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Effect of soundscape dimensions on acoustic comfort in urban open public spaces

Xu Zhang[a], Meihui Ba[a], Jian Kang[a,b,*], Qi Meng[a,*]

[a] Heilongjiang Cold Region Architectural Science Key Laboratory, School of Architecture, Harbin Institute of Technology, Harbin 150001, China
[b] School of Architecture, University of Sheffield, Western Bank, Sheffield S10 2TN, UK

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ABSTRACT

Soundscapes in public squares play important roles in urban open spaces. This study aimed to discover the effect of four soundscape dimensions, namely relaxation, communication, spatiality and dynamics, on acoustic comfort in urban open public spaces. A typical city square in China was selected as a case site. Sound environment measurements and questionnaire surveys were carried out for 8 survey positions. The results showed that the perceived dominance of sound sources had a significant effect on relaxation, communication, spatiality and dynamics. Relaxation was greater when the natural sound was perceived dominantly, while it was lower when mechanical sounds or anthropogenic sounds were perceived dominantly. Acoustic comfort had a significant correlation with the soundscape dimensions and LAeq, with spearman's correlation coefficients of 0.495 (relaxation), 0.210 (sound pressure level) and 0.288 (spatiality). In terms of the differences in perceived sound types, acoustic comfort was positively correlated with relaxation when natural sound or anthropogenic sound was perceived dominantly. As spatiality increased, acoustic comfort first decreased and later increased when relaxation was higher, while there were positive correlations between acoustic comfort and relaxation under the other situations. Moreover, when spatiality or communication was higher, there were significant correlations between acoustic comfort and dynamics. According to these results, acoustic comfort can be increased as soundscape dimensions change in an urban open public space.

1. Introduction

As urban open public spaces, squares usually play important roles in urban cultural activities, reflecting urban historical culture and art [1]. Previous studies have found that urban squares can be classified into five types: ceremonial, traffic, recreational, commercial and multifunctional [2]. With the development of urbanisation, squares will be increasingly multifunctional and integrated [3], and the crowd will be exposed to noise because of complex sound sources. Previous studies have generally focused on the influence and prevention of noise [4,5]. For example, noise maps were developed in some European countries to predict the amount of traffic noise in squares [6–9]. Different types of noise barriers have been developed in city squares to reduce traffic noise [10,11]. However, these treatments, which only concentrate on noise control, often had limited impact on improving the quality of sound environments. Recently, particular attention has been paid to soundscapes, which involves the way people consciously perceive their environment and interdisciplinary efforts including physical, social, cultural, psychological and architectural aspects [12,13]. Soundscapes, defined by ISO, are acoustic environment as perceived or experienced and/or understood by a person or people, in context [14]. In soundscape studies, different facets have been investigated, termed as soundscape dimensions, characteristics, factors, attributes etc., representing the general perception tendencies of soundscape, specific perception of soundscape, and objective measurement of soundscape [15–18], although those terms are often used in a mixed way.

Acoustic comfort is the basic feeling of users towards the acoustic environment. Previous studies showed that acoustic comfort in urban open spaces can be affected by certain spatial and environmental factors as well as users' social and behaviours characteristics [18–20]. In terms of users' social and behaviours characteristics, Yang and Kang found that the duration and frequency of visits could affect the crowd's evaluation of acoustic comfort [21]. Similarly, in indoor spaces, Meng et al. found that dining styles and crowd density affected acoustic comfort [22,23]. Some studies suggested that the social background and auditory experience in residents' daily lives might influence soundscape evaluation. Decreasing sound levels did not always improve acoustic comfort [21,24]. Moreover, it has been found that the crowd's

* Corresponding authors at: Heilongjiang Cold Region Architectural Science Key Laboratory, School of Architecture, Harbin Institute of Technology, Harbin, 150001, China (J. Kang and Q. Meng).
E-mail addresses: j.kang@hit.edu.cn, j.kang@sheffield.ac.uk (J. Kang), mengq@hit.edu.cn (Q. Meng).

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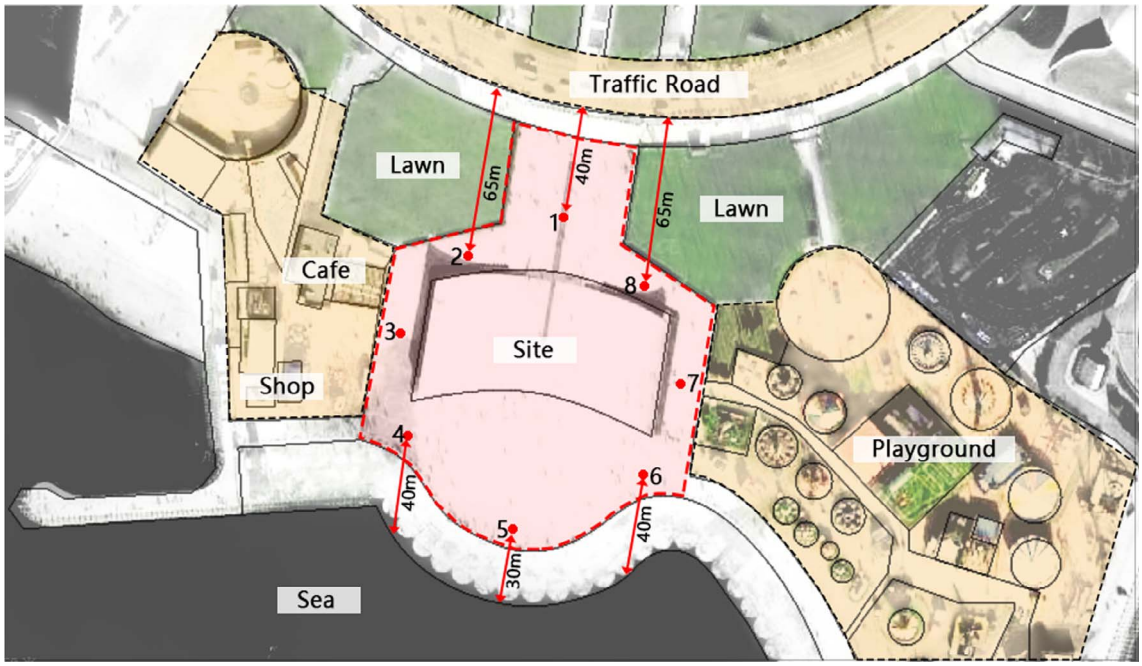

Fig. 1. Plan and survey positions of Centennial Square.

perception of sound might be influenced by physical factors such as temperature, humidity and sunlight [25,26]. Torija et al. proposed a prediction model that analyses not only the equivalent continuous sound pressure level (LAeq) but also the temporal and spectral composition in the soundscape [27]. Raimbault et al. found that the perception of sound correlated with acoustic indicators such as background noise or the standard deviation of short LAeq [28]. Some landscape factors, such as water areas and greening measures, could adjust the perception of the sound environment [29]. Jeon et al. found that both tonality and fluctuation strength play major roles as sound quality metrics that describe subjects' acoustic comfort [30]. In terms of sound sources, anthropogenic sounds such as footsteps and voices were largely unaffected by visual perception [31]. Natural sounds such as that of water effectively enhance acoustic comfort in urban open public space [32]. Previous studies have revealed that the perception of traffic noise differs substantially from that of music [33].

Soundscape dimensions have been studied in urban open public spaces [34–36]. Raimbault et al. suggested three main categories of analysis: activity, such as human presence or transport; spatial attributes, such as location; and time history, such as moments or periods [28]. Keiji et al. found that three major dimensions, preference, activities and sense of daily life, affect soundscape evaluation [15]. Kang and Zhang, using a semantic differential method, found four main soundscape dimensions for urban open spaces: relaxation, communication, spatiality and dynamics [37]. Axelsson et al. made 100 subjects evaluate 50 different soundscapes and found three main dimensions of soundscape evaluation: pleasantness, eventfulness and familiarity [16]. Della Crociata et al. defined optimal intervals for selected parameters by comparisons with subjective "comfort" thresholds [38]. Aletta et al. [39] suggested that two major dimensions which are pleasantness and calmness affect soundscape, and a third potential dimension is the appropriateness of a soundscape to a place. They also found distinguishable or indistinguishable, background or foreground, and intrusive or smooth are three important dimensions in terms of sound sources [40]. Sudarsono et al. [17] revealed that three reliable soundscape dimensions are relaxation, dynamics and communication, which are consistent with the previous study conducted by Kang and Zhang [37]. Meng et al. also found that acoustic comfort correlated with subjective loudness [18]. It has also been indicated that there were correlations between perceptions of space, namely relaxation and acoustic comfort [41]. Davies et al. found that the sonic environment had two main components that might be associated with two emotions, namely "calmness" and "vibrancy," which are related to perceptions of the sound environments [35]. While the above studies are useful to understand soundscape from different dimensions, it is important to examine systematically the relationships between acoustic comfort and soundscape dimensions, which is also vital for implementing the soundscape approach in urban planning and design. Moreover, previous studies have mainly been developed in low-density cities, and it is needed to examine the situations in high-density cities [23].

This study therefore aims to reveal the relationship between acoustic comfort and soundscape dimensions. In this study, with a typical multifunctional square as an example, sound level measurements and questionnaire surveys were carried out. Four soundscape dimensions, namely relaxation, communication, spatiality, and dynamics, were selected for subjective measurement according to Kang and Zhang's research [37]. Among them, "Relaxation" represents soundscape dimension including quiet and pleasant [16,17,37]. "Communication" is the soundscape dimension relating to social, meaningful, smooth, etc. [17,38]. "Spatiality" is mostly associated with echoed and far [17,37]. "Dynamics" is principally related to varied and fast [37]. On the basis of the survey, the study first analysed the correlations between acoustic comfort and soundscape dimensions, and then examined the relationships between acoustic comfort and soundscape dimensions with different perceived sounds.

2. Methodology

The methods included the selection of a survey site, a questionnaire-based survey, sound-level measurement, and statistics analysis.

2.1. Survey site

A city square, named Centennial Square, in Dalian, China, was selected as the case site, as shown in Fig. 1. Dalian Centennial Square, a typical multifunctional square, is nearly a circle of 135 m wide. A 15 m-wide road runs on the south side of the square, and the Bohai Sea is on the other side. There are some functional zones in the square for

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