Factors associated with soundscape experiences in urban green spaces: a case study in Rostock, Germany

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Abstract
Urban green spaces could play a more prominent role than other types of urban open space in providing high quality soundscapes. The main objective of this study was to examine the relationships between people's visit motivation, along with other social/demographical/behavioral as well as visual landscape factors and soundscape experiences in terms of the perceived occurrences and loudness of individual sounds, the preference for individual sounds, as well as overall soundscape preference in urban green spaces. This was based on a questionnaire survey of 400 users in four urban green spaces in Rostock, Germany. The results showed that street traffic sounds were the least preferred, but in a dominating position either in perceived occurrences or loudness, while bird song and water sound were the most preferred sounds. Among the social/demographical/behavioral factors length of stay was the most associated one with soundscape experiences, especially the perception of street traffic sound and bird song. All the five visit motivations were positively related to overall soundscape preference, with "Enjoy a quiet environment" showing the highest correlation coefficient (0.323). "Enjoy the scenery or atmosphere" showed the most significant relationships with perception of individual sounds, with totally 10 different perception parameters. The perception of street traffic sound, motorcycle noise, bird song and water sounds were more associated with visual landscape preference than other kinds of sound. Besides, overall soundscape preference could be affected by visual landscape preference indirectly through the perceived occurrences and loudness of certain sounds. The results suggested that sound sensibility indicated by perceived occurrences of individual sounds was more associated with the examined factors. These findings could be instructive in the soundscape and landscape planning and designing process of urban green spaces.

Key words: soundscape experience; visit motivation; visual landscape; green space

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1. Introduction

Urban green spaces refers to public and private open spaces in urban areas covered by vegetation directly or indirectly available for the users (Haq, 2011). They usually play a crucial role in providing various kinds of ecosystem service, such as air and water cleaning (De Ridder et al., 2004; Jim and Chen, 2008), preserving biodiversity (Mörtberg and Wallentinus, 2000), providing spaces with high restorative and aesthetic values (De Vries et al., 2003; Hillsdon et al., 2006; Jiang et al., 2015; Jim and Chen, 2006). Besides, green spaces are important “quiet areas” because of noise reduction function and providing other positive soundscape experiences (Fang and Ling, 2003; Van Renterghem et al., 2012). Especially, tranquillity experienced in green spaces was reported associated with levels of relaxation, reduced anxiety, lower noise sensitivity and annoyance, as well as release of the noise-induced stress (Dzhambov and Dimitrova, 2014; Watts et al., 2013).

In the research area of urban acoustics, soundscape approach has been advocated by many researchers to cope with noise problems. Soundscape has been defined by the International Organization for Standardization (ISO) as “[the] acoustic environment as perceived or experienced and/or understood by a person or people, in context” (ISO, 2014). It has been pointed out that soundscape experience could differaccordingly to places’ main functions (Hong and Jeon, 2015). Many soundscape studies have been conducted in urban open spaces, such as city parks (Liu and Kang, 2015; Liu et al., 2014; Liu et al., 2013a; Nilsson and Berglund, 2006; Zhang and Kang, 2007), squares (Yang and Kang, 2005a), and commercial streets (Meng and Kang, 2015), etc. The focuses were on soundscape experiences such as sound level, perceived occurrences and loudness, acoustic comfort, preference for soundscape and sound, etc. As for the factors associated with soundscape experiences in urban open spaces, the focuses have been on the subjects social/demographical/behavioral characteristics (Liu et al., 2013a), landscape factors (Hong and Jeon, 2017; Liu et al., 2013b), people’s expectations of a place (Bruce and Davies, 2014), and the crowd density (Meng and Kang, 2015; Meng and Kang, 2016), etc. Specifically, in urban green spaces, the noise reduction effect has been drawing increasing attention. The focuses were on either the effects of vegetation on physical reduction of noise, such as traffic noise reduction by single plants, green walls, and hedges (Fang and Ling, 2003; Horoshenkov et al., 2013; Van Renterghem et al., 2014; Wong et al., 2010; Yamada, 2006), or by land use parameters emphasizing on green spaces (Margaritis and Kang, 2016), or the psychological noise attenuation (Dzhambov and Dimitrova, 2014; Dzhambov and Dimitrova, 2015). In practical aspect, tranquillity rating prediction tool has been proposed for urban green areas (Watts et al., 2013), and was further applied to predict greening effect on tranquillity in city squares (Watts, 2017). Soundscape-based forest planning for recreational and therapeutic activities was also proposed (Yamada, 2006).

Although urban green spaces may be more prominent in terms of the noise attenuation function than other types of urban open space, soundscapes and the associated factors of soundscape experience in urban green spaces have not been enough concerned. Especially, as green spaces could supply several different ecosystem services, people who access to them may have different purposes, which may affect their soundscape experiences. In order to add to the current state of knowledge and build on the existing literature, the main aim of this study was to comprehensively examine the relationships between people's visit motivations, along with other social/demographical/behavioral as well as visual landscape factors and soundscape experiences. In this research, soundscape experience was defined as a long term experience in certain urban green spaces, and evaluated subjectively by the interviewees in terms of several soundscape perception parameters, including the perceived occurrences and loudness of individual sounds, the preference for individual sounds, as well as overall soundscape preference.

2. Method

2.1. Field survey

This study was based on a questionnaire investigation carried out in Rostock, a costal and touristic city with a population of about 0.2 million residents in Germany. And the city has conducted the noise action plan called "Rostock will be quieter" in response to the Environmental Noise Directive (END) (2002/49/EC) (Rostock-wird-leiser, 2013).

Four typical green spaces, which were recognized as quiet areas (L den ≪ 50 dB) according to the noise action plan for Rostock, were chosen as case study sites (Fig. 1), including city park complex (Aranka park, Stephan-Jantzen park, Kur park) located in the coastal tourist resort Warnemünde, Schwanenteich park and Botanical garden located in Reutershagen, and Rosen garden located in the downtown Rostock. Besides their different locations and shapes, these green spaces differ also in terms of the vegetation type and percentage area covered by trees, grass or water surface (Table 1), which could generate a variety of soundscapes with different characteristics, and provide diverse soundscape experiences for people. However, the relationships between diverse soundscapes and underlying landscapes were not discussed in depth, as the major purpose of the study was to examine the general relationships between visitor-related factors and soundscape experience, rather than to examine the differences among individual case study sites.

Through pilot investigations before the main survey, 12 different sounds regularly appearing in the parks were identified and introduced into the questionnaire to characterize the general soundscapes in the green spaces. As shown in Table 2, these sounds, including natural and artificial sounds, were further classified into five sub-class sound categories (Liu et al., 2014).

The field survey was carried out by a group of students from the Faculty of Agricultural and Environmental Science in the University of Rostock under sunny and stable weather conditions during June and July 2013. The interviewees were selected randomly on the study sites. On each site, 100 effective questionnaires were collected, and totally 400 questionnaires were available for analysis, according to a previously suggested sample size for soundscape evaluation in urban open public spaces (Kang and Zhang, 2010).

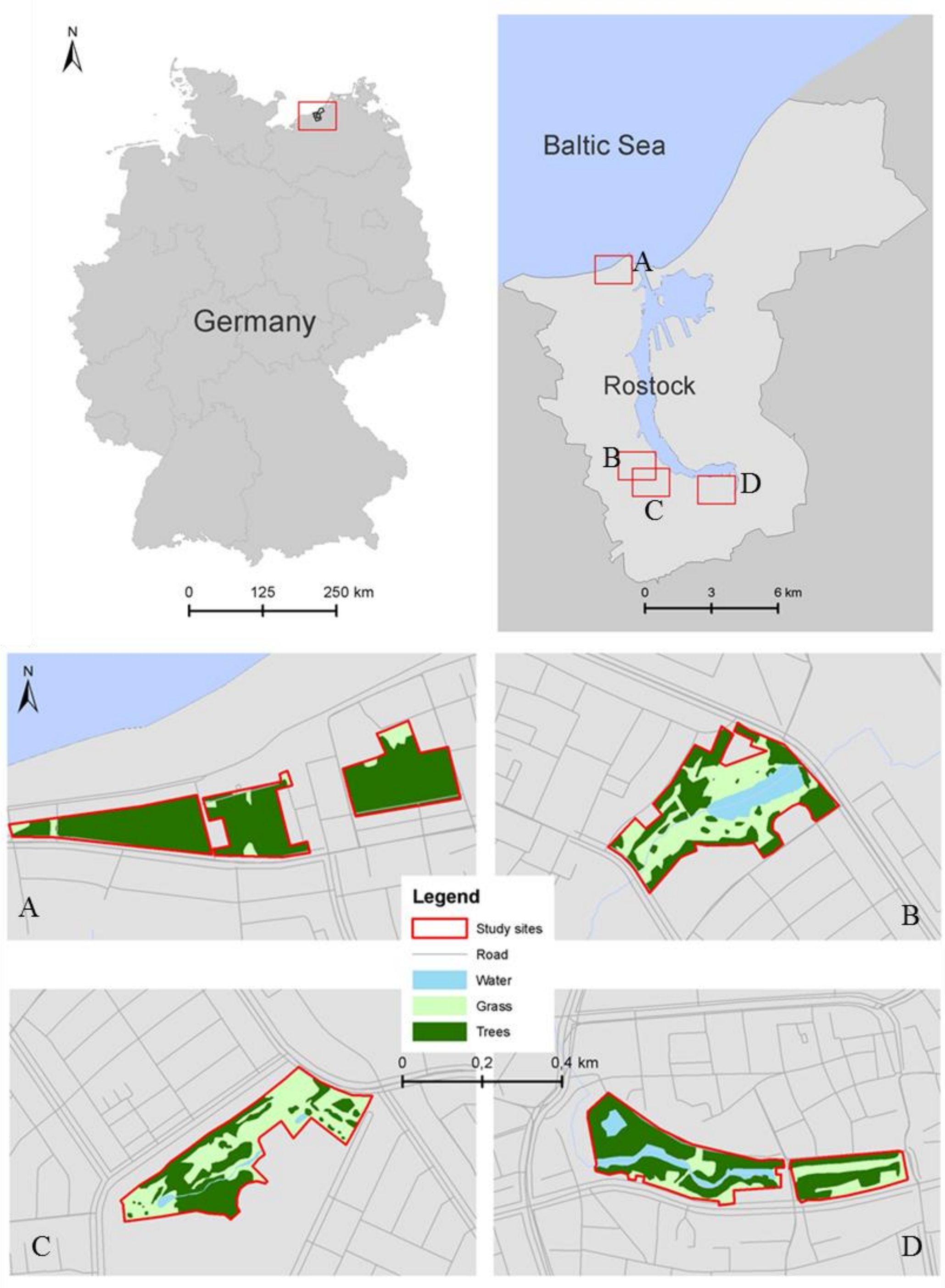

Figure 1. Location of the case study sites, and major green landscape elements in the four case study sites. A: City park complex (Aranka park, Stephan-Jantzen park, Kur park), B: Schwanenteich park, C: Botanical garden, D: Rosen garden.

2.2. Social/demographical/behavioral factors

The first part of the questionnaire was designed to collect the interviewee's social/demographical/behavioral information, including age (≤24, 25–30, 31–40, 41–50, 51–59, ≥60), education background (primary school, secondary school, and higher), occupation (student, working person, and others (including retired, unemployed and full-time housewife)), residential status (community resident, local resident, tourist), visit frequency (low frequency (≤1 x in a month), medium (≤1 x in week), high frequency (>>> 1 x in week)), and length of stay (short time (<<1 h), medium (1–3 h), long time (>>>3 h)), referring to a similar research in city parks (Liu et al., 2013a). Fig. 2 shows percentage of the interviewees categorized by different characteristics. As most of the interviewees have higher education background, the data showed large skewness. Thus, the significance of this factor on soundscape experience might be limited. Fig. 3 shows the ratio between the standard deviations (SDT) of social, demographical and behavioral characteristics of the interviewees and the respective SDT averages among the four green spaces. For most of the factors, the range of the ratio is no more than 0.32, except for education background. Thus a holistic analysis could be carried out based on the database.

Table 1. Major characteristics of the four case study sites.

	City park complex	**Schwanenteich park**	**Botanical Park**	**Rosen garden**
Total Area (ha)	11.33	10.24	8.43	9
Percentage of trees (%LAND)	92.9	41	42	63.3
Percentage of grass (%LAND)	7.1	45.8	55.4	25.1
Percentage of water (%LAND)	0	14	2.7	12.4
Description	Former cemetery, forest-like park with paths and play area (e.g. children playground, minigolf).	Oldest residential park with large lake, play areas, integrated art hall and youth club.	Park with the function of popular science for education on biodiversity and conservation of rare plant species and research.	Oldest park in Rostock, with play areas and historical architectures.

Table 2. Recognized sound sources in the green spaces and respective categories.

Main-class sound category	**Sub-class sound category**	**Sound source**
Artificial sounds	Human sound	surrounding speech, playing children, footsteps
	Traffic sound	street traffic, motorcycle noise
	Mechanical sound	bicycle riding
Natural sounds	Biological sound	bird song, insects, dog barking
	Geophysical sound	tree rustling, wind blowing, water sound

2.3. Visit motivations

Visit motivations are the reasons people come to a place for certain activities, and could be treated as behavioral related factors. With different visit motivations, people may have different expectations of the environment, which could affect soundscape perception (Bruce and Davies, 2014). Therefore, the effects of visit motivations on soundscape perception were considered separately.

According to the questionnaire survey, interviewees came to the green spaces mainly with five visit motivations (with the abbreviation and the number of people who chose this kind of visit motivation in the bracket), i.e., “Specifically to come and relax” (SR, 141), “Enjoy the scenery or atmosphere” (ES, 233), “Enjoy a quiet environment” (EQ, 130), “Physical activities” (PA, 134), and “Social purpose” (SP, 62). It is necessary to note that there is no absolutely strict boundary between these visit motivations. For example, although interviewees who came to “Enjoy the scenery or atmosphere” or “Enjoy a quiet environment” could also belong to the group of “Specifically to come and relax”, they were classified into different categories mainly because the interviewees could clearly indicate that their visit motivations were more related to visual landscape or soundscape of these places. Thus, interviewees were allowed to have multiple choices.

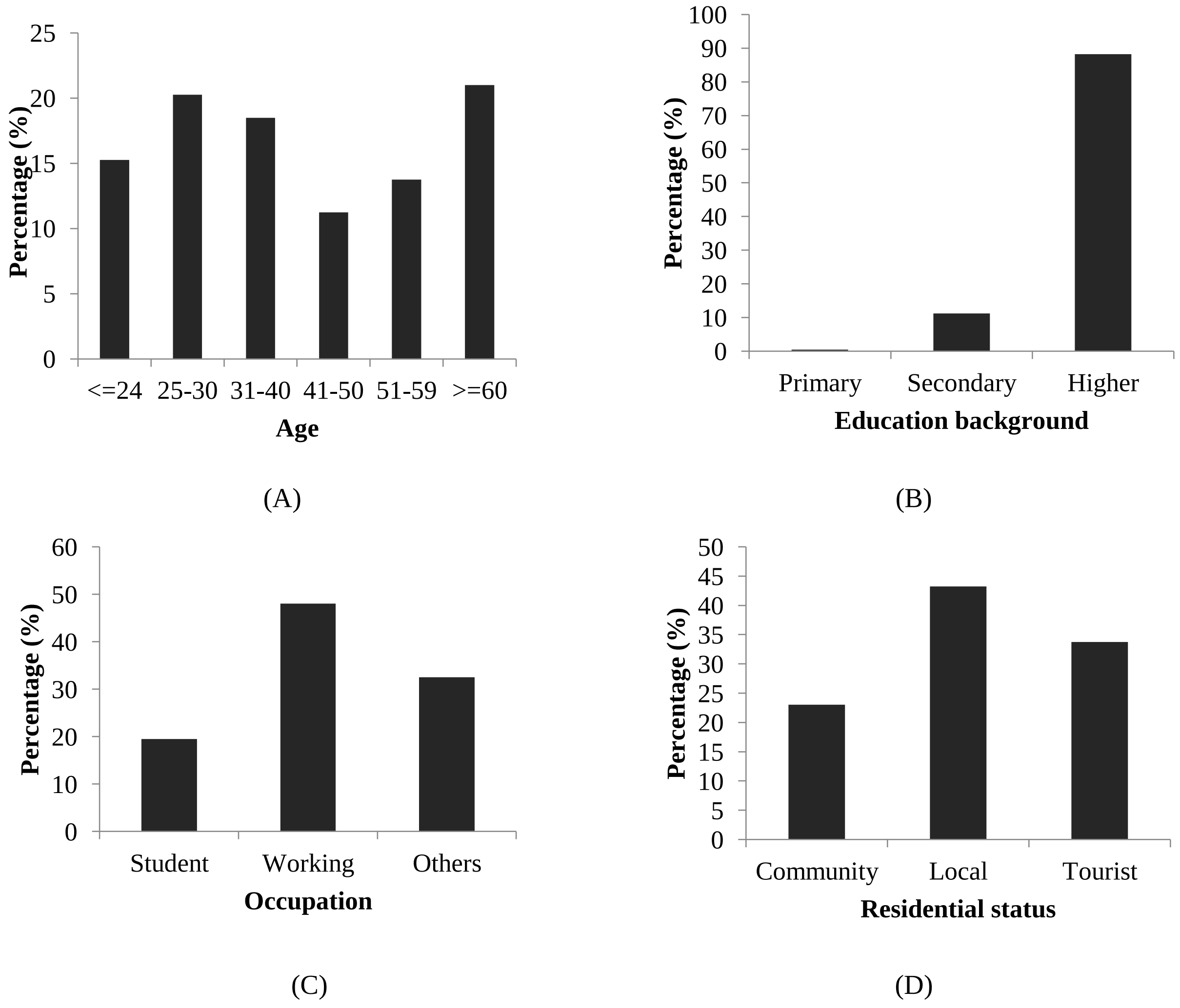

Figure 2. Percentage of the interviewees categorized by different characteristics.

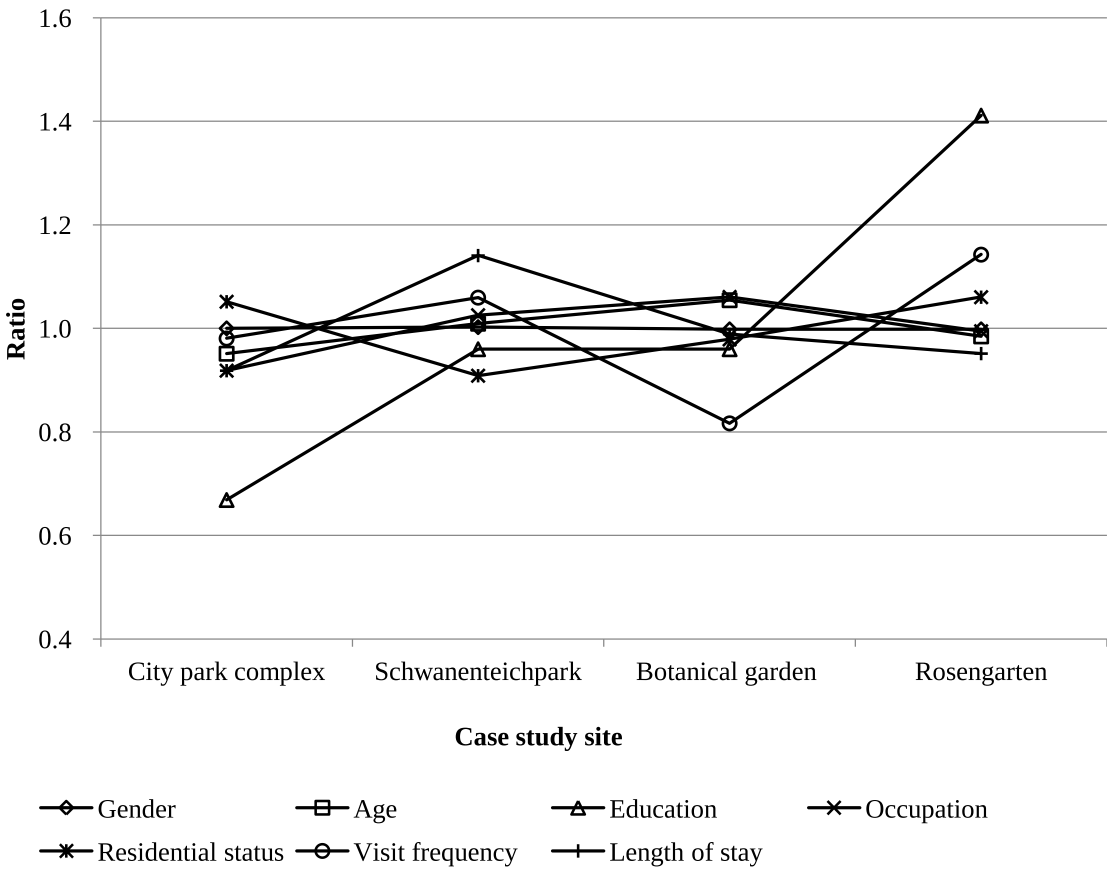

Figure 3. Ratio between the standard deviation (SDT) of social/demographical/behavioral characteristics of the interviewees and the respective STD average among the four green spaces.

2.4. Soundscape and landscape data

Soundscape is closely related to the underlying landscape (Liu et al., 2013b). With respect to the soundscape data, individual sounds were evaluated by the interviewees according to their long term experiences in the green space in terms of the perceived occurrences (POS) by using a three-point rating scale (1-never, 2-occasionally, 3-frequently), the perceived loudness (PLS) by using a three-point rating scale (1-quiet, 2-neither quiet nor loud, 3-loud), and the preference for each of them (PRE) by using a three-point rating scale (1-negative, 2-neutral, 3-positive); on the other aspect, overall soundscape preference was evaluated by using a five-point rating scale (1-very bad, 2-bad, 3-neither good nor bad, 4-good, 5-very good).

Visual landscape preference of the green space was also evaluated by using a five-point rating scale (1-very bad, 2-bad, 3-neither good norbad, 4-good, 5-very good).

3. Results

3.1. Soundscape characteristics of the green spaces

Fig. 4 shows the distribution of the interviewees' perceived occurrences of different sounds. Street traffic sound was the most frequently perceived sound in the green spaces, which indicates the fact that traffic sounds are the keynotes of most urban areas. Bird song was the most frequently perceived natural sound following street traffic sound, and the perceived occurrences of them were much more than other reported sounds. Thus, bird song could also be recognized as a keynote sound of the green spaces. Geophysical sounds including tree rustling, wind blowing and water sound were a group of sounds perceived more frequently than other sounds, although the percentage of perceived occurrences were relatively low. Human sounds and bicycle riding sound were all usually occasionally perceived by a low percent of interviewees.

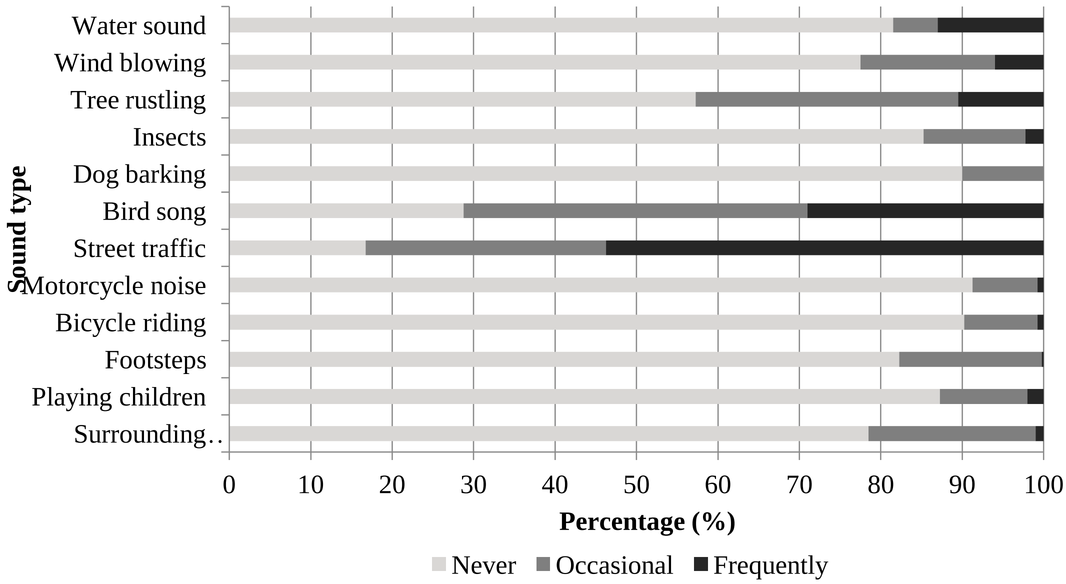

Figure 4. Distribution of the interviewees' perceived occurrences of different sounds.

Fig. 5 shows the distribution of the interviewees' perceived loudness of different sounds. Generally speaking, the perceived loudness of different sound was closely related to their physical characteristics like frequency and SPL. The results suggest that motorcycle noise could be the loudest one among all the investigated sound sources, and over 68% of the interviewees who perceived this sound considered it loud. The perceived loudness of street traffic sound was remarkable too, and over 26% of the interviewees thought this kind of sound was loud. It is clear that in the green spaces traffic sounds were in a dominating position either in perceived occurrences or loudness. Among all the biological sounds, dog barking sound was perceived loud by the most percent of interviewees (35%), while water sound was the loudest geophysical sound (20.3%). Human sounds were normally quiet in the green spaces, although the sounds of playing children might be thought loud by a few interviewees (6%). Bicycle riding was thought quiet by all the interviewees. It seems that biological and geophysical sounds were more frequently perceived and usually louder than human and mechanical sounds in the green spaces.

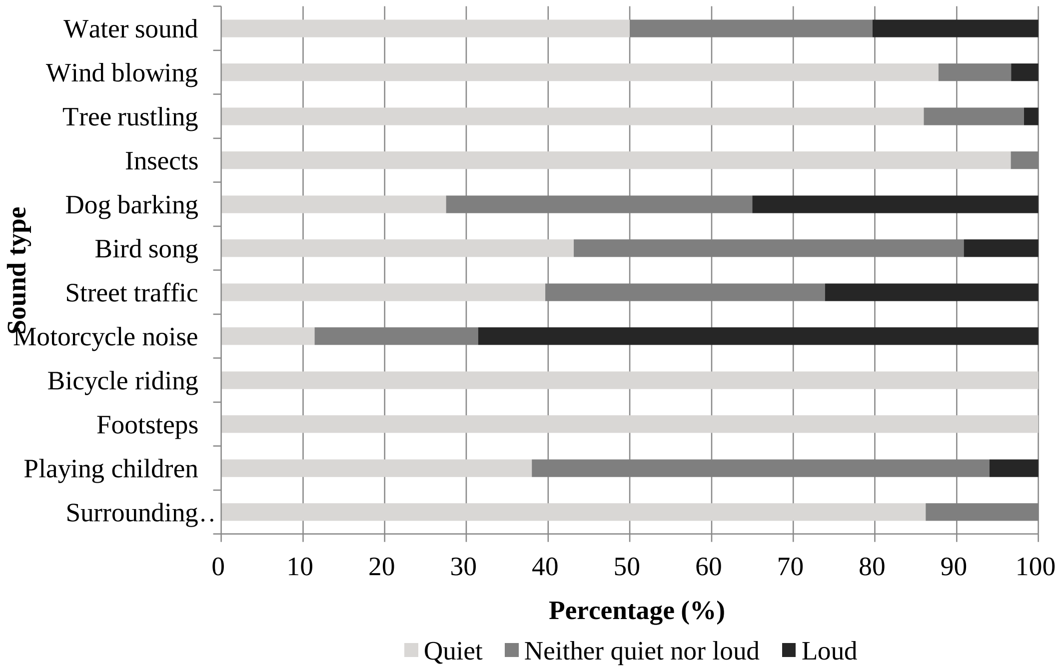

Figure 5. Distribution of the interviewees' perceived loudness of different sounds.

Fig. 6 shows the distribution of the interviewees' preference for different sounds. Water sound and bird song were the most preferred sound in the green spaces. All the other geophysical sounds (tree rustling and wind blowing) were preferred by a large percent of the interviewees, while dog barking sound was not preferred by most of the interviewees among all the biological sounds (35%). Sounds from playing children were the most preferred human sounds (59%), while the interviewees showed no obvious dislike to other human sounds and mechanical sound (bicycle riding). Motorcycle noise received the lowest evaluation followed by street traffic sound, and obviously no one likes these two kinds of sound. However, for street traffic sound more than half of the interviewees evaluated it neither favorable nor annoying, possibly due to people’s long term exposure to this kind of sound in urban areas. There is a clear tendency that people’s preference for natural sounds over artificial sounds, which is consistent with many other researches (Carles et al., 1999; Liu et al., 2013a; Yang and Kang, 2005a; Yang and Kang, 2005b).

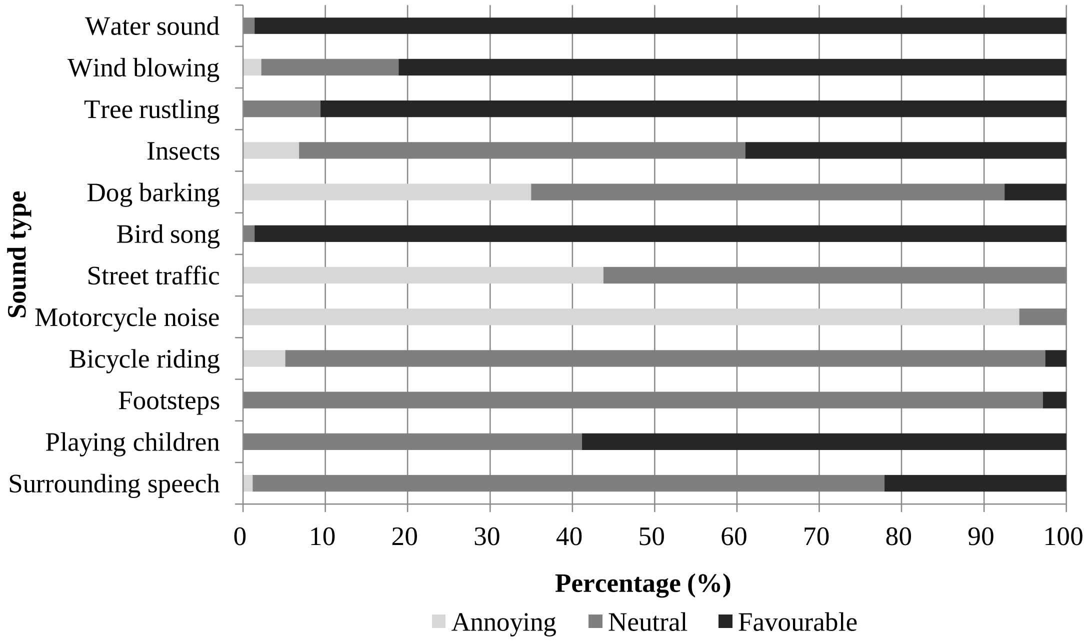

Figure 6. Distribution of the interviewees' preference for different sounds.

3.2. Effects of social/demographical/behavioral factors on soundscape perception

Strong correlations existing among the social/demographical/behavioral factors were reported by many studies (Liu et al., 2013a; Yu and Kang, 2008). As shown in Table 3, these relationships existed in this study too, and were considered later in the analysis of their influence on soundscape experience. The relationships between perception of individual sounds as well as overall soundscape preference and each of the social/demographical/behavioral factors were analyzed based on Spearman's rho correlation analysis. The results are shown in Table 4.

Table 3. Spearman's rho correlation coefficient for the relationships among the social, demographical and behavioral factors (2-tailed). Significant correlations are marked with *(p<0.05) and **(p<0.01).

	Age	**Education**	**Occupation**	**Residential status**	**Visit frequency**
Education	0.323**	1			
Occupation	0.706**	0.308**	1		
Residential status	-0.021	0.110*	-0.118*	1	
Visit frequency	0.093	-0.006	0.115*	-0.709**	1
Length of stay	0.127*	-0.019	0.149**	-0.196**	0.082

3.2.1. Effects of social/demographical/behavioral factors on perception of individual sounds

The results in Table 4 indicate that, visit frequency was the most strongly associated with the perceived occurrences of individual sounds, significantly related with five kinds of sound. The more frequently people came to the green spaces the more chances they could perceive bird song and dog barking, while they tended to show less sensitivity to surrounding speech, footsteps and wind blowing, indicated by the negative coefficients. Length of stay and residential status both showed significant relationships with the perceived occurrences of three kinds of sound. It is reasonable that the longer people stay in the green spaces the more they could perceive bird song and sounds of insects, and they tended to be less sensitive or more tolerant to street traffic sound. Indicated by the value of correlation coefficients, local residents might be more sensitive to natural sounds such as bird song and dog barking than tourists, and tourists might pay more attention to human sound like footsteps. The factors of education and occupation were related to the perceived occurrences of insects and street traffic sound, respectively. It seems that people with higher education background might be more concerned about the natural environment, as they paid more attention to sounds of insects, while people who were not working tended to be less sensitive to street traffic sound. Age showed no relationship with perceived occurrences of any sounds. The results are not totally consistent with the similar research in city parks in China (Liu et al., 2013a), as visit frequency, age and length of stay were revealed the most influential factors on people's sound sensitivity, while residential status, education and occupation did not show much effect, indicating a possible effect from cultural background difference.

Table 4. Spearman's rho correlation coefficients of the relationships between each of the perception parameters of individual sounds as well as overall soundscape preference and each of the social/demographical/behavioral factors, i.e. age, education, occupation, residential status, visit frequency and length of stay (2-tailed). Significant correlations are marked with * ($p < 0.05$) and ** ($p < 0.01$). POS: perceived occurrences, PLS: perceived loudness, PRE: preference.

Perception parameter		**Age**	**Education**	**Occupation**	**Residential status**	**Visit frequency**	**Length of stay**
POS	Surrounding speech	-0.021	-0.003	0.01	0.07	**-0.170 ****	0.067
	Playing children	0.012	0	0.056	-0.023	-0.014	0.08
	Footsteps	0.053	0.008	0.024	0.118*	**-0.126***	0.059
	Bicycle riding	0.026	-0.063	0.024	0.033	0.02	-0.008
	Motorcycle noise	0.072	0.059	0.018	0.013	0.028	-0.092
	Street traffic	-0.052	-0.032	**-0.099***	0.085	-0.025	**-0.153 ****
	Bird song	-0.026	0.072	0.027	**-0.145 ****	**0.109***	**0.160 ****
	Dog barking	0.058	-0.033	0.013	**-0.135***	**0.176***	0.033
	Insects	0.07	**0.109***	0.086	0.051	-0.073	**0.111***
	Tree rustling	-0.061	-0.024	-0.086	-0.079	0.027	0.025
	Wind blowing	-0.054	-0.043	-0.071	0.031	**-0.171 ****	0.028
	Water sound	-0.008	-0.008	-0.006	-0.046	0.067	-0.045
PLS	Surrounding speech	**-0.226***	-0.065	-0.085	0.091	0.096	-0.058

	Playing children	-0.023	-0.194	0.028	0.171	-0.084	**-0.390 ****
	Footsteps	—	—	—	—	—	—
	Bicycle riding	—	—	—	—	—	—
	Motorcycle noise	0.148	0.149	0.044	0.152	-0.062	-0.258
	Street traffic	0.008	0.014	-0.08	**0.151 ****	-0.043	**-0.193 ****
	Bird song	0.021	0.027	0.043	**-0.195 ****	**0.119***	0.035
	Dog barking	**0.424 ****	**0.393***	0.282	0.009	0.107	0.069
	Insects	0.082	0.035	0.051	0.075	-0.033	0.203
	Tree rustling	0.138	0.095	0.075	-0.05	0.106	**-0.200 ****
	Wind blowing	**-0.240 ***	**-0.272 ****	-0.155	0.026	-0.027	-0.196
	Water sound	-0.005	-0.202	0.062	-0.052	0.077	-0.004
PRE	Surrounding speech	-0.114	-0.075	-0.152	0.189	**-0.268***	0.187
	Playing children	-0.08	0.065	0.128	-0.206	0.248	0.109
	Footsteps	-0.017	0.061	-0.055	0.041	-0.137	0.179
	Bicycle riding	-0.126	0.199	-0.122	0.035	-0.021	0.09
	Motorcycle noise	**-0.351***	**-0.470 ****	-0.233	0.127	0.039	-0.211
	Street traffic	0.039	-0.041	0.077	**-0.173 ****	0.095	**0.163 ****
	Bird song	**0.156 ***	0.058	0.015	0.049	0.019	0.056
	Dog barking	**-0.338***	-0.062	-0.165	-0.047	-0.154	-0.244
	Insects	-0.072	-0.053	-0.096	-0.093	0.09	0.045
	Tree rustling	-0.011	0.008	-0.056	-0.059	0.017	0.102
	Wind blowing	0.044	-0.08	-0.073	0.093	-0.174	0.163
	Water sound	-0.164	**0.315 ****	0.024	0.012	-0.146	0.124
Overall soundscape preference		0.038	-0.093	**0.115***	**-0.223****	0.083	**0.240****

In terms of the perceived loudness of individual sounds, the results showed that the factor of age and length of stay were both related with three but different kinds of sound. The correlation coefficients indicate that older people tended to perceive dog barking louder, but they usually perceive surrounding speech and wind blowing not as loud as younger people. The reason could be attributed to the nature of these sounds, as dog barking is typically louder and contains lower frequency sound and therefore more easily perceived than speech and wind sounds by especially respondents with age related hearing problems, i.e. presbycusis. When people stayed longer at the green spaces, they tended to perceive playing children, street traffic sound and tree rustling much quieter. This indicates the importance of green spaces as quieter places for people to temporarily escape from the noisy environment full of traffic sounds in urban areas. Education showed positive and negative relationship with dog barking and wind blowing, respectively, which may be partly because of the positive relationship between education and age. It seems that people with higher education background tended to perceive dog barking louder, while they were less sensitive to wind blowing. Residential status showed positive and negative relationship with street traffic sound and bird song, respectively. Thus, tourists might perceive street traffic sound louder than local people, while local people tended to perceive bird song louder than tourists. Visit frequency only showed positive relationship with the perceived loudness of bird song, while occupation showed no significant relationship with the perceived loudness of any sound. The results indicated that, although occupation and education were found to be the most associated factors to the sound level evaluation in urban open spaces (Yu and Kang, 2008), when it refers to loudness perception of certain sounds, the influential factors could differ.

As to the preference for individual sounds, the results showed that, age was the most associated factor, significantly related to three kinds of sound, which is in consistent with other research (Liu et al., 2013a; Yang and Kang, 2005b). It seems that older people might prefer bird song more, while they might not like motorcycle noise and dog barking. Education showed significant negative and positive relationship with motorcycle noise and water sound, respectively. It indicates that people with higher education background did not prefer motorcycle noise, but prefer water sound. Both residential status and length of stay showed significant relationship with street traffic sound, negatively and positively, respectively. It is reasonable that local residents had a higher tolerance level to street traffic sound than tourists, or people might not want to hear this kind of sound in green spaces especially when they came as tourists. However, when people stayed longer, the tolerance level to street traffic sound might increase. Visit frequency showed negative relationship with surrounding speech, which indicates that people who visited the green spaces more frequently might expect soundscapes with less surrounding speech. Again, occupation showed no significant relationship with preference for any sound.

In summary, social/demographical/behavioral factors were more associated with the perceived occurrences of individual sounds, in other words, sound sensitivity. Among all these factors, behavioral factors including visit frequency and length of stay were the most associated ones, both with seven perception parameters of certain sounds, followed by age and residential status both with five perception parameters of certain sounds. Although occupation only showed significant relationship with the perceived occurrences of street traffic sound, it might affect the perception of overall soundscape. Besides, among all the sound sources, street traffic sound and bird song were more associated with these factors, each with six, followed by dog barking with five.

3.2.2. Effects of social/demographical/behavioral factors on overall soundscape perception

In terms of the effects of social/demographical/behavioral factors on the overall soundscape preference, occupation, residential status and length of stay showed significant relationships but with low correlation coefficients of 0.115, −0.223 and 0.240, respectively. It indicates in a limited degree that people who are without work and who stay longerat the green spaces may be more satisfied with the overall soundscape quality, while tourists have a higher standard of the quality of overall soundscape than local residents.

3.3. Effects of visit motivations on soundscape perception

3.3.1. The relationships between social/demographical/behavioral factors and visit motivations

The relationships between each of the social/demographical/behavioral factors and different visit motivations based on Spearman's rho correlation analysis are shown in Table 5. Obviously, age and length of stay both showed significant relationships with all the five visit motivations. It seems that, older people tended to visit the green spaces to relax and pay more attention to the visual landscape and soundscape, while younger people tended to come for physical activities and for social purpose. It is also true that when people intended to relax, they usually stayed longer at the green spaces, and the longer people stayed, the higher requirement of the overall environment quality they had. People who came to the green spaces for physical activities and social purpose usually stayed longer too. Occupation and residential status were all significantly related to four kinds of visit motivation. Occupation showed similar visit motivation patterns as age, which may due to the significant correlation relationship (0.706) between these two factors as shown in Table 3, except that there was no significant difference in physical activities among people with different occupations. In terms of the residential status, as community residents had more chances to access to the green spaces, they cared more about the soundscapes there, and they came specially to relax, for physical activities or social purpose more frequently, while tourists passed-by these places more frequently. However, expectation of the scenery and atmosphere had no significant relationship with residential status. Education and visit frequency both showed significant relationships with two kinds of visit motivation. It indicates that people with higher education background may have a higher expectation of the scenery or atmosphere of the green spaces, and these places are more attractive for people with lower education background for social purpose, which may partly due to the positive relationship between age and education. People who visited the green spaces more frequently tended to conduct physical activities, and they might have a lower expectation of the scenery and atmosphere there.

Table 5. Spearman's rho correlation coefficients between each of the social/demographical/behavioral factors and different visit motivations (2-tailed). Significant correlations are marked with * ($p < 0.05$) and ** ($p < 0.01$). SR: specifically to come and relax, ES: enjoy the scenery or atmosphere, EQ: enjoy a quiet environment, PA: physical activities, SP: social purpose.

	SR	**ES**	**EQ**	**PA**	**SP**
Age	**0.240****	**0.139****	**0.249****	**-0.107***	**-0.230****
Education	0.073	**0.133****	0.088	-0.068	**-0.292****
Occupation	**0.313****	**0.202****	**0.297****	-0.057	**-0.173****
Residential status	**-0.121***	0.063	**-0.099***	**-0.271****	**-0.103***
Visit frequency	0.058	**-0.193****	-0.042	**0.213****	-0.029
Length of stay	**0.288****	**0.353****	**0.397****	**0.154****	**0.186****

3.3.2. Effects of visit motivations on perception of individual sounds

The relationships between each of the perception parameters of individual sounds and different visit motivations based on Spearman's rho correlation analysis are shown in Table 6.

Table 6. Spearman's rho correlation coefficients between each of the perception parameters of individual sounds, overall soundscape preference as well as visual landscape preference and different visit motivations (2-tailed). Significant correlations are marked with * ($p < 0.05$) and ** ($p < 0.01$). SR: specifically to come and relax, ES: enjoy the scenery or atmosphere, EQ: enjoy a quiet environment, PA: physical activities, SP: social purpose, POS: perceived occurrences, PLS: perceived loudness, PRE: preference.

Perception parameter		**SR**	**ES**	**EQ**	**PA**	**SP**
POS	Surrounding speech	0.023	0.02	0.064	-0.04	**0.156****
	Playing children	0.049	0.066	0.072	**0.239****	0.065
	Footsteps	-0.056	0.06	0.054	0.032	0
	Bicycle riding	0.022	**-0.100***	-0.049	0.034	-0.048
	Motorcycle noise	0.014	-0.079	-0.046	**-0.108***	-0.011
	Street traffic	0.008	**-0.139****	**-0.160****	**-0.176****	0.016
	Bird song	**0.170****	**0.236****	**0.152****	**0.144****	-0.029
	Dog barking	-0.002	-0.005	-0.018	**0.134****	-0.005
	Insects	**0.151****	**0.180****	**0.281****	0.045	0.018
	Tree rustling	0.071	**0.122***	0.09	0.057	-0.01
	Wind blowing	0.023	0.013	0.075	**-0.114***	0.064
	Water sound	**0.158****	-0.032	0.012	**-0.103***	-0.026
PLS	Surrounding speech	-0.175	**-0.226***	-0.115	-0.043	0.074
	Playing children	**-0.393****	-0.113	-0.192	-0.01	**-0.322***
	Footsteps	—	—	—	—	—
	Bicycle riding	—	—	—	—	—
	Motorcycle noise	-0.233	-0.073	-0.265	-0.174	-0.089
	Street traffic	**-0.205****	**-0.234****	**-0.260****	**-0.133***	-0.102
	Bird song	0.086	0.025	0.101	0.089	-0.041
	Dog barking	-0.128	0.28	0.289	0.023	**-0.393***
	Insects	-0.01	0.095	0.139	-0.15	-0.085

	Tree rustling	-0.048	**-0.150***	-0.137	-0.068	-0.12
	Wind blowing	-0.003	**-0.400****	**-0.304****	-0.128	-0.012
	Water sound	0.033	-0.033	0.031	0.041	0.133
PRE	Surrounding speech	-0.032	0.178	-0.043	0.147	0.146
	Playing children	0.133	0.169	0.052	**0.344***	0.148
	Footsteps	-0.11	0.126	0.042	-0.129	-0.073
	Bicycle riding	0.264	0.268	0.265	-0.117	0.033
	Motorcycle noise	-0.189	-0.226	-0.145	0.215	-0.101
	Street traffic	**0.118***	0.036	0.107	0.081	0.07
	Bird song	0.097	0.108	0.093	0.033	**-0.200****
	Dog barking	-0.041	0.115	-0.103	0.151	0.1
	Insects	-0.166	0.138	-0.006	-0.143	0.074
	Tree rustling	0.048	0.028	-0.042	0.037	0.076
	Wind blowing	0.147	**0.320****	**0.224***	-0.062	0.102
	Water sound	0.12	0.13	0.084	0.064	0.046
Overall soundscape preference		**0.163****	**0.226****	**0.323****	**0.211****	**0.117***
Visual landscape preference		**0.233****	**0.228****	**0.266****	**0.132****	**0.117***

In terms of the perceived occurrences of individual sounds, it is shown that, when people came specifically to relax, they tended to be more sensitive to certain natural sounds, including bird song, sounds of insects and water sound. People who came to enjoy the scenery or atmosphere had a higher sensitive degree to natural sounds including bird song, sounds of insects and tree rustling, but had a lower sensitive degree to street traffic sound and bicycle riding sound. People who came to enjoy a quiet environment were also sensitive to bird song and sounds of insects and less sensitive to street traffic sound. It seems that people with the aforementioned three visit motivations all showed a higher sensitive degree to bird song and sounds of insects, which indicates that green spaces with more biological sounds were preferred by these people. For people who came for physical activities, they had a higher sensitive degree to bird song, dog barking and playing children, while they tended to neglect the existence of the relatively quiet natural sounds like wind blowing and water sound, and they also had a lower sensitive degree to street traffic sound and motorcycle noise. The results show that three visit motivations, including “Enjoy the scenery or atmosphere”, “Enjoy a quiet environment” and “Physical activities”, were all negatively related to street traffic sound, a typical urban keynote sound, which indicates that the green spaces do function as shields for people to escape from noisy environment. People who came to the green spaces for social purpose showed almost no relationship with the perceived occurrences of individual sounds, except for a higher sensitive degree to surrounding speech. It is reasonable that they might pay more attention to the affairs they were talking about than the surrounding acoustic environment.

In terms of the perceived loudness of individual sounds, all the four visit motivations except for social purpose showed significant negative relationships with street traffic sound, which once again verifies the traffic noise reduction effect of green spaces. Besides, people who came specifically to relax tended to evaluate the sound of playing children not that loud. People who came to enjoy the scenery or atmosphere showed the closest relationships on the perceived loudness of certain sounds. Except for street traffic, it was also negatively related to three kinds of sounds including surrounding speech, tree rustling and wind blowing, which indicates that these people tended to evaluate these sounds quieter. For people who came to enjoy a quiet environment, they also tended to evaluate wind blowing quieter. It is noted that when people came to do physical activities, only the perceived loudness of street traffic sound was significantly affected. For people who came for social purpose, they tended to evaluate the sounds of playing children and dog barking quieter.

As to the preference for individual sounds, it is clear that visit motivations showed quite limited but equal significant effects, each with only one certain sound. The reason could be that people’s preference for certain sounds are formed by a long term life experience and may not change with any motivations to visit the green spaces. Specifically, people who came to relax had a higher tolerance or acceptance level of street traffic sound. People who came to “enjoy the scenery or atmosphere” or to “enjoy a quiet environment” both showed a preference for the sound of wind blowing. People who came for “physical activities” preferred the sounds of playing children, which may because some of them came to play with their children. Social purpose was the only visit motivation showing negative relationship with the preference for individual sounds, and people who came for social purpose might not prefer certain kind of bird song.

3.3.3. Effects of visit motivations on overall soundscape preference

The results in Table 6 show that, all the five visit motivations were positively related to overall soundscape preference, which clearly indicates people’s higher requirement of the soundscape quality when they came to the green spaces for these activities. It can also be deduced that green spaces with better soundscape quality could be more popular for the public. Besides, all the visit motivations showed positive relationships with visual landscape preference. As pointed out by other researchers, tranquillity could be predicted by natural and contextual features (Watts, 2017; Watts et al., 2013). It is also verified by many researchers the existence of audio-visual interaction (Hong and Jeon, 2014; Pheasant et al., 2010). Thus, both soundscape and landscape should draw enough attention during the plan and design process of green spaces.

3.4. Effects of visual landscape on soundscape perception

3.4.1. Effects of visual landscape on perception of individual sounds

The relationships between the perception of individual sounds and the visual landscape preference are shown in Table 7. It shows that the quality of visual landscape was significantly related to the perceived

occurrences of three kinds of natural sound and two kinds of traffic sounds. On one hand, more natural sounds like bird song, tree rustling and water sound and less artificial sounds like motorcycle noise and street traffic could both contribute to a higher visual landscape satisfaction degree. On the other hand, it is possibly that better visual landscape contains elements that can produce these natural sounds or reduce of traffic sounds, such as dense trees and fountains, or minimize the opportunities to perceive the negative sounds by attracting people with beautiful scenery. As to the perceived loudness of individual sound, visual landscape showed similar relationships with motorcycle noise, street traffic, bird song and water sound as the effects on their perceived occurrences. Besides, playing children showed significant and negative relationship with visual landscape preference, indicating that it was a sensitive sound to the evaluation of visual landscape. In terms of the preference for individual sounds, higher level of tolerance to street traffic sound and bicycle riding sound and more preference for tree rustling sound could all contribute to visual landscape satisfaction, and vice versa.

It is obvious that visual landscape preference were more associated with the perceived occurrences and loudness of individual sounds than the preference for individual sounds. Specifically, the perception of traffic sounds and natural sounds like bird song and water sounds could be more affected than other kinds of sound. It is important to note that high quality visual landscape could minimize the sensitivity and perceived loudness of street traffic sound and also improve the tolerance level of them.

3.4.2. Effects of visual landscape on overall soundscape preference

The relationships between the perception of individual sounds and overall soundscape preference are shown in Table 7. It shows that, the perceived occurrences of more than half of the sound sources were highly correlated with overall soundscape preference. Specifically, existence of more natural sounds including bird song, sounds of insects and tree rustling could significantly improve the overall soundscape quality, while too much street traffic sound and motorcycle noise sound could impair soundscape quality. Increasing of the perceived occurrences of human sounds like surrounding speech and playing children were associated with the overall soundscape quality. It seems that, sounds from other people's activities in this case have a positive effect to eventful soundscapes (Axelsson et al., 2010), in the condition of their relatively little existence in the case study area as indicated in Fig. 3. As to the perceived loudness of individual sounds, motorcycle noise, street traffic sound and bird song showed similar relationships with overall soundscape preference as their perceived occurrences. High loudness level of motorcycle noise sound and street traffic sound could bring significant negative effects to the overall soundscape preference, while increasing the loudness of bird song could contribute to soundscape quality. It is obvious that the preference for or tolerance of certain artificial sounds was decisive in overall soundscape preference, and especially tolerance level of street traffic sound showed the closest relationship to soundscape quality.

Table 7. Spearman's rho correlation coefficients of the relationships between the perception parameters of individual sounds and overall soundscape preference as well as visual landscape preference (2-tailed). Significant correlations are marked with * ($p < 0.05$) and ** ($p < 0.01$). POS: perceived occurrences, PLS: perceived loudness, PRE: preference.

Sound source	**Visual landscape preference**			**Overall soundscape preference**		
	POS	**PLS**	**PRE**	**POS**	**PLS**	**PRE**
Surrounding speech	0.02	-0.178	0.068	**0.108***	0.129	-0.174
Playing children	0.024	**-0.433****	-0.088	**0.178****	0.178	**0.390****
Footsteps	-0.019	—	0.079	0.094	—	-0.068
Bicycle riding	-0.036	—	**0.324***	-0.032	—	**0.330***
Motorcycle noise	**-0.100***	**-0.340***	-0.142	**-0.205****	**-0.808****	0.228
Street traffic	**-0.128***	**-0.334****	**0.130***	**-0.467****	**-0.631****	**0.483****
Bird song	**0.211****	**0.185****	0.092	**0.286****	**0.270****	-0.033
Dog barking	0.025	0.029	0.079	0.061	-0.004	0.28
Insects	0.092	0.041	0.172	**0.166****	-0.121	0.05
Tree rustling	**0.206****	0.065	**0.167***	**0.204****	-0.077	0.053
Wind blowing	0.086	0.013	0.056	0	-0.125	0.127
Water sound	**0.178****	**0.231***	-0.108	0.05	0.075	-0.047

From Table 7, it can be seen that the quality of soundscape and visual landscape show similar relationships with the perception parameters of certain sounds, including street traffic, motorcycle noise, bicycle riding, bird song and tree rustling. As also verified by the significant correlation relationship between visual landscape and overall soundscape preference (correlation coefficient = 0.4, $p \ll 0.01$), it is possible that visual landscape may affect the perception of overall soundscape through these sounds. It is also noted that the effects may be more related to the perceived occurrences and loudness of those sounds than the preference for them. However, the result is not in line with that of a former research conducted in city parks in terms of the effective sounds, where visual landscape effects on soundscape experience were also found to be related to the perceived occurrences of and the preference for certain but fewer sounds in that study (Liu et al., 2013a). The reason could be due to the differences in soundscape characteristics in terms of soundscape composition (Section 3.1) and/or different cultural background (Yu and Kang, 2014).

4. Conclusions

Urban green spaces could supply different kinds of ecosystem service, and play a more prominent role than other types of urban open space in providing high quality soundscapes. This study examines the relationships between people's visit motivation, along with other social/demographical/behavioral and visual landscape factors and soundscape experiences in terms of the perceived occurrences and loudness of individual sounds, the preference for individual sounds, as well as overall soundscape preference in urban green spaces. The research was based on a questionnaire survey carried out at four typical green spaces in Rostock, Germany. The results suggested that street traffic sounds were in a dominating position either in perceived occurrences or loudness and the least preferred, while bird song and water sound were the most preferred sounds. The results clearly indicated the key soundscape elements of soundscape design in green spaces.

All the examined factors were found associated with soundscape experiences to some extent. Specifically, social/demographical/behavioral factors were relatively more associated with the perceived occurrences of individual sounds. Among all these factors, visit frequency and length of stay were the most associated ones on the perception of individual sounds, followed by age and residential status, and these factors were more related to street traffic sound and bird song. Length of stay, residential status and occupation showed significant relationships with overall soundscape preference. The results indicated that the characteristics of target groups worth more consideration in soundscape design in green spaces.

Visit motivations showed the most significant relationships with the perceived occurrences of individual sounds and the least but equal relationships on the preference for individual sounds. Specifically, "physical activities" was the most associated one on the perceived occurrences of certain sounds. "Enjoy the scenery or atmosphere" showed the most significant relationships with perception of individual sounds, especially the perceived loudness of certain sounds. "Social purpose" was verified to have the weakest associations with the perception of individual sounds. All the five visit motivations were positively related to overall soundscape preference and to visual landscape preference as well, reflecting people's requirement of high quality soundscape and landscape in urban green spaces, as well as the close relationship between soundscape and landscape.

Visual landscape preference showed more significant relationships with the perceived occurrences and loudness of individual sounds than the preference for individual sounds. Specifically, the perception of traffic sounds and natural sounds such as bird song and water sounds were more associated with visual landscape than other kinds of sound. It is noted that high quality visual landscape could minimize the sensitivity and perceived loudness of street traffic sound and also improve the tolerance level of them. Visual landscape could affect overall soundscape preference indirectly through perception of certain sounds, including street traffic, motorcycle noise, bicycle riding, bird song and tree rustling, and the effects could be more related to the perceived occurrences and loudness of those sounds than the preference for them.

Moreover, the results revealed that, these influential factors were interrelated to some extent. Thus, further study should be conducted to reveal the effects of their relationships on soundscape experience.

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