Humanities & Social Sciences Communications

ARTICLE

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https://doi.org/10.1057/s41599-024-03929-y OPEN

Effect of human sound component on the sociability of urban public spaces—a case study in Sheffield, UK

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Soundscape quality is important for fostering social interactions in urban public spaces. This study focuses on how and to what extent the compositions of the soundscape affect the sociability of urban public spaces where human sound is focused. Four 360° experimental soundscape samples were designed as foreground/background/no human sound type and signal sound type, based on the raw data collected in Peace Gardens, Sheffield, United Kingdom. Following Affordance Theory, sociability was analyzed by the experimental survey through two aspects—suitability and stimulation level—through a questionnaire consisting of Soundscape Quality evaluation (SQE) and Level of Willingness for social interactions (LoW), respectively. 120 participants were recruited in the same site representing the compositions of space users. Results show that only foreground human sound type significantly enhanced both suitability and stimulation levels, other samples were evaluated with either high suitability/low stimulation or low suitability/high stimulation. Results indicate people prefer a human sound dominated soundscape with high complexity and this preference was varied among different companion types and age groups. To achieve high sociability, it is suggested to create a complex and eventful soundscape within the range of pleasantness accompanied by a centripetal spatial form, and concerns users' diverse demographic backgrounds.

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Introduction

Background. Urban sounds, as one part of urban experiences, have become important in the urban design process (van Kempen et al., 2014; Hasegawa et al., 2022). Especially in outdoor spaces, sound quality can influence the social activities, public health, and physical well-being of urbanites considering various noise problems (Ludvigsen, 2006). Previous studies have sought sustainable sound strategies to influence the relationship between urbanites and their acoustic environment, to minimize the negative aspects of sounds (Fields, 1997; Hinton and Bloomfield, 2000; Kang, 2012), and to maximize the acoustic comfort level (Meng et al., 2017; Xiao et al., 2018). Soundscape evaluation was then introduced as an approach to evaluate the reactions of people toward experimental sound environments and address the perceptual aspect of sounds (Aletta et al., 2016; Brown et al., 2007; Xu and Kang, 2019). The concept of 'soundscape' emerged to emphasize the perceptual aspect of the acoustic environment in analogy to '(visual) landscape' (Cain et al., 2013). The term 'soundscape' was recently defined in ISO 12913 as: [the] acoustic environment as perceived or experienced and/or understood by a person or people, in context (International Organization for Standardization, 2014). Although massive efforts have been made for acoustic improvements and evaluations, capturing the complexity of qualitative urban auditory experience in a real-life setting remains a challenge (Bild et al., 2018; Tong and Kang, 2021; Brown et al., 2011).

Urban soundscape experiences and soundscape evaluations. Experiences in urban public spaces are greatly influenced by the acoustic environment, especially when conducting noise-sensitive activities (Yang and Kang, 2005). The concept of soundscape focuses on the perceptual aspect of the acoustic environment and gained prominence in the 1970s. After several decades of research, researchers have summarized a series of soundscape evaluation approaches for exploring sound perceptions. Kang and Zhang (2010) identified four key elements of soundscapes in urban public spaces—relaxation, communication, spatiality, and dynamics. These elements covered the main facets of the acoustic design of urban public spaces: function (relaxation and communication), space and time. The functional facet indicates that people perceive sounds through their requirements for activities (Marquis-Favre et al., 2005; Payne and Guastavino, 2013). In other words, the evaluations of soundscape should adequately reflect the supportiveness of the acoustic environment for the two activities- relaxation and communication. To conduct soundscape evaluations in outdoor settings, Soundscape Quality Evaluation(SQE) has been widely applied, addressing the overall perceptions of the acoustic environment (Aletta et al., 2016). SQE usually involves various types of adjective descriptors and phrases that describe different aspects of the soundscape in order to measure perceptions. In this study, SQE indicators for the two major outdoor activities–relaxation and communication, were built upon two previous classic studies by Kang and Zhang (2010) and Axelsson et al. (2010). Kang and Zhang (2010) identified indicators for relaxation such as comfort–discomfort, quiet–noisy, pleasant-unpleasant, like–dislike, etc. Communication indicators include social–unsocial, meaningful–meaningless, calming–agitating, etc. (Kang and Zhang, 2010; Axelsson et al., 2010). Axelsson et al. (2010) proposed a two-dimensional model with two indicators, pleasantness and eventfulness, representing relaxation and communication activities, respectively. Among these indicators, stressful (peaceful), eventful (uneventful/dull), pleasant (unpleasant/annoying) and safe (unsafe) were the mostly used descriptors in urban public spaces (Nilsson and Berglund, 2006; Axelsson et al., 2010). Various influential factors, including physical, behavioral, social/demographic and psychological factors, were suggested to be considered during the SQE process in urban public spaces (Yu and Kang, 2010; Davies et al., 2013). In recent research on public space soundscape, the companion factors, as one of the behavioral factors, have also been proven to affect sound perception and are included in field research (Yu and Kang, 2009; Bild et al., 2018).

Urban public spaces have long been considered social occasions that promote the social integration of users from different races, genders and occupations. In previous studies, it was found that other people's existence, especially other people's activities are the most attractive and can stimulate social interactions in urban public spaces (Gehl, 1987). In the research field of soundscape, similarly, Hong and Jeon (2020) found that human sound has a key influence on the perceived sound level, with the strongest relationship to physical and psychoacoustic parameters. Jo and Jeon (2020) further pointed out that the most significant factor that determines the comfort of the park's soundscape is the presence of other people. Human sounds can decrease the perceived tranquillity or peacefulness while increasing the experience of the soundscape dynamics. Other studies have also demonstrated the positive effect of socially interactive sounds (various sounds of human activity) on the soundscape evaluations of a place (Bild et al., 2018). In short, previous literature has pointed to a positive relationship between human sound and soundscape evaluation. However, the composition of the sound environment in the real setting is complex; it is still unclear what role human sound plays in stimulating sociable feelings throughout the whole acoustic environment of urban public space.

In the field of soundscape design, it was found that the compositions of identified sound sources can significantly influence people's sound perceptions; thus, it was believed that designing sound compositions can regulate and enhance acoustic environments (Liu and Kang, 2015; Hong and Jeon, 2020). Previous studies have tried to add or exclude particular types of sound sources in the laboratory, such as natural sounds, music sounds and artistically created sounds, in various simulated outside space settings (Steele et al., 2019; Cerwén et al., 2017). In recent studies, Oberman et al. (2020) defined this method as 'sound interventions' and proposed a simulated soundwalk as a tool for exploring sound interventions, which provides a flexible way to analyze various types of soundscapes in the laboratory (Oberman et al., 2020). This research method was also effective in analyzing the essential soundscape descriptors featured in ISO/TS 12913-2: 2018 (International Standard Organization, 2017). To investigate how and whether human sound, compared to other types of sound, can influence the sociability of urban public spaces, the 'sound intervention method' was applied in this study. Human sound and other types of sounds were applied as soundscape interventions in 360° experimental samples, to enable people to gain immersive experiences.

Sociability evaluation in the field of soundscape. Affordance theory raised by Gibson (1979) describes what an environment offers an animal, and what the environment provides or furnishes, either good or bad. This concept was adopted in acoustic research as 'acoustic affordances,' to indicate whether and to what extent a soundscape provides actionable properties for an object (Andringa et al., 2013; Martin, 2018; Nielbo et al., 2013). Bild et al. (2018) applied 'acoustic affordances' to evaluate how sounds support people's social activities from soundscape stimulation and suitability. Stimulation represents whether a soundscape stimulates people's social activities, and suitability indicates the level of soundscape quality that supports people's social activities. Soundscape stimulation and suitability correspond to Gehl's (1987) 'essential environment conditions' and 'favorable conditions'. Essential environment conditions offer basic environmental qualities to support people's social activities (similar to the suitability level); while 'favorable conditions' can stimulate people to stay for a longer time to perform 'resultant' social activities (similar to the stimulation level).

Stimulation is represented by 'affiliation behaviors' and 'social interactions' (Fish et al., 1978; Zemke and Shoemaker, 2007). Affiliation, which indicates the desire of people to be affiliated with others, is the primary level of social interaction. Social interaction is defined as the actual interaction between two or more people, such as talking and physical contact (Carmona et al., 2010; Lerner et al., 2015). In practice, Gaby and Zayas's (2017) smellscape research used a questionnaire method with 'How likely would you be to have a conversation with [this person]?' to indicate social interactions; and 'If you had to sit next to this person every day, it would be…? How friendly was this person's smell?' to indicate affiliations.

Research objectives. This study, therefore, considers soundscape to influence the experiences in urban public spaces, with human sounds understood as the key influential factor. In previous studies, human sounds were found to have a significant positive influence on soundscape evaluations of urban public spaces compared to other sound sources. However, the extent to which human sound, as one sound source of the total acoustic environment, can influence people's acoustic perception is not clear. Also, with the aim to promote sociability in urban public spaces, whether and how human sound can stimulate sociable feelings is not fully investigated.

Based on the previous studies related to sociability evaluation, this study concerned about two aspects of sociability: suitability and stimulation. First, it ascertains how human sound affect the level of suitability and stimulation, compared to the compositions without human sound. Second, it examines whether the sound effect on sociability varies among diverse demographic backgrounds.

In the following sections, the "Methods" section describes the research site, data acquisition methods and analysis methods of this study with the aim to achieve the research objectives; the "Results" section explains the results and implications of the data analysis; and the "Discussion" section discusses the complexity of sound environments in urban public spaces and the varied soundscape preferences of people from diverse demographic backgrounds.

Methods

Designing 360° soundscape samples with sound interventions. To explore the effect of the compositions of sound sources, four experimental soundscape samples were designed, with the targeted human sound applied as the positive intervention, and the disturbed signal sound included as the negative intervention. Each soundscape sample was displayed using a 360° video:

1. V1 (Positive intervention): Foreground human sound type, human sound was added in the foreground, with a pleasant background sound;
2. V2 (Positive intervention): Background human sound type, human sound was added in the background, mixed with a pleasant background sound;
3. V3 (No intervention)**:** No human sound type, peaceful and pleasant soundscape without human sound;
4. V4 (Negative intervention): Signal sound type, loud signal sound was added in the foreground, with a pleasant background human sound.

All four soundscape samples were based on the actual sound compositions in urban public spaces. Previous studies have found that people classify sounds into foreground and background during the initial stage of sound perception (Davies et al., 2013; Sun et al., 2019). When sounds are in the foreground, they tend to be more prominent and louder, capturing people's attention (Davies et al., 2013). In urban public spaces with dense crowds, human sounds are closer and louder, making them more noticeable. Therefore, human sounds were designed to simulate high or low crowd density by placing them in the foreground or background respectively (De Coensel et al., 2017; Sun et al., 2019). V3 was designed as a control sample with no human sound intervention. V4 was designed to be a negative sound type that would interrupt people's activities.

The workflow of designing the four 360° soundscape samples is displayed in Fig. 1.

First, raw data, including multi-track location recordings and 360° videos, were collected in Peace Gardens, Sheffield, UK, using a four-channel Ambisonic digital recorder (Zoom H3-VR) and a Ricoh Theta SC camera. Recording events took place from 9.00 a.m. to 12.00 p.m. noon and 2.00 p.m. to 5.00 p.m., during May 2019, when the weather was mild and warm. The duration of each recording lasted for 3 min. The sampling rate is 48 kHz, and the depth of the recordings is 24 bits. The duration of each recording is 3 min. The recorder and 360 camera were fixed on one tripod, which were kept the same as the normal sitting height (calculated at 115 cm from the ear level to the ground level), to ensure that the captured sound and images were at a sitting angle. In order to maintain consistency in the scene and function of soundscape samples as well as to minimize disruptions to users' activities

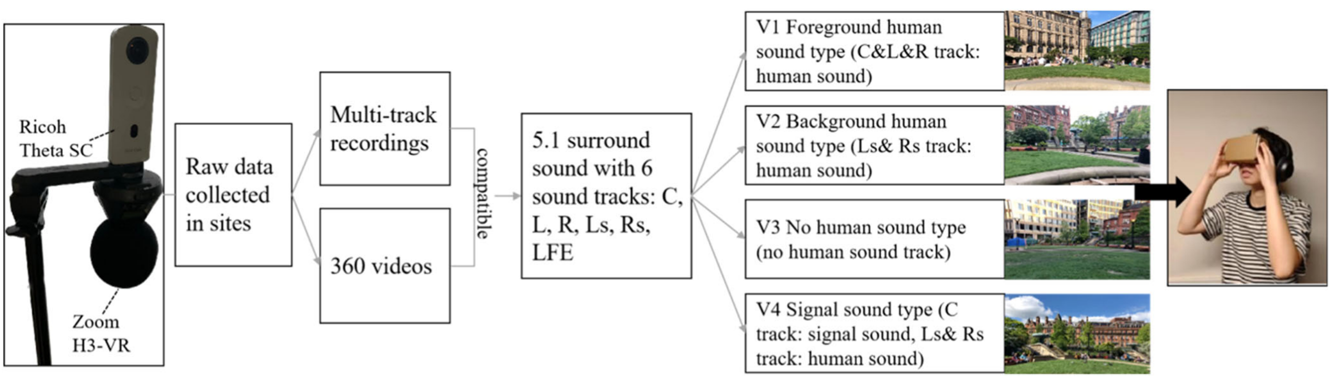

Fig. 1 Workflow of editing the 360° soundscape samples (V1,V2,V3,V4). The figures shown in the flow chart are the facilities used for raw data collection, the cover image of each 360° video, as well as the example of participant watching soundscape samples; the flow chart also present the detailed design process of six soundtracks of each sample.

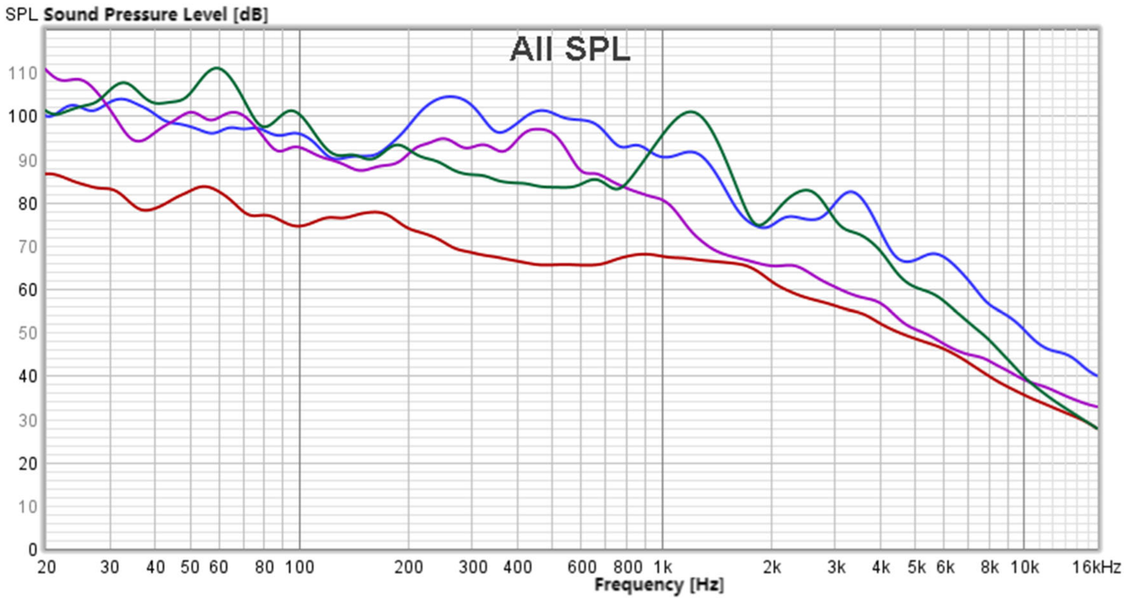

Fig. 2 Spectra from the four soundscape samples. V1—foreground human sound = blue line; V2—background human sound = purple line; V3—no human sound = red line; V4—signal sound = green line.

during the data collection process, the shooting location of all video samples was positioned at the center of the Peace Gardens, maintaining a distance from the participants. As a result, 31 recordings and 8 videos were captured, with each sample displaying the same range of frames, minimizing differences caused by variations in images.

Second, the collected recordings and videos were thoroughly reviewed and organized, in preparation for the soundscape design stage. As mentioned in the literature review section, socially interactive sounds of human activities enhanced soundscape evaluations (Bild et al., 2018). Thus, various types of human sounds, including talking, laughing, singing, and any other sounds generated during social interactions, were recorded during the fieldwork. The sound signal recorded using the Ambisonics method (First Order Ambisonics) can be computationally transformed into a number of relevant formats. This study decoded them into 5.1 Atmos format with six soundtracks: Center (C), Left (L), Right (R), Left surround (Ls), Right surround (Rs), and low-frequency effect (LFE), the particular track of human sounds were selected and prepared for the subsequent edition.

Third, the tracks and videos were edited in Adobe Audition CC according to the four targeted soundscape features shown in Fig. 1. For example, V1 was added as foreground human sound tracks in C, L and R track—people could hear human sound at a short distance. To ensure that the edited sounds corresponded with the overall content and angles of objects in the video, only suitable types of human sounds were added. The human sounds of the four samples were mainly talking and laughing sounds. Each video was about 20–30 s. Participants watched the four recorded videos on their phones through Google Cardboard glasses and a headphone. A spectrum of each soundscape sample (all tracks) is shown in Fig. 2.

Data collection. The suitability level was analyzed through Soundscape Quality Evaluations (SQE) based on past studies, indicating whether a soundscape can support users' social activities. SQE comprises four aspects of evaluations: Stressful–Peaceful (SQE-SP), Uneventful–Eventful (SQE-E), Unsafe–Safe (SQE-S), and Unpleasant–Pleasant (SQE-P). The stimulation level was analyzed through the Levels of Willingness for social interactions (LoW), including the level of *curiosity* about other users (LoW-C), the level of willingness to make *eye contact* with the other users (LoW-E), and the level of willingness to engage in *small talk* with the other users (LoW-S). The indicators of SQE adopted in this research followed the suggestions of Kang and Zhang's (2010) research, and indicators of LoW followed the guidelines of affiliation analysis (Gaby and Zayas, 2017; Zemke and Shoemaker, 2007). Four soundscape samples regarding soundscape suitability and stimulation levels were attached to the questionnaire. The questionnaire consisted of three sections:

1. *Suitability level*: Evaluated by Soundscape Quality Evaluations (SQE-SP/E/S/P) using a series of 5-point rating scales between the two extremes.
2. *Stimulation level*: Evaluated by Level of Willingness (LoW-C/E/S) using a series of 5-point rating scales from 'not at all' to 'very much'.
3. *Demographic background*: Frequency of visiting urban public spaces (never, seldom, sometimes, frequently, always), Companion types that usually go together to urban public spaces (single, friends, family and partner/spouse, from distant to close), Age range (under 19, 20–34, 35–49, 50–64 and above 65) and Gender (female, male).

The five-point scale adopted in this study was suggested by ISO/DIS 12913-3 (International Organization for Standardization, 2019). In order to prevent participants from speculating about the research intention, both the informed letter and questionnaire title were intentionally blurred regarding the human sound components.

In terms of the sample size, power calculations were applied to determine the sufficient number. According to the A-prior power calculation for the analysis of variance (ANOVA), at least 96 participants were suggested to achieve a power of 80% for the medium effect size with four groups (sound clips). In this study, 120 participants were eventually recruited, with 59 males and 61 females. Each age group was sampled, and the most represented age group was 20–34, at 42.4%, Each companion type was also

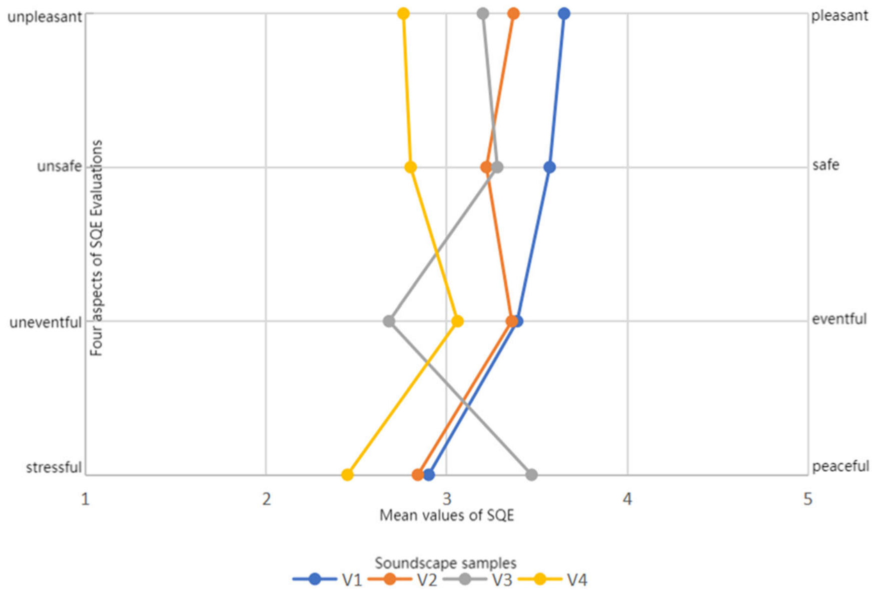

Fig. 3 Mean values of SQE-SP/E/S/P evaluations of V1-V4. 1-5 represent the evaluations between the two extremes.

sampled, and family types represented the largest demography, at 32.5%. An observational survey was conducted prior to the formal experimental survey to analyze the user compositions in Peace Gardens. The participants were then randomly recruited from the users of Peace Garden. The population compositions of the two phases of studies turned out to be similar.

Participants were recruited from the users of Peace Gardens and taken by the researcher to a booked room in the campus to be tested during May–July, 2019. Before the participants answered the questionnaire, the researcher had a short talk with them to inform them about the aims and objectives of the study, data use, and publication. Consent forms were obtained from the participants at this phase. They were required to have normal perceptibility (i.e., normal hearing abilities and sight) to fulfill the questionnaire. Their perceptibility was identified by the researcher through the short talk. The people who agreed to take part in the study were asked to watch and listen to the four recorded videos. The researcher disinfected the headphones with an alcohol pad before each test. Four soundscape samples were randomly displayed on the phone, through a YouTube 360 video attached to the Google Form applications. Questions were shown after each soundscape sample was finished. This research was approved by the ethics committee of the University (026471). The interrater reliability among the subjects was 0.877 (Cronbach's α). A Cronbach's α above 0.8 reflects a very good level of reliability (Nunnally, 1978).

Data analysis. Quantitative evaluations were applied, including statistical analysis in the SPSS software (version 26.0, IBM, USA) and clustering analysis in Matlab, to process the data. The normality of the data was first assessed using a QQ plot to gain a general picture of the data distributions. Subsequently, the Kolmogorov–Smirnov test was applied to further analyze the normality, as the sample size in this study exceeds 50. Consequently, all variables were found to follow a normal distribution. Multiple analyses were conducted in this study, including the Chi-square independence test, correlation analysis, two-sample *t*-test, and ANOVA with a post-hoc test. A frequency analysis and a Chi-Square Independence Test were performed to differentiate between the figures of the suitability/stimulation levels among the four soundscape samples (V1–V4), to compare the effect of different soundscape types. The Spearman Correlation analysis, two-sample *t*-test, and ANOVA with a post-hoc test were done to verify the differences in the suitability/stimulation levels among the four soundscape samples (V1–V4) in relation to the frequency, companion, age, and gender factors, to figure out whether the suitability and stimulation levels can be influenced by the demographic factors. A clustering analysis was conducted to differentiate the four soundscape samples by their features and to compare their suitability/stimulation levels.

Results

Suitability level: Human sound interventions influences SQE-PS/E/S/P evaluations. Figure 3 illustrates the mean values of SQE-SP/E/S/P evaluations for the four soundscape samples V1–V4. According to Fig. 3, human sound interventions significantly enhance suitability, with the mean values of V1 and V2 higher than the other samples, especially in the aspect of 'eventful'. When comparing V1 to V2, the foreground human sound type was evaluated higher than the background human sound type in all four evaluation aspects, especially in the perception of 'Safe' & 'Pleasant'. It indicates that in the setting of urban public spaces, people prefer a high density of human talking sounds. V3 was evaluated with a considerably high SQE score, except for the eventfulness aspect. For the SQE evaluation of V4, each aspect of the SQE was evaluated negatively, except for the aspect of eventfulness, which may be due to the fact that signal sounds generally carry an eventful content. In short, it was suggested that human sound can significantly enhance the suitability level, especially for the foreground human sound. The no-human sound type was also evaluated with high SQE points because of its peacefulness. Signal sounds significantly reduce the suitability level, but allow the feeling of eventfulness.

In terms of how the demographic background affects the SQE evaluation, both age and gender have no effect on the SQE evaluation, except for the companion factor. The companion factor (ranked by relationship intensity) has a negative relationship with SQE-SP& S in V3, with the coefficient figures (R) of −0.161 and −0.182. The negative coefficient figures suggest that people involved in closer relationships had lower evaluations of these aspects. Anova was applied to determine whether the differences between each pair of means of SQE-SP&S in V3 were statistically significant. As a result, no significant differences were found between the groups ($P = 0.071 > 0.05$; $P = 0.134 > 0.05$). In other words, the effect of companions on the evaluations of SQE-SP&S is limited.

In short, human sound interventions enhance the suitability level, and the effect from the foreground human sound is even more significant. In the no-human sound type, the evaluations of SQE-SP&S are influenced by the companion type, with closer groups having lower evaluations for those aspects, while their influence is limited.

Stimulation level: Human sound interventions influence LoW-C/E/S evaluations. The LoW evaluations of the four soundscape samples were found to be independent of each other when using the χ^2 independence test (asymptotic significance 2-sided $P < 0.05$), which indicates the participants' varied evaluations toward the four soundscape samples. Figure 4 denotes the detailed percentages and the mean values of LoW-C/E/S comparing V1–V4. According to the mean values shown in Fig. 4e, V4 was evaluated with the highest total mean values at 2.71, V1 ranked second at 2.69, followed by V2 and V3. The fact that V4, the least desirable acoustic environment, received the highest LoW rating may indicate that negative interventions can also stimulate social interactions, specifically stimulating the willingness of participants to be curious about others and to make eye contact. The high stimulation level of V4 corresponds to the phenomenon of 'triangulation' mentioned by Whyte (1980), which refers to the process by which some unexpected external stimulus can initiate links between people. In this case, because participants could not identify the source of the unexpected sound, they became curious and wanted to communicate with the other person for some information.

V1 was also evaluated with a fairly high stimulation level, it gains the highest mean values in terms of LoW-S, with <1/3 participants choosing unwilling ('not at all' and 'not very'). It indicates that foreground human sound can enhance the stimulation level, especially in participants' willingness for small talk. V3 was evaluated with the lowest total mean value, with a significantly lower assessment of curiosity, with over 35% of participants choosing 'not at all'. It may indicate that a soundscape without human sound can significantly hinder the stimulation level, particularly in the aspect of curiosity.

The companion factor was found to be related to the evaluations of LoW-E& S in V3, both at the 0.05 level (Table 1), with the negative coefficient figures (R) of -0.233 and -0.206. The negative coefficient numbers indicate that the social willingness for eye contact and small talk decreases as the relationship intensities grow in V3. Anova and a post-hoc test were applied to determine the differences in LoW-E&S between the companion groups of V3. The results show that the figures of LoW-E in V3 vary among companion groups ($P = 0.046 < 0.05$), while LoW-S in V3 do not ($P = 0.169 > 0.05$). In the post-hoc test, the LoW-E valuations of Partner/spouse and Family are significantly lower than those of single participants, with $P = 0.013 < 0.05$ and $0.047 < 0.05$, respectively. In other words, closer groups like Partner/spouse and Family had a significantly lower willingness for eye contact than singles in V3.

In addition to the companion factor, the age factor was found to negatively influence the LoW-C&E in V1, and the LoW-C in V2. In V3, however, the relationship between age and LoW-S is positive. A comparison of the soundscape types of V3 to V1 and V2 may suggest that the elderly prefer to have more small talk than the younger in a peaceful acoustic environment. In contrast, younger participants had higher stimulation levels in a soundscape with more human sounds.

In short, both foreground human and signal sounds were found to significantly enhance the level of stimulation, while no human sound type was found to impede curiosity. The companion factor affected LoW-E& S in no human sound type, where participants involved in closer relationships have a lower willingness to make eye contact and small talk. Further significant differences were found between Partner/spouse, Family, and single people in the evaluations of LoW-E. Meanwhile, the no human sound type inspires the elderly to talk more than younger people.

The relationship between soundscape suitability and stimulation levels. Based on the previous findings, the evaluations of suitability and stimulation were varied among the four sound types. A clustering analysis was applied to figure out the relationship between the two evaluation aspects. First, the total mean values of suitability and stimulation levels of the four soundscape types were calculated, and assigned to the X-axis and Y-axis to form four different scatter points: $V1 = (3.38, 2.69)$; $V2 = (3.20, 2.62)$; $V3 = (3.16, 2.59)$; $V4 = (2.77, 2.71)$. Then a new central point was defined by the K-means algorithm, and the four points were clustered into three different quadrants—Zones 1–3—identified by suitability/stimulation levels. The new axis (Fig. 5) divides four quadrants with the Suitability level as the X-axis, and Stimulation level as the Y-axis. Zone 1 represents High Suitability/High Stimulation, Zone 2 represents Low Suitability/High Stimulation, Zone 3 represents High Suitability/Low Stimulation, and Zone 4 represents Low Suitability/Low Stimulation. Stimulation and suitability present a mutually exclusive relationship: V4 with disturbed signal sound was evaluated with low suitability level/high stimulation level; pleasant V2 and V3, without high density of sound intervention was evaluated with high suitability level/low stimulation level. Foreground human sound in V1 was evaluated with high suitability and high stimulation levels, leading to high sociability.

Discussion: Sociable soundscape regarding various relationship groups

Soundscape dominated by human sound in relation to soundscape complexity. Previous studies have established that hearing human sounds is key to enhancing the pleasantness of a soundscape in urban public spaces (Hong and Jeon, 2020; Bild et al., 2018). This study further found that foreground human sound type significantly enhanced both suitability and stimulation levels, while background human sound type lacked stimulation. It indicates that people prefer a high complexity of soundscape for social activities in urban public spaces. Ipsen (2002) raised the soundscape complexity model to summarize the relationship between low and high complexity: as the complexity of information increases, the curiosity of humans also increases. People tend to react with annoyance if the complexity is too high and 'unreadable.' Soundscape samples of this study correspond to the complexity model: foreground human sound type was high complexity soundscape, background human sound type, and no human sound type were perceived as low complexities, and signal sound type was too complex and unreadable. Previous studies have established that hearing human sounds from others is crucial for enhancing the pleasantness of a soundscape in urban public spaces (Hong and Jeon, 2020; Bild et al., 2018). However, achieving appropriate soundscape complexity has remained a challenge in previous studies. Mitchell et al. (2022) evaluated soundscape complexity by counting the number of sound sources, but this approach alone is insufficient to generalize the entire acoustic environment. This study inspired another measurement method—assessing the suitability and stimulation levels of a soundscape sample, where samples with appropriate soundscape complexity can maintain a balance between these two indicators.

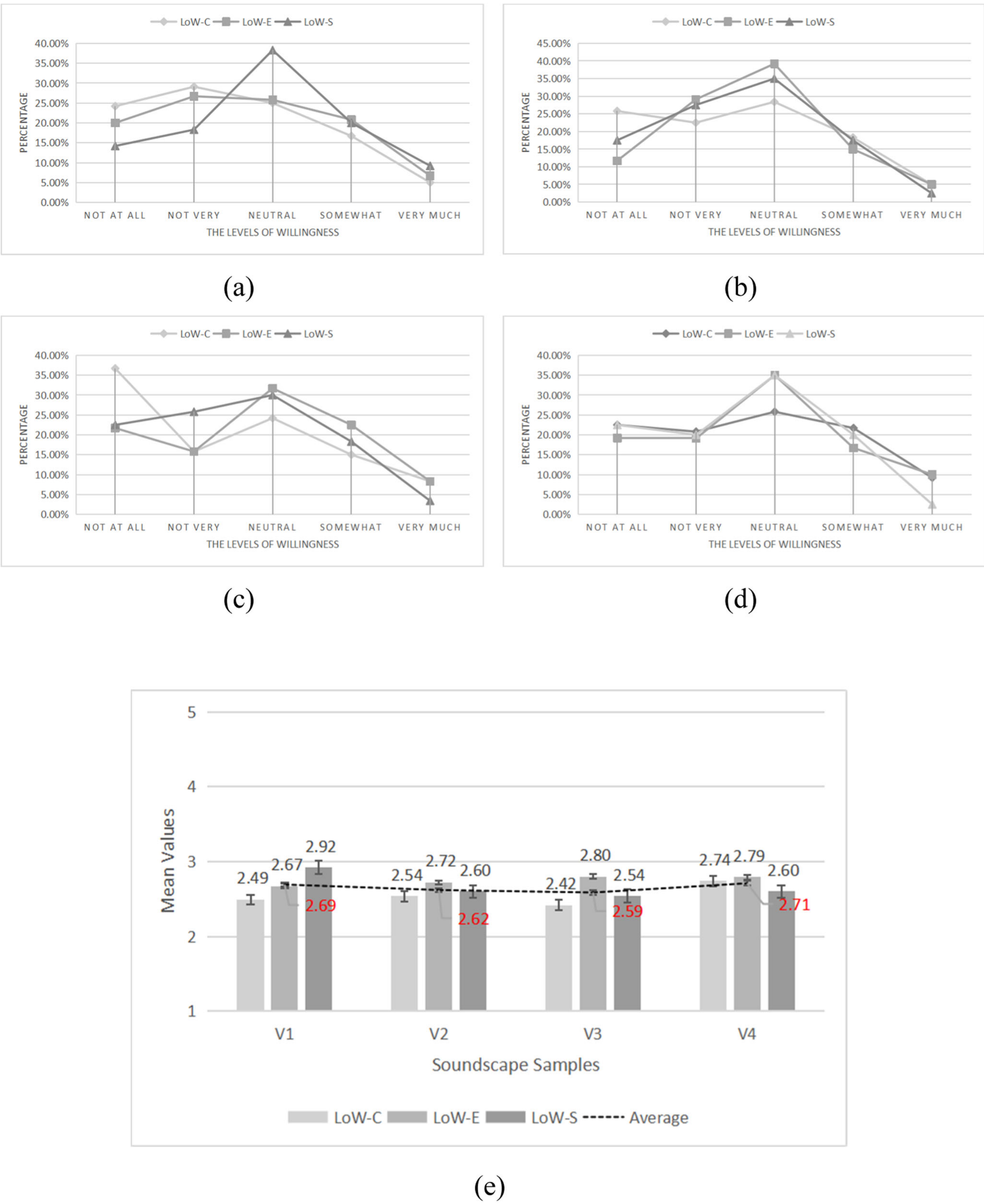

Fig. 4 Percentage of LoW-C/E/S evaluations of the four soundscape samples. **a** V1, **b** V2, **c** V3, **d** V4, and **e** mean values of the LoW-C/E/S evaluations of V1–V4 shown in histogram; Total mean values of LoW evaluations of V1–V4 shown in a dotted line.

This study enriches the concept of ‘complexity’ through the following aspects. First, in urban public spaces, people have a high threshold for soundscape complexity (Aletta and Kang, 2016). Second, human sounds can enhance complexity to an appropriate level, especially for the foreground human sound. Third, the inclusion of unusual and unexpected sound sources adds to the complexity, but negatively. In summary, other people’s presences and the high dense of human sounds are effective for creating

Table 1 Correlation analysis of social willingness levels in relation to frequency, companion types and age, and the two-sample *t*-test between males and females.

N = **120**		**Frequency (*R*)**	**Companions (*R*)**	**Age (*R*)**	**Gender (*P*)**
V1	LoW-C	−0.39	0.084	−0.194*	0.120
	LoW-E	−0.36	−0.149	−0.294**	0.632
	LoW-S	0.076	−0.133	−0.132	0.349
V2	LoW-C	−0.007	0.052	−0.292**	0.541
	LoW-E	−0.060	0.047	−0.018	0.132
	LoW-S	0.124	−0.148	0.114	0.051
V3	LoW-C	−0.073	0.164	−0.096	0.088
	LoW-E	−0.034	−0.233*	−0.018	0.547
	LoW-S	0.161	−0.206*	0.218*	0.164
V4	LoW-C	0.023	−0.089	0.008	0.721
	LoW-E	0.026	0.111	−0.053	0.349
	LoW-S	0.078	−0.169	0.091	0.894

*$p < 0.05$ and **$p < 0.01$ (two-tailed test of statistical significance).

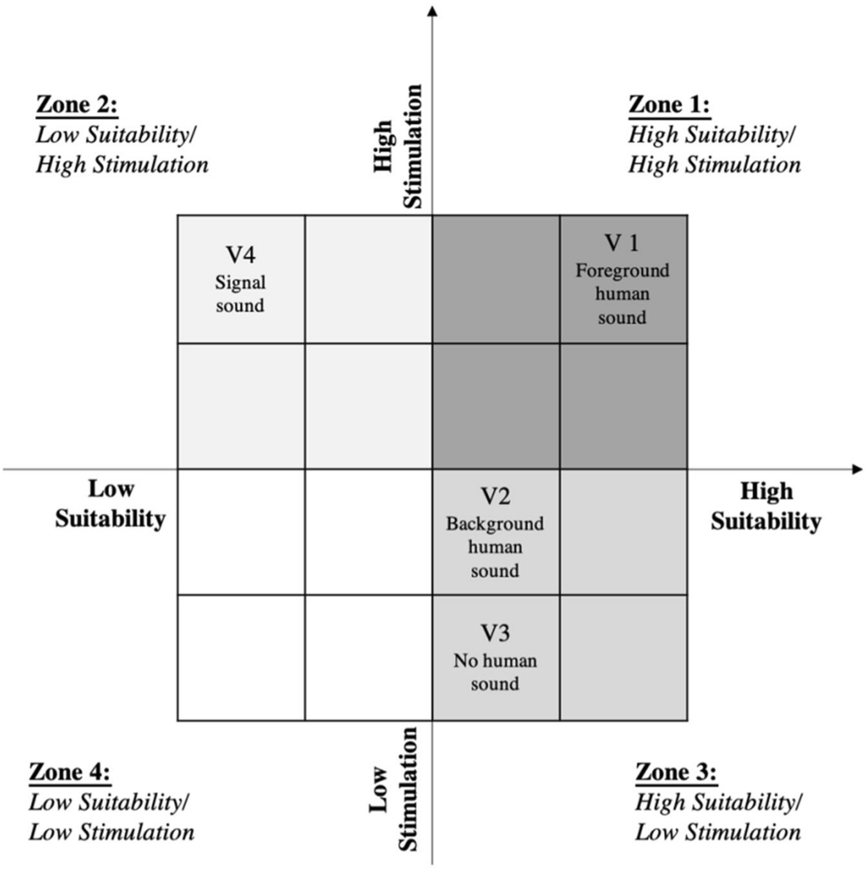

Fig. 5 The four soundscape samples (V1,V2,V3,V4) situated in three different quadrants indicating the relationship between soundscape suitability and stimulation levels. Zone 1 represents high suitability and high stimulation; Zone 2 represents low suitability and high stimulation; Zone 3 represents high suitability and low stimulation; Zone 4 represents low suitability and low stimulation.

high soundscape complexity. Nevertheless, additional investigations are essential on the mechanisms of appropriate soundscape complexity (Andringa et al., 2013; Ipsen, 2002).

Human-centered soundscape design concerning demographic factors. In relation to the various demographic factors, suitability and stimulation evaluations (in the aspect of SQE- SP&S and LoW-E&S) were found to be negatively influenced by relationship intensities in V3 (no human sound type). As the relationship intensity increased, people tended to evaluate these aspects more critically. The reason for this phenomenon may be because of the different intentions for entering public spaces. For single people, they do not normally expect to be in conversation with other people, thus their evaluations were not diminished by the absence of human sounds. In contrast, people with companions may demand a soundscape with a 'chatty context' for their socially interactive activities. In other words, the positive effect of human sound on sociability may be more significant for closer groups in urban public spaces.

Previous studies have emphasized 'appropriateness' as a potential indicator for characterizing the soundscape, indicating that people would wish the acoustic environment to be congruent with their expectations (Axelsson, 2015; Jo and Jeon, 2020). Accordingly, people in urban public spaces may have different criteria for what is considered 'appropriate', depending on their social relationships and their activity types. For those who expect to socialize in a public space, a soundscape featuring human sounds can be expected to render their activities more 'appropriate'. In previous cases, Davies et al. (2014) discovered that individuals tend to place greater emphasis on their expectations of the urban environment rather than their own personal preferences. Therefore it is necessary to include the indicator of 'appropriateness' in evaluation methods instead of solely examining soundscape preferences. Additionally, for the actual soundscape design progress, it is suggested to summarize potential soundscape stereotypes based on previous cases before the design stage and evaluate the 'appropriateness' of the soundscape during the evaluation stage.

Implications. The results of this study have implications for both soundscape design and spatial design. Firstly, hearing other people is important for fostering social interactions in urban public spaces. Previous soundscape designs have mostly focused on sound masking by constructing water fountains, planting trees, or implementing acoustic installations (Licitra et al., 2010). To enhance sociability, it may be more effective to incorporate soundscape art and installations that can create a lively soundscape triggering a 'gathering effect' (Whyte, 1980). Secondly, sociable public spaces should be designed to facilitate people gathering rather than dispersing by utilizing small-scale redundant spaces of the city and applying centripetal design with appropriate street furniture.

Moreover, diverse soundscape requirements from various types of people should be considered. Designers should have a clear vision of the future users, especially on the companionship aspect. A peaceful soundscape of urban public spaces would satisfy both single people and the elderly, but accompanied/young users prefer to socialize in a soundscape with a higher degree of stimulation. When introducing soundscape installations and sound stimuli into urban spaces, proper soundscape evaluations are needed prior to their launch, to ensure that the sound source propagates within people's perceived pleasantness range. The planning of different sound zones and refuges may be useful to satisfy people who do not find the high soundscape stimulation level attractive in urban public spaces (Raimbault and Dubois, 2005).

Limitation. However, this study had some limitations. First, it focused only on the presence and density of human sound by designing a foreground or background or no human sound. Human sounds used in this study mainly include people's talking and laughing sounds. There is a lack of comparison among diverse types of human sounds, such as people singing, children crying, etc. It is possible that different types of human sounds bring with them diverse sound perceptions.

Second, there is a lack of the interactions between sound and visual factors. During the research design stage, sound interventions were selected and designed to be compatible with the visual features. There exists the possibility that the high sociability of foreground sound type came from the combination of eventful sounds and visuals (Gidlöf-Gunnarsson et al., 2007). Further studies about the interactions between sound and visual are required.

Thirdly, the 'appropriate complexity' of the soundscape has not been fully emphasized. Human sound interventions applied in this study (people talking and laughing) were found to enhance the complexity to an appropriate level. However, further studies are still required to incorporate other types of human sounds and additional sound types in order to establish a comprehensive framework for soundscape complexity.

Conclusion

This study explored how the compositions of soundscape can influence sociability in urban public spaces, and human sound type was focused. Two aspects of sociability were analyzed by adopting the Affordance Theory. The first was suitability, which was used to analyze whether the soundscape was suitable for social activities, and the second was stimulation, used to analyze whether a soundscape can foster social interactions. Raw sound data were recorded and designed into four 360° soundscape samples, attached with Soundscape Quality Evaluation (SQE) and Level of Willingness for Social Interactions (LoW) questionnaire, to investigate the sociability level.

The results reveal that stimulation and suitability present a mutually exclusive relationship, with the background human sound type and no human sound type evaluated as high suitability/low stimulation, and the disturbed signal sound evaluated as low suitability/high stimulation. Beyond this relationship, foreground human sound significantly enhances both aspects of sociability. In relation to the demographic factors, the elderly are found to be more willing to have small talk than the young in a peaceful environment. Closer groups are found to be more critical of the no human sound type than less closed groups, which may be because peacefulness does not suit their social activities. These results indicate that public space users prefer a high complexity of soundscape, within the range of pleasantness, although this preference for complexity varied among different companion types and age groups.

The study focused on the complexity of the acoustic environment in a real setting by exploring sociable soundscapes through 360° experimental samples with designed soundscape compositions. It is expected to contribute to extending soundscape research beyond controlled laboratory settings into real-world environments. The results of this experiment further illustrate the effect of others' presence in promoting sociability in urban public spaces and guide future acoustic design: creating a high complexity of human sound dominated soundscapes accompanied by a centripetal spatial form to enhance the sociability of urban public spaces. It is expected that the findings of this study could inspire future studies to seek solutions for enhancing sociability in urban public spaces from a soundscape design perspective.

Data availability

The data that support the findings of this study are openly available in Mendeley Data at https://data.mendeley.com/datasets/mbzpmf483x/1.

Received: 6 December 2023; Accepted: 14 October 2024;
Published online: 12 November 2024

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Author contributions

Jingwen Cao: Conceptualization, methodology, analysis, writing-up. Jian Kang: Conceptualization, supervision, project administration, review and editing.

Competing interests

The authors declare no competing interests.

Ethical approval

Name of the Approval body: the ethics committee of the University of Sheffield. Registration ID Number: 026471. Date of Approval: 03/05/2019. Scope of Approval: Ethical approval must be sought for research that involves human participants, their data, biological samples, or observations about them where: Information collected from or about human participants will be used to answer research aims or questions. Outcomes of investigations/exploration of research aims and questions will be presented or published for research purposes. Grant funding is provided to conduct research activities involving human participants. Quality assurance or improvement activities that trigger the requirement for ethical review. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed consent

Before the participants answered the questionnaire, informed consent was obtained from all participants and/or their legal guardians by signing the consent form from May to July, 2019. Consent forms informed them about the aim and objectives of the study, data use, and publication.

Additional information

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