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THE EFFECT OF WALKING SOUNDS FROM DIFFERENT WALKED-ON MATERIALS ON THE SOUNDSCAPE OF URBAN PARKS

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Abstract. Urban parks are essential environmental resources in contemporary cities, for the substantial social and psychological relief they provide for local communities. In recent years, the potential of the soundscape approach for enhancing the ecological contribution of such environmental assets has been intensely investigated. Although, researchers tended to focus on the perception of people "staying" in the park, whilst it is important to consider how the sonic environment would be dynamically perceived by users walking across the park. Within this framework, the present study aimed to investigate the effect of different footpath materials on soundscape quality and walking quality perception for people walking in an urban park, considering that the experience of such users is affected by both the background acoustic environment of the park and their walking sound. To this purpose, a laboratory experiment was carried out with 25 participants. Four different walked-on materials that are likely to be used in urban parks were tested: grass, wood, stone and gravel. Results show that the material factor has a significant effect on both auditory and haptic perception. Furthermore, positive correlations can be observed between auditory and haptic variables, confirming that the soundscape appreciation for people walking in urban parks is likely to be affected also by other but aural sensory modalities. The paper ultimately points out that it is possible to re-think the approach to urban parks design and more specifically to the footpaths and the walking sounds that their materials are likely to produce.

Keywords: soundscape, urban parks, walking sound, landscape management, walking quality.

Introduction

In the context of an increasingly built-up world, urban parks represent a vital resource for modern cities and their models of sustainability. The existence of small-scale natural areas has been proved to be valuable for the quality of life: urban parks are essential environmental assets, as the accessibility to such green spaces from places where people usually live and work is likely to provide significant social and psychological benefits to communities, improving the human experience (Chiesura 2004). There is a growing belief that the urban parks' design and management should rely on a holistic approach, in order to optimise the "ecological contribution" that green spaces provide in cities (Thompson 2002). Within this process, urban planners should acknowledge the role of sounds in influencing people's choice of using the urban space (Yang, Kang 2005) and how the positive perception of the sonic environment is likely to promote healthy societies (Andringa *et al.* 2013). The holistic nature of perception, indeed, is a key aspect of soundscape, defined as the "acoustic environment as perceived or experienced and/or understood by a person or people, in context" (ISO 2014).

The soundscape of urban parks has been thoroughly investigated (e.g., Brambilla, Maffei 2006; Szeremeta, Zannin 2009; Pheasant *et al.* 2009; Brambilla *et al.* 2013a, 2013b; Liu *et al.* 2013, 2014; Axelsson *et al.* 2014). One of the main aspects that research has considered is the potential "restorativeness" of such environments and their capability to provide "tranquil" spaces and "being-away" feelings. Payne (2013) proposed a tool to assess the "perceived restorativeness" of soundscapes of urban parks, emphasising the positive consequences that they could have in terms of psychological restoration. Watts *et al.* (2013) pointed out the importance of creating "tranquil" soundscapes in urban areas. In their study, the authors claim the need for re-thinking urban parks as places where

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both natural sound sources are dominant and man-made sounds (e.g. traffic noise) are limited.

Nevertheless, the assumption underlying the studies carried out so far for the soundscape of urban parks is that of a static viewpoint, mainly referring to a target of users who are staying in the park to spend some free time. On the other hand, such contexts can also be perceived dynamically, by people who simply go across a park, as part of their trip from a place to another within the urban realm. The soundscape experience of such users will be affected by all the sound sources composing the acoustic environment of the park (either background or foreground sources) and by the sounds they actively produce by walking (i.e. the footsteps). Indeed, the urban parks paths' materials often differ from those used for normal urban pavements; while acknowledging that the choice of such materials is mainly the outcome of a landscape-related (and often cost-related) process, it is worth observing that it also implies some sound-related consequences and it might consequently affect soundscape. Walking sound –sometimes referred as drum sound– is not a new topic in acoustics. Nonetheless, it has been considered in few researches, despite of being a non-verbal sound with one of the highest ambient frequency (Ballas 1993). It started attracting interest, particularly in building acoustics, due to the experimentation of some new technologies for indoor application, like floating floors or laminate flooring, which can produce louder and sharper walking sounds (Johansson *et al.* 2004). Johansson *et al.* (2004) explored the possibility to predict individual responses to walking sound based on differences in objective measurements by means of a laboratory listening experiment. Li *et al.* (1991) investigated the individual ability to identify the gender of the walker, controlling for the surface and shoes effects and demonstrated that listeners can recognize some source characteristics from properties of the acoustic signal (e.g. high pitch and spectral information in general). Regarding the experimental conditions, both these studies rely on an "allocentric" perspective of the participants; that is: perception is linked to a reference frame based on someone else's behaviour, rather than on one's own. On the other hand, the experiments relying on an "egocentric" perspective of the participants are usually more focused on investigating the perceived cross-modal congruences or incongruences (e.g., Visell *et al.* 2009; Giordano *et al.* 2012; Turchet, Serafin 2014). Turchet and Serafin (2014) proposed an experiment to assess the participants' ability in matching pairs of simulated materials presented in auditory and haptic modalities. Giordano *et al.* (2012) investigated the identification of different materials in several non-visual sensory configurations: auditory (passive listening to walking sounds), kinaesthetic (walking with masking of sound information and vibro-mechanical perturbation of touch information), haptic (walking with masking of sound), and audio-haptic (walking).

It is noted that no research has been found to investigate the influence of self-produced walking sounds on the perception of the sonic environment for outdoor spaces (namely, the soundscape). Assuming that the acoustic environment is the result of all sound sources at the receiver in a given context, it was worthwhile questioning what effect different materials could have on the perception of both soundscape and walking qualities, and explore whether these two aspects are anyhow related. Indeed, the rationale for this study is that an individual in the act of walking produces sounds himself (i.e. footsteps) and becomes a source of his own soundscape.

Therefore, the main aims of this study were: (1) to examine the effect of walking sounds deriving from different walked-on materials on the sonic perception for people walking in urban parks, both from the soundscape and from the haptic viewpoints and (2) to explore possible cross-modal correlations between soundscape quality and walking quality. To this purpose, a laboratory experiment with twenty-five participants was carried out, using four materials that are likely to be found in urban parks: grass, wood, stone and gravel.

1. Methods

1.1. 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. Participants were selected from a sample of 120 persons who completed an online survey circulated via the established email list for student volunteers at University of Sheffield. The questions in the online survey were designed to achieve a diverse group of participants in terms of gender, age and ethnic origin. The selection of the participants aimed at extracting a smaller sample with taxonomy as similar as possible to the original one. The sample of participants mainly included young adults. Previous research showed that the age of listener can affect how the acoustic environment is perceived (e.g., Yang, Kang 2005; Kang 2007; Yu, Kang 2010). More specifically, Yu and Kang (2010) investigated the effect of personal aspects such as social, demographical, physical, behavioural and psychological factors on the sound preference evaluation in 19 cities around the world and observed that there is a statistical association between demographical factors, like age and educational level, and aspects related to the perception of the acoustic environments, like the preference of natural sounds and annoyance from mechanical sounds. In particular, elder and more qualified people tend to prefer, proportionally, sounds produced by natural sources (e.g. birdsong, rustling leaves) and are more sensitive to mechanical sounds (e.g. road traffic, construction noise). While acknowledging that age is likely to be a factor of influence on soundscape appreciation, the logic for having a sample in a specific age range was that participants were required to perform an exact task (i.e. walking with a stable speed of 2 steps/s) with a relatively homogeneous walking style. Having a broader age range (e.g. children or elders) would have implied totally different walking style, due to obvious biometrical issues, thus introducing a bias with respect to the produced walking sounds. Therefore, it was opted to control for this variable; on the other hand, the authors made every effort to achieve a diverse sample in terms of gender and ethnic origin. The sample size was designed through an a priori computation (Faul *et al.* 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.

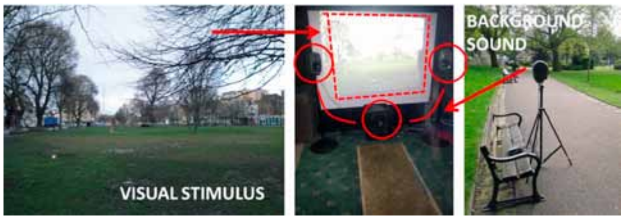

Fig. 1. Audio-visual set up of the experiment

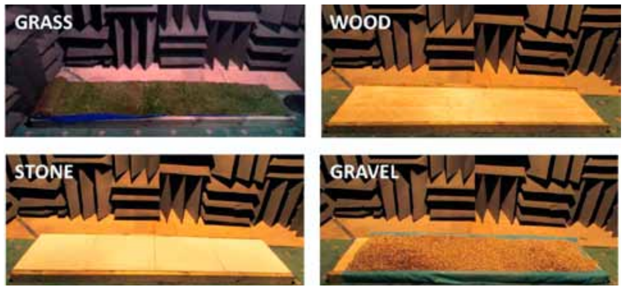

Fig. 2. The wooden platform used for the experiment, covered in turn with the four selected materials

1.2. Materials

The experiment took place in the anechoic chamber (4.00×4.00×2.40 m) 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). The background noise in the anechoic chamber caused by the projector and the corresponding laptop was less than 25 dB (cut-off frequency of the room below 100 Hz); therefore its contribution was considered to be negligible.

A generally quiet background sound (LAeq-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 sonic environment for a urban park. A picture of Valley Gardens (Brighton & Hove, UK) was taken as visual stimulus (Fig. 1). Regarding the background noise, Weston Park was selected in order to represent a usual and plausible condition with a relatively quiet background; the sonic environment was a balanced composition of natural, anthropic and non-intrusive mechanical sounds. Other possible locations were discarded for this very reason: parks with a high exposure to traffic noise, or – conversely – parks with a much quieter background noise (i.e. no traffic at all), would have negatively affected the "urban" peculiarity of a park.

A wooden platform (2400×600 mm) was realised ad hoc and located in the middle of the chamber. Four materials were selected: grass, wood, stone and gravel. Grass consisted of a lawn turf (2400×600 mm, grass height 20–25 mm) on a 20 mm layer of topsoil. Wood consisted of five elements of white wood (planed tongue and groove flooring 18×121×2400 mm). For the stone material, three slabs (600×600×35 mm) of peak smooth grey stone were used. For the gravel material, a 30 mm thick layer of stones (granulometric mix 3–12 mm) was prepared. The four selected materials were meant to cover the platform in turn (Fig. 2). Grass was meant to be a reference material, assuming that it should be the most ecologically suitable for an urban park. It could be argued that a thin layer of grass is not exactly comparable with grass on normal land, although it was selected for the natural features it provides. The rationale for the choice of the other materials was that they are representative of possible design options for footpaths in urban park and it was decided to test both solid (i.e. stone and wood) and aggregate (i.e. gravel) materials.

For descriptive purposes and further analysis, the experimenter recorded in the anechoic chamber the sound of the footsteps on the four materials by means of a binaural microphones headset (in-ear 1/8" microphones, DPA SC4060) connected to a portable recorder (Edirol R-44). The experimenter wore the binaural microphones headset and walked back and forth over each material at a speed of 2 steps/s for 15 s (Johansson *et al.* 2004). Table 1 shows the sound-pressure level (SPL), loudness (L), roughness (R), sharpness (S), fluctuation strength (Fls) and tonality (Ton) values for the four materials and the background noise recorded in Weston Park; the metrics were computed by means of the ArtemiS software (HEAD acoustics®). Psychoacoustic indicators are typical in soundscape studies (e.g., Genuit 2004; Fiebig *et al.* 2009; Hall *et al.* 2013) as they are likely to better describe how the ear works (Genuit, Fiebig 2006). Every indicator was calculated separately for each channel recording and the mean of the two channels' result was considered to be representative (Johansson *et al.* 2004). Figure 3 shows the third-octave band spectra for the four materials' walking sounds recorded in the anechoic chamber, compared to the recorded background noise in Weston Park. Likewise, Figure 4 represents the A-weighted overall level of the four materials recorded with the binaural microphones headset while walking on the platform and the background noise recorded with the dummy head at a fixed position in Weston Park.

Table 1. Acoustic metrics of the walking sounds for the four selected materials and the reference background noise

	SPL – dB(A)	L – soneGF	R – asper	S – acum	Fls – vacil	Ton – tu
Grass	28.5	0.81	0.047	2.680	0.014	0.0058
Wood	48.6	3.04	1.180	1.720	0.177	0.0122
Stone	40.1	2.23	0.628	1.880	0.051	0.0165
Gravel	66.1	15.05	3.580	2.695	0.354	0.0164
Back-ground	55.0	9.06	1.315	1.930	0.013	0.0339

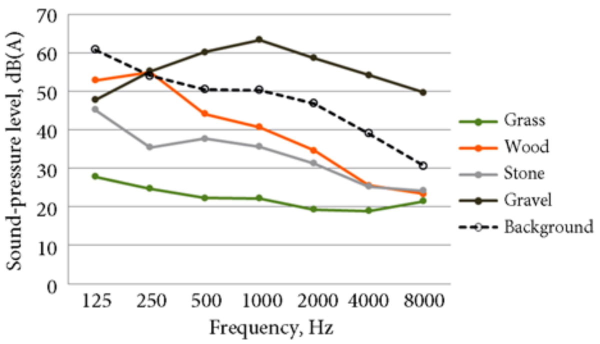

Fig. 3. Third-octave band spectra of the four recorded walking sounds compared to the generic urban park's background noise

1.3. Procedure

The experiment was designed to test the effect of different path materials on both auditory and haptic individual perception. The material factor had four levels: grass, wood, stone and gravel.

Participants were invited to the Acoustics Laboratory of the University of Sheffield. In the invitation letter, they were required to wear shoes with soft sole (i.e. "sneakers"): this request was aimed at controlling for the shoes variable and limiting as much as possible any covariant effect with this regard. Three different experimental sessions were organised (two groups of eight and one of nine, respectively): this was due to practical reasons, since participants were supposed to wait for the materials to be changed along the experiment; the sessions lasted between one and two hours each. Afterwards, participants were individually asked to enter in the anechoic chamber. The background sound recording and the picture of the park were reproduced continuously. The background sound of Weston Park was calibrated by means of a dummy head, in order to reproduce the same sound-pressure level and spectrum at the receiver's ears as recorded in situ (± 1.0 dB), considering the middle point of the platform, with the receiver facing the screen. The frequency range of the dummy head was 20 Hz–20 kHz, thus the calibration procedure was assumed to be accurate enough for the purpose of the study. Participants had a minute to familiarise with the environment, and then they were required to walk in a natural way on the platform, watching the screen and listening to the whole sonic environment, for as long as they wanted. Due to the relatively small length of the platform (2400 mm), participants were able to make 5–6 steps while watching in front of them: in case they wanted to walk again, they were instructed to get off of the platform, go back and start from the beginning. However, they

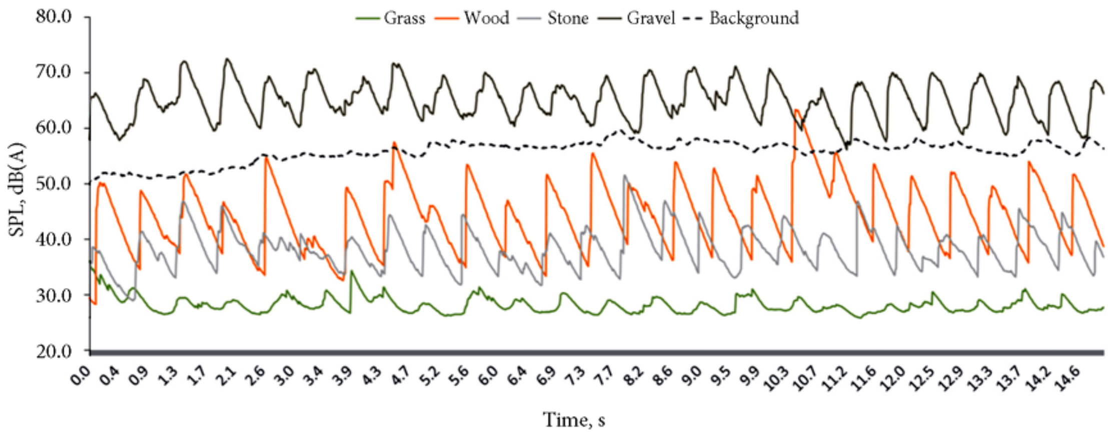

Fig. 4. A-weighted overall level of the four walking sounds recorded while walking on the platform and the background noise recorded at a fixed position in Weston Park

had been previously instructed to consider the "sound environment" as the integration of both the surrounding sounds and the sounds produced by their footsteps, thus discarding any other time interval when both these sound sources were not occurring.

For each material, participants had to answer four questions by putting a mark on a 10 cm continuous scale: (Q1) "Overall, to what extent is the sound environment appropriate to the location?" (ranging from "not at all" to "perfectly"); (Q2) "Overall, how would you describe the sound environment?" (ranging from "very bad" to "very good"); (Q3) "Overall, how comfortable is walking on this surface?" (ranging from "very uncomfortable" to "very comfortable"); (Q4) "Overall, how pleasant is walking on this surface?" (ranging from "very unpleasant" to "very pleasant"). The questions Q1 and Q2 address the aspects of appropriateness (pertinence of the material) and quality of the sonic environment; likewise the questions Q3 and Q4 relate to the specific material of the footpath and the overall walking experience, accordingly. After the rotation of all participants, the material was changed and the procedure was repeated. In order to compensate for possible order effects, different random materials sequences were used over the three experimental sessions.

Deciding to perform the experiment in the anechoic chamber indeed aimed to achieve controlled environmental conditions. The main focus of the study was overlying the sound produced by the walked-on materials; therefore, performing the experiment in a real environment would have biased the results, due to possible effects of other non-controlled factors (e.g. wind, temperature, sudden changes of the background noise). Regarding the reproduction of acoustic environments under laboratory conditions, the efforts of experts are oriented to reach a perceptually correct or plausible reproduction rather than a physically correct one (Vorländer 2008). The concept of plausibility is often referred to as the perceived agreement with the listener's expectation towards a corresponding real acoustic event (Lindau, Weinzierl 2012) and it is used to evaluate the sense of credibility of reproduced audio-visual environments. According to Pellegrini (2001), a plausible simulation of a given environment would include "a suitable reproduction of all required quality features for a given specific application" rather than a copy of "an existing environment in all its physical aspects". In this case, the specific application was about isolating as much as possible the walking sounds effect from other covariant effects, while presenting a plausible scenario, also using a visual stimulus. Overall, a number of comparative studies between real and reproduced scenarios have already shown the effectiveness of laboratory experiments in providing valuable results (e.g., Maffei *et al.* 2015). Furthermore, regarding the walking aspects of the study, it is worth saying that the technical layout of the experiment is in line with methods previously used in haptic-related research (see, for instance, Johansson *et al.* 2004; Visell *et al.* 2009; Giordano *et al.* 2012; Turchet, Serafin 2014).

2. Results

The analysis of the results consisted of two parts. In the first part, an analysis of variance (ANOVA) was performed for the individual responses to the four questions, in order to detect statistically significant effects of the walked-on materials. In the second part, a Pearson product-moment was used to investigate statistical correlations for the individual responses within the same sensory modality and between the two different sensory modalities (aural and haptic).

2.1. Analysis of variance for the materials effect

The four questions submitted to participants were examined separately. Each question was associated to an independent variable and an ANOVA was performed on the 25×4 individual responses, considering the four materials as different "treatments" for the participants. The answer scores of the four questions (Q1, Q2, Q3 and Q4) submitted to participants (N=25) were associated to four independent variables: "Sonic Pertinence" (SP), "Soundscape Quality" (SQ), "Haptic Comfort" (HC) and "Walking Quality" (WQ), respectively. A one-way repeated measures ANOVA was conducted on these variables to evaluate the null hypothesis that there is no change in participants' scores with respect to the presented walked-on materials. The results of the ANOVA showed a significant material effect: Wilks' Lambda = .635, $F(3,22) = 4.213$, $p = .017$, $\eta^2 = .365$ for the Sonic Pertinence; Wilks' Lambda = .591, $F(3,22) = 5.073$, $p = .008$, $\eta^2 = .409$ for the Soundscape Quality; Wilks' Lambda = .311, $F(3,22) = 16.237$, $p < .001$, $\eta^2 = .689$ for the Haptic Comfort; Wilks' Lambda = .306, $F(3,22) = 16.644$, $p < .001$, $\eta^2 = .694$ for the Walking Quality. Therefore, there is significant statistical evidence to reject the null hypothesis for the four considered variables. Nevertheless, follow up comparisons showed that not every pairwise difference was significant.

Regarding Sonic Pertinence, grass differed significantly from gravel ($p = .010$) and post hoc analysis revealed that gravel was considered the least pertinent material (M = 62.24, SD = 20.05), whilst grass was the most pertinent one (M = 79.64, SD = 17.75); wood (M = 68.00, SD = 21.45) and stone (M = 70.44, SD = 18.23) had intermediate values. Regarding Soundscape Quality, the gravel resulted to be significantly different from all other materials: grass ($p = .009$), wood ($p = .036$) and stone ($p = .003$). Post hoc analysis showed that gravel was the worst material in terms of Soundscape Quality (M = 56.04, SD = 19.10); the following materials were wood (M = 70.64, SD = 17.06), grass (M = 74.84, SD = 20.70) and stone (M = 75.12, SD = 15.14). Figure 5 shows the individual scores' distributions of the four materials for Sonic Pertinence and Soundscape Quality.

Considering the variable Haptic Comfort, the gravel resulted to be significantly different from all other materials: grass ($p < .001$), wood ($p < .001$) and stone ($p = .001$). Post hoc analysis showed that gravel was the worst material in terms of Haptic comfort (M = 41.40, SD = 23.16); the following materials were stone (M = 64.44, SD = 21.86), wood (M = 69.80, SD = 22.64) and grass (M = 77.44, SD = 16.53). Similarly, for Walking Quality the gravel resulted to differ from all other materials: grass ($p < .001$), wood ($p < .001$) and stone ($p = .006$). Moreover, the difference between grass and stone was also statistically significant ($p = .016$). Post hoc analysis showed that – in terms of Walking Quality– grass (M = 78.12, SD = 22.93) was more preferred than wood (M = 67.12, SD = 25.87), that was in turn more preferred than stone (M = 59.80, SD = 20.16) and gravel (M = 40.44, SD = 23.46). Figure 6 represents the individual scores distributions of the four materials for Haptic Comfort and Walking Quality.

In the investigated case, with a reasonably quiet background noise (L_{Aeq} = 55 dB), the gravel resulted to be the least appreciated material for both auditory and haptic aspects. Compared with gravel, the mean differences from the other materials range from 10.5% for Sonic Pertinence and 17.5% for Soundscape Quality, to 27.9% for Walking Quality and 29.2% Haptic Comfort.

2.2. Intra-modal and cross-modal correlations

This section investigated three possible correlations of the individual responses: (1) between the two sound-related questions, (2) between the two haptic-related questions and eventually (3) between the sound-related and the haptic-related questions. For this analysis, the material effect was disregarded and all the 25×4 responses for each question were considered together.

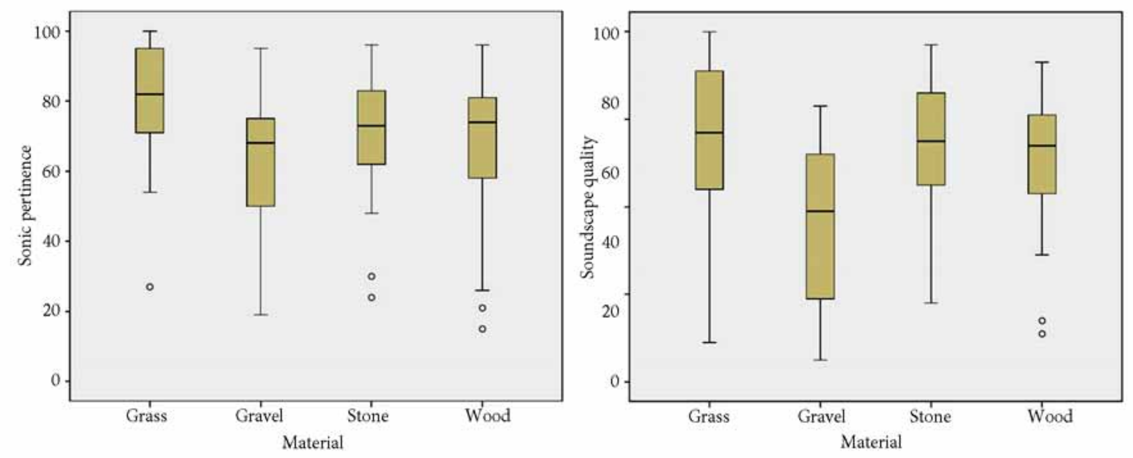

Fig. 5. Box-and-whisker plots showing individual scores distribution of the four materials for Sonic Pertinence (left) and Soundscape Quality (right)

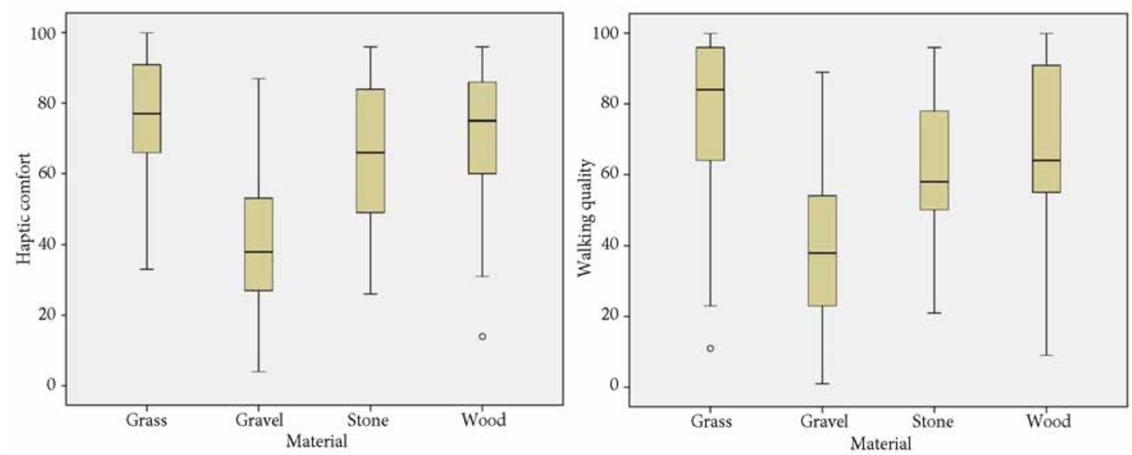

Fig. 6. Box-and-whisker plots showing individual scores distribution of the four materials for Haptic Comfort (left) and Walking Quality (right)

A Pearson product-moment correlation explored the overall relationship between Sonic Pertinence and Soundscape Quality. This analysis was found to be statistically significant, $r = .552$, $p < .01$, indicating a positive relationship between Sonic Pertinence and Soundscape Quality. This relationship was then subjected to a first-order partial correlation in order to explore the relationship controlling for the effects of Haptic Comfort and Walking Quality. The first-order correlation was found to be statistically significant, $r = .472$, $p < .01$.

Similarly, it was investigated the correlation between Haptic Comfort and Walking Quality. This analysis was found to be statistically significant, $r = .720$, $p < .01$, showing a strong positive relationship between Haptic Comfort and Walking Quality. This relationship was then subjected to a first-order partial correlation in order to explore the relationship controlling for the effects of Sonic Pertinence and Soundscape Quality. The first-order correlation was found to be statistically significant, $r = .660$, $p < .01$.

Eventually, a first-order partial correlation analysis between Soundscape Quality and Walking Quality was performed, controlling for the effects of Sonic Pertinence and Haptic Comfort. The first-order correlation was found to be statistically significant, $r = .284$, $p < .01$. Therefore, this analysis indicates that a relationship between Soundscape Quality and Walking Quality exists above and beyond the effects of Sonic Pertinence and Haptic Comfort, and it is statistically significant, showing a cross-modal interaction of the haptic and the auditory modalities, with respect to the perceived quality.

3. Discussions

The aim of this study was to explore the effects of different footpath materials on user's auditory and haptic satisfaction under an urban park circumstance. Even though the experiment engaged actively with multiple sensory modalities (i.e. auditory, visual and haptic), the focus of the study was mainly overlying the sonic component of a multisensory experience like walking in an urban park. Indeed, while acknowledging that the visual qualities, as well as other environmental aspects, are likely to have relevant impacts on the human experience, it was worth investigating the specific ecological contribution of such an environmental input, for the sense of spatial presence it provides and its high occurrence as a non-verbal sound (Ballas 1993). Therefore, the considered methods aimed to control as much as possible for potential covariant effects originating from the other sensory modalities (i.e. visual and haptic), by fixing some experimental conditions (i.e. visual stimulus and shoes type). The rationale for having a visual stimulus in general, was about making the participants' task (i.e. walking on the platform) more plausible and usual.

The variable Sonic Pertinence (SP) explores the connection between the walking sound and background sounds. This is mostly relevant from the design and planning viewpoint, as different walked-on materials are expected to perform differently in terms of soundscape perception, depending on the context. Considering that the proposed background noise was relatively quiet (L_{Aeq} = 55 dB), the grass was rated with the highest scores. This aspect is consistent with previous findings in literature, confirming that the amount of greenery of a context is an indicator for the definition of a perceived "tranquillity" dimension (Pheasant *et al.* 2009; Watts *et al.* 2013). On the other hand, in spite of being a common option for the footpaths of urban parks, the gravel resulted to have very low preference rates for both the sound-related questions. The spectral analysis pointed out that the sound produced by the footsteps on the gravel exceeded the background on almost the whole frequency range, resulting in an "intrusive" sound source that might have been perceived by the individuals as "segregative" with respect to the remaining sonic environment. It was decided to use such a quiet background sound, as it was considered to be more representative of an ideal situation for urban parks. Nonetheless, it seems fair to suppose that for design conditions with a noisier sonic environment (e.g. urban parks affected by road traffic noise) the gravel could help achieving a "masking" effect of unwanted noise sources, thus improving the soundscape perception. Likewise, clearly noticeable walking sounds can also help detecting the presence of other people and this could have positive implications with respect to perceived safety in particular contexts. Regarding the remaining cases – grass, wood and stone– the background noise was mostly higher than the walking sounds in terms of overall level. Although, this doesn't mean that the walking sounds were not audible at all; indeed, the comparison of the psychoacoustic metrics shown that they had similar or even higher values with respect to the background noise. Furthermore, it is worth observing that, due the location of the loudspeakers reproducing the background noise, participants might have accordingly experienced lower and higher levels than the middling 55 dB, while walking along the platform. This is likely to have made the walking sounds detach from the background at given moments, making them more noticeable; however such a circumstance could also be representative of real life situations, where background sounds often undergo sudden variations. Therefore in this experiment the walking sounds are relevant to soundscape perception even if they are not the prevailing sound source of the sonic environment.

Considering the relationship between the walking sounds and the background noise, it could be argued that the participants' perception was biased by an attentive listening style (i.e. participants were willingly paying attention to the walking sounds, while they wouldn't in real life). Regrettably, not much could be done to deal with this issue, since the aim of the study was obvious for the participants due to the experimental procedure. Notwithstanding, researchers generally acknowledge that people do interact in different ways with the sonic environment and diverse listening styles –either attentive or holistic– are all relevant to the soundscape approach (Botteldooren *et al.* 2011).

The variable Soundscape Quality (SQ) explores the perception of the sonic environments overall quality. It provides an additional meaning with respect to the Sonic Pertinence, as it aims to represent the holistic experience of the soundscape of an urban park, considering both the self-produced sound and the background sounds as a whole. The observed correlation between Soundscape Quality and Sonic Pertinence raises a behavioural theme, for the participants being aware that they are "co-responsible" of the final sonic environment, due to the self-produced walking sound. This awareness, and the fact of being somehow "in control" of the sound source, might have contributed to a better assessment of the sonic environment, since it was foreseen and "expected" (Bruce, Davies 2014).

Regarding the haptic-related variables, the presented questions aimed at reflecting the same approach as per the sound-related variables. The Haptic Comfort was more focused on the sensorimotor dimension; while the Walking Quality was meant to be more broadly related to the act of walking (holistic approach). For both variables the gravel reported some relevant negative score differences, showing that the material performed significantly better for the auditory modality, with respect to the haptic one. Participants often confirmed the haptic scores with spontaneous verbal feedbacks, reporting the gravel to be "tiring" or "arduous to walk on". This issue should be carefully considered by planners and landscape architects, regardless of other practical advantages that aggregate materials are likely to offer.

Some arguments could be raised about the representativeness of results collected under laboratory conditions for the effective soundscape appreciation of an urban park. There is still no clear consensus about the "ecological validity" of laboratory experiments for soundscape purposes (e.g., Guastavino *et al.* 2005). On the other hand, such methods are used more and more in research applications for the primitive need of reproducibility of the experimental conditions (e.g. Lavandier, Defréville 2006; Joynt, Kang 2010; Axelsson *et al.* 2010; Maffei *et al.* 2013).

For the current application, it is not expected that a sample of participants would assess the investigated variables exactly as they would in a real site (i.e. same scores). Although, it is likely to assume that the preference within the materials group (i.e. the materials ranking) would be consistent. Results shown that the walked-on material effect is relevant; further studies are desirable to extend the present findings, potentially to broader age ranges.

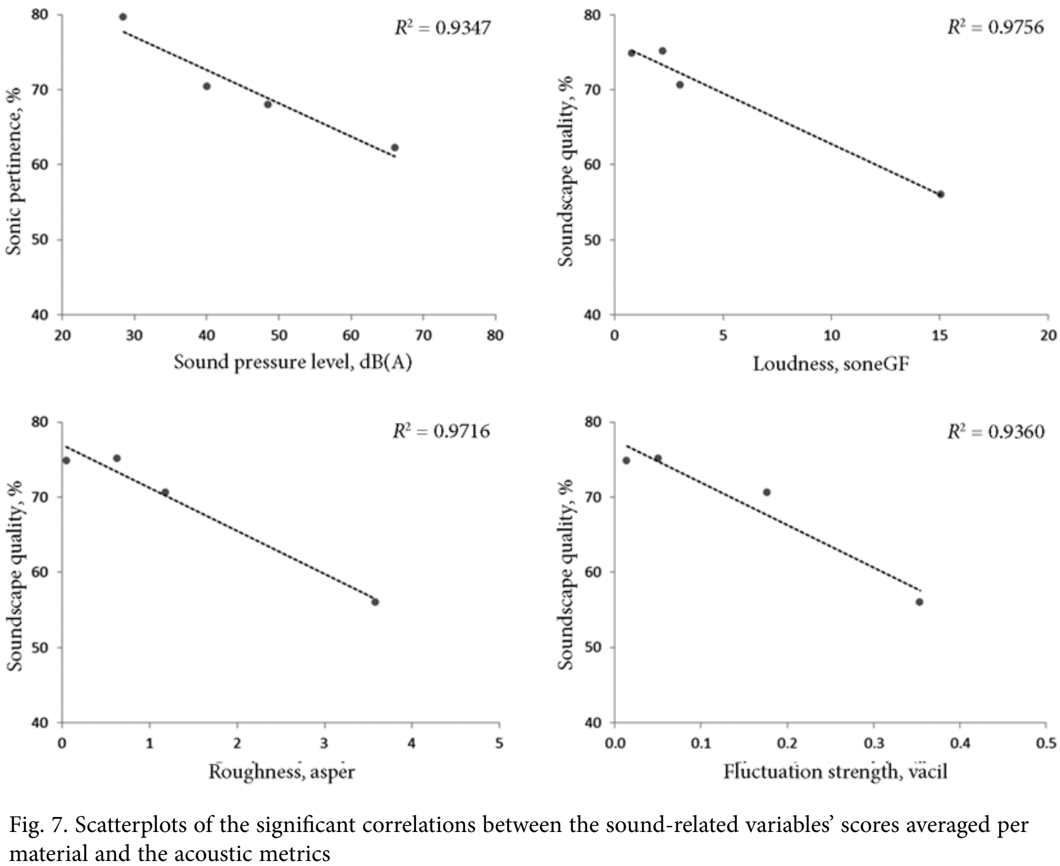

Fig. 7. Scatterplots of the significant correlations between the sound-related variables' scores averaged per material and the acoustic metrics

In order to provide a further understanding of the observed results, a Pearson product-moment was performed to investigate the relation between the mean values of the individual responses to the two sound-related questions (SP, SQ) and the acoustic metrics calculated for the walking sounds (SPL, L, R, S, Fls, Ton), recorded by the experimenter for descriptive purposes before the participants' sessions. The correlation between Sonic pertinence and Sound-pressure level resulted statistically significant, $r = -.967$, $p < .05$. On the other hand, Soundscape Quality was significantly correlated with Loudness $r = -.988$, $p < .05$, Roughness, $r = -.986$, $p < .05$ and Fluctuation strength, $r = -.967$, $p < .05$ (Fig. 7). No other statistically significant correlations were observed for the other acoustic metrics, with respect to the individual responses. Therefore –in this case– the louder, the rougher and the more fluctuating the sound produced by the footsteps, the worse the appreciation of the sonic environment.

Such considerations on the correlations between individual responses and objective metrics are far from being conclusive and are not likely to be generalised, due to the limited variations of materials and background noise. Nevertheless, they offer a new insight on walking sounds for planners (and materials' manufacturers), forasmuch as sounds from walked-on materials could become a "product sound" just like it happened for the automotive and household appliances industries.

Conclusions

In this study, a laboratory experiment was carried out in order to investigate possible effects of different walked-on materials for footpaths on both auditory and haptic perception in urban parks. Four materials were used for the experiment (grass, wood, stone and gravel): they were considered to be possible and realistic design solutions for urban parks footpaths.

The main conclusions of this study are:

- Different walked-on materials for footpaths in urban parks are likely to have an effect on soundscape perception. Indeed, a statistically significant material effect has been found on all the four defined variables: Sonic Pertinence, Soundscape Quality, Haptic Comfort and Walking Quality.
- Positive significant correlations were found between Sonic Pertinence and Soundscape Quality, between Haptic Comfort and Walking Quality and also between Soundscape Quality and Walking Quality, showing that the soundscape appreciation for people walking in urban parks is likely to be affected also by other but aural sensory modalities.

In the investigated case, with a quiet background noise, grass resulted to be the most appreciated material, while gravel received the worst assessment, for both auditory and haptic sensations. The mean differences between gravel and the other materials were: 10.5% for Sonic Pertinence, 17.5% for Soundscape Quality, 27.9% for Walking Quality and 29.2% for Haptic Comfort. However, this study pointed out that the walking sounds from walked-on materials should also be considered together with the background noise they interact with.

The ecological validity of laboratory experiments for the soundscape appreciation remains an open question. Although, an increasingly number of researchers is opting for such approach (with satisfactory outcomes) for the undeniable advantages it provides in terms of methods reproducibility. Considering the limited number of tested materials, it is not possible to generalise the observed correlations between the individual assessment scores and the acoustic metrics of the walking sound. Given the exploratory nature of this study and the time constraints for the experimental sessions derived from the procedure, it was preferred to refer to few materials to be representative of different typologies: ecological (grass), solid (stone and wood, with different physical properties) and aggregate (gravel) materials. Results suggest that there is room for implementing new design approaches to urban parks and more specifically to the footpaths and the walking sounds that their materials are likely to produce. Indeed, depending on the surrounding environmental conditions, different footpath materials could help to build a better "sonic identity" for urban parks.

In general, the findings reported in this paper claim for further attention on the soundscape of urban parks and relate to the broader issue of the need for quiet and pleasant areas in modern cities.

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