실험실 환경에서의 바닥충격음 생체신호 평가

Physiological responses to floor impact sounds in a laboratory setting

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Key Words : 바닥충격음(floor impact sound), 생체신호(physiological response).

ABSTRACT

The present study aimed to analyse the effects of floor impact noise on human using both psychological and physiological methods. Floor impact noises caused by a standard impact source (i.e. impact ball) and five real impact sources were recorded as sound stimuli. During the laboratory experiments, two factors that impact psychophysiological responses were considered: (1) types of impact sources (standard or real sources) and (2) the levels of floor impact noise ranging from 31.5 to 63 dBA in terms of A-weighted maximum sound pressure level (L_{AFmax}). The subjects' physiological responses (heart rate: HR, electrodermal activity: EDA, and respiration rate: RR) were monitored throughout the experiments. All physiological measures altered significantly due to the noise exposures; HR increased, whereas EDA and RR decreased.

1. Introduction

A number of researchers have found non-auditory health effects of noise on people in laboratory and empirical studies [1,2] and most of them analysed long-term health consequences of transportation noise such as aircraft or road traffic noise. On the other hand, there is little evidence of health problems from dwelling noise, although people spend most of their time in or around their home [3, 4].

Therefore, this study aimed to examine the physiological responses to floor impact noise through laboratory experiments. The floor impact noise was recorded in laboratory testing building using a standard impact source (i.e. impact ball) and also real sources such as human footsteps. Three simple physiological measures (heart rate, electrodermal activity, and respiration rate) were recorded when the participants were exposed to the noises. The laboratory experiments were used to examine the relationships between noise levels, source types, and physiological responses.

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2. Methods

2.1 Noise stimuli

A total of six different noise sources were used to represent all the impact noises in apartment buildings. Five real sources were used with a standard heavyweight impact source (i.e. impact ball). The real sources were classified into two groups based on their physical characteristics; 1) heavyweight impact sources and 2) lightweight impact sources. The heavyweight impact sources included human footsteps, such as an adult walking barefoot, a child running and jumping, while lightweight impact sources were the dropping of a toy and the scraping of a chair. The A-weighted maximum sound pressure levels (L_{AFmax}) of the stimuli were edited to cover ranges between 31.5 to 63 dBA in 3.5 dBA intervals without spectral adjustments.

2.2 Experimental design

The experiment consisted of five sessions. Four of the five sessions (Sessions 1-4) lasted for around 15-minutes and each session included 10 or 11 noise stimuli, whereas the duration of Session 5 was approximately 7 minutes. Sessions 1-3 included real impact sources and the standard impact source was presented in Session 4. In Sessions 1-4, each stimulus was interspersed with 50 seconds of silence and all of the stimuli lasted for 23 seconds. For physiological measurements, the first and last 2-minute silence periods were also allocated for resting time. On the other hand, Session 5 aimed to analyse the noise annoyance of each stimulus caused by both standard and real sources. The duration of each noise was eight seconds and the noise level of the stimuli covered the whole range of the sound pressure level from 31.5 to 63.0 dBA.

2.3 Measurement of physiological responses

In the current study, three simple physiological measures were used: 1) heart rate (HR) expressed in beats per minute (BPM), 2) electrodermal activity (EDA) expressed in microsiemens (μS), and 3) respiration rate (RR) expressed in beats per minute (BPM). The HR was gathered from the raw data of electrocardiographs (ECG), while the ECG was measured through electrodes attached to each participant's right wrist and both ankles. The EDA was measured using electrodes attached to the participants' index finger and the middle finger of the right hand. The RR was measured through a respiration transducer belt worn around the chest.

The participant's responses varied during baseline and noise exposure; therefore, the percentage change (%) was calculated to adjust all the different values. The percentage change was defined as the percentage of change from the baseline to noise exposure.

2.4 Participants

Twenty-one participants aged between 18 and 42 took part in the experiment. None of the participants reported hearing disabilities.

3. Results

Changes in HR, EDA, and RR were averaged for Sessions 1-4 and the mean changes were then presented for the standard and real sources in Figure 1. The HR data decreased by more than 2% for both sources and the difference between the baseline and the noise exposure was statistically significant (p < 0.05). There was no significant differences between the sources. EDA increased significantly due to noise exposure ($p < 0.05$). The mean EDA changes were less than 0.2% and the standard source resulted in a slightly higher increase than the real sources but the difference between the two types of source was not statistically significant. Similarly, significant RR increases were recorded when participants listened to floor impact sounds (p < 0.05). The RR change of standard source was higher than that of real sources which can be interpreted that the participants were more sensitive to the standard impact source, but the two changes were not statistically significant.

Figure 2 shows the mean changes of HR, EDA, and RR as a function of L_{AFmax}. Open circles indicate the results from real sources and filled circles represent the responses to the standard impact source. Repeated measures of ANOVA was used to estimate the significance of differences in physiological response changes across different source (standard or real sources) and noise levels (L_{AFmax}). Source types had no significant main effect on any of the physiological responses. However, the noise level had main effects on EDA [$F(3.125,21.877) = 4.415$, $p < 0.05$)] and RR [$F(3.025,21.174) = 5.770$, $p < 0.01$)]. The interaction between source type and noise level had no significant impact on HR and RR but influenced EDA significantly [$F(3.138,21.966) = 4.229$, $p < 0.05$)].

The findings of the correlation analysis show that, for the standard impact source, only RR was influenced by L_{AFmax} ($r = 0.26$, $p < 0.05$). For the real sources, EDA and RR were correlated with L_{AFmax} ($r = 0.23$, $p < 0.05$ for EDA and $r = 0.39$, $p < 0.01$ for RR); however, the relationship between HR and L_{AFmax} was not significant. Additional analysis was conducted to investigate whether the physiological response changes were influenced by annoyance. It was found that annoyance for the standard impact source had no impact on the mean changes of physiological measures. However, the annoyance to the real sources were correlated with EDA and RR. The mean change of EDA was influenced by annoyance ratings (r = 0.27, p < 0.05), while annoyance was also correlated with the mean change of RR. In particular, the correlation coefficient between annoyance ratings and the mean change of RR was 0.42 (p < 0.01).

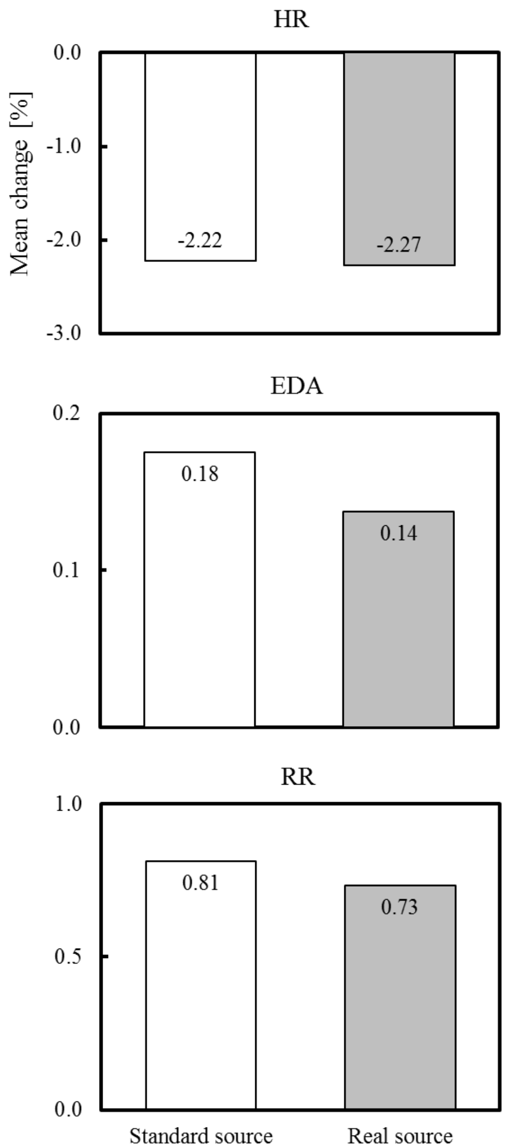

Figure 1. Mean changes of physiological responses during Sessions 1-4: (a) HR, (b) EDA, and (c) RR.

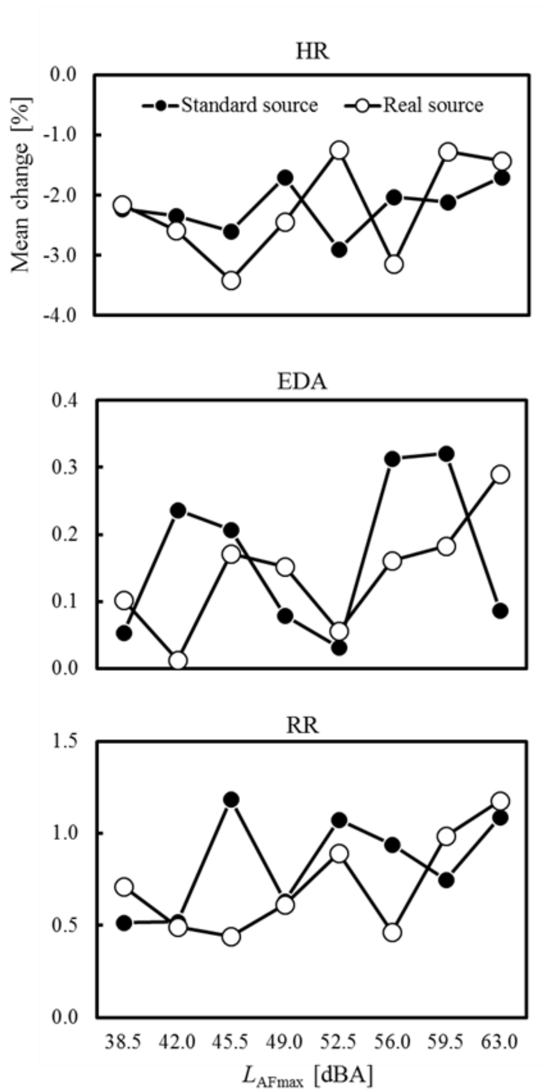

Figure 2. Mean changes of physiological responses as a function of L_{AFmax}: (a) HR, (b) EDA, and (c) RR.

4. Conclusions

This study investigated participants' physiological responses (HR, EDA, and RR) to floor impact noises produced by both standard and real sources. The physiological responses to 23-second noise stimuli were calculated from the experiment. Deceleration in HR, increases in EDA and RR were identified during the noise exposure, demonstrating that the noise stimuli influenced the arousal status of the participants. The physiological responses were not affected by the type of source (standard or real impact source), whereas the sound pressure level had a major impact on EDA and RR. In addition, annoyance for real sources was correlated with EDA and RR, whereas annoyance to the standard impact source showed no relationship with any physiological measure.

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