A study on detectability of target signal in background noise by utilizing similarity of temporal envelopes in auditory search

Misa Kusaba (0610033)

School of School of Information Science, Japan Advanced Institute of Science and Technology,
Japan Advanced Institute of Science and Technology

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1 Introduction

Audible alarm signals are used to attract the attention of persons in many everyday activities, for example, the beeps and melodic sounds of electronic products and fire alarm sounds for emergency. These signals need to be perceived accurately and efficiently by everyone. Interference is, however, produced through the masking effects by environmental noises so that this can drastically reduce detectability of alarm signals. Therefore, there is an important issue for presenting alarm signals in such a way that they can be correctly detected in any environments. It is well known that the ability to detect a target sound in the presence of noise could be improved by utilizing directional information such as interaural time difference (ITD) and interaural phase difference (IPD). We have previously studied whether spatial cues, ITD and IPD, strongly affects the improvement in detectability of alarm signals in noisy environments. Their result suggests that the difference in signal direction influences the perception of alarm signal. One the other hand, Asemi et al. studied whether the target signal against

background signal can improve detectability of the target signal via auditory search experiments. In their experiments, narrow-band noise and pure tone were used and temporal variation of the target was as a cue controlled to investigate improvement detectability of the target. Their result conduced that temporal variation of the target signal against background signals plays a role of the improvement in detectability of the target signal while no variation of the target does not do it. From their results, it can be interpreted that effective temporal variation of the alarm signal plays the same role of improvement in detectability of target alarm signals in noisy environments. However, in their experiments, target signal with temporal variation to stable noise (no fluctuation) or target signal without temporal variation to fluctuation noise was only used so that it is not clear how temporal relation between target and background affects the improvement in detectability of the target.

2 Design of Experiment

In other related studies, there are, for example, auditory search tasks, studied by Asemi *et al.*. They studied whether the target signal against background signal can improve the detectability of the target signal via auditory search experiments. In their experiments, narrow-band noise and pure tone were used and temporal variation of the target was controlled as a cue to investigate improvement of the target signal detectability. Their result conduced that temporal variation of the target signal against background signals plays a role of the improvement in the target signal detectability while no variation of the target signal against background signals does not do it. Let us, for example, consider a general problem of selective listening of the target sound in the case of sound mixtures. Here, the sound of alarm signal as the target and a white noise as background are mixed together under unpredictable conditions. Here, we assume that the task is to try to selectively hear a target sound from among the mixed sound under noisy conditions. This is the same task (SRM). In this task, we can easily selectively listen to the target sound if we know what the target is or if we can use robustly spatial cues (ITD and ILD) in noisy environments. We can also interpret this task as the auditory search problem that percept the alarm signals in noisy environments when any sound is not anchored

in position. Our approach is thus motivated that the results of Asemi *et al.* may be able to play a role of the improvement in the target signal detectability in noisy environments.

3 Condition *I* of experiments

3.1 Purpose

The aim of this work is to investigate how much can the temporal relation between target and background improve detectability of the target signal in auditory search experiments.

3.2 Prosedure

In these experiments, pure tone, 1/2-oct., 1/8-oct., and 1/32-oct. band noises were used as stimuli (target and background noise). Correlation between the target and background was used as measure of similarity. Signal frequencies of pure tones and center frequencies of band noises were set to be 200 Hz, 525 Hz, and 1380 Hz. Frequency difference between pure tone and narrow band noise was over 1 octave frequency. Sampling frequency of 20 kHz was used. Duration of stimuli was 3 sec. A sound stimulus was presented to subject via headphones. The subjects were required to press the left button on the response box when the target was presented and the right button when it was no presented. A subject reaction was recorded using the response box. Three subjects were participated in our preliminary experiments. As preliminary experiments, the results showed that low correlation between target and background signal tends to improve detectability of the target against background noise. This result suggests that the difference in similarity of temporal envelopes influences the perception of alarm signals.

3.3 Stimuli

In these experiments, stimulus were used a sinusoidal signal (pure tone: PT) and six band-limited noise (BLN) signals: (i) 1/2-oct., (ii) 1/4-oct., (iii) 1/8-oct., (iv) 1/16-oct., (v) 1/32-oct., (vi) 1/64-oct. band noises. Center frequencies of the six BLNs were as the same signal frequency of

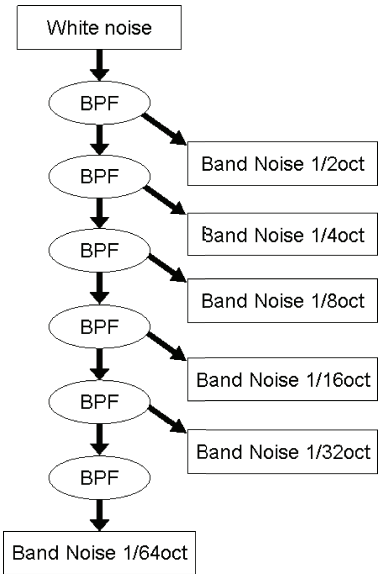

Figure 1: Stimulus generation.

the PT signal. Three signal frequencies of PTs, 200, 525, and 1380 Hz, were used. Each set of the six band-limited noises was created by using bandpass filters (BPFs), as shown in Fig. 1.

We assumed that a specific signal frequency of PT is f_m Hz. PT with f_m and six BLNs, centered at f_m, were used as the target signal. It means the seven targets were used. At this condition, if signal frequency f_m is 525 Hz, there are still twenty-four other signals (each BLNs centered at $f_m = 200$ and $f_m = 1380$ Hz). These were used as background. There are 21 stimuli we used as target. Thus, there are 20 combinations between target and background signals, for each target. There are 21 ($= 3 \times 7$) targets so that the total numbers of pairs of target and background is 420 ($= 21 \times 20$) combinations.

3.4 Apparatus and procedure

The experiment was carried out in a sound-proof room. Stimulus were presented to each subject trough head-phones (Sennheiser HDA200) while the subject was operating the response box. The subjects were required to judge whether there is a target in background. The response box has two buttons: one is for "true" and another is for "false". There are two kinds of judgments: positive and negative judgments. In the positive judgment, when a target signal and a background signal were presented head-phones,

they are requested to press “true” or “false” button on the response box. In the negative judgments, when only background signal was presented, they are requested to press “true” or “false” button on the response box. In all sessions, reaction time was recorded on the system.

In auditory search tasks, training sessions were held prior to each session. The training was ended when the subject decided to stop their training. In all task sessions, stimuli were presented randomly. The same session was repeated by the four times. In these sessions for all tasks, while errors (false-alarm errors) observed in the sessions proper, no upper limit for cancellation of a session was applied.

In the auditory search tasks, three normal hearing subjects were participated. One of the subjects was an author of this paper. All subjects were given, at least, two hours of practice.

3.5 Result

When “a pure sound and narrow-band noise” subject, the result is in agreement with Asemi et al. And, for gwide similarity variationh subject, reaction time obtained from positive judgment and negative judgment tends to increase as similarity increases. It means that the subject can easily detect the target against background.

3.6 Conclusion

In this paper, the auditory search experiments were carried out using temporal fluctuation of signals. we found that reaction time in lower similarity between the temporal envelopes of the target and background signals tends to decrease. It suggests that the target signal detectability against background noise can be improved as similarity decreases. This result also suggests that the difference in similarity of temporal envelopes influences the perception of a target signal in noisy environments.