from neighboring upper unit or outside consisted of child jumping, air conditioner of outdoor unit, plumbing, and natural sounds (birdsong and water sounds). To evaluate the soundscape for each sound scenario, we used attributes in two kinds of soundscape assessment models (ISO/TS 12913-2 and Torresin *et al*.). Each attribute was translated to Korean through a questionnaire. As a result, the results of two assessments are similar patterns, and different for some attributes. In addition, the two assessment models showed significant differences mainly in child jumping noise. Based on these results, we conducted soundscape attributes experiment to evaluate the acoustic environment of an apartment living space. This study suggested that soundscape attribute for assessment of acoustic environment in apartment is necessary.

Keywords: *indoor soundscape, multi-family housing building, soundscape assessment*

1. INTRODUCTION

The acoustic environment in indoor spaces is influenced not only by physical noise control but also by the improvement of psychological perception. Soundscape research has evolved from merely eliminating noise to creating a positive acoustic environment by using various sounds. The ISO/TS 12913-2 standard proposes a method for evaluating the perceived affective quality of acoustic environments through eight attribute scales, centered on the axes of pleasantness-annoying and eventfulness-uneventful [1].

However, these soundscape evaluation methods primarily focus on outdoor spaces, and due to the indoor and outdoor environments differ in their acoustic characteristics [2], there are limitations to applying existing evaluation models to indoor settings. Accordingly, Torresin *et al*. [2] proposed a new assessment model tailored to the characteristics of indoor residential spaces, with *Content* and *Comfort* as the main axes, and safety emerging as a significant factor. This contrasts with Axelsson *et al*. [3], where "appropriateness" was independent of the main axes, indicating a difference in the perceptual model, as safety is related to *Comfort* in indoor environments.

However, the previous study [2] was conducted on single-family homes, they didn't consider neighbor noise. Whereas in Korea, multi-family housing buildings, and residential areas are densely packed, potentially leading to differences in acoustic environment perception depending on the surrounding context. Therefore, this study aims to comparatively analyze the perceptual characteristics of composite sounds, including residential noise and natural sounds, based on existing soundscape evaluation models and the model proposed by Torresin *et al*., while investigating indoor acoustic environment evaluation attributes that reflect the characteristics of Korean residential spaces.

2. METHODS

2.1 Stimuli

The laboratory experiment used residential noises (child jumping and plumbing from upper unit, and outdoor unit of air-conditioner), natural sounds (birdsongs, water sound), and indoor noise (brown noise similar to an air conditioner) as a masking sound, which more detailed information in

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Table 1. Residential noises were recorded monaurally in multi-family housing buildings, and the outdoor unit of air-conditioner was filtered by applying the sound insulation performance value of the building facade [4]. Natural sounds were collected from websites, with types selected based on previous studies [5]. The sound sources were played as single and combined (residential noise + natural sound, residential noise + white noise), and all sound sources were adjusted to L_{Aeq} 50 dB for 60 seconds.

Table 1. Type of stimuli

Category		Types
Noise	Neighbor	Child jumping
		Plumbing (Toilet)
	Outdoor	Outdoor unit of air-conditioner
	Indoor	Brown (like air conditioner)
Natural sounds		Birdsongs
		Stream sounds
Combined		Neighbor/outdoor + indoor
		Neighbor/outdoor + natural

2.2 Soundscape attributes

For the assessment of acoustic environment of residential space in multi-family housing buildings, the soundscape affective attributes used were those from Method B of ISO/TS 12913-2 and Torresin *et al.* For the laboratory experiment, the Korean version of the soundscape attributes from ISO [1] was referenced from a previous study [6]. And the soundscape attributes proposed by Torresin *et al.* [2] were adapted by deriving appropriateness terms through studies on Korean residential spaces [7, 8, 9]. The final Korean translation attributes for the laboratory experiment were selected through a survey. In case of the attributes "Annoying" was used the results of a preliminary survey.

2.3 Laboratory experiment

The laboratory experiment was conducted in a soundproof room as living room of residential space. Stimulus were played using a woofer speaker (22 Hz–175 Hz) and headphones (100 Hz and above). Participants were asked to "*imagine being at home, relaxing in your living room. You may listen to sounds from outside or neighbor upper unit.*" And participants evaluated the degree of agreement with each attribute used in the two soundscape assessment models for each acoustic scenarios on a 5-point scale. Additionally, "Appropriateness" was evaluated on a 5-point scale. Following IRB approval, 35 participants were recruited through university website boards and SNS, and after removing outliers (IQR x 1.5), the results from 32 participants (13 male, 19 female, average age 23.6 years) were analyzed. The analysis was performed using R (version 4.3), and PCA was conducted according to the method proposed in the previous study [2].

3. RESULTS

The average scores of all acoustic scenarios were calculated for all participants. Figure 1 shows the distribution of acoustic scenarios by each attribute, indicating that negative perceptions described as 'disruptive or uncontrollable,' 'irritating,' and 'chaotic' recorded relatively high scores, whereas positive perceptions described as 'pleasant,' 'calm,' 'interesting,' and 'comfortable' recorded relatively low scores. Figure 1 also shows that, overall, the differences of perceived acoustic environment in all attributes do not appear to be significant, regardless of the type of acoustic scenarios. To examine the perceptual differences in attributes according to types of acoustic scenarios, the average values for each category stimuli presented in Table 1 were calculated and shown in Figure 2.

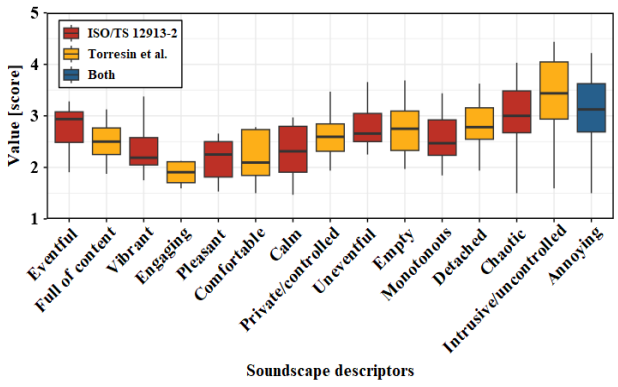

Figure 1. Comparison of attributes response distributions between two soundscape assessment models.

As shown in Figure 2, differences were observed depending on the acoustic scenarios type, particularly in soundscape

characteristics other than the main axes ('pleasant', 'comfortable', 'eventful-uneventful', 'full of content-empty'). Notably, the differences between the two soundscape assessment models were clearly in the neighbor noises (p<0.05). Additionally, a correlation analysis between each attribute and appropriateness was conducted, revealing significant correlations in some attributes (p<0.05) mainly with 'pleasant', 'comfortable', 'annoying', 'calm', 'chaotic', and 'intrusive/uncontrolled'. In particular, 'comfortable' showed a strong correlation with appropriateness (over r = 0.7).

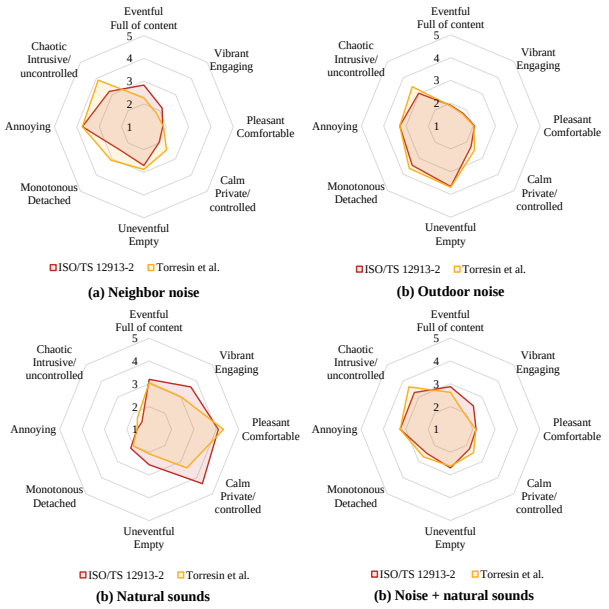

Figure 2. Perceptual characteristics of sound sources based on soundscape assessment models.

To investigate the relationships between the attributes of the two soundscape assessment models, a PCA analysis was conducted. As shown in Figure 3, the total variance was explained 93.7 %, with two components factors identified (PC1: 66.3 %, PC2: 27.3 %). Except for the attributes 'empty', 'eventful', 'uneventful', and 'monotonous', which belonged to PC2 (represented by triangles in Figure 3), all other attributes belonged to PC1 (represented by circles in Figure 3). No correlation was observed between PC1 and PC2, but the attributes within each PC exhibited strong correlations with one another. In addition, 'annoying' was positioned in the opposite direction to 'pleasant' or 'comfortable', while 'eventful' and 'uneventful', as well as 'empty', were found to be orthogonal to each other. Notably, in this case, 'full of content' belonged to PC1. In PC1, 'engaging' was high loading score following 'pleasant', 'comfortable', 'calm'.

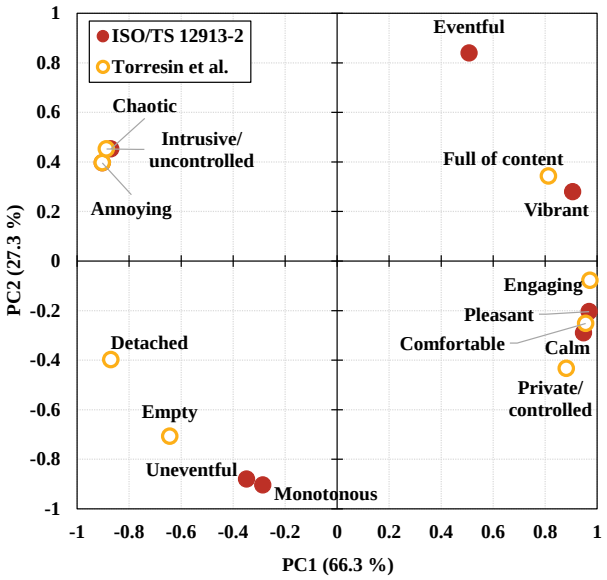

Figure 3. Loading of the 15-attribute scale to PC1 and PC2. Overall attributes scale loading range in |0.7|~|0.98|.

4. DISSCUSSION

This study conducted a comparison between previous proposed soundscape assessment models to assess the acoustic environment of residential spaces in multi-family housing buildings. The results showed a high correlation differences between the two soundscape assessment models in evaluating the acoustic environment. However, perceptual differences were observed in neighbor noise. Additionally, in assessing the appropriateness of the acoustic environment in residential spaces, it was confirmed that 'comfortable' had a stronger relationship with appropriateness than 'pleasant'. The ISO/TS 12913-2 model is centered on the axes of 'pleasant - annoying' and 'eventful-uneventful', it described as '*Pleasantness*' and '*Eventfulness*', while the Torresin *et al.* model described soundscape as '*Content*' and '*Comfort*'. Accordingly, PCA analysis showed that the most significant difference between the principal axes and other attributes in each assessment. In the ISO/TS 12913-2 model and the Torresin *et al.* model, these were considered independent dimensions, but this study found them to be correlated with

'comfortable', 'annoying', and 'full of content'. The Torresin *et al*. model, developed focused on single-family housing building, showed limitations in fully reflecting the 'intrusive/uncontrolled' characteristics of neighbor noise in Korea's high-density multi-family housing environment. Similarly, the ISO/TS 12913-2 model, designed with outdoor environments in mind, also has limitations in not accounting for the indoor environment of multi-family housing. Consequently, differences between outdoor and indoor spaces led to variations between the proposed soundscape evaluation models in this study. Compared to previous research [2], the findings indicate that neighbor noise, influenced by Korea's residential characteristics (high residential density), additionally affects acoustic environment perception. This suggests the need for developing a separate soundscape evaluation model tailored to the Korean context.

5. SUMMARY

This study comparatively analyzed the perceptual characteristics of the acoustic environment of residential spaces in multi-family housing buildings using two soundscape assessment models. By applying the ISO/TS 12913-2 model and the Torresin *et al*. model to the Korean multi-family housing building context, it was found that (1) the relationships between the main axes of the evaluation models differed, and (2) notable differences between the models were particularly evident in the perception of neighbor noise, with a high correlation observed between 'appropriateness' and 'comfort'. However, this study has some limitations due to the restricted range of acoustic scenarios used and the attributes employed to evaluate the acoustic environment of residential spaces in multi-family housing building. Additionally, it was determined that there was insufficient data for the PCA analysis. To address these issues, the our study expanded the types of sound sources to better reflect the acoustic environment of residential spaces in multi-family housing buildings and enhanced the perceptual evaluation model by adding attributes to improve the reliability of the results, followed by further laboratory experiments.

6. ACKNOWLEDGMENTS

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