PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Evaluation of frequency resolution characteristic of cartilage-conduction hearing using physiological and psychological measurement

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ABSTRACT

In bone-conduction, a transducer needs to be clamped strongly against the mastoid process of the temporal bone and this has caused severe pain and discomfort to the users. To solve such defects of bone-conduction, "cartilage-conduction" has been proposed and applied to several devices such as hearing aids and smartphones. In this study, psychophysical measurements and brain magnetic field measurements were conducted to objectively evaluate the frequency resolution characteristics of the cartilage-conduction hearing. The results indicate that in a certain range of frequencies, the cartilage-conduction hearing has nearly equal frequency resolution to that of conventional bone-conduction and air-conduction hearing.

Keywords: Cartilage-conduction, Perception, Frequency resolution

1. INTRODUCTION

The sounds that we usually perceive initially enter the auditory canal and finally the cochlea in the form of air particle vibrations, and thus this is often referred to as the air-conduction (AC). On the other hand, sound that is transmitted using body structure such as skin, muscle, and especially bone is called bone-conduction (BC). Generally, BC is presented by attaching a sound transducer to the mastoid process of the skull, and in this way, the sound is said to be transmitted as 4 components[1]: (1) the osseotympanic component, which involves sound radiated into the ear canal; (2) the inertial osteogenic component, which is based on the relative motion between the middle ear ossicles and the temporal bone; (3) the compressed osteogenic component, which results from compression and expansion of the cochlear shell; and (4) the air-conducted component. BC has been applied to devices such as headphones and hearing aids, but problems such as the causes of pain and discomfort and the difficulty of securing the transducer, have hindered its widespread application. Therefore, as a solution, "cartilage conduction (CC)" has been proposed[2]. In CC, the ear cartilage tissue is used as the main transmission medium, together with skin and bones by bringing a transducer into contact with the cartilage region of outer ear. Similar to BC, it transmits via 4 pathways and has been applied to hearing aids[3] and smartphones[4]. However, a limited number of studies have been conducted on CC and the details of the perception mechanisms remain unclear. In this study, the frequency resolution of CC hearing was evaluated. Using both psychological measurement (frequency difference limens: DLF) and brain magnetic field (mismatch field: MMF) measurement, the CC hearings were compared with AC and conventional BC hearings. In addition, in order to investigate the influence of each sound component on CC perception, measurements were also carried out in conditions where the air-conducted component was blocked by an earplug.

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2. PSYCHOLOGICAL MEASUREMENT (DLF MEASUREMENT)

Seven normal-hearing subjects participated. Two tone-bursts with slightly different frequency across a certain center frequency were presented to the subjects, and the subjects were required to choose the stimulus of higher frequency. The stimuli were presented in 4 conditions: (a) AC, (b) BC, (c)CC and (d) CC with earplugs (CCP) (Fig.1). In each condition, the DLF were estimated using 2 forced-alternative-choice of 2 down-1 up method. Across a frequency range from 0.5 to 8.0 kHz, no significant differences among presentation conditions were observed (Fig.2).

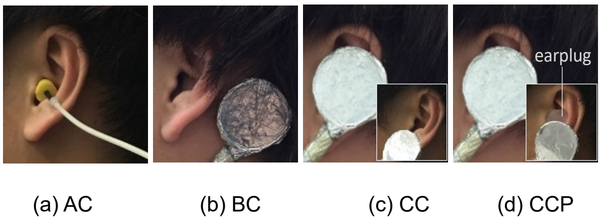

Figure 1 – Presentation of stimuli

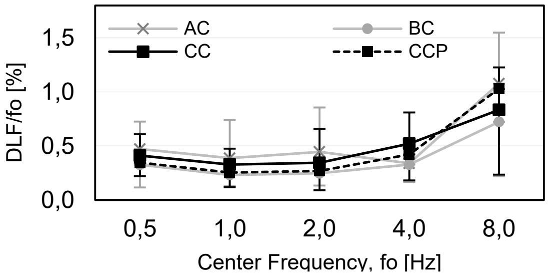

Figure2 – Estimated DLF for each condition

3. PSHYIOLOGICAL MEASUREMENT (MMF MEASUREMENT)

MMF is a kind of auditory evoked brain magnetic field induced by low occurrence stimuli when randomly presented with other stimuli of a higher rate of occurrence. MMF has been used as an objective index in sound discrimination[5]. In this measurement, 5 normal-hearing subjects participated. With the same presentation method as in DLF measurement (Fig.1), Stimulus I & II (100 ms tone-burst), were presented in 2 separate sessions in a random order.

[Stimulus I] high-occurrence stim.(85%): (std) 1.00 kHz; low-occurrence stim.(4% each):
(dev A) 1.02, (dev B) 1.04, (dev C) 1.08, (dev D) 1.16, (dev E) 1.32 kHz

[Stimulus II] high-occurrence stim.(85%): (std) 4.00 kHz; low-occurrence stim.(4% each):
(dev A) 4.08, (dev B) 4.16, (dev C) 4.32, (dev D) 4.64, (dev E) 5.28 kHz

The MMF responses evoked by low-occurrence stimuli were measured using a 306-ch whole-head brain magnetic field measurement system (Vectorview™, Neuromag Ltd.). The activation source of each MMF was estimated using the equivalent current dipole (ECD) method, and the ECD moments were then compared. It was found that, the greater the difference between dev and std, the greater the intensity of ECD moment observed. A slight decrease of ECD moment was observed in Stimulus II; however, no statistical differences among conditions were observed.

4. CONCLUSIONS

In the both DLF and MMF measurements, no significant differences among CC, AC, and BC were observed. At least in the range from 0.5 to 8.0 kHz, it is suggested that the frequency resolution of CC is nearly equal to that of the conventional BC and the AC hearing. In addition, no significant change was observed with the presence of an earplug in CC, which may have been due to the occlusion effect that compensated for the effect of the air-conducted component.

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