Differences in soundscape appreciation of walking sounds from different footpath materials in urban parks

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Differences in soundscape appreciation of walking sounds from different footpath materials in urban parks

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Abstract: The perception of the acoustic environment, namely the soundscape, in urban parks has attracted increasing attention. There is a growing belief that the management of the acoustic environment of urban parks should be addressed within a broader soundscape methodology rather than a merely noise control one. One of the most frequent sound sources in urban parks is walking sound; however walking sound perception so far has mainly been investigated for indoor environments. This paper aims to investigate the overall effect of walking sounds from different walked-on materials on people's soundscape, combined with other non-acoustical factors. Moreover, this research investigates how perception varies when the walking sound is self-produced or simply listened. To this purpose, two laboratory experiments in Italy and UK were carried out with four walked-on materials that were considered to be possible design solutions for the footpaths of urban parks: grass, wood, stone and gravel. Results showed a significant effect of materials on perceived noise annoyance and soundscape quality, as well as a partial influence of other non-acoustical factor. Considering the individual responses for the four selected materials, gravel was associated to the worst soundscape quality (M = 38.42) while grass to the best one (M = 65.05). While a group effect (Italian and UK samples) was observed for perceived noise annoyance corresponding to the materials, no significant group effect was found for soundscape evaluation. Eventually, people simply listening to the walking sounds resulted to be less tolerant towards them, with respect to people who self-produced the sounds by walking.

Keywords: soundscape; noise annoyance; urban parks; walking sounds

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1. Introduction

The Directive 2002/49/EC of the European Parliament and of the Council relating to the Assessment and Management of Environmental Noise (European Parliament and Council, 2002), also known as Environmental Noise Directive (END), requires that the Member States of the European Union define and protect ‘quiet areas’. Even though the criteria for identifying such areas are still being discussed, it is generally appreciated that within the city realm such areas tend to coincide with urban parks. Indeed, urban parks represent a vital asset for modern cities and they are therefore receiving increasingly research attention from a wide range of different disciplines like urban planning and design, environmental psychology, sociology, and acoustics (Thompson, 2002; Chiesura, 2004; Yang & Kang, 2005; Brambilla & Maffei, 2006).

There is a growing belief that the management of the acoustic environment of urban parks should be addressed also through a soundscape methodology, rather than an ordinary noise control methodology (Aletta & Kang, 2015). The definition of ‘soundscape’ has recently been standardised as the “acoustic environment as perceived or experienced and/or understood by a person or people, in context” (International Organization for Standardization, 2014). Thus, there is a clear difference between the acoustic environment (i.e. the physical phenomenon) and the soundscape (i.e. the perceptual construct), and over the years more and more models and methods are being developed to evaluate soundscape (e.g. Axelsson, Nilsson, & Berglund, 2010; Axelsson, Lundén, & Nilsson, 2013; Cain, Jennings, & Poxon, 2013). Overall, the noise control and soundscape methodologies have different approaches, but they are complementary: the first considers sound as a ‘waste’ and emphasises ‘discomfort’, whilst the latter considers sound as a ‘resource’ and emphasises ‘preference’ (Brown, 2012). Both approaches are increasingly integrated and applied together in the broader framework of ‘urban sound planning’ by researchers (e.g. Alves, Altreuther, & Scheuren, 2014; Asdrubali, 2014; Alves, et al., 2015) and local authorities (Lavia, et al., 2012; Eastel, et al., 2014).

Within the soundscape approach it is essential to deal with the nature of sounds (e.g. wanted or unwanted sounds) and great attention should be paid to how all present sound sources interact and are perceived by people in a given context. Considering the acoustic environment of urban parks, this study investigated a particular sound source, namely the walking sound. The access to urban parks is a core value in modern communities (Kornblum, 1978) and the presence of people making a walk looking for calmness, or as a part of their route across the urban realm implies that walking sounds can be a frequent sound source in such contexts, and consequently they can affect their soundscape. Many other sound sources are likely to be experienced in urban parks, corresponding to different activities other than walking (e.g. sport activities, barbecuing), however a larger variety in functions is usually associated to a larger size of the urban park, while walking can be essentially expected for any urban park, regardless of its size (Burgess, et al., 1988).

1.1 The soundscape of urban parks

Urban parks’ soundscapes have been investigated in many studies so far. Brambilla and Maffei (2006) showed that ‘expectation’ is affecting the noise annoyance perceived in urban parks. More specifically, the more congruent the acoustic environment of the urban parks, the smaller the perceived noise annoyance. In their study, non-natural sounds were found to be inappropriate to the urban parks’ context. In other studies by Brambilla and his colleagues

(Brambilla, Gallo, & Zambon, 2013; Brambilla, Gallo, Asdrubali, & D'Alessandro, 2013) they showed that some acoustic parameters like the centre of gravity of the unweighted spectrum lg(G) and the 5th percentile N_5 of the loudness could be good predictors of the perceived quality of the acoustics environments of urban parks. However, other researchers reported that many other non-acoustical factors are likely to affect the soundscape of urban parks, like environmental and urban zoning, and distance from main routes (e.g. Szeremeta & Zannin, 2009), surrounding context (e.g. Jabben, Weber, & Verheijen, 2015), or specific audio-visual sources (e.g. fountains) in the park (e.g. Axelsson, et al., 2014).
Researchers explored the potential 'restorativeness' and 'tranquillity' that the acoustic environments of such places are likely to provide and inspire, considering the positive consequences that they can have for the quality of life improvement (Payne, 2013; Jabben, Weber, & Verheijen, 2015). In terms of psychological restoration from environmental noise, the availability of such green spaces might affect the overall human experience and community life. From the soundscape point of view, it is therefore important to understand what sound sources could help to create a positive acoustic environment and what sources are, conversely, likely to spoil it.

1.2 Walking sounds in the context of urban parks

Walking sounds, i.e. the sounds produced by the footsteps of people walking, have previously been found to be a non-verbal sound with one of the highest ecological frequency (Ballas, 1993). Nonetheless, they received relatively small attention in acoustics and they were mainly investigated for indoor environments (e.g. Johansson, Hammer, & Nilsson, 2004). On the other hand, in outdoor environments, it seems reasonable to assume that walking sounds will achieve frequencies as high as per indoor environments; therefore, further investigation on this specific sound source can be valuable. Within the context of urban parks, if the characteristics of the walkers have to be discarded, the most relevant factor affecting the walking sounds will most likely be the material of the footpaths. The urban parks footpaths' materials might vary largely across countries and cities. The choice of such materials is often a consequence of landscape integration criteria, as well as cost and availability issues. However, it is worth pointing out that different materials will produce different walking sounds, which are in turn likely to result in different soundscapes.

1.3 Objectives of this research

Considering that the acoustic environment is the result of all sound sources at the receiver in a given context, it is worthwhile questioning to what extent an extremely frequent sound source like walking sound could affect the perception of the acoustic environment, namely the soundscape, in urban parks. The main objectives of this study are:

- Examining whether there is an overall effect of walking sounds from different walked-on materials on people's soundscape.
- Examining whether the above mentioned effect is influenced by a set of non-acoustical factors; namely:
  - people (i.e. different groups of users)
  - context (i.e. different background noises)
  - activity (i.e. different listening styles)
- Examining whether the above mentioned effect is changing if people are simply listening to the walking sound or producing it themselves.

To this purpose, two laboratory experiments involving eighty-eight participants in total were carried out with four plausible walked-on materials that were considered to be potential design solutions for the footpaths of urban parks: grass, wood, stone and gravel.

2. Methods

This study, following a previous study (Fuda, Aletta, Kang, & Astolfi, 2015), was designed to test the effect of different footpath materials on individual soundscape assessment of a simulated urban park acoustic environment and to explore potential differences between groups of sitting and walking listeners. Four types of material were considered, with different levels of hardness: grass, wood, stone and gravel. There were two experiments, Experiment 1 and Experiment 2, where the materials were common for both experiments. Therefore they will be reported only once, before describing separately the methods for Experiment 1 and Experiment 2 in detail, in Sections 2.2 and 2.3, respectively. Table 1 summarises the overall participants' samples composition, while more details are provided for both experiments in Sections 2.2.1 and 2.3.1 accordingly.

Table 1 Participants samples' composition for Experiments 1 and 2

Experiment	Group	M_{age}	SD_{age}	M	F	*Total*
1	University of Sheffield	27.0	4.49	11	14	*25*
	Politecnico di Torino	28.3	8.36	17	21	*38*
2	University of Sheffield	26.9	5.00	10	15	*25*

2.1 Experimental materials and settings

A wooden stage (2400 × 600 × 120 mm) was constructed and located in the middle of the semi-anechoic chamber of the University of Sheffield. Four materials were selected to cover the platform in turn, as shown in Figure 1, namely:

a) Grass: lawn turf on a 20-mm layer of topsoil (2400 × 600 mm, grass height 20-25 mm)
b) Wood: five elements of white wood (planed tongue and groove flooring 18 × 121 × 2400 mm)
c) Stone: three slabs of peak smooth grey stone (600 × 600 × 35 mm)
d) Gravel: 30-mm thick layer of stones (granulometric mix 3-12 mm)

Grass was selected as reference material, since it was assumed to be the most ecologically consistent for an urban park. The other materials were selected because they are likely to be possible design options for footpaths in urban parks and it was decided to use both solid (i.e. stone and wood) and aggregate (i.e. gravel) materials (Aletta, Kang, Fuda, & Astolfi, 2015).

Figure 1 - The wooden platform used for the experiment on the left, covered in turn with the four selected materials: a) Grass, b) Wood, c) Stone, and d) Gravel

In the semi-anechoic chamber of the University of Sheffield, the sounds of the footsteps on the four materials were recorded by an experimenter wearing a head-mounted binaural kit (in-ear 1/8” microphones, DPA) connected to a portable recorder (Edirol R-44). For each of the four materials, the experimenter walked back and forth for 15 seconds, at a speed of 2 steps per second (Johansson, et al., 2004). Even though walking speeds can vary greatly depending on several factors, the average human preferred walking speed is about 1.4 mps (i.e. approx. 2 steps per second for an adult) (Browning, et al., 2006), so this speed was overall considered to be representative for parks’ users. The experimenter (Male, 27 years old, weight 75 kg, height 175 cm) wore shoes with soft sole (this choice will be further explained in Section 2.3.2).

Furthermore, a generally quiet background sound ($L_{Aeq\text{-}15\ secs}$ = 55 dB) was recorded in Weston Park (Sheffield, UK) by means of a dummy head (Neumann KU100) connected to a portable recorder (Edirol R-44), in order to achieve a plausible acoustic environment for a urban park. Weston Park is located in the campus of the University of Sheffield. It is not directly exposed to road traffic noise and is often preferred by students and families for leisure activities. This background noise was selected to represent a realistic urban park condition, where the acoustic environment was a well-adjusted composition of natural, anthropic and non-intrusive mechanical sounds. A second background sound was recorded in the same way in a different urban park, Valley Gardens (Brighton & Hove, UK). Valley Gardens Park is in the city centre, connecting the seaside to the inner part of Brighton and it is surrounded by major roads. The rationale for selecting a second background was providing a different acoustic context, slightly more affected by road traffic noise. For the sake of convenience, the 15-second excerpt recorded in Valley Gardens was edited to achieve the same equivalent level (i.e. $L_{Aeq\text{-}15\ secs}$ = 55 dB) of the background recorded in Weston Park. The equivalent sound level is the sound-pressure level (expressed in dB), equivalent to the total sound energy over the given period of time, so the two audio excerpts were similar in terms of energy content. Figure 2 shows some differences between the two parks.

Afterwards, the recordings with the four materials were calibrated and mixed in turn with the background noise recorded in Weston Park and the background noise recorded in Valley Gardens, in order to obtain eight auditory stimuli (combination of walking sounds and background) to be used in Experiment 1. It is worth pointing out that the auditory stimuli used in this study do not represent a perfectly consistent auralisation of the investigated urban parks’ acoustic environments, since a number of factors were disregarded (e.g. directivity of the source, different absorption contributions of the materials to the background noise, etc.); however, considering the holistic perception focus of the experiments, it was assumed that they could provide the necessary ‘plausibility’ (Lindau & Weinzierl, 2012).

For descriptive purposes, a set of acoustic and psychoacoustic metrics (i.e. sound-pressure level, loudness, sharpness, roughness, and fluctuation strength) were calculated by means of the ArtemiS software (HEAD acoustics®) separately for the recordings of the four walking sounds and the Weston Park and Valley Gardens background noises. The mean values for all the computed parameters are reported in Table 2 (Fuda, Aletta, Kang, & Astolfi, 2015). Sound-pressure level is the ratio between the actual sound pressure and a fixed reference pressure (the threshold of hearing in general). Loudness is a perceptual measure of the sound energy content’s effect on the human ear. Sharpness measures the high frequency content of a sound. Roughness is a complex effect which relates to subjective perception of rapid amplitude modulation of a sound, while Fluctuation strength is used for slower amplitude modulation (Fastl & Zwicker, 1990).

Figure 2 - Pictures taken in Weston Park (left) and Valley Gardens Park (right)

Table 2 - Sound-pressure level (SPL), loudness (L), roughness (R), sharpness (S), and fluctuation strength (Fls) mean values of the four walking sounds and the background noise

Parameter	*Material*				*Background*	
	Grass	Wood	Stone	Gravel	Weston Park	Valley Gardens
SPL - dB(A)	28.5	48.6	40.1	66.1	55.0	55.0
L - soneGF	0.81	3.04	2.23	15.05	9.06	10.6
S - acum	2.680	1.720	1.880	2.695	1.930	1.890
R - asper	0.047	1.180	0.628	3.580	1.315	1.620
Fls - vacil	0.014	0.177	0.051	0.354	0.013	0.012

2.2 Experiment 1: sitting participants

The experiment took place in two different venues: the semi-anechoic chamber of the University of Sheffield and the semi-anechoic chamber of the Politecnico di Torino. The background noise in both chambers caused by electric devices was less than 25 dB.

2.2.1 Participants

Two separate groups of participants were selected at the University of Sheffield (UK) and at the Politecnico di Torino (Italy) to take part in the experiment. Sheffield's group consisted of twenty-five undergraduates and postgraduates, 21 to 41 years old (14 women and 11 men, M_{age} = 27.0 years, SD = 4.49). Torino's group consisted of thirty-eight undergraduates and postgraduates, 22 to 45 years old (21 women and 17 men, M_{age} = 28.3 years, SD = 8.36). The rationale for having two groups of participants in different countries was achieving a diverse sample in terms of socio-cultural backgrounds, since previous studies showed that differences between different cultural groups in terms of sound preference and perception might occur (e.g. Yu & Kang, 2014).

2.2.1 Procedure

The design consisted of twelve experimental conditions. Three multi-levelled factors were manipulated in the experimental design presented to participants:

- Footpath Material (FM): 4 levels (Grass, Wood, Stone, Gravel)
- Background Noise (BN): 2 levels (Weston Park, Valley Gardens)
- Cognitive Task (CT): 2 levels (Task, No Task)

The experimental design only included a sub-set of all possible combinations of the factors' levels, as reported in Table 3. The rationale was to consider a 'reference' condition (i.e. Walking sounds/Weston Park/No Task) and to manipulate the two remaining factors in turn.

Table 3 - The twelve conditions of the experimental design; black dots represent which levels were presented for the corresponding condition

Factors	Levels	Experimental conditions											
		1	2	3	4	5	6	7	8	9	10	11	12
FM	Grass	•				•				•			
	Wood		•				•				•		
	Stone			•				•				•	
	Gravel				•				•				•
BN	Weston Park	•	•	•	•					•	•	•	•
	Valley Gardens					•	•	•	•				
CT	No Task	•	•	•	•	•	•	•	•				
	Task									•	•	•	•

Both in Sheffield and Torino participants took part individually in the semi-anechoic chamber, through an automated procedure conducted via a laptop and calibrated headphones (Sennheiser HD 600). The experimental conditions were presented to participants in a randomized sequence to control for potential order effects. The cognitive task consisted of two-digit sums randomly associated to the experimental conditions.

Participants were invited to sit on chair and relax, imagining they were sitting on a bench or similar in an urban park. They were afterwards given the headphones and the session begun. The twelve auditory stimuli were submitted to participants in a randomized sequence to control for possible order effects. For each scenario, participants had to answer two questions by dragging a cursor on a 100-point scale:

- "On a scale from 0 (not at all) to 100 (extremely), how much are you annoyed by the sonic environment?" (AN)
- "On a scale from 0 (very bad) to 100 (very good), how would you assess the sonic environment?" (SQ)

When the scenarios of the 'Task' level were presented, a two-digit sum was shown on the screen of the laptop while reproducing the audio files. Participants were required to type the solution in and after to answer the same questions. Success response rate was not analysed as the goal of the task was simply to distract participants, providing a more holistic, rather than attentive, listening style.

2.3 Experiment 2: walking participants

The rationale for performing Experiment 2 was testing whether some differences exist in the soundscape appreciation of different walked-on materials when people are simply listening to the walking sounds or they produce them directly (i.e. they are the walkers). For this purpose a subset of data from a previous study was used (Aletta, Kang, Fuda, & Astolfi, 2015) in order to implement such comparison.
The experiment took place in the semi-anechoic chamber of the University of Sheffield. The room set-up included a white screen (2.30 × 2.00 m), a projector, a couple of loudspeakers (Genelec 8040B) and a sub-woofer (Genelec 7070B). A picture of the park was projected on the screen. The background noise in the semi-anechoic chamber caused by the projector and the corresponding laptop was less than 25 dB.

2.3.1 Participants

Twenty-five undergraduates and postgraduates at the University of Sheffield, 22 to 40 years old, participated in the experiment (15 women and 10 men, M_{age} = 26.9 years, SD = 5.0). The ethnic distribution of the sample was 64% White or Caucasian, 20% Asian or Pacific Islander and 16% Hispanic or Latino. To avoid potential Type I and Type II errors, the sample size was designed through an *a priori* computation (Faul, Erdfelder, Lang, & Buchner, 2007) to achieve a minimum power (1-β probability of error) of 80%, a probability of error (α) of 5% and a medium effect size (f) of 0.25 (Cohen, 1988). The 25 participants who completed the experiment were rewarded for volunteering with a 10 GBP gift card.

2.3.1 Procedure

Participants were invited to the Acoustics Laboratory of the University of Sheffield and were required to wear shoes with soft sole (i.e. ‘sneakers’): this request aimed to control for the shoes variable and to limit its effect. Participants were individually asked to enter in the semi-anechoic chamber. The background sound recording of Weston Park and the picture of the park were reproduced constantly. Participants were required to walk in a natural way on the platform, watching the screen and listening to the whole sonic environment. Due to the relatively small length of the platform (2400 mm), participants were able to make 5-6 steps: in case they wished to walk again, they were instructed to get off of the platform, go back and start from the beginning.
For each material, participants were asked to answer the following question by putting a mark on a 100-mm continuous scale: “On a scale from 0 (very bad) to 100 (very good) how would you assess the sonic environment?”. This question was asked in the same way as per Experiment 1 and will be further referred to Soundscape Quality (SQ), for the sake of comparison.
For practical reasons (i.e. time needed for replacing the materials), it was not possible to randomise the sequence for each participant. Therefore, three different experimental sessions were organised (two groups of eight and one of nine) and for each session a different sequence of the four materials was sorted in order to limit as much as possible any potential order effect.

3. Results

The results section is made of three subsections. The first subsection analyses the results of Experiments 1, basically addressing the first two objective of this research stated in Section 1.3, whilst the second subsection addresses the third main objective by comparing the results of Experiment 1 and Experiment 2. Eventually, the last subsection proposes some preliminary associations between mean subjective data and objective data associated to the walked-on materials recorded during the experimental set-up.

3.1 Experiment 1

The individual responses to the questions presented during the experiment were associated to two independent variables: '*Noise Annoyance*' (AN) and '*Soundscape Quality*' (SQ), accordingly. A one-way repeated measures ANOVA was conducted on both variables, by aggregating the No Task-Task levels, to test the null hypothesis that there is no change in participants' responses with respect to the walked-on materials (i.e. no Footpath Material effect). The ANOVA results showed a significant Footpath Material effect: Wilks' Lambda = .350, $F(3,186) = 115.240$, $p < .001$, $\eta^2 = 1.000$ for Noise Annoyance; similarly for Soundscape Quality: Wilks' Lambda = .438, $F(3,186) = 79.641$, $p < .001$, $\eta^2 = 1.000$. Therefore, there was significant statistical evidence to reject the null hypothesis for both the Noise Annoyance and Soundscape Quality variables. Regarding Noise Annoyance, gravel (M = 58.91, SD = 24.55) differed significantly ($p < .001$) from grass (M = 26.34, SD = 21.47), wood (M = 32.68, SD = 20.95) and stone (M = 24.45, SD = 19.19). Likewise, regarding Soundscape Quality, gravel (M = 32.00, SD = 21.99) resulted to be significantly different from all other materials ($p < .001$): grass (M = 58.95, SD = 20.84), wood (M = 52.98, SD = 21.38) and stone (M = 58.72, SD = 20.33). Figures 3 and 4 show the individual responses for the Noise annoyance and Soundscape Quality variables accordingly, for each materials, separately for the Background Noise factor's level and according to two groups samples (i.e. Sheffield in the UK and Torino in Italy).

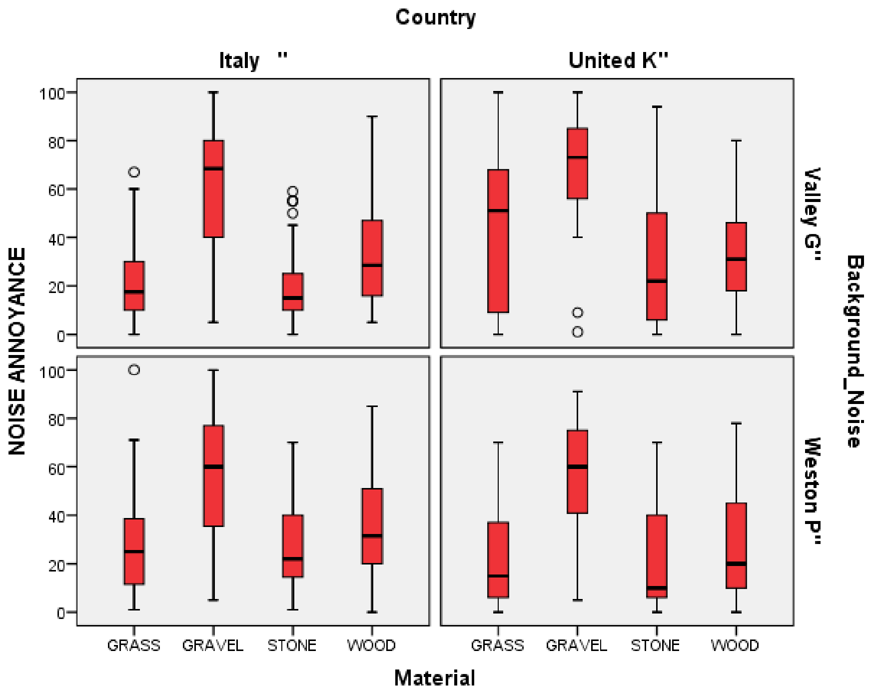

Figure 3 - Box-and-whisker plots showing individual responses for the four materials for Noise Annoyance

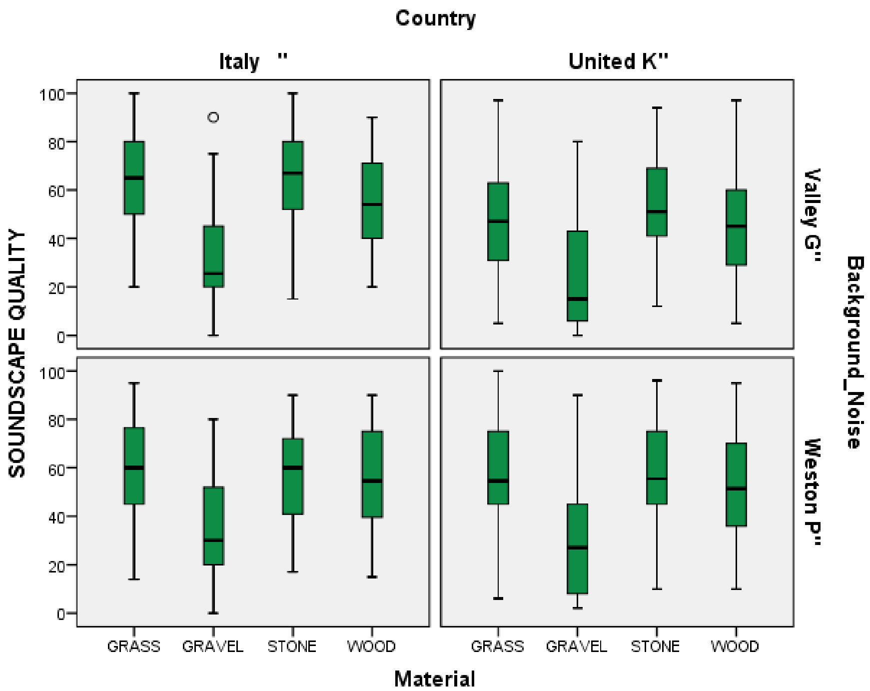

Figure 4 - Box-and-whisker plots showing individual responses for the four materials for Soundscape Quality

In order to investigate the effect of the Background Noise (related to the context) and the Cognitive Task (related to the activity) factors on the Noise Annoyance and Soundscape Quality variables, some paired samples t-tests were performed separately for the four footpath materials. Table 4 shows that there was a significant effect of Background Noise on the Noise Annoyance for the grass conditions and a significant effect on Soundscape Quality for the wood condition. On the other hand, a significant effect of the Cognitive Task was observed on both Noise Annoyance and Soundscape Quality for the wood, stone and gravel conditions.

Furthermore, an independent-samples t-test was conducted to compare Noise Annoyance and Soundscape Quality scores between the sample groups (i.e. Torino and Sheffield), but no significant differences were observed in the Noise Annoyance scores for Torino (M=35.82, SD=24.28) and Sheffield (M=35.26, SD=27.58); t (754) = 0.296, p = 0.768. Contrariwise, a significant difference in the Soundscape Quality scores was observed between the Torino (M=52.42, SD=22.88) and Sheffield (M=48.00, SD=24.99) groups; t (754) = 2.503, p = 0.013. Results suggest that for this application, cultural and personal characteristics are potentially influential factors on the soundscape appreciation (e.g. Soundscape Quality) of walking sounds in urban parks, while such factors tend to be less relevant when applied to discomfort and burden criteria (e.g. Noise Annoyance) (Liu, Kang, Luo, & Behm, 2013).

Table 4 - t-tests for paired samples for the Noise Annoyance (AN) and Soundscape Quality (SQ) variables (Sheffield and Torino samples aggregated)

Variable	Tested factor	Material	*t*	df	Sig.
AN	BN *(Weston Park/ValleyGardens)*	Grass	-2.206	62	**.031**
		Wood	-1.221	62	.227
		Stone	-.642	62	.523
		Gravel	-.888	62	.378
	CT *(No Task / Task)*	Grass	-1.677	62	.099
		Wood	-2.127	62	**.037**
		Stone	-2.639	62	**.011**
		Gravel	3.261	62	**.002**
SQ	BN *(Weston Park / Valley Gardens)*	Grass	1.467	62	.147
		Wood	2.378	62	**.021**
		Stone	-.310	62	.758
		Gravel	1.392	62	.169
	CT *(No Task / Task)*	Grass	1.427	62	.159
		Wood	3.289	62	**.002**
		Stone	2.512	62	**.015**
		Gravel	-2.610	62	**.011**

3.2 Comparison between Experiment 1 and Experiment 2

The analysis of the results presented in this section consists of two parts. In the first part, an analysis of variance (ANOVA) between groups was performed for the individual responses to the Soundscape Quality (SQ) question, in order to detect statistically significant effects of the walked-on materials. In the second part, a set of independent sample t-tests were performed for the Soundscape Quality variable for each footpath material between the sample of Experiment 1 (sitting participants) and Experiment 2 (walking participants).

3.2.1 Analysis of variance for the materials' effect

The question presented to participants in both Experiment 1 and Experiment 2 (i.e. *"On a scale from 0 to 100 how would you assess the sonic environment?")* was associated to an independent variable, 'Soundscape Quality' (SQ), and an ANOVA was performed on the 88*4 individual responses (combining the two samples together), considering the four materials as different 'treatments' for the participants. A between-subjects repeated measures ANOVA was conducted on the Soundscape Quality variable to evaluate the null hypothesis that there is no change in participants' scores depending on the presented walked-on materials. The results of the ANOVA showed a significant material effect: Wilks' Lambda = .495, $F(3,84) = 28.550$, $p < .001$, $\eta^2 = 1.000$ for the Soundscape Quality variable. Therefore, there is significant statistical evidence to reject the null hypothesis for this variable. Nevertheless, follow up comparisons showed that only gravel resulted to be significantly different from all other materials with $p< .001$. *Post hoc* analysis showed that gravel was the worst material in terms of Soundscape Quality (M = 38.42, SD = 22.82); the following materials were wood (M = 61.46, SD = 19.61), stone (M = 64.38, SD = 19.01) and grass (M = 65.05, SD = 21.35). Figure 5 shows the individual scores of the four materials for the Soundscape Quality, depending on the sitting (Experiment 1) or walking (Experiment 2) participants.

Furthermore, a between-subjects effect was found to be statistically significant: $F(1,86) = 23.913$, $p < .001$, $\eta^2 = .998$, showing that differences between the two sample groups exist in terms of Soundscape Quality assessment. Figure 6 reports the estimated marginal means of the Soundscape Quality scores for the four materials, separately for the sitting and walking samples, clearly showing such a pattern.

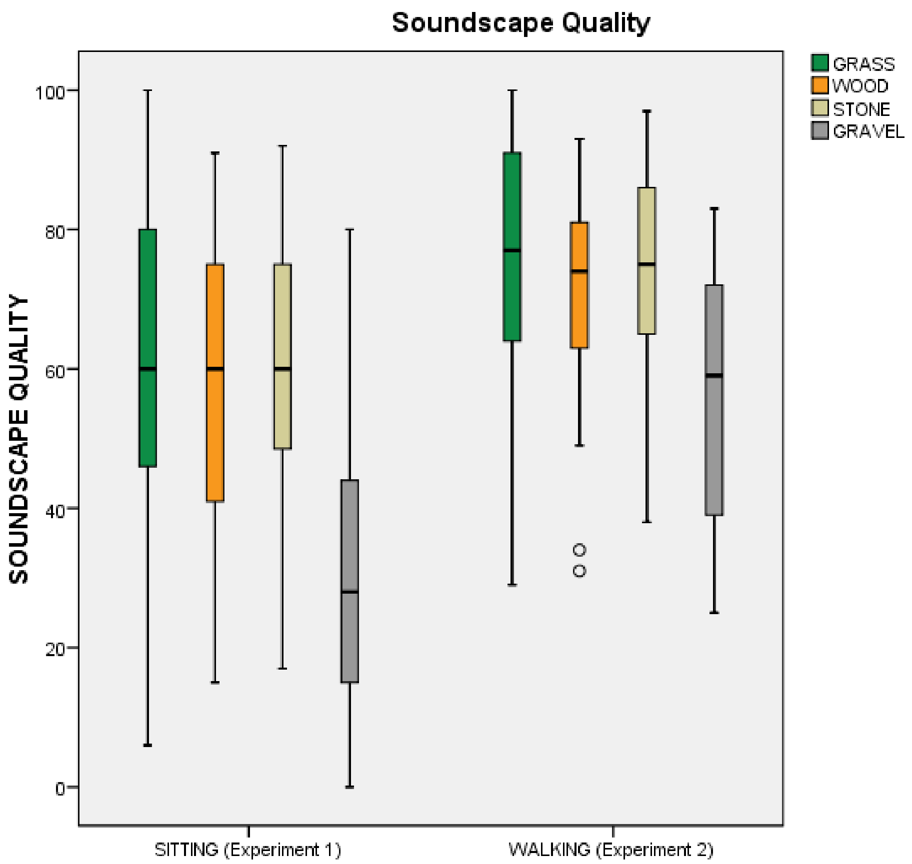

Figure 5 - Individual scores of the four materials for the Soundscape Quality (SQ) variable, depending on the sitting or walking participants

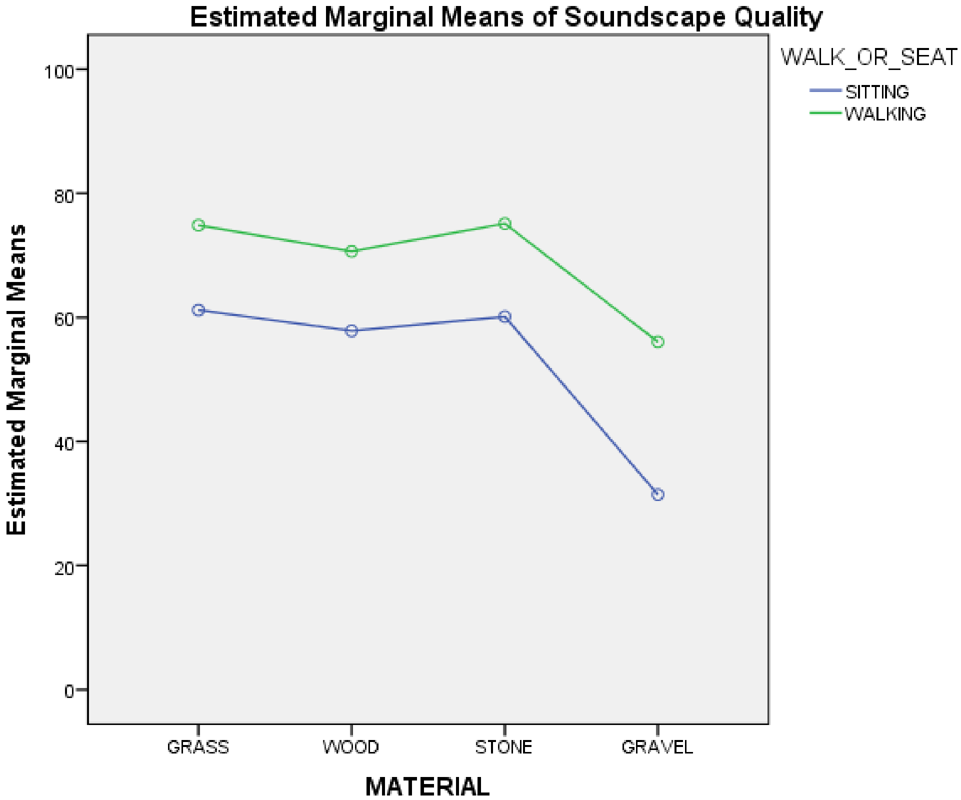

Figure 6 - Estimated marginal means of the SQ scores for the four materials for the sitting (Experiment 1) and walking (Experiment 2) samples

3.2.2 Analysis of differences between sitting and walking participants

In order to further investigate possible differences between the sitting and walking conditions in terms of soundscape assessments of the four walked-on materials, a set of independent-samples t-tests were conducted. The Soundscape Quality scores across the two experiments were compared pair-wise for each material. Table 4 reports the descriptive statistics of the Soundscape Quality scores for each material, according to the sitting-walking condition.

There was a significant difference in the scores for sitting and walking for all materials: grass, $t(86) = 2.814$, $p = 0.006$; wood, $t(86) = 2.878$, $p = 0.005$; stone, $t(86) = 3.552$, $p = 0.001$; and gravel, $t(86) = 5.199$, $p < 0.0016$. These results suggest that the sitting-walking condition does have an effect on perceived soundscape quality, regardless of the walked-on material. Specifically, the results suggest that when people are walking, thus producing the walking sound themselves, their perceived soundscape quality is higher than when they are sitting, acting as simple listeners. Figure 7 compares the mean Soundscape Quality scores between the sitting and walking conditions, separately for each material (Table 5).

Table 5 - Descriptive statistics of the individual Soundscape Quality scores

		N	Mean	Std. Deviation	Std. Error Mean
Grass	Walking	25	74.84	20.70	4.14
	Sitting	63	61.17	20.49	2.58
Wood	Walking	25	70.64	17.06	3.41
	Sitting	63	57.82	19.48	2.45
Stone	Walking	25	75.12	15.14	3.03
	Sitting	63	60.13	18.81	2.37
Gravel	Walking	25	56.04	19.10	3.82
	Sitting	63	31.43	20.37	2.57

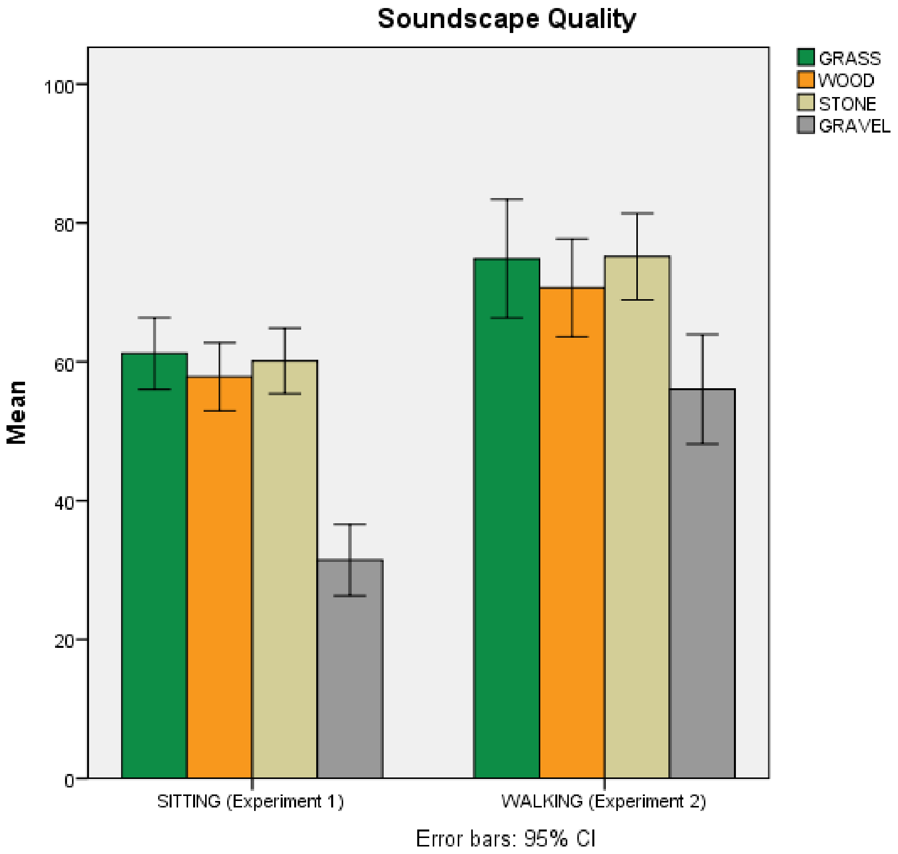

Figure 7 – Soundscape Quality assessment means of the four materials for the sitting (Experiment 1) and walking (Experiment 2) participants

3.3 Correlations between acoustic metrics and Soundscape Quality

A set of bivariate correlation tests (Pearson product-moment) were carried out to point out possible associations between the mean values of the individual scores for the Soundscape Quality variable (aggregated over the two experiments) and the acoustic parameters calculated for the different walked-on materials, associated to the walking sounds recorded by the experimenter before the participants' sessions. The correlation between Soundscape Quality and Loudness resulted to be statistically significant, $r = –.998$, $p = .002$, as well as the correlation between Soundscape Quality and Roughness, $r = –.982$, $p = .018$. Figure 8

shows the Soundscape Quality scores plotted vs Loudness and Roughness. No other statistically significant correlations were found between Soundscape Quality and the other acoustic parameters. Therefore, in this case, the louder and the rougher the walking sounds, the worse the appreciation of Soundscape Quality.
Due to the limited dataset and the small errors generated by the aggregation of the individual responses, it is not likely that such correlations can be generalised. However this suggests that walking sounds could be approached in the future within a broader framework for the design of walked-on materials.

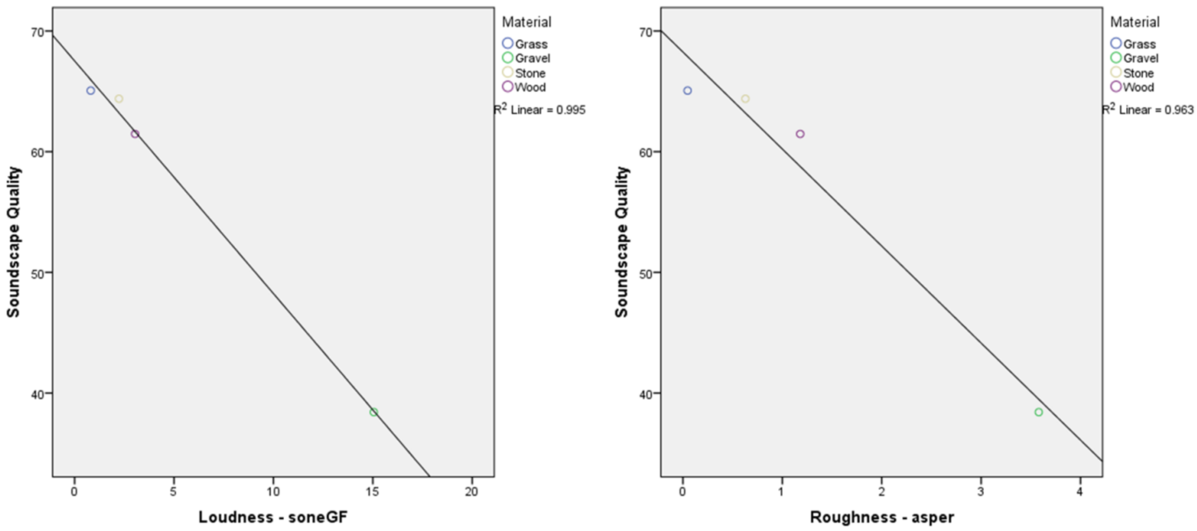

Figure 8 - Scatterplots of the correlations of Soundscape Quality with Loudness (left) and Roughness (right)

4. Conclusions and discussions

In this study, two laboratory experiments were carried out in order to investigate potential differences in soundscape appreciation of walking sounds generated from different footpath materials in urban parks contexts. There is an ongoing debate about the ‘ecological validity’ of soundscape data collected under laboratory conditions (e.g. Guastavino et al., 2005). On the other hand, a number of comparative studies between real and reproduced scenarios have already shown the effectiveness of laboratory experiments in providing valuable results for the perception of acoustic environments (e.g. Maffei et al., 2015).Within the framework of this research, four materials including grass, wood, stone and gravel were selected for the experiments, as they were considered to be plausible design solutions for footpaths in urban park.
The main conclusions of this study are:

(1) Different walked-on materials are likely to have an effect on people’s soundscape appreciation: indeed, a statistically significant materials’ effect was observed on both the Noise Annoyance (AN) and Soundscape Quality (SQ) variables. In the investigated cases, gravel received the worst assessment: the mean differences between gravel and the other materials were: 31.1% for AN and 24.9% for SQ
(2) No statistical differences were found between the Italian and the UK sample groups for SQ, while a small statistical mean difference (4%) was observed for AN.

(3) The factors Background Noise (BN) and Cognitive Task (CT) are not affecting the AN and SQ responses related to the different walking sounds in a systematic way and statistically significant differences only occur for some materials.
(4) Statistically significant differences were observed in SQ scores for all materials between the two experiments of sitting and walking participants, the bigger difference being for gravel (24.2%) and then for stone (15.0%), grass (13.7%) and wood (12.8%). Overall, the walking participants gave higher SQ scores, while sitting participants were less tolerant.

In the investigated cases, grass resulted to be the most appreciated materials, while gravel was the least appreciated. Nonetheless, this study suggests that other factors interacting with the walking sounds (e.g. background noise, listeners' activities) should also be considered. Further research could also consider a broader range of walking styles (e.g. jogging, running).

In order to test the ecological validity of the results, it would be valuable to compare them with data collected on site with real scenarios. However, this study overall suggests that there is room for implementing new design strategies to urban parks, in particular for the footpath materials and their corresponding walking sounds. In general, this claims for further investigation on the soundscape of urban parks and the management of quiet areas in the urban realm.

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