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Effects of noise sensitivity on psychophysiological responses to building noise

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ABSTRACT

The present study aims to explore the effects of noise sensitivity on psychophysiological responses to floor impact noises and road traffic noise. A standard impact source (i.e. an impact ball) and two real impact sources (i.e. an adult's walking and a child's running) were used to record floor impact noises, while road traffic noise was introduced as an outdoor noise stimulus. A total of 34 subjects were recruited based on their self-rated noise sensitivity and classified into low and high noise sensitivity groups. During the laboratory experiments, all the noise stimuli were presented for 5 min each, and the subjects rated their annoyance with each stimulus at the end of each session. Their physiological responses (heart rate: HR, electrodermal activity: EDA, and respiratory rate: RR) were measured throughout the experiment. The obtained noise annoyance ratings increased with increasing noise levels for all the sources, and the high noise sensitivity group exhibited higher annoyance ratings than the low noise sensitivity group. All physiological measures varied significantly with the duration of noise exposure. In particular, the EDA and RR values decreased sharply after 30 s, demonstrating strong habituation over time. Noise sensitivity was found to significantly affect physiological responses, whereas noise levels showed no significant influence.

1. Introduction

It is well-known that both acoustic and non-acoustic factors contribute to noise annoyance [1–6]. In particular, noise sensitivity has been reported as a significant non-acoustic factor affecting annoyance. Several studies have concluded that subjectively reported noise sensitivity alters the effect of noise exposure on annoyance [7–9], while others have confirmed that annoyance ratings are greater for people with higher noise sensitivities [10,11]. Recent studies have also indicated that the prediction of noise annoyance can be considerably improved by adding noise sensitivity [12,13]. However, research to date has tended to focus on outdoor environmental noise (i.e. road traffic and aircraft noise), while little attention has been paid to indoor noise such as noise from neighbours.

Recent evidence has highlighted that annoyance is related to non-auditory effects of noise, such as physical and mental health problems [5,14–16]. Guski [5] suggested that a relationship exists between annoyance and negative feelings caused by noise, while Stansfeld and Matheson [14] reported that noise might have serious psychological effects. Furthermore, Maschke and Niemann [16] found that annoyance induced by neighbour noise had negative effects on both physical and mental health, such as cardiovascular health risks, migraine, or depression. More recently, a series of studies on building noise proposed the relationship between the annoyance caused by floor impact noise and health-related complaints [17,18]. So far, however, there has been little discussion on the relationship between annoyance and physiological responses. In particular, physiological measurements have been mainly used for emotional states [19–21] and physical health risks [22–25].

Physiological parameters are responsive to various emotional states including threat, frustration, anger, startle, and (un)pleasantness. Therefore, an experimental setting with various stimuli (e.g. acoustic modalities) is widely used to investigate affective responses through physiological measures [20]. Several attempts have also been made to explore physiological changes due to arousal-evoking stimuli [26]. For instance, it was found that heart rates decelerate, while electrodermal activity and respiration increase [20,27–29] after presentation of stimuli. It was also observed that subjective estimations, particularly arousal and pleasantness, were linked to physiological changes [30–33]. In addition, several studies tried to investigate the impacts of acoustic stimuli on physiological responses. Björk [34] found that electrodermal activity increased for the stimuli exceeding 70 dBA.

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Stansfeld [35] claimed that most physiological responses to noise habituated rapidly and suggested that noise sensitivity was related to higher electrodermal activity and heart rate, indicating physiological arousal to noise [35]. Hume and Ahtamad [33] reported that unpleasant acoustic stimuli caused larger falls in heart rate, while more pleasant sound stimuli resulted in bigger rises in respiratory rate. However, the acoustic stimuli used in the aforementioned studies are steady-state sounds and only lasted for short time periods ranging from 4 to 30 s; thus, the impacts of acoustic stimuli on physiological responses are still questionable for realistic situations with longer durations of noise exposure.

Stansfeld [35] provided an extensive review on relationships between noise sensitivity and various responses to environmental noise. It was suggested that, for noise sensitive individuals, greater awareness of external events contributes to the physiological responses or vice versa [35]. In particular, it was reported that high noise sensitivity is associated with higher level of physiological arousal, phobic, and defence/startle responses, as well as slower habituation to noise [35]. These mechanism between noise sensitivity and physiological responses has been empirically validated by studies on environmental noise [8,11,35,36]. Bigger changes in heart rates [8,35], higher skin conductance levels, and slower habituation [11,35] were observed from noise sensitive subjects while they were exposed to high noise levels. In addition, Heinonen-Guzejev et al. [36] found a significant increase in cardiovascular mortality from noise sensitive subjects. On the other hand, there is a lack of evidence explaining the link between noise sensitivity and physiological response in the research field on building noise. It has been found that noise sensitive individuals reported higher annoyance to various kinds of indoor noise [37] including floor impact noise [17,18]. Furthermore, noise sensitivity has been reported to increase health complaints either directly or indirectly [17,18]. While the association noise sensitivity and physiological responses to building noise was not explored in detail, it is worth examining the response evoked by building noise and compare the responses between different noise sensitivities.

The main purpose of this study is to develop an understanding of how noise sensitivity might affect perception of noise and physiological responses to noise. It was hypothesised that psychophysiological responses to noise might be different across subjective noise sensitivity and types of noise sources. Therefore, the subjects were recruited based on their self-rated noise sensitivity and classified into low and high noise sensitivity groups. Transient building noise transmitted from the neighbours was used as a major type of noise stimuli, and steady-state noise (road traffic noise) was added for comparison. Laboratory experiments were conducted by using 5 min long noise stimuli. Noise annoyance was evaluated after each stimulus presentation, and three physiological measures (heart rate, electrodermal activity, and respiratory rate) were monitored throughout the experiment.

2. Methods

2.1. Subjects

A simple online survey was conducted in order to examine subjects' experience and attitude to floor impact noise. A link of the survey was emailed to people who showed their interest in participating in the experiment. They were asked to answer several questions about their demographic characteristics, residential situation, previous experience of being exposed to floor impact noise, noise sensitivity, and attitude to the noise source. For the attitude to the source, six questions about the upstairs neighbours [18] including ‘I am happy with living downstairs of my upstairs neighbours’ were asked, and the replies were rated on a 5-point scale. Noise sensitivity was evaluated using the 21 questions developed by Weinstein [38].

This study aimed to recruit more than 26 participants since this number of participants are required to obtain 0.8 of statistical power in correlation analysis. A total of 34 Korean subjects were chosen based on their responses. They included 13 males and 21 females aged between 30 and 48 (mean = 38.8, std. deviation = 5.3). Half of them were in their 30s, and the other half in their 40s. The median noise sensitivity score of the subjects (median = 81.5) was computed and used to split the subjects into one group exhibiting ‘low noise sensitivity’ (median = 61 and std. deviation = 6.6) and another exhibiting ‘high noise sensitivity’ scores (median = 99 and std. deviation = 5.9). As listed in Table 1, either group contained 17 subjects. Thirteen subjects were either not married or married but had no children, and others reported that they had one or more children. It was found that 14 subjects showed positive attitude to their upstairs neighbours, whereas negative attitude was found for 20 subjects. Attitude score difference between the low and high noise sensitivity groups was not significant. The mean duration of residency in their current accommodation was three years; thus the subjects were also divided into two groups based on whether they lived in their current residence for less or more than three years. Eighteen subjects had lived in their current residence for less than three years, while the rest had lived in their residences for more than three years. It was found that 12 subjects had experience of making noise complaints regarding the noise from their upstairs neighbours.

Table 1
Demographic and attitudinal factors for the subjects (N = 34).

		Number	%
Gender	Male	13	38.2
	Female	21	61.8
Age	30s	17	50.0
	40s	17	50.0
Noise sensitivity	Low	17	50.0
	High	17	50.0
Child(ren) at home	Yes	21	61.8
	No	13	38.2
Attitude to upstairs neighbours	Positive	14	41.2
	Negative	20	58.8
Length of residency	Less than 3 years	18	52.9
	More than 3 years	16	47.1
Experience of making noise complaints	Yes	12	35.3
	No	22	64.7

2.2. Stimuli

In the present study, both transient and steady-state noises were used as noise stimuli. Floor impact noise, which represented the transient noise, consisted of real and standard impact noises induced by human footsteps (hereinafter ‘real’ or ‘R’) and a standard heavy-weight impact source (impact ball, hereinafter ‘ball’ or ‘B’). Road traffic noise (hereinafter ‘traffic’ or ‘T’) representing the steady-state noise was introduced for comparison with transient noises. Floor impact noises were recorded in a test building with a low background noise level (~25 dBA). The floor layer of the test building consisted of a 210 mm thick concrete slab, 30 mm thick resilient material, 40 mm thick lightweight concrete, and 40 mm thick mortar. The room where the recording was carried out was furnished with wooden flooring. An adult walking barefoot (70 kg) and a child running barefoot (24 kg) were chosen as the dominant real sources in residential buildings [39], while an impact ball [40] dropped from 1 m height was used as standard impact noise. All the floor impact noises were recorded binaurally using a head and torso simulator (Brüel & Kjær Type 4128C) positioned on a sofa in the receiving room downstairs. The road traffic noise was recorded near a motorway in the suburb of Liverpool. A microphone (Behringer ECM8000) connected to a digital recorder (ZOOM H4n) was positioned 2 m away from the motorway and 1.5 m above the ground. The motorway width was 11 m (35 feet), and the average vehicle speed was ~60 km/h (37 mph). The traffic flow was fluctuating due to a