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A study on the precedence effect in various background sounds

FUJIKAWA Takahiro, AOKI Shigeaki

Kanazawa Institute of Technology, Ishikawa, Japan

PACS: 43.66.Qp Localization of sound sources

ABSTRACT

In this paper, we investigated the precedence effect in combination of four signals and three background sounds with three level differences between the signal and background sound.

In subjective tests, four signals were male voice, female voice, siren tone and sweep tone. Three background sounds were recorded in a mall, a hotel and a corridor of school. The durations of signals were 3-8 seconds. The background sound started two seconds before the head of the signal and stopped two seconds after the tail of the signal. The level differences between the signal and background sound were -6, 0 and +6 dB. The test signals were created on the assumption that a direct sound and the first reflective sound surrounded by non-directional background sound. The direct signal and the first reflective signal came from loudspeakers that were set at the 45 degrees point left and right from the median plane of a listener, respectively. Not only direct signal from the loudspeaker to the listener but also crosstalk-signal from the opposite loudspeaker to the listener were calculated using HRTFs (Head related transfer function). The distance between the loudspeakers and the listener was 1.4 m due to measurement condition of the HRTF. The delay time of the first reflective signal were changed from 0 to 80 ms in twelve steps. Non-directional background sound was designed that background sound was radiated from 36 loudspeakers arranged at equal intervals on the circumference of 1.4 m in radius and was calculated using the HRTFs. One listening session consisted of five trials in each delay time. The kinds of delay times were twelve. The listeners randomly listened to a test signal 60 times in each session. There were three sessions for each condition. Two males in age of twenties took part in the tests.

The subjective test showed that the level difference between the signal and background sound and the combination of signal and background sound contributed to the direction of sound localization when the precedence effect occurred. Moreover, the combination of signal and background sound influenced the stability of sound localization. The female and male voices showed the almost same tendency, however, non-voice signals, that is, siren tone and sweep tone showed the different tendency from the voices. It was confirmed that when the precedence effect occurred in background sound, the complicated structure of signal had an effect on the degree of the occurrence.

1. INTRODUCTION

When we localize the direction of a sound source in an environment with reflective sounds, information of the direction on the sound that reaches the listener first contributes to the localization predominantly [1]. Since the sound image is localized in the direction of the direct sound that reaches the listener first, this phenomenon is called the precedence effect [2]. Moreover, the time delay (ITD: Interaural Time Delay) and the level difference (ILD: Interaural Level Difference) between sounds of the left and right ears contributes to the localization of the sound image greatly [3]. HRTFs (Head related transfer functions) consist of the information of ITD and ILD.

We have investigated the precedence effect in an environment with reflective sounds to realize an emergency alert public system. So far, we conducted subjective tests to make clear the occurrence and disappearance of the precedence effect under single background sound, in which the delay time between the direct and reflective sounds was varied. [4].

In this paper, we conduct subjective tests to investigate the precedence effect in combination of four kinds of signals and three kinds of background sounds by setting three level differences between the signal and background sound. Moreover, we discuss the test results in terms of the occurrence and disappearance of the precedence effect.

2. SUBJECTIVE TESTS

In subjective tests, the four kinds of signals were male voice, female voice, siren tone and sweep tone. Three background sounds were recorded in a mall, a hotel and a corridor of school. The durations of signals were 3-8 seconds. The background sound started two seconds before the head of the signal and stopped two seconds after the tail of the signal. The level differences between the signal and background sound were -6, 0 and +6 dB. The image of test sound is shown in Figure 1.

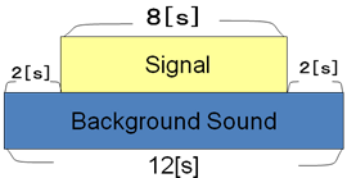

Figure 1. Example of relationship between signal and background sound (Voice).

The direct signal and the first reflective signal came from loudspeakers that were set at the 45 degrees point left and right from the median plane of a listener, respectively. Not only direct signal from the loudspeaker to the listener but also crosstalk-signal from the opposite loudspeaker to the listener were calculated using HRTFs (Head related transfer function). We used the HRTFs which MIT Media Lab offers. The distance between the loudspeakers and the listener was 1.4 m due to measurement condition of the HRTFs. The delay time of the first reflective signal were changed from 0 to 80 ms in twelve steps. The relationship between the direct and crosstalk signals was shown in Figure 2.

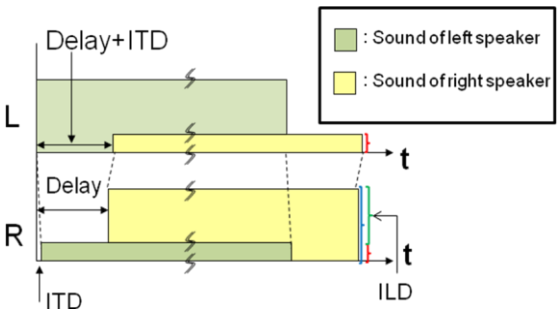

Figure 2. Relationship between left and right signals including crosstalk-signals.

Non-directional background sound was designed that background sound was radiated from 36 loudspeakers arranged at equal intervals on the circumference of 1.4 m in radius and was calculated using the HRTFs. The image of background sound is shown in Figure 3. The test sounds were created on the assumption that a direct signal and the first reflective signal surrounded by non-directional background sound. Since power of signal was different in each delay time, the signal power was equalized in using the signal to background sound ratio.

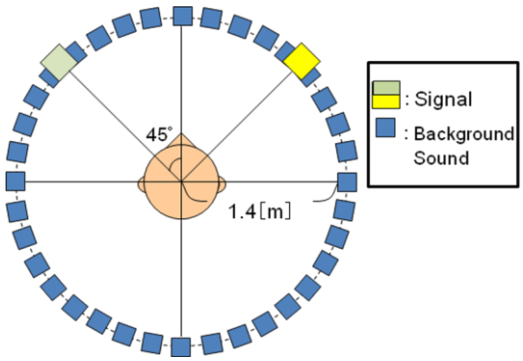

Figure 3. Arrangement of 36 loudspeakers when non-directional background sound was designed.

Listeners listened to the test sound from the personal computer in an anechoic room using the headphone of Sony-Z900HD. In order for the listener to check the localized direction of sound images, before listening test sound, the listener tried listening to the sample signals whose sound localization was designed to be centre, right and left directions. One listening session consisted of five trials in each delay time. The kinds of delay times were twelve. The listener randomly listened to test sounds 60 times in each session. There were three sessions for each condition. Moreover, the sequence of the test sound was in random. Two males in age of twenties took part in the tests.

The directions of sound image localization were answered using -2, -1, 0, +1 and +2. They were defined as left, middle-left, centre, middle-right and left directions, respectively.

3. RESULTS AND GENERAL DISCUSSION

3.1 INFLUENCESOF LEVEL DIFFERENCE BETWEEN SIGNAL AND BACKGROUND SOUND

The influences of the level difference of signal and background sound to the occurrence and disappearance of the precedence effect are investigated by comparing test results with three patterns of 0 and ±6 dB. The test results are shown in from Figure 4 to Figure 15.

When the level of the signal became large in comparison with the background sound, the tendency was that the sound images were localized on left-hand side more. On the other hand, when the level of the signal became small in comparison with the background sound, the tendency was that the sound images were localized toward the centre side. This tendency was remarkably shown in the case of the siren tone.

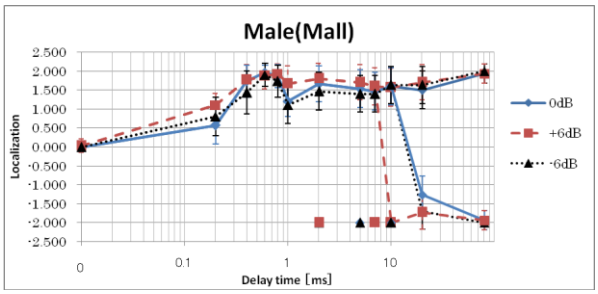

Figure 4. Localization in each level difference of the signal (Male voice) and the background sound (Mall).

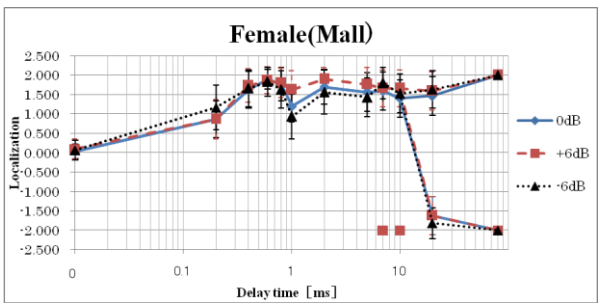

Figure 5. Localization in each level difference of the signal (Female voice) and the background sound (Mall).

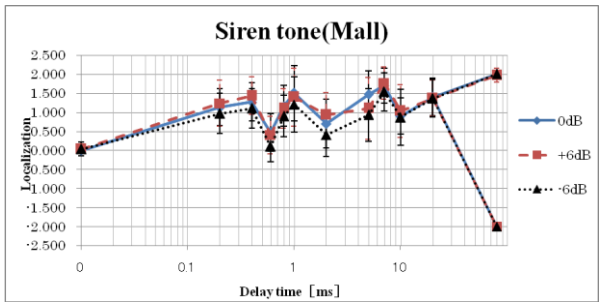

Figure 6. Localization in each level difference of the signal (Siren tone) and the background sound (Mall)

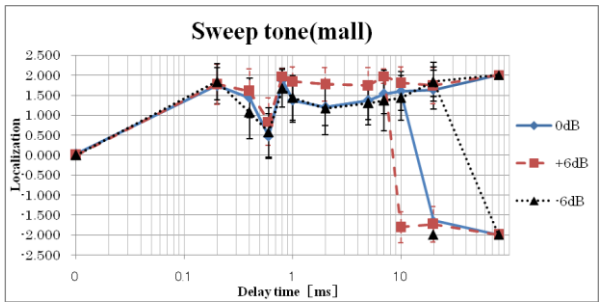

Figure 7. Localization in each level difference of the signal (Sweep tone) and the background sound (Mall).

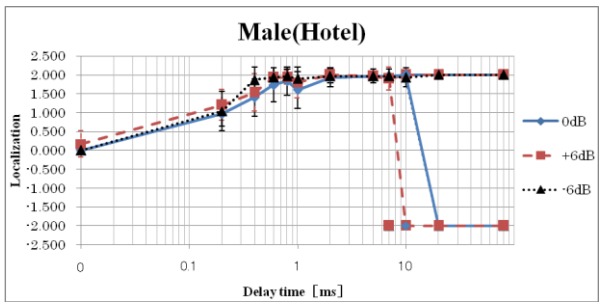

Figure 8. Localization in each level difference of the signal (Male voice) and the background sound (Hotel).

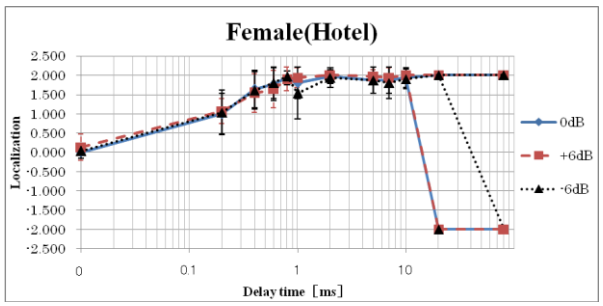

Figure 9. Localization in each difference of the signal (Female voice) and the background sound (Hotel).

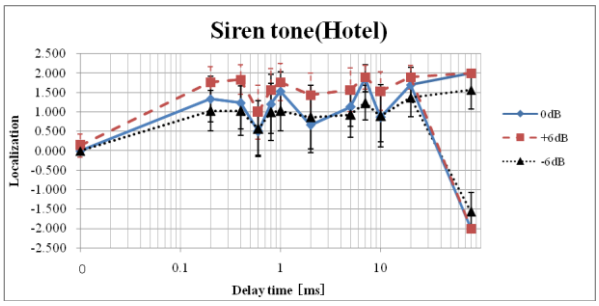

Figure 10. Localization in each level difference of the signal (Siren tone) and the background sound (Hotel).

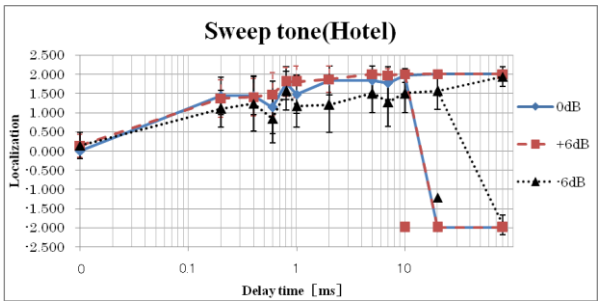

Figure 11. Localization in each level difference of the signal (Sweep tone) and the background sound (Hotel).

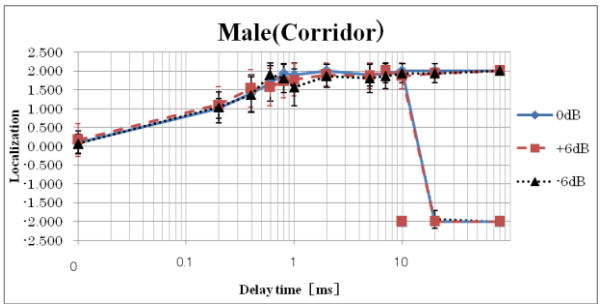

Figure 12. Localization in each level difference of the signal (Male voice) and the background sound (Corridor).

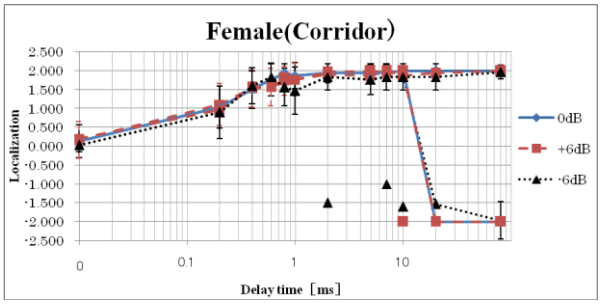

Figure 13. Localization in each level difference of the signal (Female voice) and the background sound (Corridor).

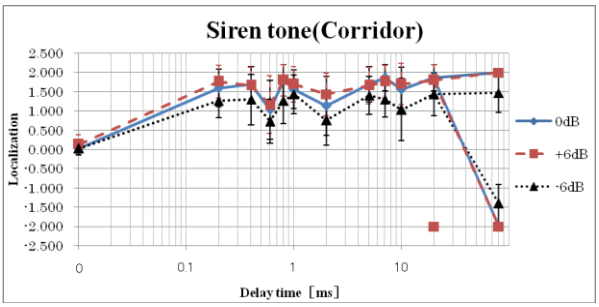

Figure 14. Localization in each level difference of the signal (Siren tone) and the background sound (Corridor).

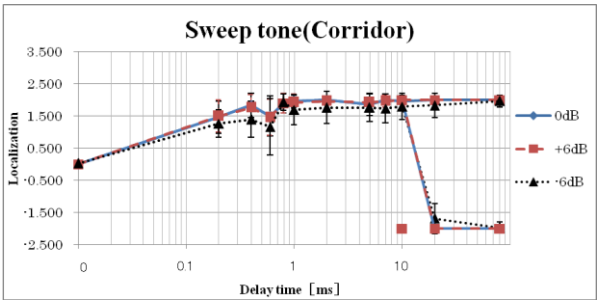

Figure 15. Localization in each level difference of the signal (Sweep tone) and the background sound (Corridor) .

3.2 LOCALIZATION OF EACH SIGNAL UNDER THE SAME BACKGROUND SOUND

The influences of the kinds of signal and back-ground sound to the occurrence and disappearance of the precedence effect are investigated by comparing test results with four kinds of signals, that is, the male voice, female voice, siren tone and sweep tone when background sound is fixed. Moreover, test results are shown in from Figure 16 to Figure 18.

It was found that the tendency of male voice and female voice were similar in terms of the normal localization and the separated localization. On the other hand, it was found that non-sounds such as the siren tone and sweep tone showed peculiar tendencies respectively. Compared with other signals, the localization of siren tone for every delay time was unstable. Moreover, delay time for the separated localization was longer than other signals. The localization of sweep tone for short delay time was unstable. However, when delay time became longer than 0.8 ms, the tendency of the sweep tone was similar to that of the male and female voices.

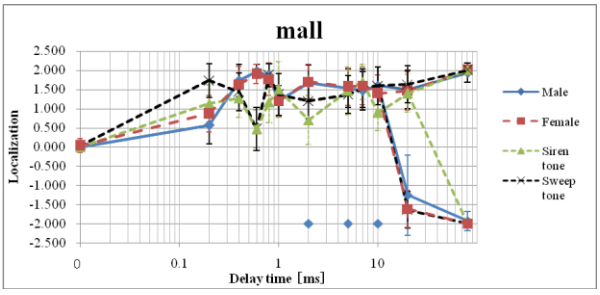

Figure 16. Localization of each signal in the background sound (mall).

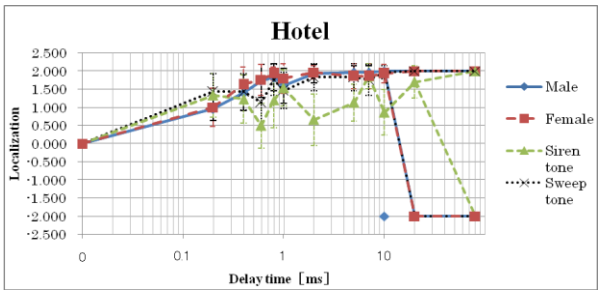

Figure 17. Localization of each signal in the background sound (Hotel).

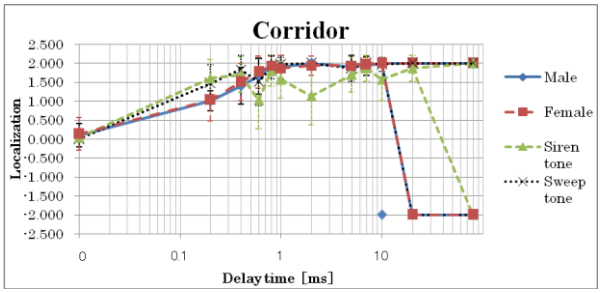

Figure 18. Localization of each signal in the background sound (Corridor).

3.3 INFLUENCES OF BACKGROUND SOUND TO LOCALIZATION OF SIGNALS

When the kind of signal was fixed, the influence of three kinds of background sounds to the occurrence and disappearance of the precedence effect were investigated. The three kinds of background sounds were recorded in a mall, a hotel and a corridor. The spectrograms of the background sound are shown in Figure 19. The test results are shown in from Figure 20 to Figure 23.

Test results show that the tendencies of the background sound of hotel and corridor were very similar. However, it was found that the width of sound localization in the background sound of the mall was a little narrower. Moreover, the tendencies of male and female voices showed the same. Although the widths of sound localization of non-voices, that is, the siren tone and the sweep tone were a little different, the patterns of sound localization were almost the same. Especially in the case of the siren tone, the localization was very unstable under three kinds of background sound and however the kind of background sound did not influence sound localization. Moreover, the spectrogram of background sound of the mall was steady in comparison with other background sounds. When the spectrogram of background sound was steady, the widths of sound localization of male and female voices and sweep tone were narrow and the sound localizations were unstable.

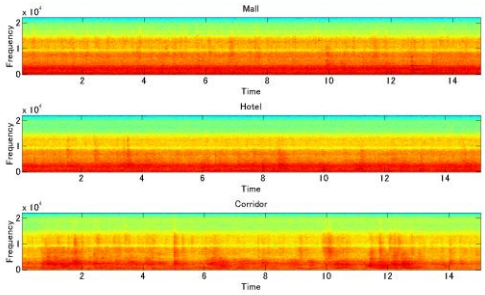

Figure 19. Spectrograms of three kinds of background sounds.

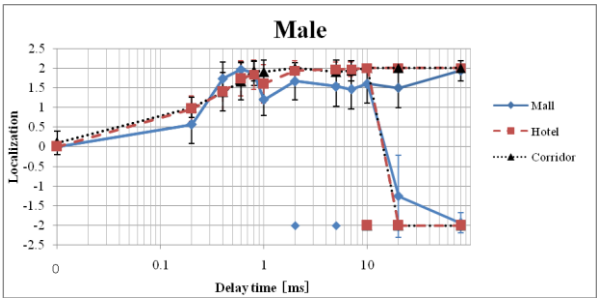

Figure 20. Influence of background sound to the localization of the signal (Male).

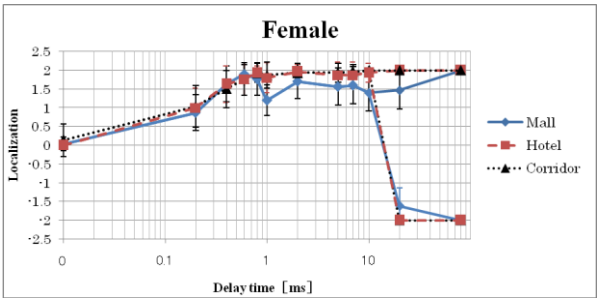

Figure 21. Influence of background sound to the localization of the signal (Female).

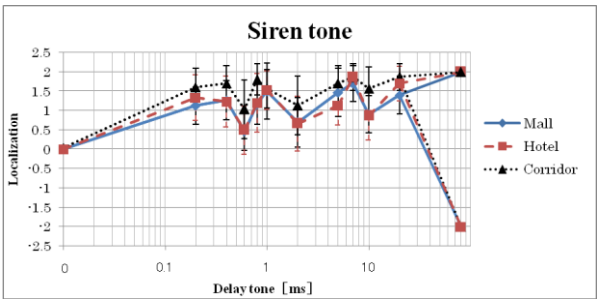

Figure 22. Influence of background sound to the localization of the signal (Siren tone).

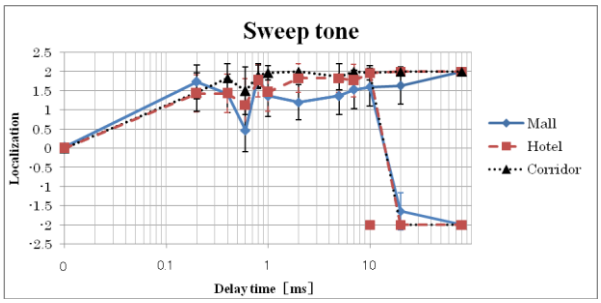

Figure 23. Influence of background sound to the localization of the signal (Sweep tone).

4. CONCLUSION

This research investigated occurrence and disappearance of the precedence effect under background sound from three viewpoints. It was considered that the level between the signal and background sound influenced the width of the sound image localization. Moreover, the difference of the precedence effect between the kind of voices, such as male voice or female voice, was not observed clearly. On the other hand, it was shown that difference of the precedence effect between the voice and the non-voice was remarkable. That is, it was found that the complexity of a signal influenced the precedence effect greatly. Therefore, it is considered that a signal that is divided into the syllables like a voice is suitable for signal that the precedence effect occurs steadily. Moreover, it was found that the localization of a sound image was affected more strongly when spectrogram of background sound was steadier. Furthermore, it was confirmed that the width and stability of the sound image localization were influenced by the kind of background sound and the combination of a background sound and a signal.

5. REFERENCES

1 M. B. Gardner, “Historical background of the Haas and/or precedence effect”, J. Acoust. Soc. Am. 43, 1243-1248 (1968).

2 H.Haas, “Über den Einfluss eines Einfachechos an die Hörsamkeit von Sprache”, Acustica 1, 49-58 (1951).

3 Blauert,J.”Spatial Hearing”, Kashima Publication meeting ,54-126, (1986).

4 Takahiro Fujikawa, Sigeaki Aoki, “A study on the precedence effect in various background sounds”, Proc. of Autumn Meeting of the Acoustical Society of Japan, 555–556(2009).