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The restorative potential of soundscapes: A physiological investigation

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ABSTRACT

Acoustic environments can have negative or positive effects on human health and wellbeing. Two studies investigating the impact of soundscapes on physiological measures obtained after a stressor or a period of rest, are reported. Subjective appraisals of the soundscapes were also considered when examining the relationship between soundscape and physiological response. Following a stress task, larger decreases in heart rate were associated with the least eventful, soundscapes. When at rest, sounds perceived as pleasant produced lower skin conductance levels compared to sounds perceived as unpleasant. Together these findings suggest that autonomic function during stress recovery and at rest can be influenced by subjective response to the acoustic environment. Further, the co-variance between subjective estimates of, and physiological response to, soundscapes suggests there is some worth in developing self-report soundscape surveys as a tool to use when considering soundscapes accessible to the public.

1. Introduction

Humans relate to their acoustic environments on an emotional level by interpreting the sensory information they afford, this giving rise to the concept of the soundscape: "the acoustic environment as perceived and understood, by people, in context" [1]. In particular, soundscape characteristics mark an environment as a desirable or undesirable place to occupy, as uniquely judged by the individual. Localities hosting acoustic stressors (i.e., noise) tend to induce negative emotions, and motivate an avoidance response (the so called *defensive motivation system*), while localities free from such stressors may induce positive emotions and motivate an approach response (the *appetitive motivation system*). Generally, people are motivated to seek places that minimize stress and maximize restoration. As a consequence, town planners, architects, and acousticians work together to provide such areas: typically parks, green spaces, and natural or wilderness areas.

There is evidence suggesting that quiet areas make a positive contribution to public health [e.g., 2] and enhance physiological recovery from stress [3]. It is argued that natural environments can facilitate restorative physiological processes by either inducing positive emotions [4] and "undoing" the physiological changes brought about by negative emotional states [5], by restoring attentional capacity and reducing mental exhaustion [6], or a combination of the two [7]. To date, however, much of the research has been biased towards visual stimuli, focusing on pictures and videos of natural environments or urban settings [8], either without sound, without exploring interaction effects [9], or without controlling for important acoustical variables such as sound pressure level [3].

Physiological measures such as heart rate (HR) and skin conductance level (SCL) reflect autonomic activity, whereby the sympathetic ("Fight or flight") or parasympathetic ("rest and digest") branches adopt a dynamic balance depending on the demands of the hosting environment. For both visual and auditory stimuli, autonomic measures such as HR and SCL co-vary with self-report levels of valence (i.e., "pleasantness") and arousal (i.e., degree of perceived autonomic response), respectively [10], results that are consistent with the valence–arousal model of emotional response [11]. Intrinsic to the valence–arousal model is the role of cognitive evaluations of sound, and thus the importance of collecting both physiological and subjective ratings when undertaking investigations of the covariance between environmental factors and human response. The importance of subjective assessment of soundscapes has recently been explored in the literature [12], supporting a survey approach to soundscape impacts. However, self-report surveys measuring emotional responses to soundscapes risk over- or under-estimation due to response biases, and objective physiological measures coupled to subjective soundscape evaluations have been recommended [13]. Hume and Ahtamad [13], adopting an approach very similar to Bradley and Lang [10], reported that

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significant differences in HR and respiration rate were evident between pleasant and unpleasant sounds when self-report measures of valence were obtained, emphasizing the covariance between subjective and objective measures.

In this communication we report two studies that were conducted to investigate physiological correlates of soundscape impact on stress recovery (Study One) or while at rest (Study Two). While there are multiple studies examining the impacts of music on physiological activity [14,15], only a handful of studies have directly considered soundscapes. Study One extends Alvarrsson et al. [3] investigations by using real world soundscapes presented at equal sound pressure levels, and analytically by including the influence of subjective evaluation on recovery. The second study extends those reported by Bradley and Laing [10] and Hume and Ahtamad [13] by presenting six real world sounds for longer durations (i.e., 2 min compared to the 6 and 8 s used in those studies). Specific questions posed include whether soundscapes can reduce (positively evaluated) or maintain (negatively evaluated) negative emotional states induced by stressors, and following a period of restful silence, whether soundscapes can induce negative or positive emotions.

2. Study one

The first study aimed to document differences in physiological response to different soundscapes presented after a stressful task. It is hypothesized that positively evaluated soundscapes will be associated with a faster recovery (i.e., decreasing HR and SCL) compared to unnatural noises [4,6]. Also, current theories of human response to sound [e.g., 1] predict that the most pleasant and familiar, and the least arousing, dominant and eventful, sounds will facilitate faster physiological recovery than their polar opposites. Participants were exposed to a thirty minute sequence consisting of five stress periods of two minutes each, each followed by a stress recovery period of four minutes (see Fig. 1). During the five stress recovery periods the participants were exposed, in a randomized order, to one of four different environmental sounds or one sound-free (henceforth "silence") condition.

2.1. Participants

Participants were 45 unpaid postgraduate students or members of staff, with normal hearing function as assessed by standardised audiometric testing (Otovation Audiometer, model Amplitude T3). The mean age of the sample was 29.4 years (*SD* = 10.9; *Min* = 19; *Max* = 60), consisting of 20 males and 25 females. All the participants were asked to refrain from caffeine-containing beverages for at least two hours before the experiment.

2.2. Stimuli

Four high quality sound samples (16 bit, 44.1 kHz) were created, each four minutes in duration, consisting of recordings made in a forest during the dawn (hereon 'birdsong'), waves recorded on a calm day at a beach ('ocean'), a busy motorway intersection ('road noise'), and at a building construction site ('construction'). The road noise, recorded during peak time (08:00 am) on a weekday, contained a mixture of continuous and pulsed flow movements, with vehicles being stationary or potentially accelerating up to 100 kilometres per hour. For comparative purposes, the average flow of traffic at this time and locality was observed to be approximately 55 vehicles per minute, of which 80% were cars, 14% light-to-medium commercial vehicles, and 6% heavy commercial vehicles. The samples were normalized using Adobe Audition's (CS5.5) batch process, equilibrated to a reference RMS value, and from there scaled to an average sound level of 64 dB SPL using a Bruel and Kjær sound level meter coupled to Sennheiser HD 250 (linear II) headphones.

2.3. Physiological measurement

Continuous recordings of cardiac activity and skin conductance were obtained using a NeXus 10 device and BioTrace software [16]. Electrocardiograms (ECG) were obtained using a triangular chest configuration (i.e., standard Lead II placement) with pre-gelled silver-silver chloride (Ag/AgCl) electrodes at a rate of 2048 samples-per-second. Heart rate was calculated by taking the peak-to-peak distances between successive heart beats, affording an estimate of beats-per-minute (BPM). Skin conductance was measured using a sample rate of 32 Hz. One electrode each was positioned on the volar surface of the medial phalanges on the index and middle fingers of the non-dominant hand, following cleansing with an exfoliating agent and an alcohol swab. Artefact removal was undertaken using BioTrace's inbuilt signal-conditioning functions. Conductance between electrodes is impacted by sweat gland activity, which itself is controlled directly by the sympathetic nervous system. Sympathetic activity, in turn, is associated with a mobilisation of the body's "fight or flight" response, and thus changes in skin conductance reflect changes in physiological stress and arousal.

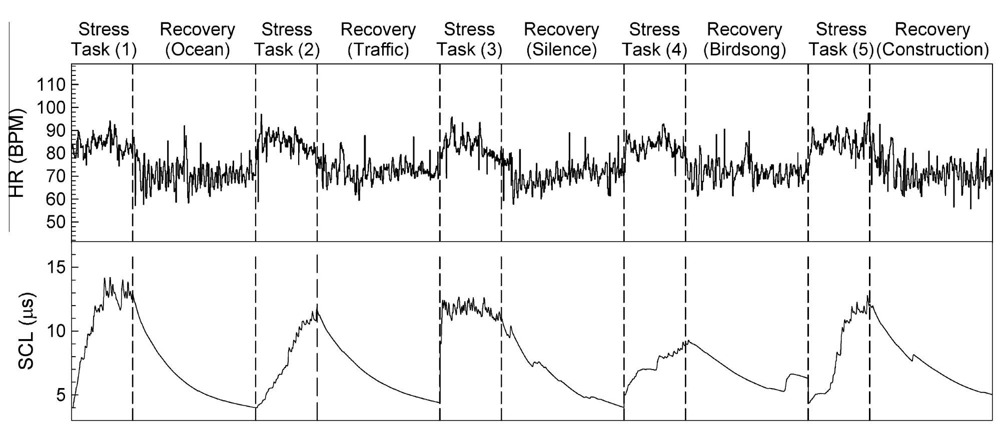

Fig. 1. Columns denote the configuration of stress tasks (two minutes each) and recovery periods (four minutes each). Rows give physiological data for heart rate (HR) and skin conductance (SCL). Data was obtained during the testing phase of the study, and is representative of that collected later.