

AN ANALYSIS OF SOUND LOCALIZATION PERFORMANCE PROVIDED BY THE PRESENT SOUNDS OF AUDIBLE TRAFFIC SIGNALS FOR VISUALLY IMPAIRED PEDESTRIANS

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SUMMARY

In order to improve present sonic guidance systems used at intersections by vision impaired pedestrians traveling alone, we adopted multiple speaker systems, putting two speakers at the destination of crosswalk, instead of a single speaker. Using this system that may provide more precise navigational clue than before, we have analyzed the sounds of present audible traffic signals (ATS) from the points of view of accuracy of sound localization capability and simplicity of discrimination. Two simulated bird songs, a chirp and a cuckoo, which are widely used in Japan for ATS and brief gaussian noise sounds were presented in front of the subject. A pair of the one of three sounds was presented from the two speakers placed in front of the subjects. To assess the spatial resolution capability of the subjects, the distance between the speakers was changed systematically, and the subject reported if the sound source consisted of the one speaker or the two speakers. The results showed that the discrimination performance was the best for brief noise sounds, poor for cuckoo sounds, and bad for chirp sounds. For example, when the angle between two speakers was set at 7.6 degree, the rate of correct answer for two consecutive sound signals of brief noise, cuckoo and cheep sounds were 86.4, 36.4 and 27.3 percent, respectively. To obtain more than 85% discrimination performance, 15.2 and 22.6 degrees were necessary for cuckoo and cheep sounds, respectively. The results of simplicity of discrimination showed that brief noise was the simplest, cuckoo sound was second. It was suggested that the sounds of present ATS were not suitable in our multiple speaker system for providing reliable navigational clues to users since very wide distance between two speakers is necessary to obtain sufficient spatial resolution.

INTRODUCTION

ATS has been used at crosswalks for about 35 years in Japan to assist visually impaired persons' mobility. ATS is well known as a classic assistive equipment for vision impaired persons traveling on their own, and they are used worldwide. Through recent research, however, it has become evident that the only function of these very widely used ATS is to inform visually impaired pedestrians steady green walk signal phase [1,2]. Since they do not possess features for indicating the direction to cross, vision impaired pedestrians must experience considerable stress to find clues for orientation taking [2]. Without the clues they

might encounter dangers during crossing and experience difficulties to finish crossing. For this reason serious consideration must be taken when we proceed with future installation to improve the present ATS to incorporate navigational features.

Recently, a new type of audible traffic signal using a pair of speakers has been developed and is now actually being used at crosswalks in Japan [3,4,5]. This new type of ATS alternately emits different sounds from speakers located on both sides of a crosswalk, in contrast to conventional ATS that emits the same sound simultaneously from two speakers. With this new sonic guidance system it become possible to provide vision impaired pedestrians clues to help them to take the direction in which they should start before they cross the street and to confirm their position and make any necessary adjustments while they are crossing. With this sonic guidance system using a pair of speakers, pedestrians are able to localize the sound sources all the way along crosswalk as long as they highly concentrate to localize sound sources on both side of the crosswalk. However, localizing sound sources is sometimes not feasible because it is difficult to deal with the effect of environmental noise and acoustic reverberations generated by many environmental factors.

It seems necessary to develop a sonic guidance system to inform pedestrians about reliable direction clues by some means. Therefore, we tried to adopt two pairs of speakers instead of a pair of speaker as is used in present ATS system. In this new system, two speakers are located on both sides of a crosswalk and sound signals are emitted alternately from two speakers placed side by side. In this system, directional cues provided by two pairs of speakers are supposed to be stronger than that of one pair of speakers against environmental noise as well as sound reflection. Our previous study demonstrated that the sonic guidance system using multiple speakers has a potential to provide two dimensional localization cues with simplicity [6]. Although it is desirable to use present ATS sounds for new guiding system using two pairs of speaker, no evaluation has yet been made in relation to spatial resolution capability using those sounds. Previous studies of sound localization reported that localization performance was excellent for brief gaussian noise sounds presented in front of the subject [7]. However, if sounds are filtered to reduce the width of the spectrum, they result in illusions of sources that are different from the actual locations [8].

In this study, we analyzed spatial accuracy of sound localization capability and simplicity of discrimination given by the presently used ATS sounds and by gaussian noise. We found that the spatial resolution obtained by the ATS sounds was inferior to that obtained by gaussian noise sound. It appeared that the sounds of present ATS were not useful in intersection having longer crosswalk because those sound only provide poorer spatial resolution even at unrealistically wider frontal speaker distance.

RESEARCH METHODS

A. Subjects

Experiments were conducted with 22 subjects, 8 male and 14 female, aged 20-38 years. Subjects wore an eyemask during the experiment. All subjects had no known audiological deficits, and this was the first experience for psychophysical acoustical experiment for all of them.

B. Apparatus and sound signals

Experiments were conducted in a semi-anechoic room (6.45 x 7 x 3-m). Sound signals were presented through two speakers (Tannoy, model CPA 5) in each trial. In one trial, the

same sound signal was presented twice. Each sound signal was generated on the left speaker first. After 0.4s delay, the second sound signal was generated on the right. The speakers were placed in front of the seated subject on a chair at a distance of 6m (Fig. 1). Two speakers were put side by side on a straight line parallel to the subjects. The distance

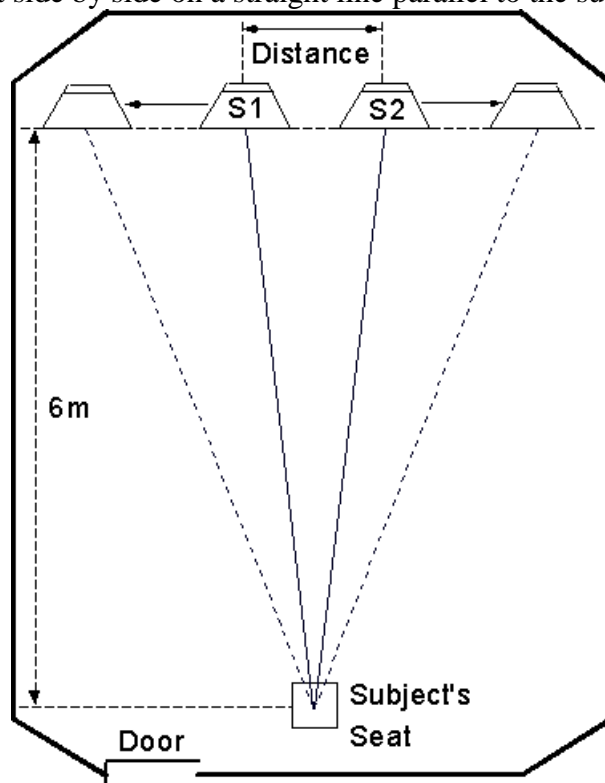


Figure 1 Schematic drawing of the analyzing system of sound localization performance. The subject was seated in front of the speakers (S1 and S2) at a distance of 6m. The distance between the two speakers ranged from 40cm to 440cm, corresponding to the angle between the speakers to the subject from 3.8 to 40.3 degrees. Distinguishable angles of each sound were measured when each of gaussian brief noise sounds, cuckoo sounds and chirp sounds were presented through both of two speakers alternately.

between two speakers was changed by 40cm step from 40 to 440cm keeping them parallel. The height of the speakers was fixed to 1.1m.

Sound signals were synthesized and generated digitally with an acoustic workstation (Cameo Interactive Co., model DPP200). The workstation consists of a Power Macintosh computer with an interface card, an A/D and D/A converter (Digidesign, model 882 I/O audio interface), and audio control software (Digidesign, ProTools). Using the acoustic workstation, it is possible to generate 1-8 multiple sounds (1-8 channel) independently through speakers at random timings. The sounds used in the experiments were brief (150ms) white noise, or sounds with audible traffic signals in use in Japan (2 simulated bird sounds, a cuckoo and a cheep). The main frequency of the cuckoo and cheep sounds is 1.6kHz and 2.5kHz, respectively. Sound level was adjusted to 67 dB in each speaker by using a sound-level meter (Rion, model NA-23).

C. Experiment Procedure

Each subject blindfolded was seated, with his/her head toward the center of the two speakers. A pair of sounds (gaussian noise and two simulated bird sounds) was presented through both of two speakers consecutively, and the distance between the speakers was changed in each trial in ascending order. At the beginning of the experiment subjects were exposed to examples of the three sounds.

The subject was instructed to discriminate the location of each sound sources by answering whether two sounds come from the same or different sources together with confidence grades of discrimination. Confidence scale ranged from one to four, one as very weak and four as very strong. This is introduced to evaluate not only accuracy of the spatial resolution capability but also simplicity of sound discrimination. The distance between the two speakers ranged from 40cm to 440cm and this range corresponds to the angle between the speakers to the subject from 3.8 to 40.3 degrees. Each experimental session consisted of eleven patterns of speaker location. Subjects completed three sessions, and in each session the presented sound signals were chosen from the three kinds of the sounds in turn.

RESULTS

Each of gaussian brief noise sounds, cuckoo sounds and chirp sounds were presented through both of two speakers alternately. The distance between the speakers was changed to find distinguishable angles between the two sound sources. Distinguishable angles of each sound may be interpreted as a measure of resolution of sound localization capability of the subjects. To evaluate simplicity of sound source discrimination of each sound, confidence grade was taken in each trial. Confidence grade of each sound could be interpreted as a measure to estimate of simplicity of sound source discrimination.

Distinguishable angles

A. Gaussian noise

Gaussian brief (150ms) noise sounds were examined. The results are shown in Fig.2. When the angle between two speakers was set at 3.8 degree, 36.4 percent of the subjects reported the sound source consisted of the two speakers. When the angle was increased to 7.6 degree, 86.4 percent of the subjects reported the sound source consisted of the two. If the angle was more than 11.4 degree, all subjects reported that the sound source was two. We regarded that most of the subjects (more than 85 percent of the subjects) will distinguish the sound sources at the angle more than 7.6 degree.

B. Cuckoo sounds

Cuckoo sounds were examined in this experiment. As shown in Fig.2, When the angle between two speakers was set at 3.8 degree, 18.2 percent of the subjects reported the sound source consisted of the two speakers. When the angle was increased to 7.6 degree, 36.4 percent of the subjects reported the sound source consisted of the two in contrast to 86.4 percent in brief noise sounds. When the angle was increased to 15.2 degree, 90.9 percent of the subjects reported the sound source consisted of the two. If the angle was more than 26.3 degree, all subjects reported that the sound source was two. Thus the angle more than 15.2 degree, most of the subjects will distinguish the sound sources.

C. Chirp sounds

Chirp sounds were examined in this experiment. When the angle between two speakers was set at 3.8 degree, only 4.5 percent of the subjects reported the sound source consisted of the two speakers (Fig. 2). When the angle was increased to 7.6 degree, 27.3 percent of the subjects reported the sound source consisted of the two. Lower percentage of correct answer was obtained compared to cuckoo sounds with the same angle. When the angle was increased to 15.2 degree, 81.8 percent of the subjects reported the sound source consisted of the two, slightly lower

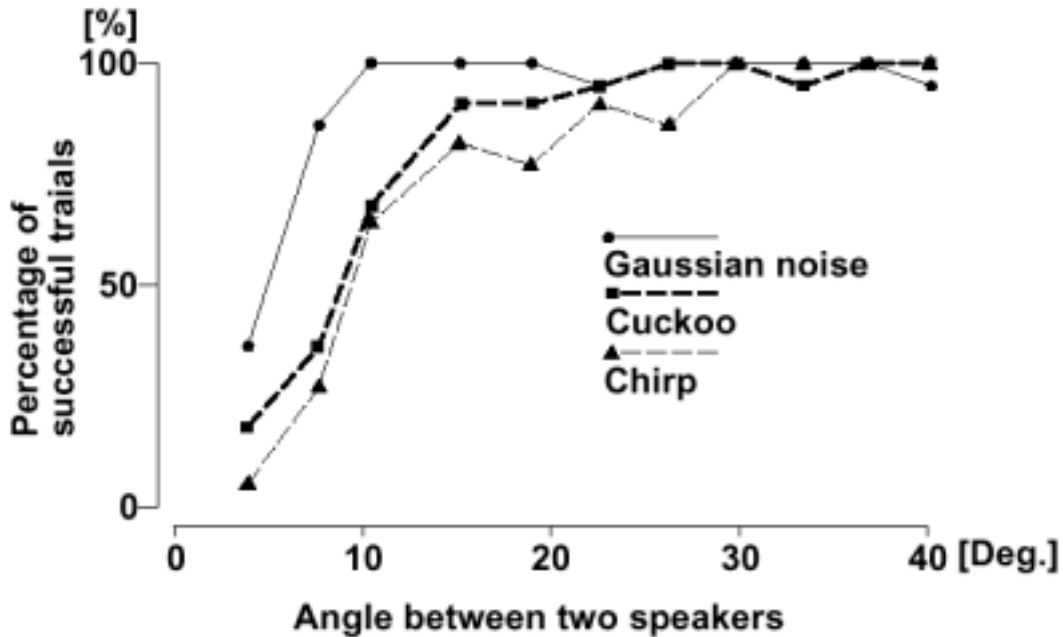


Figure 2 Comparison of sound localization capability when three different sounds (gaussian noise, cuckoo and chirp) were presented from two speakers. Percentages of the subjects, who discriminate the sounds come from different source, are shown as a function of angle between these two speakers. In each trial, signal sound was presented from two speakers at 1.3sec interval.

percentage compared to cuckoo sounds. When the angle was increased to 22.6 degree, 90.9 percent of the subjects reported the sound source consisted of the two. If the angle was more than

29.9 degree, all subjects reported that the sound source was two. Thus the angle more than 22.6 degree, most of the subjects will distinguish the sound sources.

Confidence grades

To evaluate simplicity of sound source discrimination, the subjects were also asked to report confidence level of their judgement on the number of the sound sources. The confidence scale consisted of four grades such as weak, relatively weak, relatively strong, and strong.

As in Fig. 3, with gaussian noise sounds, all of the subjects reported the sound source consisted of the two speakers when the angle was set at 15.2 degree. At the same angle, the percentage of the subjects who answered that the sound source is the two with relatively strong (grade 3) or strong (grade 4) was as many as 86.4. This result indicates that most of the

subjects distinguish the two sound sources without distinct difficulty at this angle. At the same angle, with cuckoo sounds, 90.9 percent of the subjects reported the sound source consisted of the two. However, the percentage of the subject who answered that the sound source is the two with relatively strong (grade 3) or strong (grade 4) confidence was 50. This result suggested that almost the half of the subjects feel much difficulty when they distinguish the sound sources, in contrast to 86.4 percent of the subject under using gaussian noise sounds. At the same angle used above, with chirp sounds, 81.8 percent of the subjects reported the sound source consisted of the two. The percentage of the subject who answered that the sound source is two with relatively strong (grade 3) or strong (grade 4) was only 31.8. This result suggests that almost 70 percent of the subjects feel difficulty when they distinguish the sound sources. After the experiments, we asked the subjects what the simplest sound for discrimination task was. The 65 percent of subjects reported that brief noise sounds were the simplest, the rest of them reported cuckoo sounds were the simplest.

The results of the experiments of distinguishable angles and the distribution of confidence grade for each sound seemed to indicate that the simulated bird sounds used for present ATS were difficult for sound localization compared to gaussian noise sounds.

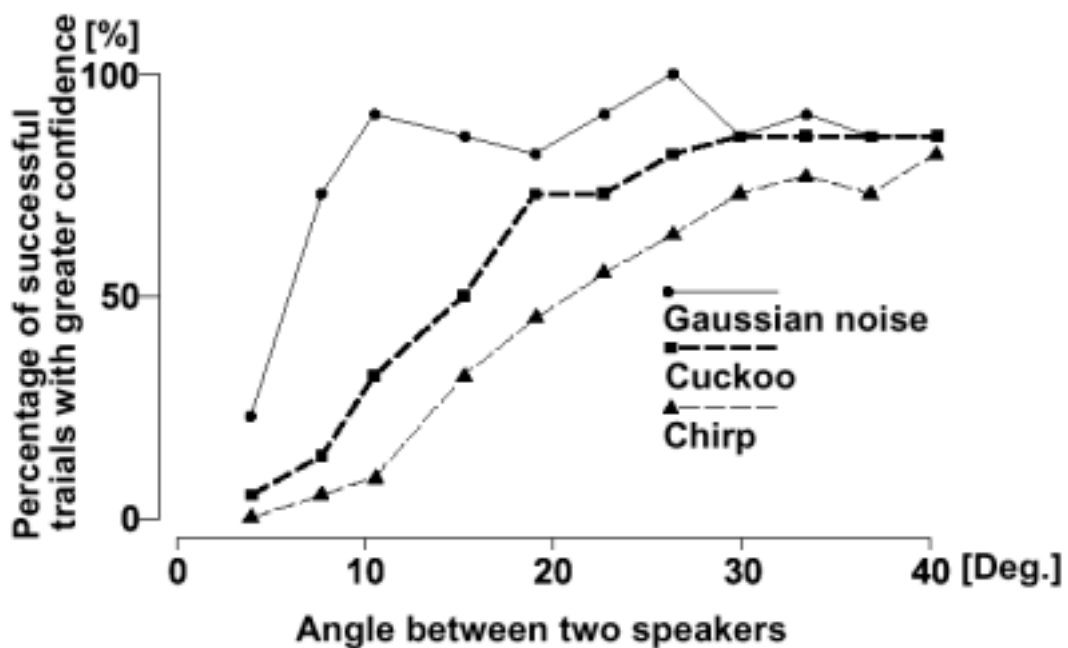


Figure 3 Comparison of sound localization capability with evaluation of confidence grade provided by the three different sounds (gaussian noise, cuckoo and chirp). Percentages of the subjects are shown as a function of angle between the speakers, who discriminate the sounds come from different source with relatively strong (grade 3) or strong (grade 4) confidence. In each trial, signal sound was presented from two speakers at 1.3sec interval.

DISCUSSIONS

Providing appropriate assistance in certain mobility environments is especially important when vision impaired persons are performing tasks that must be completed within a limited amount of time or are navigating dangerous places, such as street crossing, train platform and so on. Sonic guidance, our main focus here, is one of main possibilities to constitute a simple and economical assistance system that can indicate remote environmental objects to vision impaired persons' auditory sense that may substitute their visual or tactile senses at least partially.

A sonic guidance system using two pairs of speaker examined in the present study may provide a reliable way to inform direction to walk to pedestrians. However, if the presently used sound signals for ATS were installed to this sonic guidance system, they requires more than 15 degree of the angle between two speakers in front of the pedestrian to distinguish the sound sources. For example, the width of the two speakers has to be at least more than 5.3m in a 20m length of crosswalk, 8.0m in a 30m length of crosswalk. Only a few crosswalks exists that has more than 8.0m width. Therefore, present sound signals for ATS are not suitable for narrower crosswalks.

One of solutions for this problem is to find or create the sound signals that satisfy the requirement for better sound localization. Previous sound localization studies suggests that the stimuli of frequency is key to promote accuracy of sound localization performance. Thus we must investigate relationship between sound localization performance and sound signal frequency to improve sonic guidance systems. Efforts must be made to find proper sounds for sonic guidance system adopting two pairs of speakers taking adaptability of vision impaired users into consideration.

CONCLUSIONS

The aim of this study was to evaluate the sounds used for present ATS on the point of view of sound localization performance. We characterized the resolution of sound localization capability by measuring the distinguishable angle of sound sources provided by each sound. In addition, we characterized the simplicity of sound discrimination by using confidence grade. It has been suggested that the sounds of present audible traffic signals were not profitable for narrow crosswalks because the present sounds cannot provide enough resolution of sound localization performance. Thus further investigation on relationship between sound localization performance and sound signal frequency is required.

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