Title	耳音響放射を用いた聴覚末梢系の時間分解能の評価
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Abstract

The temporal resolution of the auditory system is the sensitivity to the time-varying amplitude envelope information of sound, playing an important role in speech comprehension. Speech perception and the ability to hear sounds in noisy environments are influenced not only by the frequency selectivity of the auditory system but also significantly by temporal resolution of the auditory system. Temporal resolution of the auditory system can be primarily considered in terms of the ability to capture the time changes in the amplitude envelope of the sound waveform and the ability to capture the time changes in the temporal fine structure. Information about the time changes in the amplitude envelope represents variations in the loudness of the sound. Additionally, information about the time changes in the temporal fine structure represents rapid frequency changes. These pieces of information play different roles in speech perception, where changes in the amplitude envelope are crucial for understanding speech, and changes in the temporal fine structure are important in conditions involving competing sounds.

In cases of hearing impairment, early interventions and support such as the use of hearing aids, cochlear implants, and providing appropriate auditory environments are essential. Age-related hearing loss is identified as a contributing factor to cognitive decline, and countermeasures against this problem have become an issue. Therefore, early detection of hearing impairment is crucial, and during hearing tests, it is important to prioritize examinations that can identify the decline in temporal resolution, not just relying on measurements of sensitivity to the loudness and pitch of sounds, as commonly done in traditional audiograms. Despite symptoms of difficulty in speech clarity, conventional hearing tests often struggle to diagnose hearing impairment, leading to the concept of "hidden hearing loss." The decline in temporal resolution, one of the causes of hidden hearing loss, often goes unnoticed in conventional pure tone hearing threshold measurements.

Temporal resolution of the auditory system measurements are difficult to perform on newborn babies and infants because they are based on subjective evaluation. Additionally, the lengthy nature of the measurement makes it difficult to accurately assess temporal resolution in older individuals and those with hearing impairments. Therefore, there is a need for an objective assessment of temporal resolution.

As an objective indicator of the auditory system, there is otoacoustic emissions (OAEs). Otoacoustic emissions is a phenomenon where faint sounds are emitted into the ear canal due to the active function of the cochlea. This occurs by inserting a probe into the ear to record the emissions in response to presented stimuli, commonly used during auditory screening for newborns and infants. If the waveform of otoacoustic emissions is not detected, there is suspicion of hearing impairment.

Otoacoustic emisiions is generated during the latent vibration of outer hair cells when the basilar membrane vibrates in response to sound stimulation. Therefore, examining otoacoustic emissions has the potential to capture the vibration of outer hair cells in response to the presented sound.

The perception of time-varying sounds, including temporal modulation, often involves the use of modulation filterbanks. It is believed that these filterbanks may be related to nonlinear effects within the cochlea. Otoacoustic emissions is thought to be associated with the stretching and contraction of outer hair cells within the cochlea, which act on the nonlinear effects in the cochlea. Nonlinear effects within the cochlea involve the amplification of weak vibrations of the basilar membrane and the sharpening of frequency selectivity. Therefore, it may be possible to estimate the temporal resolution of the auditory system by examining otoacoustic emissions.

This study aims to investigate whether or not the temporal resolution of the auditory system can be estimated by examining otoacoustic emissions. Thus, this paper studies the relationship between the auditory temporal resolution and otoacoustic emissions.The gap detection threshold, temporal modulation transfer function (TMTF) and frequency modulation difference limen are used as the index of auditory temporal resolution. In the gap detection task, the threshold is measured to assess the ability to detect gaps (silent intervals) inserted into the stimulus sound. Therefore, a narrower detectable gap implies higher temporal resolution in the auditory system. In tasks related to the discrimination of amplitude modulation depth, the threshold for detecting the temporal changes in the amplitude envelope of the stimulus sound is measured. The threshold is then expressed as the temporal modulation transfer function (TMTF), representing the function of modulation frequency. A higher sensitivity of the threshold in TMTF and a wider range signify higher temporal resolution. In tasks related to the discrimination of frequency modulation depth, the threshold is measured to assess the ability to detect temporal changes in the temporal fine structure (TFS) of the stimulus sound. Therefore, a broader frequency modulation frequency shift implies higher temporal resolution.

As a result of investigating the relationship between indicators of temporal resolution obtained through measurement experiments and the characteristics of otoacoustic emissions, it was found that there is a significant correlation between the peak sensitivity of TMTF and the peak level of otoacoustic emissions. While there are no significant correlations between other combinations of them. Therefore, it suggests that the peak sensitivity of TMTF can be only estimated by using the peak level of otoacoustic emissions.