Study on detectability of target signal in background noise by utilizing differences between movements in temporal envelopes of target and background signals

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Audible alarm signals are used to attract the attention of people in many everyday activities, e.g., the beeps and melodic sounds of electronic products that alert us of providing start and end times and the sounds of fire alarms in emergencies. Therefore, these signals must be perceived accurately and efficiently by everyone. Alarm signals with many different stimulus signatures have been studied for this purpose to check if they can be adequately perceived, e.g., by Mizunami *et al.*. There are, however, cases where alarm signals cannot be correctly perceived in real environments because they are masked or partially masked by background noise, and only the person they are intended for knows when and what events have occurred. Therefore, it is important to present alarm signals in such a way that they can be correctly detected in any environment. Here, we can replace the detectability of target signals with auditory search tasks.

Asemi *et al.*, in a study that had a close relationship to ours, carried out research on auditory search tasks. Narrow-band noise and pure tones were used and temporal fluctuations in the target were controlled in their experiments as cues to investigating improvements in the detectability of

target signals. Their results indicated that temporal fluctuations in the target against background signals played a role in improving detectability. Based on their results, Kusaba *et al.* investigated how much temporal fluctuations between the target and background signals could improve detectability of the target signal in auditory search experiments. Their results suggested that less similarity in temporal fluctuations between the target and background signals could improve the detectability of the target in noisy environments. However, as they used directed narrow-band noise as stimuli in their experiments, the temporal fluctuations were not controlled. Thus, it was still unclear what characteristics of the movements that could contribute to the improvement were.

In this study, we investigated whether difference between movements in temporal envelopes of the target and background signals could improve the detectability of target signal against background signals. The movements in the temporal envelopes of signals were defined as the mean value of slopes, i.e., the first-order approximation of the temporal envelopes. The movements were systematically controlled by band-pass filtering on the modulation spectrum of the signals. The movements tended to increase as the center frequency of filter increased and/or bandwidth of them widens.

Auditory search experiments (I) were conducted to investigate the detectability of targets with regard to movements in temporal envelopes. In the Auditory search experiment (I), The movements that we used in the experiment were 44, 154, 264, 374, 484, 594, and 704 mV/s. The movements of target signals were set at 264, 374, 484 mV/s. The movements of background signals in each target were set to be different from the movements between target and background signals. Stimuli were composed of different temporal envelopes with a noise carrier. 1/2-octave band-noise as a carrier was used in which the center frequency of the carrier was 1380 Hz. The results obtained from auditory search experiments demonstrated that the detectability of each target signal could be improved when the movements of the target and background signals differed. The results revealed that the difference in the movements of the temporal envelopes of signals affected the detectability of the signals.

Auditory search experiments (II) were conducted to investigate the detectability of targets with regard to movements in temporal envelopes and

center frequencies of carriers for perception of alarm signals in real environments. In the Auditory search experiment (II), Stimuli were generated by multiplying one of three processed temporal envelopes (movements of 88, 700, and 1313 mV/s) with one of three different noise carriers (1/2-octave bandwidth at the center frequencies of 200, 525, and 1380 Hz). The results showed that the detectability of target signal could be improved as the difference of the movements increases, in which the center frequency of target signal was the same as that of the background signal. This tendency constantly appeared when the movement of the target signal was faster than that of the background signal. These results suggest that greater difference of the movements improves the detectability of the target signal.

These results also suggest that the detectability of alarm signals can be improved by utilizing differences between movements in temporal envelopes of alarm signal and background noises in real environments.