

A NEW AUDIBLE TRAFFIC SIGNAL THAT HELPS BLIND PEDESTRIANS TO CROSS INTERSECTIONS BY PROVIDING NAVIGATION CLUES

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SUMMARY

Analysis of the behavior of visually disabled persons crossing intersections equipped with or without audible traffic signal (ATS) showed that the choice of direction is crucial to ensuring a safe street-crossing (1,2). In the present study, we studied whether the sonic patterns generated by presently used ATS assists blind and visually impaired pedestrians to choose directions. A new ATS intended to provide enhanced sonic navigational cues for directional choice was developed and evaluated in comparison with presently used ATS. Present ATS generate tones simultaneously, from a pair of speakers positioned on each end of crosswalk. The new ATS, by contrast, generates sounds alternately, with either the same or different tones from each speaker. Psychological and behavioral experiments indicated that ATS of current design are particularly poor at providing cues that assist persons to choose directions appropriately during the initial half of the distance traversed between paired speakers. On the other hand, the newly designed ATSS (those producing sounds alternately) appeared to generate a navigation cue that is useful across the full length of the distance traversed. A functional difference between two alternate ATSS was discussed.

INTRODUCTION AND PURPOSE

The primary purpose of an audible traffic signal (ATS) is to provide information about the status and relative position of pedestrian light signals to blind or visually impaired pedestrians who walk alone. The first ATS in Japan was installed in 1964 in Tokyo area (3). Thereafter the number of ATS increased continuously, with about 9 thousands ATS now installed throughout Japan (4). The type of ATS now used in Japan typically consist of a pair of speakers, located on each end of a crosswalk, that simultaneously emit sounds (melodies or a birdcall) whenever the traffic light signal turns green for that crosswalk. The ATS seems to help visually disabled persons

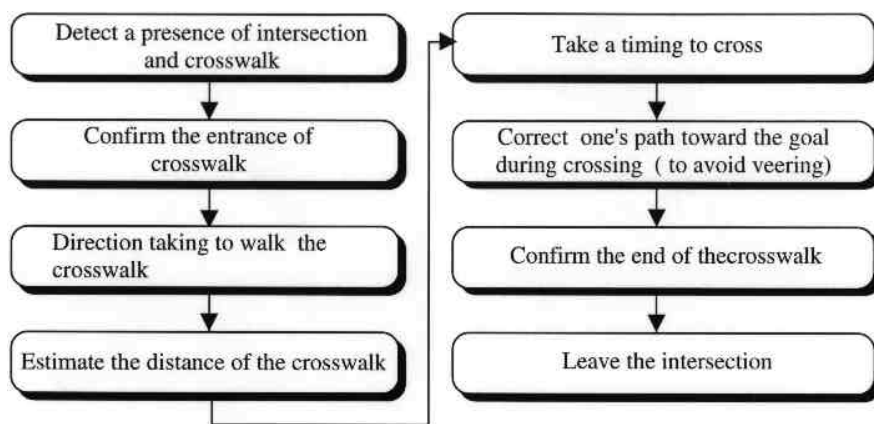


Figure 1. Schematic diagram showing a series of tasks required to visually disabled to cross intersection

travel independently in many respects, by providing an audible signal corresponding to the visible "go" and "stop" signs of a traffic "light" signal (Fig. 1). However, these types of ATS do not necessarily ensure safe, rapid, and accurate crossing of roads because they are functionally limited to informing when it is safe to walk. The use or design of audio signals to provide information about direction -- to orient visually disabled persons -- has yet to be regarded specifically or sufficiently. Our past survey of visually disabled solo travelers demonstrated that they still have trouble crossing intersections equipped with an ATS. One of their complaints about ATS was that the sound from speakers on the far side of the street being crossed was barely audible (5). This suggests that ATS systems may not provide sound cues that are sufficient for appropriate determination and selection of directions. Given the lack of other clues to orientation, it is important to evaluate whether present ATS speakers provide sounds that enable a person to direct themselves, from the moment they step into a crosswalk until they finish crossing it. During this entire time, it is fundamentally important for blind pedestrians

crossing the roadway to be oriented toward the end of the crossing. If presently used ATS systems do not fill this need, we are obliged to consider other means to provide reliable directional information. In the present study, we evaluated three different kinds of ATS in terms of the orientational clues they provide to visually disabled users at various distances between two speakers. They were the present form of ATS that emits sound simultaneously (referred to hereafter as the "simultaneous sound" pattern), one newly developed ATS that emits the same sound alternately (referred to hereafter as the "alternate same sound" pattern), and another type of newly developed ATS that emits two different sounds alternately (referred to hereafter as the "alternate different sound" pattern) respectively. The latter two ATS were developed with the intention of enhancing sound clues for orientation.

EXPERIMENTAL METHODS AND MATERIALS

SUBJECT: Twelve blindfolded (but sighted) and one totally blind subjects participated in the present experiments. Ten of these subjects participated in experiments #1 and #2; the other 3 subjects participated in experiment #3). Four of the subjects were males.

ATS: The sounds for these experiment were made by an audio-workstation (ProTool III, Digidesign) and generated through speakers (Koito Industry, 21 type). This system allowed the repetition rate, duration, volume, and other properties of the sound emitted from each speaker to be controlled separately. The sound patterns that characterize each of the three different ATS -- simultaneous sound, alternating same sound, and alternating different sounds -- were created and recorded in computer memory. Sound signals were emitted at a frequency of 0.7 Hz. Volume was set to 65 dB at a distance of 1 m from the speaker. For the alternating sounds, the repetition rate for one speaker was once per 2.8 sec, and once per 1.4 sec (0.7 Hz) as a system.

THE SOUND OF ATS: Japanese standardized ATS sounds were used (6). These were the chirping sound of a bird, or a cuckoo sound, respectively. For ATS using the "alternating different sound" pattern, single and double chirp sounds were used for each

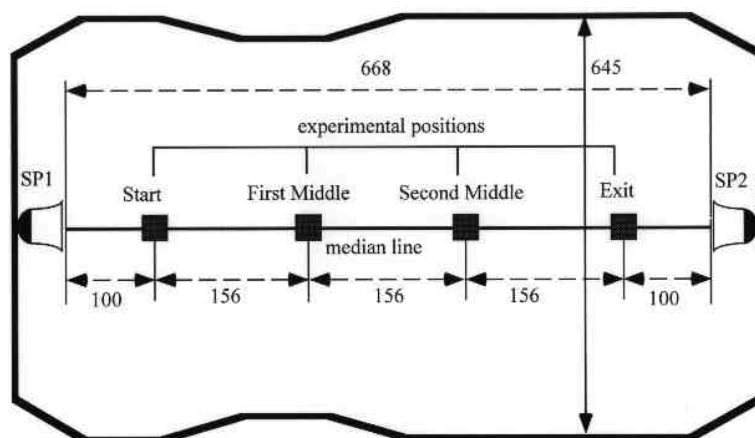


Figure 2. Outline of the experiment room

one of a pair of speakers. For a cuckoosound, it was separated into -- cu -- and -- ckoo -- sound and used for each speaker.

EXPERIMENTAL ROOM: Two types of experiments (#1 and #2) were carried out in a sound-proof, semi-anechoic room to avoid unexpected noise from the outside, and from sound reflections, that might interfere with distinguishing the location of sound by the subjects. Two speakers were set on the ceiling (at a height of 2.3m), 7 m apart, and placed facing each other to simulate a crosswalk (Fig. 2) . Between the two speakers, four free-rotating chairs were set at experimental positions. These positions --named entrance, first middle, second middle, and exit - - were set at 1.0, 2.56, 4.12, and 5.68 m from the rear speaker, respectively. On the supporting bar of the back of each chair, a laser pointer was set to point protractor on the floor to measure the angle of the chairs against the front speakers.

EXPERIMENT PERFORMED OUTSIDE: Some experiments were done in a parking lot. The effective area to be used for the experiment was 40 X 40 m. Two speakers were positioned 20m apart, and each of them was set 2.4 m above the ground using an adjustable pole. The parking lot was chosen so that there were no buildings nearby that could reflect sound. However, two sides of the rectangular shape parking lot were surrounded by bushes. This experimental location was used specifically to compare the "alternating same sound" versus "alternating different sound" patterns.

EXPERIMENT 1: In the experimental room, subjects sat on one of the four chairs, and faced the front speaker after being completely disoriented. At the beginning of each trial, the subjects was positioned toward the front speaker, without their knowledge. When sounds were emitted by the speakers, each subject was asked to distinguish the sound of the front speaker from that of the rear speaker. The subject then turned toward the location of sound emitted by the front speaker. The sound was generated for 11 sec for both the simultaneous sounds, and the "alternately same sound" patterns, and the subject was asked to finish the task within this period.

EXPERIMENT 2: The same experimental set up was used as in Experiment 1. In this experiment, subjects were positioned at certain angles (from 0 to 15 degrees) from the front speaker. No movement of the body or chair was allowed while listening to the sound. Subjects were asked to identify the direction of sound from the front speaker. That sound was displayed for only a limited period of time: one cycle for the "alternate same sound" pattern, and two cycles for the "simultaneous sound" pattern. The subjects expressed the identified direction of the sound as middle, right, or left to their median saggital plane.

EXPERIMENT 3: This experiment was done outside. Subjects were asked to walk the distance between two speakers. The sound patterns used were "alternate same sound" and "alternate different sound". In this experiment, the subjects lifted one hand if they had difficulty differentiating the front speaker from the rear speaker while they were walking. They kept their hand raised as long as this differentiation was difficult, and the distance they walked with a

raised hand between the two speakers was measured.

RESULTS AND DISCUSSION

ACCURACY OF IDENTIFYING DIRECTION OF SOUND SOURCE (EXPERIMENT 1)

Subjects were positioned in chairs between two speakers, allowed to listen to a series of test sounds (11 sec), and then asked if they were able to identify the direction of sound emitted from a front speaker. Two sonic patterns were used: "simultaneous sound" and "alternate same sound". Each subject's performance in each trial was measured by the angle of the subject's chair against the front speaker. Subjects were allowed to scan the signal sounds, and to choose a direction within the period of the sound presentation. If the subjects could not decide on an orientation within this period,

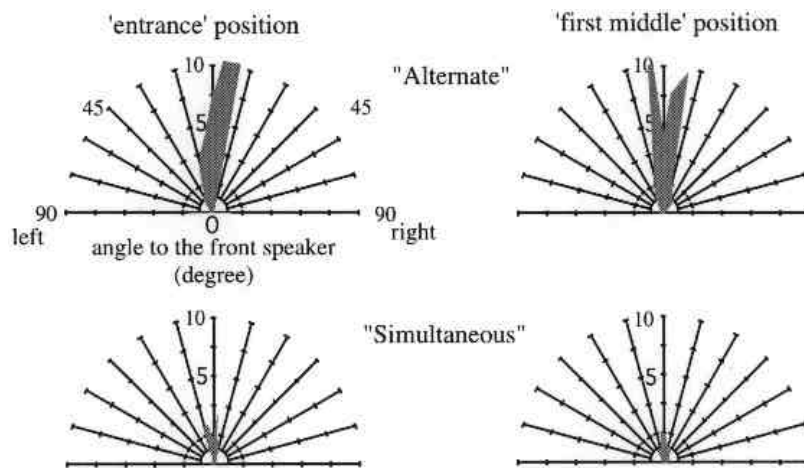


Figure 3. Scattering of direction and frequency taken by the subjects toward the signal sounds emit from front speaker

Top row shows angles taken in alternate same sound pattern. Bottom row shows those in simultaneous sound pattern. The numbers on the vertical bar indicate frequencies. 'Entrance' position is 1.0 m and 'first middle' is 2.56 m from the rear speaker respectively.

the trial was judged as unsuccessful. Subjects were allowed to scan for sounds within a range of angles not more than 60 degrees to the left or right of the front speaker (so that subjects would not misidentify the rear speaker as the front speaker).

Remarkable differences were found between the "simultaneous sound" pattern and the "alternate same sound" pattern. When simultaneous sound were presented, almost none of the subjects were able to distinguish the sound of the front speaker from that of the rear speaker at the 'entrance' and 'first middle' chair positions (Fig. 3). In the latter half of the crosswalk being traversed, the signal from the front speaker could be rather correctly identified. For the "alternate same sound" pattern, almost every subject could determine the correct direction at any of the chair positions. In the majority of these, the distribution of angles selected was within +/-

10 degrees relative to the front speaker. These results agree well with results we obtained previously with different experimental paradigm (7). Altogether, these results suggest that the present ATS using simultaneous sound does not have enough capacity to indicate the direction to which pedestrians should walk in the first half distance of crosswalk.

SOUND LOCALIZATION PERFORMED WITHIN A SHORT EXPOSURE TIME TO THE SOUND (EXPERIMENT 2)

In this experiment, subjects were asked to localize sound emitted by the front speaker, at hearing angles ranging from 0 to 15 degrees relative to the front speaker. Sounds were presented in both "simultaneous sound" and "alternate same sound" patterns. In this experiment, subjects were exposed to the signal sounds for only very limited periods of time (one cycle for the alternate same sound, and two cycles for the simultaneous sound patterns). Within these periods, the subjects had to judge the direction of the sound source, and then express the direction of the sound source as middle, right, or left to their median saggital plane. This experimental condition was designed to study how visually disabled pedestrians might decide the direction to walk very soon after detecting a signal sound at a crosswalk (particularly in the midst of other pedestrians and moving vehicles). When simultaneous sounds were presented, subjects

were, for the most part, hardly able to differentiate sounds emitted from the front versus rear speakers. An exception to this was when subjects were initially separated from the speakers by smaller angles at every position in the first half of the distance (Fig. 2). The higher rate of correct answers at these smaller angles probably reflected the ability of subjects to obtain directional clues by sounds emitted from the rear speaker.

Subjects correctly distinguished sounds from the front and rear speakers much more often in the latter half of the distance across the crosswalk for simultaneous sounds, and at all positions within the crosswalk for the alternate same sound pattern. Even more correct answers were obtained than when subjects were positioned at small angles relative to the front speaker. Moreover, the rate of correct answers was significantly higher for the "alternate same sound" pattern than that of the "simultaneous sound" pattern. The lower rate of correct answers observed at small angles to the front speaker (for both simultaneous and alternate same sound patterns) might indicate that a sound presented from the front of a subject was better localized when the body angle of the subject was oblique to it, consistent with the binaural sound localization mechanism of human (8). Overall, the "alternate same sound" pattern was found to provide more reliable clues for orientation than simultaneous sound pattern, by which clues for orientation is obtained only limited range of distance on crosswalk.

**COMPARISON OF ALTERNATE SAME SOUND AND ALTERNATE DIFFERENT SOUND PATTERNS
(EXPERIMENT 3)**

As described above, the "alternate same sound" pattern facilitated excellent sound localizing performance under laboratory conditions. In spite of this, we have encountered at least one problem inherent to this system, arising from the fact that the balance of sound intensity emitted from a pair of speakers differs with the position between the two speakers. At the starting position, the ratio of sound energy of rear to front speaker is maximum, and it reaches a minimum at the position of the opposite speaker. Halfway between the speakers, the loudness ratio approaches unity (1:1), and in this situation the subject seemed to confuse the sound sources. This confusion -- and thus danger -- is bound to be exacerbated in real traffic situations, by various noises and other environmental factors that increase mental stress. Such stress, defined as mental workload, would disturb visually disabled pedestrians who rely on sound signals from ATS to make quick and correct judgments necessary to cross streets successfully.

	same sound pattern	different sound pattern
indistinguishable trial /total	11/15	0/15
average of ambiguous distance (m)	4.5	0

Table 1. Functional difference between "alternate same sound pattern" and "alternate different sound pattern"

A comparison of sound patterns was made for completing given task (to distinguish one sound from the other) and generating zones at which subjects become indistinguishable the sound of the front speaker from that of rear speaker. The zone (ambiguous distance) was identified by lifting hand of the subjects while they walked 20 m distance between two speakers.

This circumstantial evidence suggests that the "alternate same sound" pattern in an ATS is not necessarily easy to use within a certain distance on crosswalk. Therefore, we developed a "modified alternate sound" pattern that utilizes different tones for each of the two speakers. These different sounds were alternated to decrease the ambiguity (described above) in the middle of crosswalk.

This experiment was conducted in the outdoor site, so that subjects were challenged with longer crosswalks. (Subject appeared to walk through the middle section of short crosswalks without much uneasiness, because it was not difficult to maintain the walking direction that was adopted at the starting position.) For this reason, we used a walking distance of 20 m, a distance that is common for crosswalks in Japan. As indicated in Table. 1, most subjects had difficulty differentiating sound sources emitting the "alternate same sound" pattern. On average, the distance, parallel to the median line that connects two speakers, of such an ambiguous region

was 4.5 m in middle of the crosswalk. By contrast, subjects were able, without exception and throughout the length of the crosswalk, to localize (and distinguish) sounds when the "alternate different sound" pattern was used. This result indicates that, so far, the "alternate different sound" pattern best provides clues about direction within crosswalks. Although the "alternate different sound" pattern worked well compared to the other two system used in the present study, the balance of sound intensity from two speakers changed in the same way as would an "alternate same sound" pattern. Therefore, neither of these sound patterns will alleviate the trouble faced by visually disabled pedestrians that fail to remember the correspondence between direction and sound. It seems to be necessary to test "alternate different sound" patterns in more complicated situation that would increase mental workload of subjects.

ACKNOULEGEMENTS

We are very much grateful to Professor Andrew T. Ishida (University of California, Davis) for reading this manuscript and giving us useful comments.

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