THE EFFECTIVENESS OF AUDIBLE AND TACTILE HEADING CUES FOR PEDESTRIANS WHO ARE BLIND AT COMPLEX INTERSECTIONS

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ABSTRACT

This research extends the results of laboratory research on wayfinding at intersections for pedestrians who are blind. The effectiveness of standard accessible pedestrian signals (standard APS), a prototype beaconing accessible pedestrian signal (beaconing APS), and a raised guidestrip were evaluated for their ability to assist in establishing and maintaining a heading for street crossings. Experiments were conducted at large, complex, signalized intersections in Alpharetta, GA, Austin, TX, and Towson, MD.

Both the guidestrip and the beaconing APS resulted in more accurate street crossing performance than standard APS with respect to alignment (i.e., initial heading) accuracy, rates of being within the crosswalk, distance from the center of the crosswalk at various points during crossing, and the likelihood of being well outside of the crosswalk (6 feet (2 m) or more). For the most part, performance with the guidestrip or the beaconing APS was equivalent. Limitations and additional concerns with respect to these two treatments are discussed.
INTRODUCTION

To maintain independence in everyday life, people who are blind cross streets of varying width and complexity in both familiar and unfamiliar areas. The Americans with Disabilities Act requires that pedestrian facilities such as sidewalks and crosswalks be accessible to all users, including those with visual impairments. Three of the tasks involved in street crossing are the wayfinding tasks of locating the crosswalk, establishing an appropriate initial heading, and maintaining the heading while crossing. With the increasingly complicated geometry of modern intersections, these tasks have become very challenging particularly at locations where a crosswalk is skewed relative to the roadway, where there are exceptionally wide crossings with little or no traffic traveling parallel to the crosswalk, or where there are more than two streets at the intersection.

Previous research on the effects of accessible pedestrian signals (APS) on measures of timing, wayfinding and independence found that the installation of APS decreased starting delay and significantly increased the number of crossings that blind participants began within the walk interval and completed before the signal changed. The presence of an APS also resulted in increased independence in locating the crosswalk. However, the standard pushbutton-integrated APS with a tactile arrow, locator tone, and audible and vibrotactile walk indications was not shown to improve participants’ wayfinding, as measured by establishing and maintaining a correct heading within the crosswalk. A prototype beaconing APS that provided an ‘alignment tone’ for establishing heading prior to crossing and an audible beacon during the pedestrian clearance interval resulted in a significant improvement in staying within the crosswalk, but not in establishing an initial heading. The sound source for the alignment tone and audible beacon was a loudspeaker mounted on the pedestrian signal head at the far end of the crosswalk.

More recent laboratory research by this team has also focused on the tasks of establishing and maintaining an accurate heading. In two experiments conducted in a large parking lot, participants who were totally blind traveled down simulated curb ramps and across simulated crosswalks using a variety of tactile and audible cues. Cues investigated with respect to maintaining an accurate heading across the distance of a 6-lane street were a bar tile oriented perpendicular to the crosswalk, remote infrared audible signage, beaconing APS described above, raised crosswalk lines (edgestrips) and a single raised guidestrip. The most effective cues were the beaconing APS, the guidestrip, and the edgestrips.

Based on these results, experiments were conducted at large, complex, signalized intersections in Alpharetta, GA, Austin, TX, and Towson, MD. At each intersection, the same three treatments were compared: a standard APS (no beaconing), the prototype beaconing APS, and a raised guidestrip. The edgestrips were not tested, as they provided no advantage over a single raised guidestrip.

METHOD

Participants

Participants were adults who were totally blind or who had light perception only. Participants were experienced long-cane users, regularly crossed streets, and were unfamiliar with the intersections being studied. They walked with a normal gait, did not have peripheral neuropathy, and their hearing was no worse than mild hearing loss. Data from 54 individuals was included in the final analysis, 16 participants in each city, with a total of 33 males and 21 females ranging in age from 21 to 73.

Participants received an honorarium for participation in the research and all
transportation costs were paid by the project. The studies were approved by the Institutional Review Board of Boston College (Alpharetta) and Western Michigan University (Towson and Austin), and all participants gave their informed consent before participating.

Intersections

The intersections, shown in Figure 1, were chosen in consultation with the jurisdiction’s traffic engineers, with the goal of testing treatments at crosswalks where some of the traditional cues used by blind pedestrians were absent. Crossing lengths ranged from 56 to 115 ft (17.1 to 35.1 m) and all crosswalks except one were 10 ft (3.0 m) wide (Bolm Rd. crosswalk in Austin was 8 ft (2.4 m) wide). These are all large signalized intersections with relatively complex signal phasing.

FIGURE 1 Overhead photos of experimental intersections; crosswalks used for experimental trials are marked with stars. A) Windward Pkwy. & GA-Highway 9, Alpharetta, GA. B) Dulane Valley Rd. & Fairmount Ave., Towson, MD. C) Airport Blvd, Shady Ln. & Bolm Rd., Austin, TX.
Equipment
As noted earlier, for each participant, each experimental crosswalk had standard APS and either a guidestrip or beaconing APS. The beaconing features could be turned off so the same units could be used as standard or beaconing APS. The guidestrip was moved and the beaconing was turned on and off during the course of the study so that each treatment was encountered on each crosswalk by 1/3 of the participants.

Standard APS
The standard APS were installed on poles near the crosswalks; the locations varied across intersections and cities. Features included a pushbutton locator tone, a tactile arrow aligned with the direction of travel on the associated crosswalk, automatic volume adjustment, and vibrotactile and audible walk indications. At each of the four corners of the intersection in Alpharetta Georgia, two APS devices were installed on a single pole, so speech walk indications were used to differentiate the walk indications for the two crosswalks at each corner. In Towson and Austin, the devices were on separated poles so rapid tick walk indications were used. All features and messages conformed to requirements in the Manual on Uniform Traffic Control Devices (MUTCD), Section 4E.09–4E.13 (12).

Guidestrip
In this condition, standard APS as described above were present. Additionally, the guidestrip was installed along the inside edge of the crosswalk line farthest from the center of the intersection, beginning at the street edge of the gutter. It was a raised strip of polymer tape, 4 inches wide and 0.25 inches high (marketed as temporary rumble strip).

Beaconing APS
The beaconing APS had the same features as the standard APS plus additional prototype audible beaconing features, described earlier, emitted from a loudspeaker mounted on the pedestrian signal head at the opposite end of the crosswalk. Beaconing was triggered by a button press of one second or more, after which participants heard seven repetitions of a loud tone (1/second) from the far-end loudspeaker. The choice of seven repetitions was determined in earlier research (9). The onset of the walk interval was provided by typical, relatively quiet, walk indications heard from the nearby APS. (12; Section 4E.11). The loud beacon from the opposite end of the crosswalk sounded again for the duration of the flashing don’t walk (FDW) interval. The alignment tone and the tone during the FDW were the same tone and repetition rate as the pushbutton locator tone, just louder and from an additional speaker at the far end of the crosswalk. This was to avoid the need to remember a complex “code” of different meanings. Participants only needed to remember that the WALK was a speech message or a rapid ticking tone coming from the pushbutton; the once per second locator tone was always directional information.

Procedure
There were 18-21 participants in each city. For each experimental session, one crosswalk had standard APS, one had beaconing APS, and one had a guidestrip. Each participant crossed each of the three experimental crosswalks twice from each direction. A fourth crosswalk, equipped for all cue conditions, was used for familiarization with the cues and procedure. The crosswalks and treatment conditions were evenly balanced across participants. The trials of each cue condition were presented in a block, beginning with an introduction and practice at the
familiarization crosswalk. There were typically two practice crossings for each cue with additional practice trials if needed. The order of the cue conditions was fully counterbalanced.

Participants began each trial on the sidewalk a random distance (40’-80’) from the crosswalk. They located the crosswalk, and aligned to cross using any cues available, including vehicular and pedestrian traffic, and crossed when they judged it appropriate. Participants were accompanied by a Certified Orientation and Mobility (O&M) Specialist who provided assistance, if requested, and monitored participant safety, intervening only if a participant was proceeding into direct conflict with moving vehicular traffic.

An experimenter recorded information about participants’ accuracy and independence in locating the crosswalk, their alignment (heading) before crossing, their location relative to the crosswalk at several points during the crossing, and when in relation to the pedestrian signal they began and completed their crossing.

RESULTS
To meet counterbalancing requirements, data from 54 participants were included in the analyses, the majority of which were Repeated Measures Analyses of Variance (RM ANOVA) using the data collected in each city individually. Post-hoc comparisons were conducted using dependent t-tests and the Holm-Bonferroni procedure for multiple comparisons with $\alpha = 0.05$. The lack of fundamentally different findings across cities made between city analyses unnecessary. For many nominal variables (e.g., alignment within crosswalk, away from intersection, or toward intersection), percentages were computed which reflect the percentage of trials with a given cue in which the participant performed accurately (e.g., aligned within the crosswalk). These percentages were then used in inferential analyses. For each variable of interest, only data obtained during independent participant performance was included in the analyses. For example, if an intervention by the O&M specialist was necessary during a crossing, no data was recorded regarding signal phasing at the end of that crossing.

Alignment, and Heading During Street Crossings
The beaconing APS and guidestrip treatments are specifically designed to provide information that can assist blind pedestrians with aligning their body toward the end of the crosswalk and with staying within the crosswalk while crossing.

Alignment
Alignment (i.e., initial heading) of the participants was recorded in a qualitative manner by a researcher just before the walk interval began: participants were aligned “within the crosswalk,” “toward the intersection,” or “away from the intersection.” The average rate of accurate alignment was dependent upon treatment condition in all three cities [GA, $F(2,26)=12.92$, p<.001; MD, $F(2,34)=4.28$, p<.05; TX, $F(2,34)=15.22$, p<.001].

Participants consistently established more accurate alignment using the guidestrip or beaconing APS than when using the standard APS. In all three cities, participants aligned more accurately with the guidestrip than with standard APS [GA, $t(13)=4.45$, p<.001; MD, $t(17)=3.20$, p<.01; TX, $t(17)=3.64$, p<.01]. Collapsing across all three cities, participants aligned accurately on an average of 36.3% of trials with standard APS as compared to 71.0% with guidestrips. In no city were the differences in alignment significantly different between the beaconing APS and guidestrips.

Participants established more accurate alignment using beaconing APS than when using standard APS in two cities [GA, $t(13)=4.41$, p<.001; TX, $t(17)=5.63$, p<.001]. While the
observed average rate of accurate alignment in Towson, MD was also higher with beaconing APS (57.4%) than with standard APS (46.8%), the difference was not significant \( t(17)<1.0 \).

Collapsing across all three cities, participants aligned accurately on an average of 36.3% of trials with standard APS compared to 68.1% with beaconing APS. It is important to note that some of the beaconing loudspeakers in Alpharetta, GA, and Towson, MD, were not within the width of the crosswalks they signaled. Thus it was possible for a participant to have established an alignment towards the beacon which was not in line with the crosswalk (and thus counted as misaligned). The beacons were most accurately and consistently positioned in Austin, TX, and it is in that city where participants achieved the highest rate of accurate alignment (80.6%) across all cities and treatments.

**Remaining Within the Crosswalk**

At four distances from the beginning of the crossing, participants’ positions relative to the crosswalk width were recorded. A two-way RM ANOVA for each city evaluated participants’ position relative to the crosswalk for the three cue conditions and the four distances. Figure 2 shows that, while the average rates of remaining within the crosswalk vary some from city to city (a reflection of a number of factors that include but are not limited to the intersection geometry and the amount and pattern of traffic flow), the pattern of performance as it relates to the three treatments is very consistent.
FIGURE 2  The effect of three treatments on average percentage of trials in which a participant was within the crosswalk at various points throughout the crossing.

For Alpharetta, there was a non-significant interaction \([F(6,54)=1.01, p>.05]\) and a non-significant main effect of distance from the start \([F(3,27)<1]\). The main effect of treatment condition was significant \([F(2,18)=39.70, p<.001]\) with both the beaconing APS (86.9%) and the guidestrip (97.3%) resulting in a greater average percentage of trials in which participants were within the crosswalk than with standard APS (40.6%) \([t(9)=6.01, p<.001; t(9)=7.39, p<.001; \text{respectively}]\). The guidestrip also resulted in a higher average rate of remaining within the crosswalk than the beaconing APS \([t(9)=2.37, p<.05]\).

For Towson, the findings were similar, with a non-significant interaction \([F(6,90)<1.0]\) and a significant main effect of treatment \([F(2,30)=15.15, p<.001]\). In Towson, the main effect of distance from the start was also significant \([F(3,45)=3.52, p<.05]\). As in Alpharetta, both the beaconing APS (67.8%) and the guidestrip (83.6%) resulted in a greater average percentage of trials in which participants were within the crosswalk as compared to standard APS (47.0%) \([t(15)=2.71, p<.05; t(15)=7.50, p<.001; \text{respectively}]\). The guidestrip also resulted in a higher rate of remaining within the crosswalk than the beaconing APS \([t(15)=2.22, p<.05]\). The significant main effect of distance is largely the result of increasing rates of traveling outside of the crosswalk between a point 10 feet (3 m) from start and the crossing midpoint \([t(15)=3.13, \text{respectively}]\).
Once more, performance in Austin was similar, although in Austin all aspects of the omnibus analysis were significant; interaction \(F(6,102)=5.45, p<.001\), main effect of distance from start \(F(3,51)=19.70, p<.001\), and main effect of treatment \(F(2,34)=39.49, p<.001\). As in both other cities, both the beaconing APS (79.5%) and the guidestrip (92.1%) resulted in participants being within the crosswalk on a higher percentage of trials than standard APS (35.8%) \([t(17)=5.21, p<.001; t(15)=8.75, p<.001;\) respectively]. The guidestrip also resulted in remaining within the crosswalk more than the beaconing APS \(t(17)=2.76, p<.0.5\). The significant interaction is the result of increasing rates of traveling outside of the crosswalk as the distance increases in the standard APS condition [simple main effect, \(F(3,51)=24.67, p<.001\], compared to a lack of such an effect of distance in the beaconing APS condition [simple main effect, \(F(3,51)<1.0\)]. The effect of distance on rates of remaining within the crosswalk in the guidestrip condition was statistically significant [simple main effect, \(F(3,51)=3.86, p<.05\]; however, the magnitude of the effect is rather small with participants remaining within the crosswalk on an average of 95.8% of trials at the first 10’ (3 m) mark, and remaining within the crosswalk on an average of more than 90% of trials at all other distances.

**Positions Relative to the Crosswalk**

As described earlier, at each data collection point, the participants’ positions relative to the crosswalk width were recorded. In Towson and Austin, this included information about where within the crosswalk the participant was located relative to the center of the crosswalk. In Alpharetta, when the participant was within the crosswalk, their position was simply recorded as “within”; therefore, analysis of the average position of participants relative to the center of the crosswalk is only possible for Towson and Austin.

When a participant was outside of the crosswalk, the distance was recorded on a scale from one foot to six feet (.3 m to 2 m), and anything greater than six feet (2 m) was recorded as “greater than six feet,” and entered into the analysis as seven feet (2.1 m) outside the crosswalk. Measurements were converted to a distance from the center of the crosswalk; for example, if the data showed the participant was greater than six feet (2 m) outside a ten foot (3 m) wide crosswalk, the position was entered as 12 feet (3.7 m) from the center). This procedure allowed for two-way RM ANOVAs to consider the effects of wayfinding condition and distance from the start on participants’ position relative to the center of the crosswalk, but does create an artificial cap on the obtained average distances.

The Towson data (see Figure 3) reveals a non-significant interaction \(F(6,96)=1.40, p>.05\) and significant main effects of treatment \(F(2,32)=7.09, p<.01\) and distance from the start \(F(3,48)=9.34, p<.001\). The guidestrip resulted in smaller average linear error (deviation from crosswalk centerline) (4.2 ft, 1.3 m) than standard APS (6.0 ft, 1.8 m) \(t(16)=5.51, p<.001\), while the use of Holm-Bonferroni post-hoc procedure resulted in a non-significant difference between average linear errors in the beaconing APS (4.6 ft, 1.4 m) and standard APS conditions \(t(16)=2.328, p=.033\). However, the means were in line with the hypothesized benefit of the beaconing APS and with evidence of such a benefit found in simulated crossing research (11); while the difference would be statistically significant with an unprotected post-hoc procedure, it was not with the use of Holm-Bonferroni. The average linear errors in the guidestrip and beaconing APS conditions did not significantly differ \(t(15)<1.0\). Note again that the beacon speakers in Towson were not consistently installed within the crosswalks they signaled. Thus it was possible for a participant to travel directly toward the beacon and have that result in linear errors, even ending the crossing outside of the crosswalk.
FIGURE 3 The effect of three treatments on average distance from the center of the crosswalk at four points during street crossing. (crosswalk boundary noted in table is not accurate for the one crosswalk in Austin which was only 8 feet (2.4 m) wide)

The simple main effect of distance for the guidestrip in Towson was not significant \( F(3,48)<1.0 \), revealing consistent linear errors at all measurement points. While there was a slightly larger range of average linear errors in the beaconing APS condition (4.0 feet at 10 feet from the start and 5.0 feet at the crossing midpoint), the simple main effect of distance was not significant \( F(3,48)=1.795, p>.05 \). The main effect of distance was thus largely driven by the very large increase in average linear errors as participants traveled the first half of crossings with standard APS [simple main effect, \( F(3,48)=6.207, p<.01 \)]. If, for the sake of analysis, the maximum distance outside the crosswalk had not been limited to seven feet, the linear error might be found to be greater as participants travelled the last half of the crossing.

The pattern is highly similar for Austin-- all three omnibus effects are significant; interaction \( F(6,102)=14.780, p<.001 \), main effect of distance from the start \( F(3,51)=36.716, p<.001 \), and main effect of treatment condition \( F(2,32)=7.094, p<.01 \). In this case, both the guidestrip (3.8 ft, 1.2 m) and the beaconing APS (3.3 ft, 1 m) resulted in smaller linear errors than standard APS (7.2 ft, 2.2 m) \( [t(17)=4.891, p<.001, t(17)=5.377, p<.001, \text{respectively}] \). The average linear errors in the guidestrip and beacon conditions did not significantly differ \( [t(17)=1.28, p>.05] \).

Once more, neither of the simple main effects of distance for the guidestrip and beaconing APS cues were significant \( F(3,51)<1.0, F(3,51)=2.518, p>.05, \text{respectively}] \). Thus both the interaction and the main effect of distance were largely driven by the very large increase in the magnitude of average linear errors as participants travelled the length of the crossings with standard APS [simple main effect, \( F(3,51)=50.653, p<.001 \).
Table 1 presents data collapsed across all three cities in order to consider the frequency and severity of travel outside of the crosswalk in the different conditions. The first block of cells in the table looks at all position data points and the second block of cells describes only those data where participants were outside of the crosswalk. Within a given treatment condition, data was collected at 4 points during each of 4 crossings by 18 participants in each of 3 cities for a total of 864 data points representing participant positions during crossings.

**TABLE 1 Effect of Treatment on the Frequency and Magnitude of Linear Errors**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Standard APS</th>
<th>Beacon APS</th>
<th>Guidestrip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Of All Position Data, How Often and How Far Outside of the Crosswalk? †</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of all position data in which participants were outside of the crosswalk but within 2 ft (.6 m) of the crosswalk</td>
<td>13.2%</td>
<td>12.6%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Percentage of all position data in which participants were between 3 and 5 ft (1 and 1.5 m) away from the crosswalk</td>
<td>16.6%</td>
<td>9.2%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Percentage of all position data in which participants were 6 ft (2 m) or more away from the crosswalk</td>
<td>28.1%</td>
<td>4.3%</td>
<td>3.3%</td>
</tr>
<tr>
<td>Percentage of all position data in which participants were outside of the crosswalk (sum of previous three rows)</td>
<td>57.9%</td>
<td>26.1%</td>
<td>11.9%</td>
</tr>
</tbody>
</table>

| When Outside of the Crosswalk – How Far? † |              |            |            |
| Percentage of instances in which participants were outside of crosswalk, in which they were within 2 ft (.6 m) of the crosswalk | 22.8%        | 48.2%      | 59.4%      |
| Percentage of instances in which participants were outside of crosswalk, in which they were between 3 and 5 ft (1 and 1.5 m) from the crosswalk | 28.7%        | 35.3%      | 12.9%      |
| Percentage of instances in which participants were outside of crosswalk, in which they were 6 ft (2 m) or more from the crosswalk | 48.5%        | 16.5%      | 27.7%      |

† Data from all three cities has been combined for these descriptive measures

Participants in the standard APS condition were outside of the crosswalk 57.9% of the time, and they were outside of the crosswalk by 6 feet (2 m) or more 28.1% of the time. In the beaconing APS and guidestrip conditions, overall rates of travelling six or more feet outside of the crosswalk are relatively low (4.3% and 3.3%, respectively). Overall, it appears that participants were more likely to be outside the crosswalk with the beaconing APS (26.1% of the time) than with the guidestrip (11.9% of the time); however, both rates are less than half that observed in the standard APS condition (57.9%).

The lower half of Table 1 provides a sense of the magnitude of errors when they did occur. In the beaconing APS condition, when errors occurred, about half of the time participants were within 2 feet (.6 m) of the crosswalk, and more than 80% of the time they were within five feet (1.5 m) of the crosswalk. When errors occurred in the guidestrip condition, participants had what appears to be a higher tendency to commit very large errors (28% of the time).

**Interventions Due to Significant Safety Concerns During Crossings**

It should be expected that the more often participants were outside of the crosswalk, and the farther from the crosswalk they were, the higher the rates of safety interventions. Such an
expectation is largely confirmed by one-way RM ANOVAs conducted for each city. On average, Alpharetta participants required an intervention on 26.8% of standard APS crossings, 1.8% of beaconing APS crossings, and 3.6% of guidestrip crossings [$F(2,26)=24.53$, $p<.001$]; both beaconing APS and guidestrip resulted in fewer interventions than standard APS [$t(13)=5.51$, $p<.05$; $t(13)=4.76$, $p<.05$; respectively]. Similarly, Towson participants required an intervention on 11.6% of standard APS crossings, and no interventions on beaconing APS or guidestrip crossings [$F(2,34)=6.01$, $p<.01$].

Intervention rates were uniformly low in Austin, with interventions averaging 2.8% on standard APS crossings, 0.0% on beaconing APS crossings, and 1.4% on guidestrip crossings [$F(2,34)=1.00$, $p>.05$]. However, participants in the standard APS condition were nonetheless outside of the crosswalk by six feet (2 m) or more 38% of the time, above the rates in the other cities where the intervention rates were much higher. Of the 72 crossings attempted in Austin with standard APS, 12 involved the participant traveling on a diagonal heading across the intersection. Thus 16.7% of standard APS crossings in Austin resulted in participants attempting to cross an active intersection diagonally. The geometry of the intersection as well as the traffic flow on streets parallel to the experimental crosswalks in Austin was such that participants could make diagonal crossings but rarely be in danger of a crash.

Independence, Crossing Initiation, and Crossing Completion Measures

There were no consistent significant differences attributable to wayfinding condition with respect to rate of independence in locating a starting position (91.2%) [value in parentheses is the average rate across all conditions and all cities], rate of locating an accurate starting position (82.1%), rate of independence aligning to cross (98.7%), rate of independence determining when to initiate crossings (98.33%), rate of initiating crossings during a walk interval (76.9%), latency to begin crossing after the onset of WALK (3.6 seconds), or rates of completing crossings before the onset of perpendicular green (99.4%). Thus there were no unanticipated adverse consequences attributable to wayfinding treatment condition found in any of these measures.

DISCUSSION

While not all intersections need special cues or treatments to facilitate crosswalk accessibility, additional information for blind pedestrians appears to be needed at very long or complex crosswalks such as those used in the experiments reported here. Whereas each test intersection had different characteristics, their common feature was the lack of readily available wayfinding cues such as the lack of traffic traveling parallel to the crosswalk direction, the most commonly used cue for maintaining heading. While standard APS provide sufficient information for pedestrians who are blind to make accurate starting time judgments ($8,9$), participants in this research were outside the crosswalk area almost 60% of their crossing time in the standard APS condition. Both the guidestrip and the beaconing APS resulted in much more accurate crossing performance with respect to being within the crosswalk at various points during crossing, average distance from the center of the crosswalk at various points during crossing, and the likelihood of being well outside of the crosswalk (6 feet, 2 m or more).

The pattern of the magnitudes of errors when participants were outside the crosswalk reflects some observed differences in how participants used each treatment. With standard APS, more than half of the time participants were out of the crosswalk, they were out by six or more feet, making them very likely to be in the path of potential through traffic in the intersection, or in the path of vehicles idling on the street they were crossing. The wayfinding challenges of the crossings left participants in the standard APS condition with little information to help them...
regain a correct heading once they lost it. With beaconing APS and guidestrips, when
participants were out of the crosswalk, they were out by six feet (2 m) or more 16.5% and 27.7%
of the time respectively.

With beaconing APS, it was common to see corrections in heading when the quiet walk
indication ended and the far-side audible beacon tone began, and also when participants
approached the end of the crossing. With beaconing APS, no participant was observed to miss
the destination corner, although some were outside the crosswalk (and on some crossings where
the audible beacon speaker was outside the crosswalk, they were actually being led to a
destination outside the crosswalk.) With the guidestrip, as long as participants remained in
contact with the guidestrip, they were likely to be within or nearly within the crosswalk, the
distance outside the crosswalk being related, in part, to which side of the guidestrip they were
walking on and the technique they were using to follow the guidestrip. However, if they lost
contact with the guidestrip because there was some surface irregularity that made them uncertain
about the location of the guidestrip, or they had to go around a vehicle idling in the crosswalk, or
for some other reason, they were fully dependent on other wayfinding cues, which were minimal
at these crossings, for re-orientation. As a consequence, when they lost contact with the
guidestrip, they may have finished their crossings quite far from the crosswalk, and sometimes in
the parallel street.

Cross-city comparisons should be viewed as exploratory as there are a number of
potentially confounding variables which could not be controlled (e.g., intersection geometry,
traffic patterns, average travel skill of participants). With this in mind, and considering only the
data from beaconing APS trials, participants did align more accurately on a greater percentage of
trials in Austin than in Towson [80.6% vs. 57.4%; independent t(34)=2.389, p<.05] and an
exploratory mixed-model two-way ANOVA of distance from the center of the crosswalk by city
and distance from crossing start reveals a significant main effect of city [F(1,34)=5.983, p<.001]
with average distances of 3.27 ft (1 m) in Austin and 4.6 ft (1.4 m) in Towson. So while it
should not be viewed as conclusive, evidence suggests that accurately centering the beacon
speakers may be quite important with regards to maximizing pedestrian safety.

While alignment and heading accuracy were quite good with both the guidestrip and
beaconing APS, some concerns remain. Where the raised guidestrips were used in the field,
participants had considerable difficulty locating them. Guidestrips were not installed across the
gutter due to concerns about drainage, so participants had to search for the guidestrip
approximately 2 feet (.6 m) from the curb line. Most participants found the guidestrips, but they
had been made explicitly aware that the guidestrips were present at the crosswalk, which would
not be the case in a natural environment. There has been no research on cues that may help
pedestrians who are blind locate raised guidestrips. More broadly, no systematic research has
been conducted on providing cues for locating the crosswalk, but early research under this
project provided ample documentation of the difficulty blind pedestrians have in locating
channelized crosswalks (6,13), especially when they are at atypical locations such as midblock, at
roundabouts, and recent and not yet published research by these
investigators has begun to look at the effect of a prototype guidance material on locating the
crosswalk at midblock and roundabout crossings.

Additionally, there are concerns about the durability of any kind of tactile guidestrip,
particularly in locations where snowplows are used, and there may be issues of detectability
when snow and ice cover the roadway. The material used in these experiments was not a
permanent material and was chosen because of the need to move the material for testing.
Materials for permanent installation need to be explored further. One of the qualities that seemed

to make guidestrips usable by blind participants was the rigid vertical edge on the material,

unlike the rounded edge of typical crosswalk marking materials. Indeed, there were crosswalks

where the many layers of thermoplastic tape used for some of the crosswalk lines were mistaken

for the guidestrip, and participants had difficulty maintaining contact with guidestrips throughout

the crossing.

An issue to be considered with respect to beaconing APS is whether an intersection

outfitted with beaconing for all crossings might create the potential for situations in which

pedestrians use the wrong beacon during a crossing, causing a dangerous situation. Having the

audible beacon activated by an extended pushbutton press (a press of one second or more) helps

minimize the potential of such errors because it would likely be a relatively rare occurrence that

multiple audible beacons would be activated during a single pedestrian cycle. However,

potential beaconing confusion could lead to dangerous crossings. The authors have now

addressed this issue with an experiment in which an experimenter pushed the button to call the

audible beaconing for another crosswalk. Data is currently being analyzed.

As described in the methods, the prototype beaconing APS used in this investigation

included an “alignment tone” from the distant speaker following the extended button press, a

quieter audible walk indication during which no specific beaconing information was provided,

followed by the loud tone from the opposite end of the crosswalk, which provided a heading cue

that sounded throughout the flashing don’t walk interval. For a crossing with a walk interval that

is typical in length (5-7 seconds), this creates a progression in which it is expected that the

participant will align and wait, initiate their crossing during WALK, and then hear and be able to

use the audible beacon to guide the completion of the crossing. However, where the walk

interval is longer than 7 seconds, the audible beacon may not begin until individuals are more

than halfway across the street. In the investigation reported here, the timing of one crossing in

Towson was modified before the start of data collection in order to reduce the duration of

WALK and make its timing more similar to all other crossings investigated. If this had not been
done, we hypothesize that accuracy in Towson would have been less. Future modifications to the

software of the beaconing APS could probably address this issue.

CONCLUSIONS

Prototype beaconing APS or tactile guidestrips should be considered as options for making

challenging crossings accessible to pedestrians with visual impairments. Challenging crossings

that may benefit by installation of one of these treatments include, but are not limited to, ones

that are very wide, as well as those with little parallel traffic, skewed crosswalks or heavy turning

traffic. Beaconing APS may be the preferred option at signalized intersections, especially in

northern climates, while guidestrips may be a good option at some challenging unsignalized

crossings such as channelized turn lanes and roundabouts, or for travelers who are deaf-blind.
The particular type of beaconing used in this research should be preferred over other types of

beaconing because it resulted in accuracy that was superior to other types of beaconing

previously investigated by this team (8). For a review of previous research on beaconing at

accessible pedestrian signals, see Accessible Pedestrian Signals: A Guide to Best Practices,

Appendix C, Research on the source of the walk signal.(14)

The choice of whether to install beaconing APS or guidestrips at an intersection should

include consideration of the cost associated with placing beaconing speakers within the

crosswalk and maintaining not only guidestrips, but also the roadway surface and other markings

on the roadway. Neither treatment will function optimally without attention to these details.
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