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Blind Pedestrians and the Changing Technology and Geometry of Signalized Intersections: Safety, Orientation, and Independence

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Abstract

This study documented that blind pedestrians have considerable difficulty locating crosswalks, aligning to cross, determining the onset of the walk interval, maintaining a straight crossing path, and completing crossings before the onset of perpendicular traffic at complex signalized intersections. Revised techniques and strategies are suggested for alleviating these difficulties.

Pedestrians who are visually impaired (that is, are blind or have low vision) often travel in unfamiliar areas and cross at signalized intersections. The tasks that are involved in crossing a street include detecting the street, locating the crosswalk or crossing location, aligning (establishing a heading toward the opposite corner), determining an appropriate time to cross, and traveling in a straight path while crossing (Guth & Rieser, 1997; Tauchi, Sawai, Takato, Yoshiura, & Takeuchi, 1998). Nonvisual techniques to accomplish each of these tasks have changed little over the past 30 years (Allen, Barbier, Griffith, Kern, & Shaw, 1997; Hill & Ponder, 1976; Jacobson, 1993; LaGrow & Weessies, 1994; Willoughby & Monthei, 1998).

However, today's signalized intersections differ from the intersections of 20 years ago, and modern traffic signals do not function in the same manner. Intersection geometry and signalization are designed to move vehicles as rapidly and efficiently as possible, but pay minimal attention to the movement of pedestrians. Intersections are wide, commonly more than four lanes, often with designated lanes for right-turning or left-turning traffic. Corners are rounded to facilitate fast and easy turns for large vehicles. When an intersection is wide, has abundant turning traffic, or is noisy, it can be difficult to hear and recognize which lanes are moving or beginning to move (Bentzen, Barlow, & Franck, 2000; Carroll & Bentzen, 1999). In addition, fluctuations in the flow and volume of traffic and the lack of vehicular lanes parallel to some crosswalks may contribute to disorientation, since the sounds of vehicles are used to determine the location of crosswalks, to establish a heading toward the opposite side of the street, and to travel straight across the street.

The advent of actuated traffic control has revolutionized strategies for traffic signalization. Unlike the consistent signal cycles that existed when orientation and mobility (O&M) techniques were developed, signals now respond to the traffic that is present at one intersection or at a series of related intersections along a corridor. Sensors can be installed for each lane of vehicular traffic, so the length of each phase may change with each signal cycle, and the sequence and order of the signal phases may change within each cycle because phases are skipped when no traffic is present in that lane at the beginning of the phase.

If pedestrians do not use the pedestrian pushbutton when crossing major arterial streets, the time before perpendicular traffic is permitted to move may be too short for them to cross because the signal is timed for the needs of vehicles (vehicular timing). Pushing the pedestrian pushbutton is often required to request the pedestrian timing, a combination of the walk interval time and the pedestrian clearance interval time (flashing Don't Walk signal). The clearance interval is a calculated time in seconds, typically the street width divided by 4 (representing the average pedestrian walking speed of 4 feet per second) (Federal Highway Administration, 2003; McKinley, 2001).

The use of pushbuttons can also affect the alignment task. Traditional alignment techniques that pedestrians who are blind use when crossing at unfamiliar intersections involve maintaining the approach alignment and then waiting through a signal cycle after arriving at the curb to confirm their alignment by listening to vehicles that are traveling parallel to their path. When the signal is push-button actuated, pedestrians must divert from their approach alignment to use the pushbutton and then cross during the next pedestrian phase after they push the button, eliminating the opportunity to listen through a cycle to establish their alignment.

At a small minority of modern intersections, priority is given to pedestrians in the form of a leading pedestrian interval (LPI), in which pedestrians receive an indication to walk a few seconds before vehicles are permitted to move. The LPI is intended to give pedestrians a head start and prevent conflicts with vehicles that are turning into their path. However, without accessible signal information, pedestrians who are blind will wait during the LPI and start crossing when the vehicles begin to move, when drivers are not expecting pedestrians to be starting to cross. At other locations an exclusive pedestrian phase has been implemented during which vehicles from all directions have a red signal. The exclusive pedestrian phase can be difficult to distinguish from a gap in traffic at locations where there is intermittent traffic, and exclusive pedestrian phases are usually installed at locations where crossing with parallel traffic is dangerous, such as locations with a high volume of turning traffic.

The research reported here was undertaken to investigate the safety, orientation, and independence of pedestrians who are blind while crossing at complex, signalized intersections with some of the features just described. This article is one of several that will report the results of tests of street crossing by pedestrians who are blind at complex, signalized intersections without accessible pedestrian signals (Bentzen, Barlow, & Bond, 2004). The aim of this article is to provide a descriptive analysis of broad measures of safety, orientation, and the need for assistance or intervention for safety in crossing, and implications for O&M instruction.

Method

Participants

Sixteen local participants who were unable to see crosswalk lines, poles, or pedestrian signals made 8 or 9 crossings in each of three cities (a total of 48 participants and 416 crossings). All the participants were accustomed to crossing independently at signalized intersections using a long cane or a dog guide. The participants' demographic characteristics were similar across all three cities. The 48 participants (30 men and 18 women) ranged in age from 20 to 78, with a mean age of 46. The majority of participants used a long cane as their mobility device, and fewer than 4 in each city used a dog guide. Forty-four of the participants rated themselves as good to excellent travelers, and 4 rated themselves as fair travelers.

Locations

The data were collected at two signalized intersections in each of three cities: Portland, Oregon; Cambridge, Massachusetts; and Charlotte, North Carolina (see Figure 1). These sites provided examples of intersections with various levels of complexity. In Charlotte and Portland, the pedestrian signals at the intersection of a major street were actuated, meaning that pedestrians had to push the pushbutton to get a Walk signal and pedestrian timing. The pedestrian signals to cross the minor streets were "on recall," meaning there was adequate time in every cycle to cross that street and no pedestrian pushbuttons were provided. In Cambridge, an exclusive pedestrian phase was provided to cross the major street at one intersection, and an LPI was provided for the major crossing at the other intersection. Other intersection complexities included left- and right-turn arrows, split phasing (green signals provided for northbound traffic and southbound traffic at different times), signalized and unsignalized channelized (separated) right-turn lanes, offset intersections, skewed intersections, and median islands.

Procedure

All the participants were tested individually and traveled two routes at each of two intersections, with each route requiring two to three street crossings. One route in Portland and one route in Charlotte included a channelized right-turn lane, which was considered the separate third crossing. Routes were L-shaped, requiring one crossing of the major street and one crossing of the minor street. At each intersection, one route included clockwise crossings, and the other included counterclockwise crossings. The participants were not familiar with the intersections, and the order of traveling intersections and routes was systematically varied among them.

The participants were asked to assume that they needed to cross for an appointment. They were instructed to cross the street in front of them (perpendicular) and then to cross the street beside them (parallel). They were to use their usual mobility device and techniques to approach the intersection, determine where to cross, align for crossing, determine when to begin to cross, and complete the crossing. They could request assistance from the researchers with all or any part of the crossing task if they would typically request assistance from other pedestrians in a similar situation. While the participants were locating the crosswalk and aligning to cross, the researchers intervened only when the starting location and alignment would result in their crossing the wrong street or at a clearly hazardous location or direction. Intervention occurred when the participants started to cross, or while they were crossing the street, only when they were in, or stepping into, the path of moving vehicles.

The participants were accompanied at all times by one of the researchers, who communicated instructions for the experimental procedure and monitored their safety. Another researcher obtained data using direct observation and a stopwatch. Both researchers were certified orientation and mobility specialists. Data were obtained for the following 12 variables in relation to the participants: finding pushbuttons, using pushbuttons, location in relation to the crosswalk at the beginning and end of the street crossing, travel path in relation to the crosswalk, crossing alignment, delay in beginning crossing after the onset of the walk interval or of parallel through traffic, right cue or wrong vehicular cue, pedestrian signal status at the beginning and end of crossing, vehicular signal status at the end of crossing, and requests for assistance or the need for intervention for safety in any part of the sequence of crossing tasks. If the researcher intervened on a crossing subtask or if the participant requested assistance on a task, data on that portion of the task were not recorded. However, data on subsequent tasks were recorded if the participants continued to cross independently.

Results

Safety

Pedestrians are at risk if they complete crossings after perpendicular traffic has received a green signal. The longer that pedestrians delay starting to cross, the more likely they are to still be in the street after the onset of perpendicular traffic. The mean starting delay across all three cities was 6.4 seconds. The pedestrian interval during which pedestrians begin crossing is indicative of safety. Traffic engineers time pedestrian signals with the expectation that pedestrians will begin crossing when the Walk signal is on, and the length of the pedestrian phase is based on that assumption (Barlow, Franck, Bentzen, & Sauerburger, 2001; McKinley, 2001). The percentage of crossings that were initiated during each interval of the pedestrian phase and the percentage that were completed after the onset of perpendicular traffic are presented for each city and across all cities in Table 1. For all three cities, only 48.6% of the crossings started during the walk interval, and 26.9% of all independent crossings ended after the onset of the perpendicular traffic.

The need for pushbutton actuation of the walk interval affected the likelihood that the participants would begin crossing during the walk interval. At crossings where pushbutton actuation was required, the participants looked for, found, and pushed the button on only 16.3% of these crossings in Portland and on none of the crossings in Charlotte. They began crossing during the walk interval on only 19.5% of these pedestrian-actuated crossings compared to 71.7% of the crossings where the pedestrian phase was on recall (that is, was included in every cycle) in these two cities. In Portland, the participants began crossing during the walk interval on only 24.6% of pedestrian-actuated crossings, and on 50.0% of these crossings, they failed to complete their crossings before the onset of perpendicular traffic. When the pedestrian phase was on recall, 82.1% started during the walk interval, and only 5.7% completed crossing after the onset of perpendicular traffic. A similar pattern was observed in Charlotte. Pedestrian-actuated crossings resulted in 11.4% of the crossings starting during the walk interval, with 37.8% of the crossings ending after the onset of perpendicular traffic, contrasted with 58.1% and 20.9%, respectively, of the crossings where the pedestrian phase was on recall.

Orientation

It is common for a crossing that is started outside the crosswalk or from a poorly aligned heading to be corrected midcrossing using information that is provided by vehicles that are moving parallel to the pedestrians' desired direction of travel or by the crown of the roadway, the slope of the roadway toward the corner. Although approximately three-quarters of the crossings began with appropriate alignment, location, or both, about 50% of them ended outside the crosswalk (see Table 1).

Independence

The participants could request assistance for any, or all, of the street-crossing tasks, and the researchers had to intervene for safety on some crossings. During each of these street-crossing tasks, the majority of street-crossing decisions were made independently (80%–90% across three cities; see Table 2). The proportion of interventions to requests for assistance varied, depending on the point in the street-crossing process. When the participants were locating the crosswalk, aligning to cross, and determining when to start crossing, assistance occurred more often in response to requests than as interventions. Out of the total number of requests and interventions for each task, the percentages of requests for assistance were 53% (33 out of 62) for starting location, 60% (23 out of 39) for alignment, and 73% (55 out of 75) for determining when to start crossing. Once the participants were in the street, interventions were much more common than requests, with only 7% (3 out of 42) of the assistance occurring as a result of the participants' requests. Once the participants began crossing, they continued to cross unless the researcher intervened. Although the researcher was closely following them, the participants had no opportunity to request assistance unless they stopped on a median or otherwise had contact with the researcher; this happened once in each city.

The participants requested assistance or required intervention less often in Cambridge than in either Portland or Charlotte. Our observations led us to conclude that they may have done so because of the narrower street crossings, lower average speeds, and high number of pedestrians, combined with the drivers' expectation of pedestrians and willingness to yield, in Cambridge.

Discussion

Determining the time to cross

The causes of the failure to begin to cross during the walk interval appear to have been different for each city. In Portland and Charlotte, at the major street at all four intersections, plus the signalized right-turn lane (nine crossings), pedestrian timing was pedestrian actuated--and most participants did not use the pushbuttons, so they never had a pedestrian timing phase. The volume of traffic on the minor streets, to be used as a starting cue when crossing the major street, varied. All crossings in Cambridge had pretimed Walk signals, but no concurrent traffic began to move at the onset of the walk interval at the major street crossings because of the LPI or exclusive pedestrian phases. Thus, in Cambridge, when the pedestrians crossed the major street, they did not have precise vehicular movement to indicate the onset of the walk interval. In all three cities, there was usually an adequate surge of traffic on the major street to use when crossing the minor street.

Some O&M instructors and pedestrians who are blind do not consider the status of the pedestrian signal to be an appropriate measure of the safety of a crossing. However, they should be aware of the laws regarding obedience to pedestrian signals. Many individuals mistakenly believe that pedestrians always have the right-of-way. The Uniform Vehicle Code (UVC) provides standard laws that form the basis for traffic laws in the United States. Some states have adopted slight variations from the laws described next, but most use the UVC language. The UVC specifically limits pedestrian right-of-way where pedestrian signals are installed (National Committee on Uniform Traffic Laws and Ordinances, 2000). UVC § 11–501(a) requires pedestrians to "obey the instructions of any official traffic control device specifically applicable to such pedestrian," and UVC § 11–203 explains the meaning of the pedestrian control signals. At locations with pedestrian control signals, pedestrians are legally crossing if they begin their crossing during the Walk signal. It is legal to complete a crossing during the flashing Don't Walk signal if they began during the Walk signal, but it is not legal to begin to cross during the flashing or steady Don't Walk signal.

Assuming that pedestrians who are blind should start crossing during the walk interval to make a legal crossing, do the current techniques work? This question is important in light of the research reported here. The participants were observed to make crossing judgments that put them at risk, such as stepping out into a lane of cars that were turning left with a green arrow, completing their crossing well after the perpendicular traffic had a green signal, or crossing in a gap in traffic while vehicles on the perpendicular street had a green signal. Overall, interventions that were made when the participants started to cross occurred in 5% of the crossings, and interventions that were made during the crossings occurred in 11% of the crossings; intervention during these two tasks indicates a safety concern.

Locating and using pedestrian pushbuttons

The participants looked for, found, or used the pedestrian pushbuttons on 16.3% of the actuated crossings in Portland and none of the crossings in Charlotte. This lack of use of pushbuttons resulted in a high proportion of crossings when the Don't Walk signal was on that were not covered by any legal provision of right-of-way. What is of greater concern is that 45.4% of all these pedestrian-actuated crossings resulted in individuals being in the street when the perpendicular traffic began to move. The participants' responses to questions after their crossings indicated that many did not understand the function of pedestrian pushbuttons, thinking that they would make the signal change faster.

Many participants stated that they used pushbuttons only when they knew that the pushbuttons were there and knew where to find them. No techniques are described in the O&M texts for searching for and using pedestrian pushbuttons. The need to use pedestrian pushbuttons can affect all aspects of the street-crossing task. One of the most common techniques for alignment, particularly in the absence of traffic, is to maintain the approach line of travel (Hill & Ponder, 1976; LaGrow & Weessies, 1994; Willoughby & Monthei, 1998). Diverting from the approach path to locate the pushbutton prevents travelers from using that information. After one uses a pushbutton, it is necessary to realign quickly and be prepared to cross with the next parallel surge of traffic or go back and push the button again. A strategy that has been suggested by some experienced O&M instructors is to travel to the edge of the street first, maintaining the approach alignment; to assess the street crossing and locate a tactile clue to use in realigning; to use systematic search patterns to determine if there is a pushbutton for the crossing; and then to return to the predetermined location and tactile cue. An accessible pedestrian signal (APS) with a push-button locator tone may make it easier to locate the button, but modifications in traditional approach-and-alignment techniques are still necessary.

Traffic lanes used as a cue for crossing

On numerous crossings, the participants were observed to start crossing when traffic began moving on the parallel street, which was often moving with a leading left-turn phase, when vehicles had a green left-turn arrow to drive through the crosswalk and the legal right-of-way. We observed that this situation was the cause of many interventions while our subjects were crossing the street.

The traditional technique used by pedestrians who are blind, as described in O&M textbooks, is to initiate a crossing when there is a surge of parallel traffic. Travelers may delay the initiation of the crossing until they are sure that the traffic is going straight and they are not starting their crossing with a vehicle turning right on red rather than with the surge of traffic on green (Allen et al., 1997; Hill & Ponder, 1976; Jacobson, 1993; LaGrow & Weessies, 1994; Willoughby & Monthei, 1998). With current signalization patterns, this technique needs refinement and additional detail. Using the movement of traffic in any lane of the parallel street is inadequate with today's complex signal timing because pedestrians who use this strategy may begin crossing when vehicles have a green left-turn arrow to cross the crosswalk (and perpendicular traffic sometimes also has a right-turn arrow at that time). Parallel crosswalks may also have Walk signals at different times, which can cause confusion for pedestrians who are visually impaired.

The pedestrian Walk signal is usually coordinated with the movement of the traffic in the parallel through-lane nearest to the pedestrian (or the near-side parallel lane). As is shown in Figure 2, traffic in this lane may be traveling in the same direction as the pedestrian or may be coming toward the pedestrian from across the intersection. That traffic begins moving after any dedicated left-turn phase is completed; vehicles may still be permitted to turn left, but they no longer have the right-of-way and are required to yield to oncoming traffic or to pedestrians in the crosswalk. When traffic in the near-parallel lane is moving and steady, it blocks left-turning traffic from driving through the crosswalk.

Although this technique prevents pedestrians from crossing into left-turning traffic, there are intersections where there is intermittent or no parallel traffic and the signal status cannot be adequately determined by traffic sounds. At such intersections, including those with exclusive pedestrian phasing or LPIs, an APS can provide access to information from the Walk signal.

Assistance and intervention

The difference in requests for assistance and interventions in the three cities was likely attributable to a combination of factors. Crossings in Charlotte and Portland were at locations with moderate pedestrian traffic, transit stops at the intersection, and heavy, fast-moving vehicular traffic. In Cambridge, the curb line was modified to slow traffic and shorten the lengths of crosswalks (see Figure 1), which slowed traffic and shortened the lengths of crosswalks. There was also a large number of pedestrians. Although several participants made serious errors in the timing of their crossings in Cambridge, the drivers were aware of pedestrians and yielded the right-of-way. According to their responses to questions after each set of crossings, the participants in all cities often did not realize that they had made any kind of crossing error or had been at any particular risk when the drivers yielded.

Orientation

Orientation issues, such as completing crossings within the crosswalk, can also have an impact on safety. The intersections that were used in this research had wide, marked crosswalks. For consistency, we used these marked crosswalks as the defined areas where pedestrians were “supposed to cross,” although we are aware that blind pedestrians and O&M instructors are sometimes not concerned with crosswalk markings as long as the crossing is made from a location that is near to the corner. However, drivers may not be expecting pedestrians when the pedestrians are not within the defined areas of the crosswalk.

As can be seen in Figure 1, several of the crossings were skewed or located somewhat away from street corners. In Charlotte, the participants completed crossings within the crosswalk in only 43.5% of the trials. It is possible for a crossing that is started outside the crosswalk or from a poorly aligned heading to be corrected during the crossing. Across the three cities, 31.6% of the crossings that began outside the crosswalk and 25.0% of the crossings that began poorly aligned ended within the crosswalk. A high proportion of crossings (89%) that started within the crosswalk and were properly aligned ended within the crosswalk.

Our observations suggested that the participants were most successful in starting to cross within the crosswalk when they used the location of curb ramps to indicate the location of the crosswalk. Although this is generally a reliable indicator of the location of a crosswalk, appropriate techniques are needed to maintain alignment while assessing such clues and for aligning while on or beside curb ramps that may not slope in the direction of travel on the crosswalk. Previous research indicated that pedestrians who are blind are more likely to veer into the parallel street if they locate and travel down a curb ramp that is at the apex of the corner (Hauger, Rigby, Safewright, & McAuley, 1996).

Conclusion

From discussions that we have had during presentations to O&M professionals, it has become obvious that many O&M instructors are not adequately educated on traffic signalization, laws regarding pedestrians’ right-of-way, and techniques and strategies to use at actuated intersections. The lack of awareness of laws and signal-timing issues puts blind pedestrians at risk of injury and O&M instructors at risk of being considered liable for giving clients incorrect information. Updated techniques for evaluating intersections, using pedestrian pushbuttons, aligning to cross, and determining the appropriate crossing time are needed. However, at many intersections, strategies and techniques will not resolve the difficulties or provide enough information for crossing safely without access to the signal information.

APS, with characteristics that were demonstrated in previous research in this project to facilitate detection and localization (Wall, Ashmead, Bentzen, & Barlow, 2004), have now been installed at all six intersections, according to guidelines in *Accessible Pedestrian Signals: Synthesis and Guide to Best Practice* (Barlow, Bentzen, & Tabor, 2003). Ongoing analyses of data have suggested that APS decreased the delay in starting to cross, increased the number of crossings that participants began independently and within the walk interval, increased the number of crossings that were completed before the signal changed, and reduced the number of requests for assistance. The results of postinstallation testing will be used to refine the technology and its installation, so the APS functions optimally for providing accessible information and is minimally obtrusive in the environment.

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References

Allen, W.; Barbier, A.; Griffith, A.; Kern, T.; Shaw, C. Orientation and mobility teaching manual. Vol. 2. New York: CIL; 1997.

Barlow JM, Franck L, Bentzen BL, Sauerburger D. Pedestrian clearance intervals at modern intersections: Implications for the safety of pedestrians who are visually impaired. Journal of Visual Impairment & Blindness 2001;95:663–667.

Barlow, JM.; Bentzen, BL.; Tabor, L. Accessible pedestrian signals: Synthesis and guide to best practice. Berlin, MA: Accessible Design for the Blind; 2003.

Bentzen BL, Barlow JM, Bond T. Challenges of unfamiliar signalized intersections for pedestrians who are blind: Research on safety. Transportation Research Record: Journal of the Transportation Research Board 2004;1878:51–57.

Bentzen BL, Barlow JM, Franck L. Addressing barriers to blind pedestrians at signalized intersections. ITE Journal 2000;70(9):32–35.

Carroll J, Bentzen BL. American Council of the Blind survey of intersection accessibility. Braille Forum 1999;38:11–15.

Federal Highway Administration. Manual on uniform traffic control devices for streets and highways. Washington, DC: Author; 2003.

Guth, DA.; Rieser, JJ. Perception and the control of locomotion by blind and visually impaired pedestrians. In: Blasch, B.; Wiener, W.; Welch, R., editors. Foundations of Orientation and Mobility. New York: AFB Press; 1997. p. 9-39.

Hauger J, Rigby J, Safewright M, McAuley W. Detectable warning surfaces at curb ramps. Journal of Visual Impairment & Blindness 1996;90:512–525.

Hill, E.; Ponder, P. Orientation and mobility techniques: A guide for the practitioner. New York: American Foundation for the Blind; 1976.

Jacobson, W. The art and science of teaching orientation and mobility. New York: American Foundation for the Blind; 1993.

LaGrow, S.; Weessies, M. Orientation and mobility: Techniques for independence. Palmerston North, New Zealand: Dunmore Press; 1994.

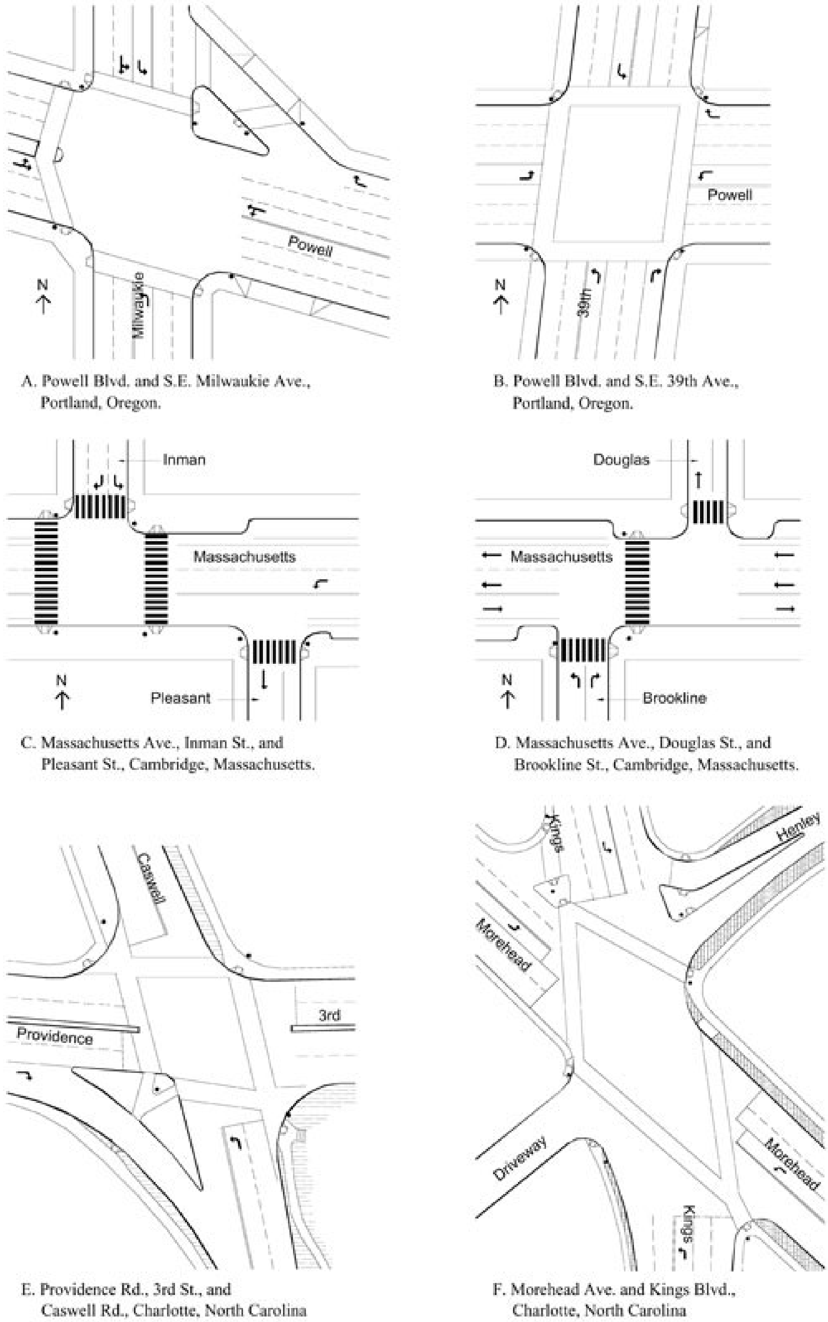
McKinley, D. Traffic signals. In: Pline, J., editor. Traffic control devices handbook. Washington, DC: Institute of Transportation Engineers; 2001. p. 261-362.

National Committee on Uniform Traffic Laws and Ordinances. Uniform Vehicle Code: Millennium edition. Alexandria, VA: Author; 2000.

Tauchi, M.; Sawai, H.; Takato, J.; Yoshiura, T.; Takeuchi, K. Development and evaluation of a novel type of audible traffic signal for the blind pedestrian. Proceedings: The Ninth International Mobility Conference; Atlanta: Rehabilitation Research and Development Center, Atlanta VA Medical Center; 1998. p. 108-111.

Wall RS, Ashmead DH, Bentzen BL, Barlow JM. Directional guidance from audible pedestrian signals for street crossing. Ergonomics 2004;47:1318–1338. [PubMed: 15370850]

Willoughby, DM.; Monthei, SL. Modular instruction for independent travel. Baltimore, MD: National Federation of the Blind; 1998.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Douglas
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Brookline
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D. Massachusetts Ave., Douglas St., and Brookline St., Cambridge, Massachusetts.
Caswell
3rd
Providence
E. Providence Rd., 3rd St., and Caswell Rd., Charlotte, North Carolina
Kings
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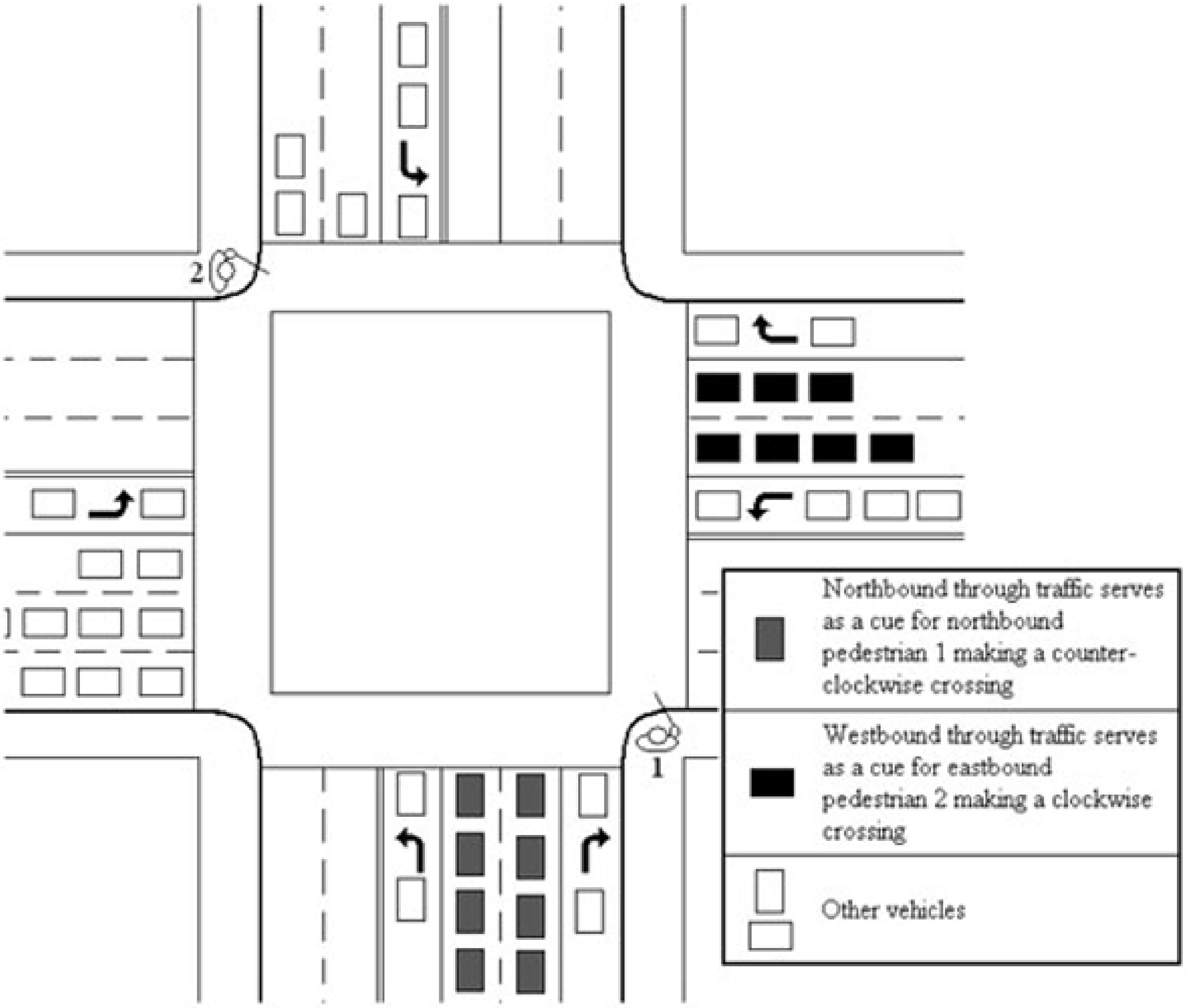
Figure 1.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Northbound through traffic serves as a cue for northbound pedestrian 1 making a counter-clockwise crossing
Westbound through traffic serves as a cue for eastbound pedestrian 2 making a clockwise crossing
Other vehicles

Figure 2.

Table 1

Participants' safety and orientation in crossing (percentage)

Measure	Portland	Charlotte	Cambridge	Three-city mean
Safety				
Started during the Walk signal	50.4	34.5	57.1	48.6
Started during the flashing Don't Walk signal	12.0	19.5	15.1	15.1
Started during the Don't Walk signal	37.6	46.0	27.7	36.3
Completed the crossing after the onset of perpendicular traffic	29.2	28.8	23.3	26.9
Orientation				
Started from within the crosswalk	82.4	70.3	61.9	71.7
Started from the aligned position	76.7	65.8	76.6	73.4
Ended within the crosswalk	62.8	43.5	65.8	58.4

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Table 2

Independence in crossing (percentage).

Measure	Portland	Charlotte	Cambridge	All three cities
Independent				
Locating the crosswalk	81	78	97	85
Aligning to cross	94	79	98	90
Determining when to start crossing	79	71	94	81
While crossing the street	86	82	96	88
Requested assistance				
Locating the crosswalk	10	10	3	8
Aligning to cross	5	10	2	6
Determining when to start crossing	12	24	5	14
While crossing the street	1	1	1	1
Intervention				
Locating the crosswalk	9	11	0	7
Aligning to cross	1	11	0	4
Determining when to start crossing	9	5	1	5
While crossing the street	13	17	3	11