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How can soundscapes affect the preferred walking pace?

Justyna Maculewicz *, Cumhur Erkut, Stefania Serafin

Sound and Music Computing, Aalborg University Copenhagen, Denmark

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ABSTRACT

In this paper we describe an experiment whose goal is to investigate the role of the footstep sounds and soundscapes to affect the pace of a person walking in place (mimicking the act of walking without leaving the current position). Subjects were exposed to different simulated footstep sounds and soundscapes, generated in realtime while walking in place. The results show that, indeed, participants adapted their walking pace to the presented sounds, and not only footstep sounds but also soundscapes affect the walking pace. We could observe as well that perceived ease of walking correlates with the perceived naturalness of ambient sounds.

1. Introduction

1.1. Soundscape

The term soundscape was introduced by R. Murray Schafer in 1960s and the research on this topic was pioneered by The World Soundscape Project (WSP) - an educational and research group established by R. Murray Schafer at Simon Fraser University. A soundscape can be defined as the component of the acoustic environment that can be perceived by humans. Soundscapes mediate the relations between environment and people who perceive them. According to The International Organization for Standardization (ISO) a soundscape is a perceptual construct, related to but distinguished from a physical phenomenon (acoustic environment) (ISO 12913-1:2014). Soundscapes exist through human perception of the acoustic environment. From our perspective, the working theory used in The Positive Soundscape Project [7] includes all of the important aspects of the soundscape and focuses on its perception: "the totality of all sounds within a location with an emphasis on the relationship between individual' s or society' s perception of, understanding of and interaction with the sonic environment".

In Ref. [2] the importance of sound of places is described from an interdisciplinary perspective, ranging from architecture, acoustics and anthropology. The book presents how spaces speak, and the acoustic environment has a meaning which can be interpreted from and engineering point of view as well as an aesthetical and anthropological point of view. Soundscapes provide also benefits from the medical point of view. As a matter of fact, immersing people into soundscape sounds was proven to improve patients' health [16]. Lindborg [16] investigated the relationships between soundscape features and physiological responses linked to relaxation and stress. They discovered that peripheral temperature was negatively correlated with loudness and with calm-to-chaotic scales. Their results indicated as well heart rate (HR) negatively correlated with timbral brightness and fluctuation strength. They explained this effect by a correlation of high temperature (indication of reduced system activation) and low heart rate with relaxation and low peripheral temperature with stress. Hume and Ahtamad [14] monitored HR and respiratory rate (RR) while listening to pleasant and unpleasant soundscapes. HR was lowered and RR raised as an effect of this listening task. More specifically, more unpleasant soundscapes caused larger false in HR and the pleasant soundscapes caused greater rise in RR.

The results of a project called The Positive Soundscape Project, which are summarized in [7], indicate that humans' assessment of the soundscapes is driven by high-level cognitive features rather than low-level acoustic characteristics. The meaning and emotions carried by soundscape sounds are the main indicators of what people perceive as positive or negative soundscape. It is important that natural sounds and human sounds are incorporated into the soundscapes. Similarly, in the research of Dubois et al. [8] soundscapes with human activity were perceived as more pleasant than those with predominant mechanical sounds. Further results of The Positive Soundscape Project indicated participants' need of having behavioural and cognitive control over it. Soundscape sounds should provide information and the sounds comprising the soundscape should not require listeners' attention. If the soundscape require more attention allocation (by being loud or persistent) it

* Corresponding author.
E-mail addresses: jma@create.aau.dk (J. Maculewicz), cer@create.aau.dk (C. Erkut), sts@create.aau.dk (S. Serafin).

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tends to be perceived as negative. Sounds, which 'blend together', are assessed as positive. Memory of a past events also influences the evaluation in a significant way. The authors claim that distinction between sound and noise in a context of soundscape is rather emotional and two dimensions, calmness and vibrancy, seem to be responsible for this emotional response [7].

Research on combined landscapes and soundscapes also draw interesting conclusions in a context of our research. Brambilla and Maffei [4] proved that the more the sound is congruent with the listener's expectation, the level of evoked annoyance is lower and its acceptability higher. The rate of acceptability of the sound increases with a decrease of its sound level and detectability of non-natural sounds. Van Renterghem et al. [30] pointed as well that unidentified sound sources are judged differently.

Until this time we did not find any research which assesses human rhythmic behaviour when exposed to the various soundscapes. The general assumption can be derived from Boltz [3], where people tended to speed up their preferred tempo when exposed to annoying sounds and slow down when exposed to relaxing music. Franěk [12] monitored rhythmic behavior of their subjects when walking in natural environment. They observed that humans walk faster in places without greenery and with a higher level of traffic and noise in places with greenery and with a low level of traffic and noise.

Studies on music effect on the speed of the motor behaviour can indicate possible directions of our study and help to structure hypothesis. In a study of Kallinen [15] participants were asked to read while listening to music. Results showed that reading rate and efficiency were higher with faster tempo. What was interesting as well, in no-music condition (women) and slow music condition (men) participants judged the read news more positively. In other studies it was shown that walking and running [9,26], eating and drinking [20], and drawing [22] can be as well influenced by the speed of the background music.

1.2. Preferred tempo

Fraisse [11], as the first one, discovered the phenomena of spontaneous tempo, which is highly linked to the concept of the preferred tempo. He found that people are surprisingly consistent when asked to simply tap at the rate that is comfortable. The behaviour varies across individuals but the general conclusion is that humans prefer tempi with a beat period around 600 ms. This rate is similar with the rate at which people walk, but has nothing to do with the persons heartbeat [27]. After 20 years, Moelants [21] showed that the range between 120 and 130 BPM (120 BPM = 500 ms) is more realistic for being shown as preferred rate. The tempo limit, which is possible to synchronise with, ranges from 100–300 ms to 2000–2500 ms (reviewed in: [1,19]). The limit of fast tempo partly depends on the limits within the motor system [1]. The limit of slow tempo is linked the limits of temporal capacity in working memory [25]. Differences in preferred tempo are associated with age and between individual fluctuations. Other factors such as gender, handedness, or body size appear not to affect the preferred tempo [19].

Until now, few studies have shown the role of interactive auditory feedback produced by walkers in affecting walking pace. As an example, in Turchet et al. [29] it was shown that subjects walking speed changes as a function of the interactively simulated ground material. In our previous research, we explored as well walking as a rhythmic action and experimentally investigated the effect of auditory feedback [18] in a closed-loop interactive sonification framework [13]. Different kinds of auditory feedback were compared, including ecological feedback such as footsteps on wood and gravel as well as a non-ecological feedback such as a sinetone. In the present study we assumed that different soundscapes classified as fast or slow will affect walking pace of the participants. Since, it was already proven that feedback sounds coming from each step influence walking pace [18] we combined these with soundscapes to investigate whether the addition of soundscapes affect the preferred pace of a person and to monitor the effect of congruency between feedback and soundscape sounds. According to our hypothesis, a soundscape creates a sense of place and affects the pace: people walking at the beach tend to walk slower than people walking in a busy city environment. In order to test this hypothesis, we designed an experiment described in the following section.

2. Experiment design

We designed an experiment to further explore the influence of footstep sounds and additional soundscape on preferred pace of a person. In 20 trials we tested four auditory feedback conditions (gravel, wood, sine wave, silent), four different soundscapes (cafe, busy office, sea shore and street) separately and combined together and one silent conditions. All trials were presented in randomized order.

Our previous research [18] showed that different types of auditory feedback, which are the effect of walking performance can influence our preferred walking pace. We decided to use soundscapes to emphasize and reinforce the meaning enclosed in the auditory feedback. In this experiment we assumed that a restaurant and a busy office soundscapes are congruent with feedback of footsteps on wooden floor. A seashore and a street is congruent with gravel feedback. Each pair of soundscapes included one, which in our opinion could induce fast, and a second one – slow pace of walking. In addition we tested combination all soundscapes and non-ecological feedback – sine wave. Table 1 summarizes the experiment design. In each of the 20 trials participants were asked to walk in place on an aerobic stepper in their own preferred pace. After each trial participant were asked several questions which are specified in the list below.

- **Q1** Evaluate the sense of effort you experienced while walking (1: no effort - 7: high effort).
- **Q2** It was easy to walk while listening to the sounds of footsteps and soundscapes (1: very easy - 7: very hard).
- **Q3** The pace I kept while walking was: (1 very slow - 7 very fast).
- **Q4** Feedback felt as a natural consequence of walking. Consider only footsteps sounds (1: strongly disagree - 7: strongly agree).
- **Q5** Feedback felt as a natural consequence of walking. Consider footsteps sounds and soundscape (1: strongly disagree - 7: strongly agree).
- **Q6** Feedback was congruent with soundscape (1: strongly disagree - 7: strongly agree).

Table 1
Summary of the experiment design. The experiment was divided into four sections with the respective number of trials. The number of trials was dictated by a combination of all soundscapes and footstep sounds used in each section.

Section	Soundscape	Feedback	Trials
A1	Seashore, busy street, restaurant, busy office	Gravel, wood, sine wave	12
A2	Seashore, busy street, restaurant, busy office	None	4
B	None	Gravel, wood, sine wave	3
C	None	None	1