Which Crosswalk? Effects of Accessible Pedestrian Signal Characteristics

IN THE STUDY DESCRIBED IN THIS FEATURE, BLIND PEDESTRIANS AND BLINDFOLDED, SIGHTED PEDESTRIANS JUDGED WHICH CROSSWALK HAD THE AUDIBLE WALK SIGNAL AT A SIMULATED 90-DEGREE FOUR-LEG INTERSECTION. SPEAKER POSITIONING, MODE AND THE NUMBER OF CROSSWALKS SIGNALED WERE VARIED.

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THE TRANSPORTATION EQUITY Act for the 21st Century directs that pedestrian safety considerations, including the installation of audible traffic signals, where appropriate, shall be included in new transportation plans and projects.[1]

In addition, the *Manual on Uniform Traffic Control Devices* (MUTCD) has provided guidance since the 2000 edition on the installation of accessible pedestrian signals (APS)—signals that communicate pedestrian timing information in audible and/or vibrotactile modes.[2]

MUTCD Section 4E.06 requires that: "The information provided by an accessible pedestrian signal shall clearly indicate which pedestrian crossing is served by each device." However, the most commonly used APS in the United States has been found to provide ambiguous information.

The use of two different sounds has been thought to provide definitive information about which crosswalk is being signaled at an intersection. The most common sounds are a "cuckoo" for north-south crossings and a "chirp" for east-west crossings.[3] However, blind pedestrians sometimes find this confusing because they cannot remember which sound is associated with which direction, they do not know the direction they are traveling, they do not know the direction of the crosswalk, or the crosswalk is not well aligned with cardinal directions.[4]

MUTCD Section 4E.06 provides the following guidance: "Provision of different sounds for crosswalks in different directions has been found to give ambiguous information to blind pedestrians."[5]

Speech walk signal messages also have been suggested for providing unambiguous crosswalk identification. However, speech messages cannot be made understandable in all ambient noise conditions and may be of limited use if a pedestrian is not well oriented or not familiar with the area.[6] Research on the usability of APSs with speech messages is ongoing under the National Cooperative Highway Research Program Project 3-62, "Guidelines for Accessible Pedestrian Signals."

In the most typical installation, sound is emitted simultaneously from loudspeakers at both ends of the crosswalk. Although APSs mounted on the pedestrian signal head and aimed across the street have been thought to provide directional information, the signal from the opposite side of the street is not easily heard until after leaving the curb. Where both crosswalks at a corner have audible indications, it may be especially difficult to discern which crosswalk has the walk signal because the pedestrian's listening experience is dominated by the loudspeaker on that corner.

In the United States, the placement of APSs with respect to crosswalk and corner locations varies widely. The experiment described in this feature is the first systematic investigation of the effects of variations in loudspeaker locations on identifying which crosswalk has the audible walk signal.

The effect of three different signal modes on crosswalk signal determination also was investigated: simultaneous; alternating end-to-end of crosswalk; or presented only from the far end of the crosswalk. Finally, performance was compared when either a single crosswalk or two parallel crosswalks were signaled concurrently.

METHOD

Participants

The participant groups comprised eight sighted, blindfolded adults and six totally blind adults aged 27 to 42 (M = 35.75, SD = 6.94) and 27 to 65 (M = 46.33, SD = 16.51), respectively. The group sizes differed because of a scheduling complication. All participants had normal hearing within 20 decibels on a pure tone test.

Procedure

As shown in Figure 1, a mock 90-degree four-leg intersection with 16-meter-long crosswalks was laid out in a parking lot. Commercial APS pedhead-mounted devices (Novax DS 2000, Vancouver, British Columbia, Canada) were positioned 2.44 meters (8 feet) high on tripods to simulate pedestrian signal heads. Each corner provided a different arrangement of devices to investigate the effect of typical placements on pedestrians' ability to tell which crosswalk had the walk signal.

Figure 1 shows the directional alignment of the speakers at each corner. At corners 1, 2 and 3, the speakers were 3.05 meters (10 feet) apart. At corner 4, the speakers were directly next to one another as if they were mounted on the same pole. Preliminary testing verified that the various separations between loudspeakers were distinguishable from one another by listeners standing on that corner but not from across the street.

The audible signal used as the walk signal was a percussive "tok" with a 10-Hertz within-burst repetition rate. Each burst lasted 1 second; the total signal was on for 7 seconds. This signal was found in previous research to be detectable and localizable in traffic noise. It resembled APSs used in Australia and some European countries.[7]

The sound measured 72 dB-A at ear level 2 meters in front of each speaker and 54 dB-A from the far end of the crosswalk. To simulate a traffic intersection, pre-recorded traffic sounds were played through a four-loudspeaker public address system at 70 dB-A measured in the middle of the intersection. APS speakers at each end of a crosswalk were yoked together, as would be typical in an intersection installation (for example: AB, CD, as shown in Figure 1).

Three different signal modes were used: simultaneous, with the signals from both ends of a crosswalk sounding concurrently; alternating, with signals presented alternately from each end; and far side only, with the signal presented only from the far end of the crosswalk(s) relative to the pedestrian.

Within a block of six trials on any given crosswalk, the alternating signal always was presented initially from one end or the other, but the end varied randomly across the four crosswalks as well as across trial blocks. Another signal characteristic was whether a single crosswalk or two parallel crosswalks were signaled.

Considering all the variables, there were 24 experimental conditions (each corner accounted for six conditions). The six conditions for corner 1 are summarized in Table 1. At corner 1, the participant always faced in the direction shown by the pedestrian icon in Figure 1 (northward). From that corner, the crosswalk that had the walk signal was either from corner 1 to 4 or from corner 1 to 2.

For example, if two crosswalks were signaled, the signal mode was simultane-

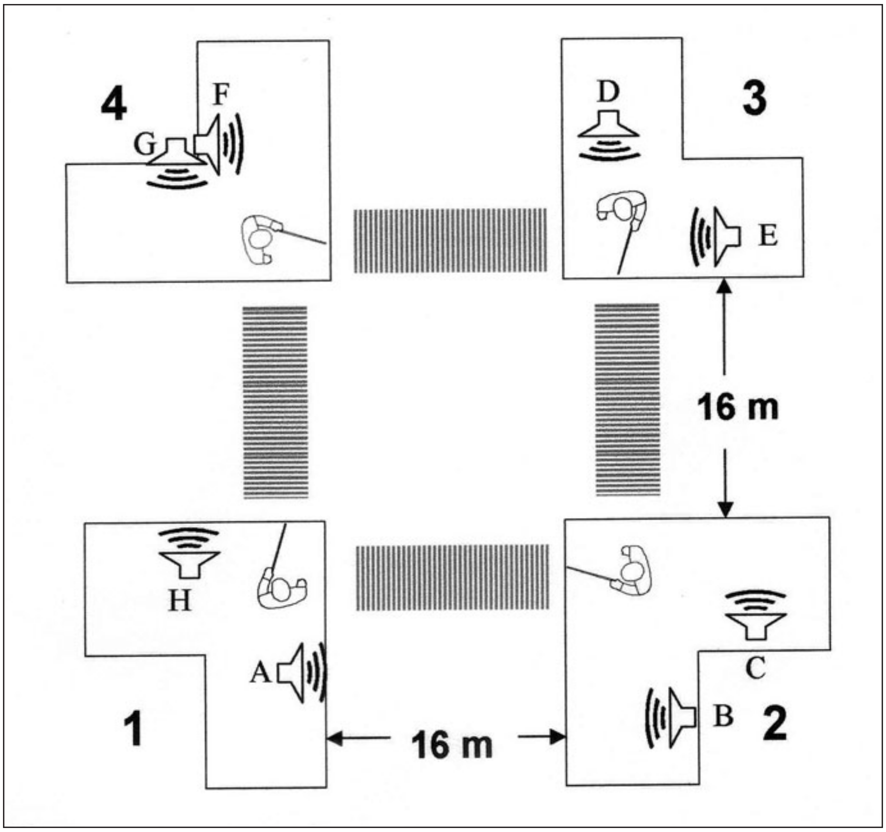

Figure 1. Positions and headings of loudspeakers and pedestrians at each corner.

** Note: The question to the pedestrian always was, "Which has the walk signal, the crosswalk straight in front of you or the one to your right?" Corner 1: loudspeakers near curb on outside of crosswalk line. Corner 2: loudspeakers near back edge of sidewalk on outside of crosswalk line. Corner 3: loudspeakers near curb but facing across pedestrian's position. Corner 4: loudspeakers near back edge of sidewalk mounted on the same pole. The figure is not drawn to scale.*

Table 1. Loudspeakers active during six trial types from corner 1.

Number of crosswalks signaled	Signal mode	Correct choice crosswalk	
		From corner 1 to corner 2	From corner 1 to corner 4
One	Simultaneous	AB	GH
	Alternating	AB	GH
	Far end only	B	G
Two	Simultaneous	AB, EF	GH, CD
	Alternating	AB, EF	GH, CD
	Far end only	B, E	G, D

Note: See Figure 1 for a diagram of corner numbers and loudspeaker letter names.

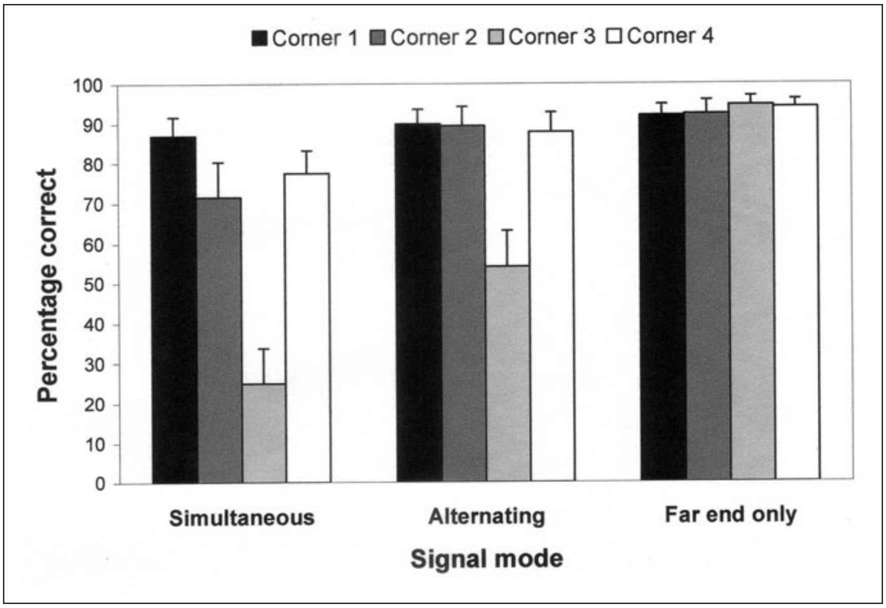

Figure 2. Percentage of correct judgments, by signal mode and corner, of which crosswalk had the walk signal.
** Note: Error bars show +1SE.*

ous and the correct choice crosswalk was from corner 1 to corner 4, then loudspeakers C, D, G and H all presented the walk signal at the same time. In this case, the crosswalk from corner 2 to corner 3 also had the walk signal, but for the participant standing at corner 1, the relevant choice was whether the walk signal was to proceed to corner 2 or corner 4.

Within each condition, each participant was tested on a single block of six trials. The order of experimental conditions was counterbalanced within the constraints of the large number of conditions. Participants were tested in groups of two to three, all standing at the same corner and facing the same direction. This approximated a typical street crossing situation, but participants were spread out a bit to avoid acoustic interference. At a given corner, participants always were aligned as shown by the symbols in Figure 1 (with one crosswalk straight in front and the other 90 degrees to the right).

The task was to listen to the audible walk signal and indicate, by pointing with one hand, which crosswalk had the walk signal. An experimenter assigned to an individual participant recorded whether the participant chose the crosswalk straight in front or the crosswalk to the right. The experimenter also recorded the stopwatch time from signal onset to pointing response.

Participants were instructed to make judgments quickly but accurately. With respect to APS speaker positions at the different corners, participants were informed only that each crosswalk had speakers somewhere on the corners at both ends. With respect to signal mode and the signaling of one versus two crosswalks, participants were informed about which mode and number were in effect for a set of trials.

RESULTS

Percentage of Judgments Correct

In each of the 24 listening conditions, there were six trials from which a proportion correct was computed for each participant. As is frequently done for proportional data (p), the scores were transformed for statistical analyses: $y = 2\arcsin(\sqrt{p})$. To facilitate presentation of the findings, however, the descriptive results reported in this feature are in percentages of correct units.

The transformed data were analyzed with a mixed model analysis of variance with vision group (blind or sighted) as the between groups factor and the following repeated measures factors: signal mode (simultaneous, alternating, or far end only); APS speaker arrangement (on the four corners as shown in Figure 1); and number of crosswalks signaled (one or two in parallel).

The main effects of signal mode and loudspeaker arrangement were significant. However, the significant interaction between these factors was of greater interest, $F(6,72) = 7.724$, $p < .001$.

Figure 2 shows percentages correct at each corner for the three signal modes. In the far end only mode, performance was very good at all four corners. This demonstrates that participants were good at distinguishing between distant sound sources located 90 degrees apart. Another important result not shown in Figure 2 was that performance was excellent whether only one crosswalk or two parallel crosswalks were being signaled.

In both the alternating and the simultaneous signal modes, accuracy was lower when participants were standing at corner 3 than at the other corners, according to Tukey multiple comparison tests. For the simultaneous signal, participants were correct in only one-fourth of trials. In other words, they consistently chose the wrong crosswalk. This is probably because, with sound from the far end masked by sound from the loudspeaker on corner 3, they assumed that the crosswalk being signaled was the one near the active loudspeaker.

For the alternating mode, performance from corner 3 was at 50 percent, or chance level, probably because sound from the far end of the crosswalk provided accurate information whereas sound from corner 3 was misleading.

Performance was very similar across the blind and sighted groups of participants. This has been found in previous studies of audible pedestrian signals. However, there was a borderline interaction between signal mode and vision group, $F(2,24) = 3.287$, $p < .055$, indicating that blind participants did somewhat better than sighted participants in the simultaneous mode but vice versa in the alternating mode.

For sighted participants, the means (and *SE*s) were 59 percent (4.8) in the simultaneous mode, 86 percent (5.1) in the alternating mode and 95 percent (2.4) in the far end only mode. For blind participants, the corresponding means were 72 percent (5.5), 75 percent (5.9) and 92 percent (2.8). The nature of this interaction may reflect greater familiarity on the part of blind participants with audible pedestrian signals, most of which are in the simultaneous mode in the United States.

In the analysis of variance, there also was a significant three-way interaction between signal mode, number of crosswalks and vision group, but this did not yield a ready interpretation and was regarded as spurious.

Response Times

Because of a logistical problem, response times were collected for only 11 of the 14 participants (5 blind and 6 sighted). In an analysis of variance, there was a significant effect of signal mode, $F(2,18) = 3.628$, $p < .047$, but this was qualified by a borderline interaction between vision group and signal mode, $F(2,18) = 3.378$, $p < .057$. The mean response times for each group in the three signal modes are shown in Figure 3.

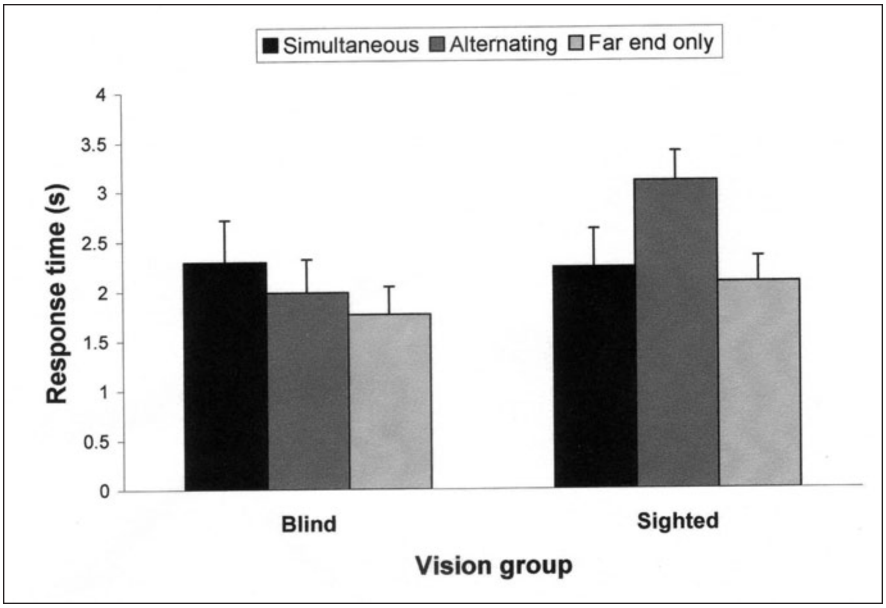

Figure 3. Response time (in seconds) by signal mode for each vision group.

** Note: Error bars show +1SE.*

Sighted participants took an extra second or so to respond in the alternating signal mode. All other response times for both groups were approximately two seconds. In general, the response times were fairly quick, indicating that participants based their judgments on the first one or two bursts of the signal, as would be the case in a real street crossing situation in which time matters.

There was no evidence that response times differed across the four corners, that is, for the different speaker arrangements. This suggests that the inaccurate judgments made from corner 3 about which crosswalk had the walk signal did not reflect uncertainty but rather were mistakes of which the participants were largely unaware.

DISCUSSION

This experiment shows that both the positioning of loudspeakers and the mode of signal presentation influence the accuracy of judgments about which crosswalk has the walk signal. Under the most typical signal mode—simultaneous presentation from both ends of the crosswalk—the best performance occurred when signals were placed as shown for corner 1 in Figure 1. In this case, a pedestrian could tell easily which of the two loudspeakers at the corner was active because each loudspeaker was close to the position of pedestrians waiting to cross at the associated crosswalk. Note that this was true despite the fact that both signals on the corner had the same sound.

Other arrangements of loudspeakers, such as at corner 2 and corner 4, resulted in somewhat worse performance. The arrangement at corner 3 led to consistently wrong judgments. Unfortunately, this arrangement is common in some jurisdictions where the pedestrian signal head associated with one crosswalk is closer to the other crosswalk.

The alternating and far end only signal modes used in this experiment are not in widespread use. Both of these modes have been considered to enhance directional beaconing for crossing by allowing users to hear a signal from the far end of the crosswalk without masking from the closer speaker.[8–11] The findings indicate that these signal modes also overcome, to some extent, the problems of inconsistent loudspeaker positioning.

Further investigation is required, however, to resolve questions as to whether these signal modes can provide adequate audibility of the far end signal in real traffic situations and whether there would be complications when pedestrians are waiting to cross from both ends of a crosswalk during the same pedestrian phase.

To provide realistic evaluation while ensuring pedestrian safety, future research will require the collaboration of practicing traffic engineers who can arrange for on-the-street installations. Pedestrian access under the investigative signal conditions should be limited to periods of formal data collection.

In the case of the alternating signal mode in the current study, it was interesting that participants often made incorrect judgments when standing at corner 3, as shown in Figure 2. This suggests that pedestrians have a strong tendency to link a loudspeaker on their own corner with the crosswalk it is near, even when they can hear a signal coming from the far end of the other crosswalk. Again, this argues for consistency of loudspeaker placements, preferably as shown in corner 1.

This experiment also suggests that audible signaling of two parallel crosswalks does not cause interference, at least with respect to deciding which crosswalk has the walk phase. Previous research suggested a slight veering tendency during crossings when parallel crosswalks both were signaled.[12]

This research indicates that if APSs are positioned close to the curb and near the side of the crosswalk farthest from the center of the intersection, as shown for corner 1 in Figure 1, typical simultaneous signals provide accuracy that is essentially equal to that provided by signals that alternate or that come from the far end only, when APSs are in other locations on the corner. This is true when all signals have the same sound; therefore, users do not need to remember the association between travel direction and signal or know the direction of the crosswalk.

However, if APSs cannot be located in ideal positions, unambiguous information can be provided by providing the walk signal from the far end of the crosswalk only. For some APS positions, unambiguous information also can be provided by alternating the signal from one end of the crosswalk to the other.

The only way to provide unambiguous information if APSs are mounted as for corner 3 in Figure 1 is to have walk signals that come from the far end of the crosswalk. However, even when pedestrian signal heads are located as shown for corner 3, APSs can be mounted and wired so that the APS closest to a pedestrian's waiting location is the APS that provides a walk signal for the crosswalk to which it is closest.

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THE POSITIONING OF LOUDSPEAKERS AND THE MODE OF SIGNAL PRESENTATION INFLUENCE THE ACCURACY OF JUDGMENTS ABOUT WHICH CROSSWALK HAS THE WALK SIGNAL.

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