A study on the influence of headphones used for auditory perceptual function
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<Abstract>
The focus of this study is a human’s ability to make full use of listening and hearing. This ability consists of dividing auditory information into a signal and a noise. To evaluate the risk of using headphones, the study investigated the auditory perception when a warning sound is given in the presence of environmental noise. In an experiment, an event-related potential (P300) was measured in three conditions: 1) not using headphones, 2) using ordinary headphones, and 3) using noise-canceling headphones. In an outdoor situation, when a subject wearing normal headphones played music at a volume that prevented the hearing of ambient environmental noise (medium volume), the subject was distracted and did not pay full attention to the target stimulus sound, resulting in a great decrease in the subject’s ability to distinguish the target stimulus sound from the noise.

Keywords: Event-related potential (P300), Listen and Hear, Headphone

1. Introduction
In the human acquisition of external auditory information, external information is classified as a signal. Instantaneous active seeking of information to a signal is known as listening, and passive sensing of sound without conscious effort is known as “hearing”. Such processing is performed for information segments that cannot be visually perceived.

A bias against listening has emerged in recent years due to the growing use of noise-cancelling (NC) headphones, which greatly reduce external noise. The underlying importance of the balance between listening and hearing, however, is inherent and unchanging. Disruption of this balance impedes hearing, which plays a key role in auditory perception, and may thereby increase the risk of accidents.

The present study is focused on the state of imbalance between listening and hearing when headphones are used outdoors.

2. Purpose
This study assessed the risk associated with using headphones in outdoor environments in terms of the differences in auditory perception. These differences are indicated by changes in the composition of brainwaves corresponding to cognitive processes measured by event-related potential (ERP). In an experiment, the perception of ambient sounds was measured under the following three basic conditions of (a) not using headphones (b) using ordinary (non-NC) headphones, and (c) using NC headphones.

3. Experimental method
The criteria in the experiment included both objective assessment by ERP (P300) measurement and subjective assessment.

The subjects were four adult males in good mental and physical health with no hearing impairment and who customarily use headphones or earphones to listen to music.

The experiment was conducted in the acoustic and electrostatic shielded room at our university and was thus unaffected by the external environment.

The measurements were made target stimulus discrimination under the abovementioned three basic conditions (headphone non-use, non-NC headphone use, NC headphone use), three target stimulus conditions of 4500, 2000, and 200 Hz, and three headphone music volume conditions of low, medium, and high, for a total of 21 condition sets.

With the EEG electrodes affixed, the subjects silently counted the occurrences of the target stimuli in an ambient-noise environment. In accordance with the literature, the recording electrodes were fixed to the three midline positions of Fz, Cz, and Pz, which are known to facilitate P300 measurement, and the reference and body ground electrodes were affixed to the both of earlobes.

The measurement time was from 100 msec before the stimulus presentation and 700 msec after the stimulus presentation period. In addition, signal averaging of the brainwave data for 50 repetitions.

The ambient noise, comprising the sounds of a busy shopping area (70 dB), was emitted by speakers located in the front and rear of the shielded laboratory.

The selection of music played on the headphones was based on the questionnaire completed before hand by the subjects. The music sound level used in each trial was one of the three iPod touch volume settings: low (vol 6), medium (vol 9), and high (vol 12). The stimuli were the peak frequencies of risk-associated sounds determined by FFT analysis of the following actual sounds: 4500 Hz (bicycle bell), 2000 Hz (grade crossing or fire truck), and 200 Hz (passenger car engine). The measurements were performed for combinations of the three sounds (e.g., when the target stimulus was 4500 Hz, the two sounds at
2000 Hz and 200 Hz were used as non-target stimuli. The proportions of stimulus presentation were 10% for the target stimulus and 45% for each of the two non-target stimuli, emitted at random by a speaker located behind the subject. The objective in each trial was clearly explained to the subjects prior to the trial.

4. Results and discussion

In this section, we discuss the presence or absence of P300 and its amplitude under the target stimulus conditions of 4500 Hz and 200 Hz and the music volume conditions of high, medium, and low.

With ordinary (non-NC) headphones and music played at high volume, no P300 generation was found in the region of 300 ms after stimulus initiation. This result indicates that with non-NC headphones, a bias toward listening occurred due to the high music volume, which apparently reduced the attentiveness to the target stimulus. Similar results were obtained with the NC headphones playing music at high volume.

With the NC headphones and music played at low volume, no P300 generation was found in the region of 300 ms after initiation of the target stimulus of 200 Hz. This is presumably attributable to the absence of target stimulus recognition due to elimination of the 200 Hz sound by the noise-cancelling function of the NC headphones.

Table 1 Generation of P300 (n = 4)

<table>
<thead>
<tr>
<th>Volume</th>
<th>Low (vol 6)</th>
<th>Medium (vol 9)</th>
<th>Loud (vol 12)</th>
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<tbody>
<tr>
<td>4500 Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No headphones</td>
<td>O</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Nomal headphones</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC headphones</td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td>2000 Hz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No headphones</td>
<td>O</td>
<td>x</td>
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<tr>
<td>Nomal headphones</td>
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<tr>
<td>NC headphones</td>
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<td>x</td>
<td>x</td>
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<td>200 Hz</td>
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<tr>
<td>No headphones</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nomal headphones</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>NC headphones</td>
<td></td>
<td>x</td>
<td>x</td>
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</tbody>
</table>

(0) indicating the presence of P300 generation
(x) indicating the absence.

Table 1 shows the findings for all of the 21 condition sets used in this study.

As shown, P300 generation was found in the region of 300 ms after stimulus initiation for all nine condition sets with no headphones, but for only three condition sets with non-NC headphones and low-volume music and for only two condition sets with NC headphones and low-volume music.

It is generally known that when attention is directed toward a given task (e.g., target stimulus discrimination) a large increase in P300 amplitude is generated at the time of target signal discrimination. For the condition sets indicated by the circles in Table 1, it was possible to readily identify the occurrence of P300 generation and thus readily distinguish between listening and hearing.

The condition sets in which no P300 generation was found and no target stimulus was discerned were those sets at medium or high music volume with either the non-NC or the NC headphones and the set with NC headphones and a 200 Hz target stimulus at low music volume.

In outdoor environments, information representing a signal may be present even in the low-frequency region of 200 Hz. The results thus indicate that listening to music even at a low volume with NC headphones clearly entails risk because it precludes discrimination of the signal from noise. With NC headphones, moreover, although sounds in the 4500 Hz and 2000 Hz regions are not eliminated by the noise-cancelling function, and it may therefore seem likely that discrimination of target stimuli in those frequency regions should be possible. The results of the present study indicate that such discrimination is impeded if the music volume is increased, and so the outdoor use of NC earphones also entails substantial risk.

5. Conclusions

The results of this study demonstrate the possibility of objectively measuring the influence of external factors on auditory perception. The results indicate that listening to music with ordinary (non-NC) headphones outdoors at a volume (vol 9) rendering ambient environmental noise inaudible impedes attentiveness to target stimuli and thereby greatly reduces functional discrimination.

The results also indicate that, with NC headphones and listening to music at a volume (vol 6) at which ambient noise remains audible, attention to the target stimulus of a car engine (200 Hz) is ineffective due to cancellation of the 200 Hz frequency region by the headphones. This in turn indicates that outdoor use of NC headphones entails substantial risk even with a sound volume (vol 6) at which ambient environmental sounds remain audible.

Further investigation is needed to determine the sound volume boundaries for target stimulus discrimination while using headphones, and the influence of musical genre and target stimulus types.

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