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Guidelines for Accessible Pedestrian Signals

Final Report

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Summary

In 2000, two sections on APS were added to the *Manual on Uniform Traffic Control Devices (MUTCD),* which became the first set of national standards for APS in the U.S. The *MUTCD* defines an APS as "…a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces" (*1*). The rest of the *MUTCD* language provides standards, guidance and options, but does not specify walk messages or address many possible device features. In 2002, the U.S. Architectural and Transportation Barriers Compliance Board (Access Board) published draft recommendations and requirements for APS installation in *Draft Guidelines for Accessible Public Rights-of-Way (2).* The *Draft Guidelines* call for the use of pushbutton-integrated signals that provide audible **and** vibrotactile indications of the walk interval.

The objective of this research was to develop guidelines and training materials for implementation of accessible pedestrian signals (APS). The guidelines explain how APS provide optimal information through media such as tones and tactile or verbal indicators, and under what circumstances their installation is recommended. The training materials are intended to facilitate application of the guidelines and installation and operation of APS. This training is oriented toward technical issues and public education.

Two separate research experiments were undertaken in this project to develop the recommended guidelines for APS features and APS installation. The purpose of first study was to determine the effect of APS features, which are commonly found on most of the APS equipment marketed in the U.S., on the ability of pedestrians who are blind to locate and use pushbuttons, determine time to cross, determine appropriate heading for crossing, and maintain alignment while crossing. The second study was conducted to evaluate the effects of pole location, number of poles used in relation to number of APS devices, and type of WALK indication on the ability of pedestrians with visual or cognitive impairments to determine which crosswalk at a corner had the WALK signal. In addition to these two research studies, additional information about APS performance was gleaned from an engineering evaluation of the equipment installed during this research study, as well as from a series of cold weather case studies.

This research was the basis for more precise and well-supported standards and guidance on APS for inclusion in the *MUTCD* and the U.S. Access Board *Guidelines.* The research results have been forwarded to the Signals Technical Committee of the NCUTCD and to the Federal Highway Administration (FHWA) as background and support for changes in Part 4 of the *MUTCD,* as well as to the U.S. Access Board.

The training materials consist of a set of PowerPoint presentations that comprise a one-day training course and a companion resource document, *Accessible Pedestrian Signals: A Guide to Best Practice*. These materials are available at www.walkinginfo.org/aps and provide guidance on where and how APS should be installed. The training is directed at three main audiences – traffic engineers, orientation and mobility (O&M) instructors, and signal technicians.

One of the first questions that must be answered by local engineers and others responsible for the installation of APS devices is when and where is it appropriate to

install such devices in other than new construction and alteration/reconstruction. In many cases, there is a need to prioritize intersections for APS installations. The *MUTCD* currently provides some guidance on this matter, but a more definitive approach is needed by practitioners. As part of this research effort, an intersection prioritization tool was developed, applied by practitioners, and then validated by comparing the objective ratings achieved with the tool to the subjective ratings of pedestrians with visual impairments and O&M specialists. The tool itself, which includes a set of instructions for application, is also available on the web at www.walkinginfo.org/aps.

The results of this research have produced a set of recommended guidelines for APS installation and operation that will make it easier and safer for pedestrians with visual impairments to cross streets at signalized intersections. In time, the results will make their way into the *MUTCD* and other guides, which will lead to greater uniformity in the field.

CHAPTER **1**

INTRODUCTION

SUMMARY OF THE PROBLEM

All pedestrians, including those with visual impairments, must accomplish five primary tasks to safely cross a street at a signalized intersection:

1) Locate the street and the crosswalk,
2) Determine the form of signal actuation for the walk interval (and locate the pushbutton if required),
3) Establish the appropriate heading (alignment) for initiating the crossing,
4) Identify the time at which it is legal and safe to begin crossing, and
5) Maintain the appropriate heading during the crossing.

In the technique most often utilized for crossing at signalized intersections, pedestrians who are blind or visually impaired begin to cross when they hear a surge of traffic parallel to their direction of travel. While many intersections pose little difficulty, some intersection geometries and traffic conditions make it very difficult for persons with visual impairments to cross safely and independently. To assist visually impaired pedestrians and make street crossings a task that can indeed be done independently and safely, pushbuttons and audible signals have been used in this country with varying degrees of success. In fact, the Transportation Equity Act for the 21st Century (TEA-21) modified 23 USC 217(g) by directing that pedestrian safety considerations be accounted for in transportation plans and projects, including installation of audible traffic signals and signs at street crossings where appropriate. However, research indicates that some of the current audible signals, widely used in some parts of the United States, have a number of problems, including the following:

a) Users did not know whether a pushbutton was present.
b) Users found it difficult to locate the pushbutton.
c) Users could not tell which signal (crosswalk) was actuated by the button.
d) Users could not push the button and return to the point of crossing before the Walk interval began due to the long distance between the button and the intersection corner.
e) The signal was too quiet or too loud.
f) Users could not localize the sound and use it for guidance across the street.
g) Where the “chirp” or “cuckoo” sounds were used, users crossed against the signal when they heard a bird rather than the signal, and
h) Users failed to cross with the signal due to thinking it was an actual bird.

The research undertaken in this project, in coordination with research on accessible pedestrian signals (APS) that was conducted under concurrent related projects, discovered or developed solutions to most of the user-oriented problems identified above. In addition, guidance for design and installation of APS that provide information for pedestrians who are deaf-blind was developed. The research under this project also obtained engineering data and knowledge required for addressing issues such as general installation requirements, and physical installation, operation, and maintenance requirements.

This research was the basis for more precise and well-supported standards, guidance and support on APS for inclusion in the *Manual on Uniform Traffic Control Devices (MUTCD)* and in the *Guidelines for Accessible Public Rights of Way* (the Access Board rule providing minimum design guidelines implementing the ADA in public rights-of-way) (*1, 2*). The research results were forwarded to the Signals Technical Committee of the National Committee on Uniform Traffic Control Devices (NCUTCD) and to the Federal Highway Administration (FHWA) as background and support for changes in Part 4 of the *MUTCD*, as well as to the U.S. Architectural and Transportation Barriers Compliance Board (Access Board). The NCUTCD approved revisions to Part 4E of the *MUTCD*, which would implement the recommendations of this report at their June 2006 meeting, and sent them to FHWA for their consideration for the next *MUTCD* edition.

The results and products of this research may be used to increase the safety and mobility of pedestrians at signalized intersections, including those persons who are blind or visually impaired as well as those persons who are both visually and hearing impaired, by providing them with standardized information functionally equivalent to that provided to other pedestrians.

OBJECTIVE

The objective of this research was to develop guidelines and training materials for implementation of accessible pedestrian signals (APS). The guidelines explain how APSs provide optimal information through media such as tones and tactile or verbal indicators, and under what circumstances their installation is recommended. The training materials are intended to facilitate application of the guidelines and installation and operation of APS. This training is oriented toward technical issues and public education.

ORGANIZATION OF REPORT

This report provides a summary of prior research on APS, documents the results of all human subject experiments and other evaluations conducted, and provides recommended guidelines for APS installation and operation. The components of this report are as follows:

- Chapter 2 – Research Synthesis – includes a summary of research on APS that was used in designing the trials in this project and developing the recommendations
- Chapter 3 – Experimental Trials on Accessible Pedestrian Signal Features – includes the trials conducted in Tucson and Charlotte, which included an evaluation of multiple pushbutton-integrated APS devices and their effects on crossing behaviors by pedestrians with visual impairments.
- Chapter 4 – Experimental Trials on Pushbutton Location and WALK Indicator – includes the trials conducted in Portland to specifically evaluate the effect of number of poles and pole placement, as well as type of WALK indicator, on crossing behaviors by both visually impaired and cognitively impaired pedestrians.

- Chapter 5 – Cold Weather Case Studies – includes a summary of the case studies prepared as related to the installation, operation, and maintenance of APS in cold weather environments.
- Chapter 6 – Engineering Evaluation – includes the results of the engineering evaluation that has been completed to date.
- Chapter 7 – Recommended Guidelines – provides a discussion of the guidance recommended on the basis of the experimental results.
- Chapter 8 – Intersection Prioritization Tool – includes a discussion of the effort to develop a tool for assessing and prioritizing intersections with respect to crossing difficulty by pedestrians with visual impairments.
- Chapter 9 – Training and Resources – provides a discussion of the plans for the development of the training materials in the next phase of the study and includes an outline for the materials.
- Chapter 10 – Conclusions – includes a summary of the study objectives, project findings, and recommended guidelines.

ADDITIONAL RESOURCES

- *Accessible Pedestrian Signals: A Guide to Best Practice* – This companion document (referred to hereafter as the *Guide*) provides training information for engineers, orientation and mobility specialists, and signal technicians on when, where, and how to install APSs. See more information on the *Guide* in Chapter 9.
- PowerPoint Presentations – these presentations are the materials for a one-day training course that covers the most critical information in the *Guide*. The presentation files include scripts to ensure that they can be read and understood outside of the course. See more information on the presentations in Chapter 9.
- Web site (www.walkinginfo.org/aps) – This site includes all of the materials produced as part of this project, including this report, the *Guide*, the PowerPoint presentations for training, and the Intersection Prioritization Tool to assist practitioners in prioritizing locations for APS installation.

CHAPTER 2

Research Synthesis

Provided in this chapter is a summary of the APS research that is related to the research undertaken in this effort. A more comprehensive synthesis of this research can be found in Appendix C of the *Guide*.

INTRODUCTION

Although APSs have been widely used in Japan and Sweden since the 1960s, the early development of APS in those countries was not, as far as these authors have been able to ascertain, based on research. The first substantial research on APS appears to have been done in 1976 by Frank Hulscher, an electrical engineer with the Department of Motor Transport, New South Wales, Australia. Hulscher's research was the basis for the well developed, fully standardized, and highly successful pushbutton-integrated APS system in use in Australia today.

Substantial research on APS in the U.S. began with a project undertaken by the San Diego Association of Governments in 1988 to investigate the "bird call signals" widely used in Japan, and being imported into the U.S. at that time. The results of this project were the basis for a policy of implementing standard signals at intersections in San Diego where a city access committee recommended them, following a systematic evaluation including use of a rating scale.

Since 1996, there has been a concerted research effort related to APS. Several research studies and surveys have documented problems of pedestrians who are blind or who have low vision at signalized intersections without APS (*3, 4, 5, 6, 7, 8*). Several studies in the U.S. have compared travel by blind pedestrians with and without APS (*9, 10, 11, 12, 13, 14, 15*). In these studies, some of the APSs have been signals mounted on the pedestrian signal head, while others have been receiver-based systems, and others been pushbutton-integrated devices. Methods of these studies are described below; results and conclusions are cited topically.

San Diego Association of Governments surveyed 71 national, regional, and local organizations representing and/or serving elderly persons and persons who were visually impaired to determine their involvement in installation of audible signals and the level of support for audible signals; 36 responses were received (*8, 16, 17, 18*, hereafter referred to collectively as San Diego research). A separate survey was also sent to members of California Association of Orientation and Mobility Specialists to gather information about their experience with audible signals. Surveys were mailed to 67 members, and 27 responses were received.

In 1998, the American Council of the Blind (ACB) and the Association for Education and Rehabilitation of the Blind and Visually Impaired (AER) conducted similar surveys to determine problems experienced by blind pedestrians during street crossings. Problems with audible signals currently installed were also identified by the surveys.

- ACB survey – surveys administered orally, in groups, to 158 pedestrians who are visually impaired (*6*, hereafter referred to as ACB survey)
- AER survey – mailed to 1000 orientation and mobility specialists. 349 surveys returned (*5*, hereafter referred to as AER survey).

Murakami et al. conducted a survey of 50 blind pedestrians in Japan (*7*). Uslan et al. compared crossings by 27 legally blind pedestrians at three intersections in Huntington Beach, California, having "bird call" signals and one control intersection without APS (*14*).

In research by The Smith-Kettlewell Eye Research Institute, 20 blind participants made a total of 80 crossings at 4 fixed-time signalized intersections in downtown San Francisco, both with and without Talking Signs® (*10, 11, 12*, hereafter referred to collectively as SKERI research). Talking Signs is a receiver-based APS. Intersection signal phases were pretimed, and pushbutton use was not required. There were nine measures, including measures of crossing timing (safety), orientation (precision), and independence.

Marston and Golledge compared crossings by blind participants with and without APS, using the receiver-based APS system, Talking Signs, in a study investigating the use of Talking Signs remote infrared audible signs for a number of transit tasks (*13*).

The effects of a pushbutton-integrated APS, a receiver-based APS manufactured by Relume, and typical visual pedestrian signals without APS on the street crossing behavior of 24 totally blind participants were compared by Williams, Van Houten, Ferraro, and Blasch (*15*).

As part of a project on blind pedestrians at complex intersections, funded by the National Eye Institute, National Institutes of Health, a series of studies on crossings by blind pedestrians with and without APS is in progress in four cities, Portland, Oregon; Charlotte; Tucson; and Cambridge, Massachusetts. Objective data on measures of street crossing performance by sixteen participants who were blind was obtained at two complex, signalized intersections in each city. Measures were similar to those used in the SKERI research, including nine broad measures of crossing timing, orientation, and independence. Results from all four cities are not yet analyzed, but slightly different analyses have been reported in several articles. Results from pre-installation testing in two cities, Portland and Charlotte, are reported in Bentzen et al. (*4*, hereafter referred to as NEI-2 cities) and Barlow et al. (*3*, hereafter referred to as NEI-3 cities) reports on three cities, Portland, Charlotte, and Cambridge. Barlow et al. (*9*, hereafter referred to as NEI Portland pre-post) compares results of testing with and without APS in one of these cities, Portland, Oregon.

PROBLEMS WITH SPECIFIC TASKS AT SIGNALIZED INTERSECTIONS BY PEDESTRIANS WHO ARE BLIND OR WHO HAVE LOW VISION

Locating the Crosswalk

In SKERI research and NEI research-3 cities, research participants requested assistance in locating the crosswalk on about 17% of street crossings. On approximately 29% of crossings in both studies, subjects who located the crosswalk independently began crossing from outside the crosswalk.

Establishing and Maintaining the Correct Heading

In the AER survey, 97% of O&M specialists who responded indicated that their students had difficulty aligning to cross the street, while 66% indicated that their students sometimes had difficulty knowing where the destination corner was.

In SKERI research, participants started crossing from an aligned position on 48% of crossings without use of APS, and completed their crossings within the crosswalk on 58% of crossings. In the NEI-3 cities research (without APS), participants started from an aligned position on 73.4% of crossings. Participants requested assistance or required intervention for safety while aligning to cross on 10% of crossings. Of participants who aligned independently, 58.4% completed their crossings within the crosswalk.

The broadcast sound from speakers mounted on the pedestrian signal head has not seemed to provide usable directional information. ACB and AER surveys indicated that pedestrians who are blind are sometimes not able to localize the sound of an APS in order to use it for guidance across the street. ACB – 6%; AER – 39%. 85% of ACB respondents indicated that they were sometimes confused by unexpected features such as medians or islands, while 64% of O&M respondents indicated that their students had difficulty with medians or islands.

Finding and Using Pushbuttons

In the ACB and AER surveys, many respondents indicated that they or their students had difficulty with pushbuttons (ACB - 90; AER – 94%). Reasons were: 1) they couldn't tell whether they needed to push a button; 2) they had difficulty locating the button; 3) they couldn't tell which crosswalk was actuated by the button; or 4) the pushbutton was so far from the crosswalk that they couldn't push the button and then return to the crosswalk and establish a heading before the WALK interval began.

Uslan et al. also found that the major problems 27 legally blind participants had with "bird call" type APSs were in locating the pole and the pushbutton and determining which pushbutton was for which crosswalk (*14*). Participants traveling with guide dogs experienced the most difficulty locating the pole. Sometimes participants first located the incorrect button and subsequently located and pushed the correct button after waiting and listening through one or more cycles.

This replicated the findings of San Diego research (*16*). Gallagher and Montes de Oca also noted this problem in research on vibrotactile-only APSs (*19*).

In the NEI-2 cities results, at crossings where pushbutton-actuation was required, participants looked for, found, and pushed the button on only 16.3% of these crossings in Portland, and none (0%) of the crossings in Charlotte.

Identifying the Onset of the WALK Signal

In the surveys conducted by ACB and AER, many respondents indicated that they or their students sometimes had difficulty knowing when to begin crossing (ACB – 91%; AER – 98%). Reasons were: 1) the surge of traffic was masked by right -turning traffic; 2) traffic flow was intermittent; 3) the intersection was too noisy; and 4) the surge of traffic was too far away. In the AER survey, 79% of respondents indicated that blind students sometimes had difficulty determining the onset of the WALK interval at intersections having exclusive pedestrian phasing.

On 24% of trials in SKERI research, blind pedestrians requested assistance in knowing when to start crossing at crosswalks where they did not use APS. On 34% of trials on which they independently initiated crossings, they began crossing during the flashing or steady DON'T WALK.

In the Japanese survey, 46% of respondents stated that "to take a timing to start" was difficult without APS, and Uslan found that, at the control intersection without APS, which was considered the easiest to cross without APS, 4 out of 15 participants began crossing during DON'T WALK.

The NEI-3 cities research found that pedestrians who were blind independently began crossing during the walk interval on only 48.6% of crossings and completed crossings after the onset of perpendicular traffic on 26.9% of crossings. The need for pushbutton-actuation of the walk interval affected the likelihood that participants would begin crossing during the walk interval. On the pedestrian-actuated crossings, participants began crossing during the walk interval on only 19.5% of the crossings compared to 71.7% of crossings where the pedestrian phase was on recall (the pedestrian phase was included in every cycle). Mean latency in beginning crossing (the time between onset of the WALK signal or near-side parallel traffic and the participant beginning to cross) was 6.41 seconds without APS.

Common Problems with APS in the United States

ACB and AER surveys reported the experience of pedestrians with visual impairments in using APS that had "bird call" signals, bells, and buzzers. There were problems both with APS being considered too quiet and too loud. Uslan et al. found that at one intersection with split phase timing, where the bird call signals for parallel crosswalks had separate timing, three of 15 blind participants initiated their crossings with the signal for the parallel crosswalk, walking into the path of left-turning vehicles (*14*).

These surveys also looked at data from blind pedestrians and O&M specialists from California, whose experience with APS is almost exclusively with "bird call" signals that are intended to provide unambiguous information regarding which street has the WALK interval. Many respondents indicated that they or their students sometimes did not know which crosswalk had the WALK interval (ACB – 68%; AER – 72%) Reasons were: 1) users forgot which signal was associated with which crossing direction; 2) users didn't know which direction they were traveling; and 3) the intersection was not aligned with primary compass directions.

Uslan et al. found that on many trials blind participants failed in their attempts to cross streets because of indecision regarding the pole or button, even though all participants were fully familiar with the "bird call" signal, they knew what to listen for at each intersection, and they could listen through as many cycles as they desired (*14*). Sometimes participants located the incorrect button and then pushed the correct button after waiting and listening through one or more cycles.

AER and ACB surveys confirmed that blind pedestrians really do confuse the sounds of birds with APS sounds. These surveys also indicated that many blind pedestrians are sometimes unable to localize the sound of an APS and use it for guidance across the street. Furthermore, when APSs are too loud, and are at intersections that are close together, the APS for one intersection may be heard from another, leading some pedestrians to incorrectly think they have the WALK interval.

Respondents to the Japanese survey indicated that "direction taking at the starting position" and "keeping direction while walking in the crosswalk" were a problem, even with APS.

EFFECT OF APS ON STREET CROSSINGS BY BLIND PEDESTRIANS

Since it is known that pedestrians with visual impairments have difficulty with many of the tasks that, taken together, comprise street crossing, it would be convenient to assume that APS would improve all measures of crossing at signalized intersections. To determine the extent to which this is true, a number of research projects have obtained objective data comparing street crossings with and without APS on one or more of the following measures.

- Locating the crosswalk.
- Aligning to cross and maintaining alignment while crossing.
- Use of pushbuttons.
- Identifying the walk interval.
- Delay before beginning to cross.
- Independence in any or all crossings tasks.

Projects that have already been mentioned are: SKERI research; NEI Portland pre-post; Uslan et al. (*14*); Marston and Golledge (*13*); and Williams et al. (*15*). There are several additional studies that shed light on this topic. Hulscher reported an estimate by Leith (personal communication) comparing starting delay pre- and post-APS installation (*20*). Wilson conducted a pre- and post-APS installation study of behavior of adult, non-disabled pedestrians at one intersection (*21*). As part of NEI research, in three different experiments Wall, Ashmead, Bentzen and Barlow, blind and blindfolded sighted participants made crossings at a simulated intersection, in the presence of recorded traffic sound to determine the effect on crossing accuracy with signals comprised of bird calls, percussive "toks," a click train, or a female voice (*22*). The signals, all of which were mounted at a height of eight feet, came either simultaneously from both ends of a crosswalk (typical practice), alternated from one end to the other, or came from the far end of the crosswalk only. These researchers also compared crossing accuracy when signals came from two parallel crosswalks (typical practice), or from a single crosswalk. A further comparison was between Walk signals with a typical 7 sec. duration versus a 7 sec. Walk signal followed by a locator tone.

Locating the Crosswalk

SKERI research found that starting crossing from within the crosswalk increased from 70% to 97% with use of the APS.

NEI Portland pre-post research found significant increases in participants' ability to begin crossings from within the crosswalk at locations where pushbutton use was required, and pushbutton locator tones were installed. Pre-installation, 77% of crossings began from within the crosswalk; post-installation, 97% of crossings began within the crosswalk, indicating that locating the crosswalk was significantly improved by the presence of pushbutton-integrated APS. (*9*)

Orientation (Aligning to cross and maintaining alignment while crossing)

On 48% of crossings in SKERI research, where APS information was not available, blind pedestrians were not facing directly toward the opposite corner when they started their crossing;

they were facing somewhat toward or away from the center of the intersection. With the use of receiver-based APSs, participants were well aligned when beginning 80% of crossings.

However, in NEI Portland pre-post research, alignment showed only a very small trend toward improvement, with 70% of independent crossings starting from an aligned position pre-installation and 84% post-installation. NEI research at a simulated crossing found the presence of a locator tone during the second half of the crossing had a positive effect on alignment (*22*).

Using Pushbuttons

Data reported in NEI pre-APS installation testing indicated that blind pedestrians typically didn't search for and use pedestrian pushbuttons at unfamiliar intersections without APS (*3, 4*). However, the addition of pushbutton locator tones and the knowledge that an APS might be installed resulted in participants looking for the pushbuttons on over 98% of crossings, although looking for the pushbutton did not always result in finding and using the correct pushbutton. Participants independently looked for and used the pushbuttons on 93% of crossings after pushbutton-integrated signals with locator tones were installed (*9*).

Initiating the Crossing

Delay in beginning to cross

Hulscher cites a personal communication from Leith in which Leith estimated that, following APS installation, delay in beginning crossings was reduced an average of 2-3 seconds for all pedestrians (*20*).

Wilson, in a pre- and post-APS installation study of adult non-disabled pedestrian behavior at one intersection, found the following results (*21*):

- For pedestrians using the pushbutton, delay in beginning crossings was reduced by 20%, from 2.7 sec to 2.1 sec.
- The time taken to cross by persons who started during the walk interval decreased by about 5%; crossing time for other pedestrians was unchanged.
- For pedestrians who arrived at the crossing during the flashing or steady Don't Walk and who waited to cross until the onset of the walk interval, the proportion who failed to complete their crossings before the onset of opposing traffic was reduced by one-half, from 22% to 11%.

Williams et al. found that mean latency in beginning crossing without APS was more than 5 seconds, which was reduced to 2.2 seconds with a receiver-based APS device with a tone WALK indication and 3.8 seconds with a pushbutton-integrated APS using speech messages (*15*). Williams also assessed participants on total number of signal cycles missed before crossing. Without APS, mean wait time was almost 2 full cycles, while with either type of APS the mean wait time was just over a half a cycle.

In NEI Portland pre- post research, in 144 crossings pre- and post-APS installation at two intersections in Portland, Oregon, the weighted mean starting delay for blind pedestrians without APS was 5.1 seconds, and after APS installation, the delay was only 2.9 seconds. Uslan et al. also found significant differences between speed of crossing at a control intersection and intersections where APS were installed; crossings at locations with APS were completed faster (*14*).

Starting during WALK, and completing crossing before the onset of perpendicular traffic

In SKERI research, participants began crossing during the walk interval on only 66% of crossings without APS, but on 99% of crossings with APS.

In NEI Portland pre-post-installation, pre-installation, the pedestrian-actuated crossings were highly problematic for pedestrians who are blind. Pre-installation, participants began crossing during WALK on only 25% of crossings. Post-installation, there was dramatic improvement in participants correctly determining the appropriate time to start crossing, with 84% of crossings initiated during WALK. Similarly, participants completed crossing after the onset of perpendicular green on 50% of crossings pre-installation, with a significant decrease post-installation to 12% of crossings completed after the onset of perpendicular green.

Furthermore, only 77% of decisions about when to start crossing were made independently pre-installation as opposed to 95% post-installation. Pre-installation, the total number of crossings where the individual independently determined a start time and actually began crossing during the walk interval was less than a quarter of crossings. Post-installation, with the addition of the APS, there was a significant increase both in independence and in beginning to cross at the appropriate interval.

For crosswalks where the pedestrian phase was on recall, the APS sounded at the beginning of the walk interval, regardless of whether the pushbutton was used or not. However, the WALK indication only sounded for the first seven seconds of the walk interval, unless the pushbutton was pushed again. Pre-installation, 70% of independent crossings began during the walk interval; post-installation, this increased to 100%.

Marston and Golledge found that at crossings without APS, almost half (48%) of the participants attempted to cross during the steady don't walk interval, a time recorded as unsafe by the researcher (*13*). With access to the pedestrian signal information provided by APS, no participant started crossing at an unsafe time.

Effect of APS on Independence and Confidence

Both the NEI research and the earlier SKERI research on which the method was based measured independence on three street-crossing tasks both with and without APS: locating the crosswalk; starting to cross within the walk interval; and completing the crossing. The NEI research also measured independence on aligning to cross. The percentage of crossings on which participants were independent on each task is as follows.

Task	Without APS		With APS	
	SKERI	NEI	SKERI	NEI
Locating crosswalk	81%	81%	99%	95%
Aligning to cross	NA	94.5	NA	97%
Starting to cross during WALK	76%	79%	100%	92%
Completing the crossing	81%	86%	97%	96%

Table A-1. **Percentage** of crossing tasks on which participants were independent.

Marston and Golledge measured confidence in street crossing with and without APS (*13*). The range of responses for the no APS condition, by street crossing task, was 2.7-3.5 (5 pt. scale;

1=no confidence, 5=very confident), while the range of responses by task for the APS condition was 4.8-5.0.

Detectability of WALK Signal

Hulscher found that, because of the masking of high frequency signals by predominantly low frequency traffic noise, and because a majority of blind pedestrians have some upper frequency hearing loss, the optimal fundamental frequency of the WALK tone should be between 300 Hz and 1000 Hz, and the tone should be comprised of multiple short bursts of sound to aid localization (*20*).

Staffeldt, in research cited by Hulscher, conducted extensive testing of APS at crossings where they were mounted on the pedestrian signal head, and found that an 880 Hz signal was most detectable in a background of traffic noise (*20*).

Hulscher's recommendation and Staffeldt's result was supported by Poulsen, who compared the noise spectrum of traffic as attenuated by windows to arrive at a recommended signal frequency (880 Hz) that would not be largely masked by traffic noise, but would also not transmit through windows and become a public annoyance (*23*).

In San Diego research, laboratory measurements of "birdcall" signals from Nagoya Electric Works of Japan found that neither signal was highly directional; however, the cheep was more detectable than the cuckoo. The cheep was produced by a continuous frequency variation with a fundamental frequency base of 2800 Hz, and the cuckoo consisted of two frequencies with a combined frequency base of 1100 Hz. (Currently available "cuckoo/cheep" signals may vary from this manufacturer's standard.)

Hall, Rabelle, and Zabihaylo worked with audiologists to develop a signal that provided the most localizable melody for an accessible signal and recommended a melody that was composed of fundamental frequencies between 300 Hz and 1000 Hz, but including harmonics extending to 7000 Hz (*24*).

In NEI research (unpublished data), Wall, Ashmead, Barlow, and Bentzen carried out a series of experiments on detectability of WALK signal indications in a laboratory setting (*25*). Experiment 1 evaluated the detectability of signals in white noise, Experiment 2 evaluated the detectability in traffic noise, and Experiment 3 evaluated detectability in traffic noise for subjects with age-related hearing loss. Signals evaluated were an 880 Hz square wave, a bird chirp, a cuckoo, two click trains, two percussive signals ("bink" and "tok"), a four-tone melody, and female and male voice signals. Results indicated that audible signals of a more percussive nature with predominantly lower frequencies were best heard in background traffic noise. In addition to one of the percussive signals, participants with age-related hearing loss were better able to detect male voice signals. Signals with a simple percussive nature tended to need less gain to be heard in noise, relative to the levels necessary to be heard in quiet. In other words, percussive signals were more detectable at lower volumes. When asked their preference, most participants liked voice signals best, but all of the voice signals needed more gain to be heard. Note that the measurement in these studies was the point at which the signal was detected, not the point at which the message was easily understandable. Intelligibility of voice messages was not evaluated or assessed by participants. The cuckoo and chirp, most commonly used in the U.S. as an audible signal at the time of the study, required the most gain to be detectable amid background noise.

Localizability of WALK Signal

An additional factor, if audible pedestrian signals are to be used as beacons to guide pedestrians with visual impairments across a street, is how well signals can provide directional information. Laroche, Giguère, and Poirier compared localization of cuckoo and cheep signals to localization of 4 four-note melodies varying in fundamental frequencies, harmonics, note duration, and temporal separation between notes (*26*). In combined objective and subjective testing, the cheep and a melody with minimal harmonics were found to be less localizable than the cuckoo and the other three melodies. In a follow-up study, Laroche, Giguère, and Leroux compared the typical cuckoo-cheep sounds used in Canada with a cuckoo having a lower fundamental frequency, and the melody that was recommended as a result of their 1999 research (*27*). In both studies, the signal was 36 seconds long (much longer than typical U.S. WALK indications) and the measurements were in a simulated pedestrian corridor in a quiet environment. In situations with actual traffic sounds, the cheep was found to result in significantly greater veering and longer crossing time than any of the other signals, which did not differ from each other.

In NEI research, Wall, Ashmead, Bentzen, and Barlow found no significant differences in localizability among several disparate signals, including cuckoo, chirp, "tok" and voice messages, when tested in research that involved multiple crossings of a simulated street, in the presence of recorded vehicular sound (*22*). The five signals used were representative of signals in wide use or that showed promise for directional beaconing. None of the analyses indicated any systematic differences between the five signals. Further experiments focused on presentation mode and signal location, rather than signal sound characteristics.

Speech WALK Indications

Listeners with normal hearing require that speech be 15 dB louder than background noise for intelligibility to reach 90% (*28*). This means that, in order to be intelligible, speech messages should be louder than tone indications. The effect of that louder sound level on the ability of blind pedestrians to hear other sounds in the intersection, or on near neighbors, may limit the acceptability of speech messages.

Bentzen, Barlow and Franck conducted research to obtain information from stakeholders regarding the structure and content of speech messages for APS WALK messages and for "pushbutton messages" that are only available during the flashing and steady DON'T WALK intervals (*29*). WALK messages convey that the WALK signal is on and provide the name of the street being crossed. Pushbutton messages provide intersection and crosswalk identification information, and they may also provide information about unusual intersection signalization and geometry. The research utilized an expert panel of stakeholders, who prepared a survey comprised of sample messages to rate and items to determine respondent understanding of messages. The survey was administered to people who are visually impaired, O&M specialists, transportation engineers, and APS manufacturers. The resultant recommended model messages are contained in the *Guide*.

Van Houten, Malenfant, Van Houten, and Retting found that redundant information conveyed by audible pedestrian signals increases the attention of all pedestrians to turning traffic and may contribute to a reduction in pedestrian-vehicular conflicts and crashes at signalized intersections (*30*). This signal also gave participants who were blind precise information about the onset of the walk interval and which street had the walk interval.

Accuracy and Speed in Identifying WALK Indication for a Given Crossing

In NEI research, Ashmead, Wall, Bentzen, and Barlow investigated how location of APS speakers in different positions relative to the crosswalk affected the accuracy and speed of identifying the correct crosswalk (see Figure 2-1 below for APS positioning used in research), using typical placements seen in the U.S. (*31*) . All loudspeakers emitted the same WALK indication.

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.

Under the most typical signal mode, simultaneous presentation from both ends of the crosswalk, the most accurate performance occurred when signals were placed close to the curb line, near the side of the crosswalk that was furthest from the center of the intersection (see corner 1 in Figure 2-1). The pedestrian could easily tell which of the two loudspeakers at the corner was active because each loudspeaker was close to the position of the pedestrian 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 resulted in somewhat worse performance. Accuracy at corner 3 was poor, with participants answering correctly on only 25% of trials in the simultaneous presentation condition and 50% of trials in the alternating presentation condition.

There was no evidence that response time differed across the four corners, that is, for 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.

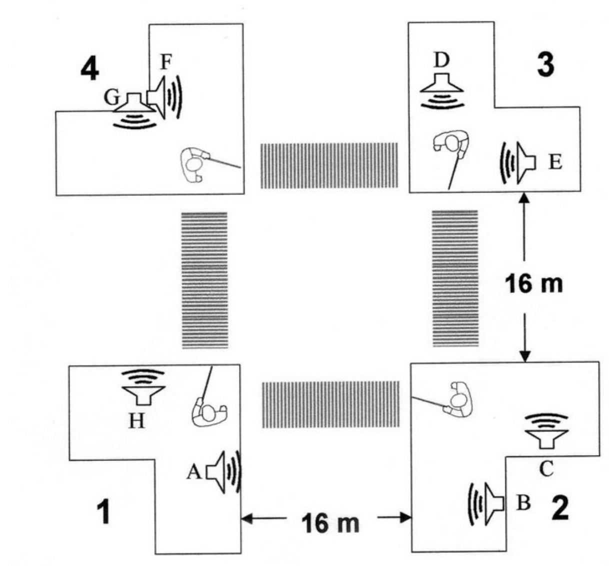


Figure 2-1. Positions and headings of loudspeakers and pedestrians at each corner in NEI research. (Figure from Ashmead, et al., 2004). The figure is not drawn to scale.

Figure 2-2 illustrates the recommended placement of APS devices in relation to the crosswalk provided in the APS Synthesis in 2003. This arrangement was based on the NEI research described above. The NEI research was the basis for additional research on pushbutton location within the current project.

Research on Source of WALK Signal

A number of investigators have tackled the problem of improving localization of WALK signals (beacons) by varying the source of the sound. All investigators used some measure of the straightness of the path of travel from one end of the crosswalk to the other; some also measured initial heading.

Stevens (*41*) and Tauchi, Sawai, Takato, Yoshiura, and Takeuchi (*32*) found that alternating acoustic signals result in performance superior to that of simultaneous signals, as did Laroche et al. (*27*). However, when Laroche et al. compared simultaneous and alternating signals at a real intersection there was no significant difference. Tauchi, Takami, Suzuki, Kai, Takahara, and Jajima found better performance when the alternating signals at each end of the crosswalk were different (e.g. “chirp” vs. “chirp, chirp”) than when they were the same (e.g. “chirp” and “chirp”) (*33*).

Poulsen compared simultaneous acoustic WALK signals with signals at the far end of the crosswalk and found superior performance with signals at the far end (*23*). Wall et al. compared simultaneous, alternating (same sound), and far end signals, and found the far end signals resulted in significantly better performance than either simultaneous or alternating signals, which were equal (*22*).

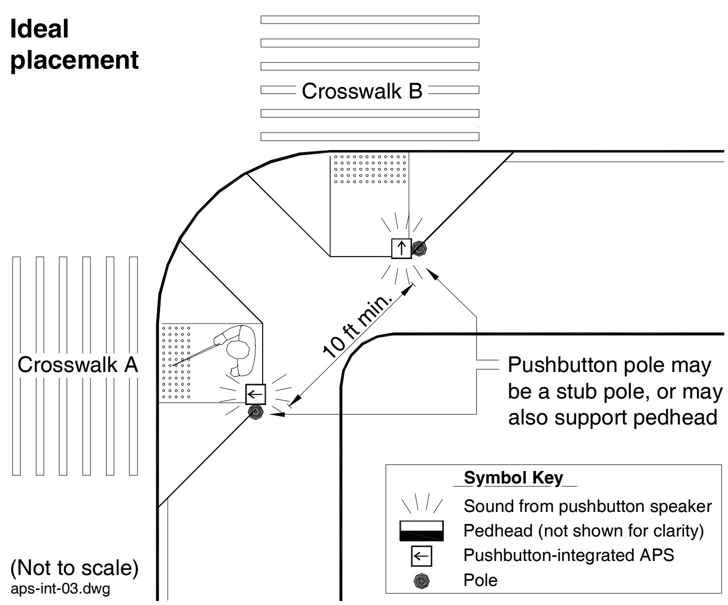


Figure 2-2. Optimal location of pushbutton-integrated APS.

CHAPTER **3**

Experimental Trials on Accessible Pedestrian Signal Features

INTRODUCTION

The most commonly used accessible pedestrian signals (APSs) in the U.S. have been pedhead-mounted devices, where speakers are attached to the visual pedestrian signals. These APSs can make a variety of sounds, but commonly use birdcalls (cuckoo and cheep). A different type of APS, known as a pushbutton-integrated APS, has been used in much of Europe and in Australia and is now becoming more common in the U.S. On pushbutton-integrated APSs, the speaker is located in the pushbutton housing, and the device typically provides a pushbutton locator tone in addition to an audible WALK indication. The pushbutton locator tone repeats constantly, at one-second intervals to tell pedestrians that there is a pushbutton and to help them locate and use the pushbutton. Tactile arrows are also a standard feature to help blind pedestrians determine which street the device serves (*see Figure 3-1*). The arrow vibrates during the walk interval to communicate walk signal information to pedestrians who cannot hear or who want to tactually confirm audible signal information. Various other features are currently available on some devices.

Until 2000, when two sections on APS were added to the *MUTCD*, there were no national standards for APS in the U.S. The *MUTCD* now defines an APS as "…a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces" (*1*) The rest of the *MUTCD* language provides standards, guidance and options, but does not specify walk messages or address many possible device features. In 2002, the U.S. Access Board published draft recommendations and requirements for APS installation in *Draft Guidelines for Accessible Public Rights-of-Way*, which were further updated in November 2005 *(2).* The *Draft Guidelines* call for the use of pushbutton-integrated signals that provide audible **and** vibrotactile indications of the walk interval.

Figure 3-1. Pushbutton-integrated APS with tactile arrow.

Research was needed to expand upon or modify the APS guidance now available to ensure that the information being provided to pedestrians who are blind or who have low vision (including those with hearing loss) is consistent among intersections and will allow users to safely, efficiently, and independently cross at signalized intersections. The purpose of the study documented in this chapter was to determine the effect of APS features, which are available on devices of the type recommended in the Access Board's *Draft Guidelines*, on the ability of pedestrians who are blind to locate and use pushbuttons, determine time to cross, determine appropriate heading for crossing, and maintain alignment while crossing.

In this experiment, four pushbutton-integrated APSs were evaluated in comparison to each other. APSs from each of four manufacturers were installed at all crosswalks at one of four intersections in each of two cities. Psychophysical data on street crossings by approximately 20 blind pedestrians were obtained for each manufacturer's APS installed with their "standard features" in each city. These technologies differed from one another in interface designs and features, such as the pushbutton locator tone, pushbutton size and shape, design, and location of tactile arrow, type of actuation indicator/confirmation tone (speech, tick, tones), type of walk indication (speech message, rapid tick, bird call tones), and availability of additional features such as tactile map of the crosswalk, additional information about the intersection or audible beaconing. APS features are described in detail in the *Guide*. The following descriptions of features are condensed from that report.

- Pushbutton locator tone: "A repeating sound that informs approaching pedestrians that they are required to push a button to actuate pedestrian timing and that enables pedestrians who have visual disabilities to locate the pushbutton." (*MUTCD* 2000; 4E.08) (*1*). Pushbutton locator tones sound during the flashing and steady DONT WALK intervals. The locator tone informs pedestrians of the need to push a button, provides an audible cue to the location of the pushbutton, and may provide a clue as to the destination corner when approaching on the crosswalk. In available products, the pushbutton locator tone varies from a click sound to a beep-type tone. *MUTCD* standard requires that "…the tone shall repeat at 1 second intervals and shall have a duration of 0.15 seconds or less" (*1*) The pushbutton locator tone typically has automatic volume control that adjusts the volume according to changes in ambient sound level.
- Pushbutton size and shape: Pushbuttons are required by the *Draft Guidelines* to be at least 2 inches in diameter and to require less than 5 lbs force to push (*2*).
- Tactile arrow: A raised (tactile) arrow is incorporated into the device to help users know which crosswalk is actuated by the pushbutton. The arrow may be part of the pushbutton, above the pushbutton, or on top of the device. This arrow also vibrates during the WALK interval.
- Actuation indicator: A tone or voice message indicates to pedestrians that the button has been pushed and a WALK signal requested.
- Additional intersection information (pushbutton information message): A pushbutton information message is a speech message that provides additional information when the pedestrian pushbutton is pushed during the flashing or steady DONT WALK intervals. When used, this message identifies the intersection, provides the name of the street that the pushbutton controls, and may provide other intersection geometry or signalization information. The message is intended to be audible when standing at the pushbutton location. Pedestrians may be required to press the pushbutton for approximately three seconds (see extended button press) to call up this additional speech message. Recent

research indicates that pressing the button for one second or longer is optimal timing (*34*).

- Walk indication: The walk indication provides an audible and vibrotactile indication of the WALK interval. The audible indication can be provided by tones or speech messages and generally repeats for the entire WALK interval. Different manufacturers currently provide different walk indications, but any of the devices could provide any of the sounds used. In this research, one manufacturer provided bird calls (cuckoo-cheep), one provided a rapidly repeating tone, and two provided speech messages. The *MUTCD* and *Draft Guidelines* recommend that the walk indication be the same volume as the locator tone, and no more than 5 dB above ambient sound levels, unless there is special activation of audible beaconing. The vibrotactile indication of the WALK interval is typically provided by a tactile arrow on the pushbutton device that vibrates during this interval.
- Audible beaconing: Beaconing is the use of an audible signal in such a way that blind pedestrians can home in on the signal from the opposite corner as they cross the street. This is intended to provide directional orientation. APS currently provide audible beaconing in one of two ways: from pedhead-mounted speakers aimed in the center of the crosswalk approximately one-third of the way across the street, and by using pushbutton-integrated speakers that elevate the volume of the walk indication and the subsequent locator tone for one pedestrian phase, which is called by an extended button press.
- Crosswalk map: One manufacturer's signal incorporates a raised schematic map showing what will be encountered as the pedestrian negotiates the crosswalk controlled by that pushbutton. The map shows just the crosswalk controlled by that signal, not the entire intersection, and includes: number of lanes to be crossed; whether these are vehicular or bicycle lanes or tracks for rail vehicles; which direction traffic will be coming from in each lane; and whether there is a median.

METHOD

Overview

Data were collected in two cities (Tucson, Arizona, and Charlotte, North Carolina) for 40 visually impaired participants (20 in each city) crossing at four intersections. Each intersection was equipped with pushbutton-integrated APS devices from a different manufacturer. The full range of features currently in use on pushbutton-integrated devices in the U.S. was represented across these four manufacturers. In each city, participants crossed at the same intersections two or three times under two or three information conditions designed to represent typical experiences of pedestrians who are blind.

One information scenario, defined as the "no information" condition, represented the situation in which pedestrians who are blind know that there will be an APS at the intersection, but do not have any information about the APS features and probably have not had previous experience with pushbutton-integrated APS. This condition was only used in Tucson. The "general information" condition represented the situation in which the participants had heard a general description of the devices. They knew there would be a new type of APS at the intersection and had been told about possible features of APS devices, similar to someone who has heard or read about new types of APSs, but has had no experience with them (Tucson and Charlotte). A third information condition, defined as the "specific information" scenario, represented the situation in which a blind pedestrian knows the intersection will have an APS and knows from prior experience and instruction with the APS device how it will function and what features it will have (Tucson and Charlotte). During the break between the general information and specific information conditions, participants were shown a working demonstration unit of each device and given the opportunity to manipulate it and to experience all the types of information that it provided. Immediately before beginning each crossing in the specific information condition, participants were told which of the devices would be present at that crossing, and the features of the device were reviewed.

In Tucson, each participant crossed at each intersection 3 times, once for each condition, for a total of 12 crossings. In Charlotte, the no information condition was dropped due to the amount of time required to travel between intersections, so each participant made eight crossings, two at each intersection. Although participants returned to each intersection two or three times, several procedures minimized the possibility of learning about specific intersections or about the APS at specific intersections. Participants were not told that they would be returning to the same intersections; order of intersections was different in each block of crossings; each approach to the intersection was different; and parking locations were usually different. Few participants indicated that they recognized that they were returning to the same intersections.

Measures recorded included speed and accuracy in locating and pushing the correct pushbutton, speed and accuracy in beginning crossing during the WALK interval, crossing alignment and crossing path. Data on the traffic sound levels and movement were also collected. After each crossing, a series of questions was asked to learn what information participants used to make the crossing and to obtain their perceptions about the APS at that crossing.

Participants

Twenty participants who are blind were tested in each city. All had insufficient vision to see crosswalk lines, pushbutton poles, or pedestrian signals. All participants were accustomed to crossing independently at signalized intersections using a long cane or guide dog and none were familiar with the intersections being used for testing. Ages were similar across cities, ranging from 24 to 70, with a mean age of 44. There were 24 male and 16 female participants. The majority of participants used a long cane as their travel aid, with only four in each city using a guide dog . Thirty-nine of the participants rated themselves as good to excellent travelers; one participant rated his travel ability as fair. Thirty-two (16 in each city) of the participants stated that they traveled independently more than 5 times a week.

An attempt was made to recruit up to five participants in each city who met the criteria for vision loss and independent street crossing, and who also had moderate to severe hearing loss. Recruiters were unable to obtain this number of deaf-blind persons in each city who cross streets independently. In Tucson, two participants were identified with mild hearing loss and one other had moderate to severe hearing loss, with bilateral hearing aids. Only one participant in Charlotte reported mild hearing loss; three others may have had some hearing loss, based on researcher observations and notes, but such loss was not diagnosed or self-reported in participant interviews.

Location

Cities and Intersections

Several cities were considered to participate in this study, including Boston, MA; Cambridge, MA; Charlotte, NC; Milwaukee, WI; Minneapolis/St. Paul, MN; Portland, OR; San Diego, CA; and Tucson, AZ. Charlotte and Tucson were selected for participation as field sites on the basis of meeting the following criteria:

- Availability of appropriate intersections (see criteria for intersections below).
- Willingness to temporarily install APSs at four intersections.
- Ability to provide necessary technical support for data collection during human factors testing.
- Ability to provide engineering evaluation of the different technologies.
- Willingness to provide information on installation and maintenance of the equipment.
- Population that enabled the recruitment of 20 blind or deaf-blind participants.
- Availability of a local orientation and mobility specialist who is capable, willing and able to participate in subject recruitment, scheduling, and data collection.

Four intersections were selected for APS installation in each city. The criteria originally established for these locations included:

- Semi-actuated or fully-actuated, with pedestrian push buttons for each crossing direction.
- Concurrent pedestrian signal phasing.
- Four-way intersection of a busy arterial and a minor street with little traffic.
- Arterial with four travel lanes and minor street with two travel lanes.
- Similar geometric and operational characteristics.
- Similar pedestrian signal head and push button configurations (each pole and pushbutton controls the signal for one crosswalk).
- Within easy walking distance of each other (i.e., walking the circuit can be completed within 1 hour).

Upon visiting the various cities and examining sites, it was determined that the last criterion could not be met. In order to obtain locations with enough similarities, it was necessary to use intersections that were not within walking proximity. Thus the subjects were transported between sites by vehicle. The other criterion that was adjusted was the number of lanes and traffic volume on the minor street. Information on the number of lanes and traffic volumes is provided below, in the descriptions of intersections in each city. Controllers and wiring also had to be capable of accommodating the pushbutton-integrated APS equipment.

Tucson

Intersections used in Tucson were quite wide and relatively busy. Major street volumes were between 30,000 and 40,000 vehicles per day. Traffic counts were not available on the minor streets at each intersection. Each intersection had two phase signalization, fully actuated, with a 7 second WALK signal. The major street crossings required the traversal of four through lanes and a left turn lane; total crossing widths varied from approximately 60 ft to 78 ft. The minor street configuration required crossing one through lane and a left turn lane; total crossing widths ranged from approximately 41 ft to 58 ft. Curb ramps were diagonal and pedestrian pushbutton poles were fairly consistently located near the outside line of each crosswalk. Location in relation to the sidewalk (back of sidewalk or on street side) varied. An illustration of one of the Tucson intersections is shown in Figure 3-2.

One site had a right-turn-only lane (northbound to eastbound) from the minor onto the major; crossings in both the general and specific information conditions were made on the west crosswalk of the major street to keep all crossings as comparable as possible and to avoid possible conflicts and auditory confusion. At this crosswalk, one crossing was made in one direction, and one was made in the other direction, which minimized learning about the specific crosswalk or corners.

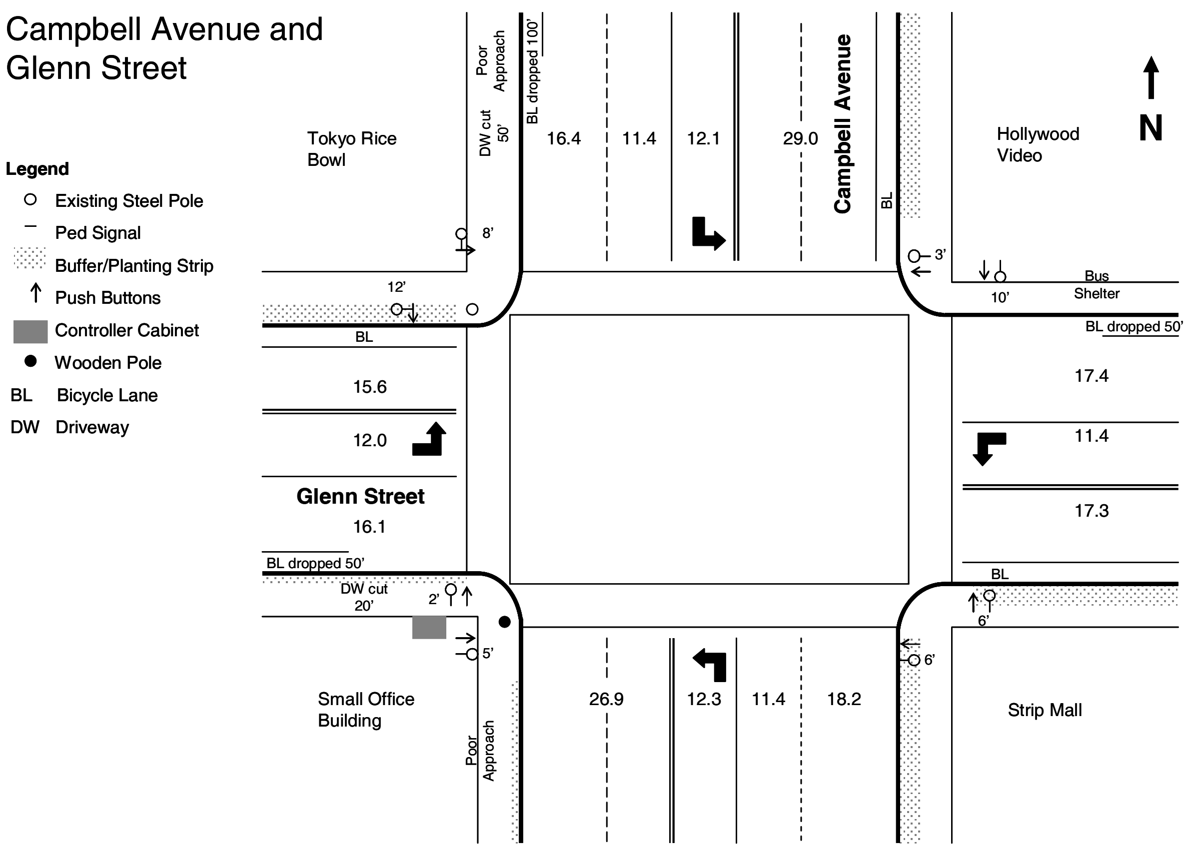


Figure 3-2. Intersection of Campbell Avenue (major street) and Glenn Street (minor street) in Tucson, AZ where APS devices were installed for the experiments.

Charlotte

Intersections selected in Charlotte were, on average, somewhat narrower than the Tucson intersections. Major street crossings at three sites required traversal of four through lanes and ranged in width from 49 feet to 83 feet. The fourth intersection (with approach widths of 79 and 83 ft) had parking lanes on each side of the street and an exclusive left-turn lane on both approaches. Minor street crossings were 34 to 53 ft in width. Traffic volumes on the major roads ranged from 20,000 to 25,000 vehicles per day, while minor street volumes ranged from 3,000 to 6,000 vehicles per day. Most curb ramps were in line with the crossing. Originally, pushbuttons were provided only for the major street crossing or two pushbuttons were located on the same pole. Additional stub poles were installed in order to provide separation of the APS. An illustration of one of the Charlotte intersections is shown in Figure 3-3. At two intersections, sidewalk location or street geometry made it impossible to install separate poles on one of the intersection corners. That corner of each intersection was used as a destination corner only during the experimental trials.

APS Device Features

Four manufacturers (Campbell Company, Novax Industries Corporation, Polara Engineering, Inc., and Prisma Teknik) of pushbutton-integrated APS were asked to provide

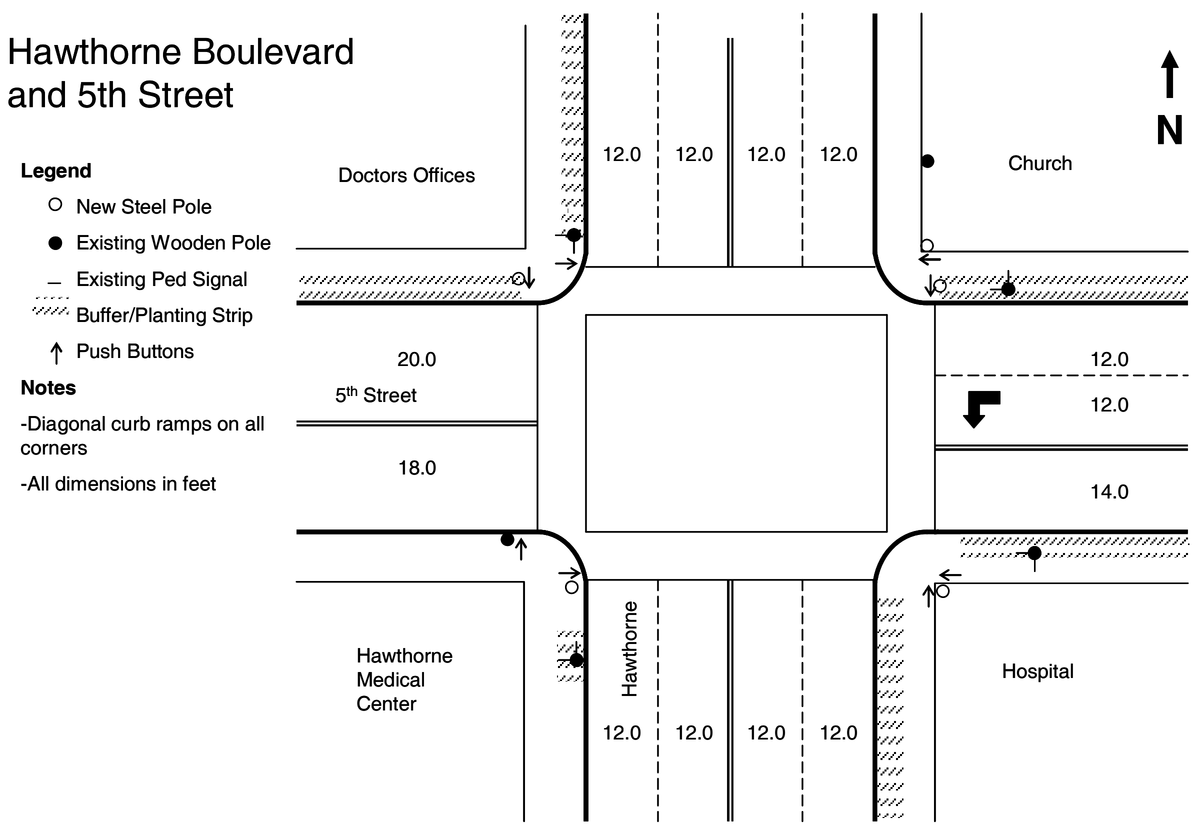


Figure 3-3. Intersection of Hawthorne Boulevard (major street) and 5th Street (minor street) in Charlotte, NC where APS devices were installed for the experiments.

devices with their 'standard features' for the project. The devices provided and tested are shown in Figure 3-4. These four APSs represented all that were being actively marketed in the U.S. at the onset of this research. While all pushbutton-integrated APS devices are capable of providing most of the features evaluated in this project, some manufacturers provide certain features as standard and others as optional. All APS had a pushbutton locator tone, an audible actuation indicator, an audible walk indication, a tactile arrow that vibrated during the walk interval and automatic volume adjustment. Because more than a year elapsed between data collection in Tucson and Charlotte, the manufacturers of devices B and C had developed new models, so the devices used in the two cities were not identical.

In the analysis that follows, the results are presented in terms of APS A, B, C and D. The purpose of the project was NOT to assess each product, but rather to determine the effectiveness of the specific features (e.g., pushbutton style, locator tone, etc.) on the ability of a pedestrian with visual impairments to safely cross the street. The recommended guidelines developed as a result of the research discuss the required features, which may be provided by multiple manufacturers.

Figure 3-4. Pushbutton-integrated APS units from four manufacturers were deployed for the experiments.

APS A

The locator tone was a bright beep (same tone as APS C) from a speaker at the pushbutton. The APS pushbutton unit was a rectangular box approximately 4 in wide x 11 in high x 2.5 in deep, with a 2-inch diameter rounded plastic pushbutton, a speaker below the pushbutton, and an arrow above the pushbutton. Apertures for the sound were located on the front and the side of the pushbutton speaker unit. There was an additional speaker attached to the pedestrian signal head. The tactile arrow was on a panel above the pushbutton, inside a raised circle. A relatively loud pushbutton actuation tone sounded when the button was pushed. The WALK indication was a cheep or a cuckoo that came from an overhead speaker installed on the pedestrian signal head. The arrow also vibrated during the WALK signal.

APS B

This APS had an electronic sounding locator tone. In Tucson, this unit had a 2-inch diameter, rounded metal pushbutton which protruded out at the bottom of the device below a rectangular sign (pedestrian symbol and print arrow); the tactile arrow was on the sign above the pushbutton. In Charlotte, the pushbutton was still rounded and at the bottom of the device, but it was plastic and the arrow was part of the pushbutton itself. A speech message, stating "Wait," sounded in response to pushing the button as a pushbutton actuation tone. If the pushbutton was held for three seconds or longer, additional information about the crossing was provided by a speech message "Wait to cross [street name] at [street name]." When the WALK signal was illuminated, a speech message "[Street name], Walk sign is on to cross [street name]," which was repeated approximately three times. The arrow vibrated during the WALK interval in both cities, but had a noticeable clicking sound in Charlotte.

APS C

APS C had a beeping locator tone (very similar or identical to tone of APS A). The APS was a combination pushbutton and pedestrian sign, available with either a print pedestrian symbol and arrow or an informational plaque. It was basically rectangular with a rounded bottom and measured 14 in high x 6 in wide x 2 in deep. The pushbutton was in the middle of a flat tactile circle near the bottom of the device, and there was a raised tactile arrow on the pushbutton. A quiet click tone indicated to users that they had successfully pushed the button; the button was electromagnetic and did not seem to move or push. If the pushbutton was pressed for three or more seconds, it provided additional information about the crossing following the same model as APS B. The WALK signal was a speech message following the same model as used in APS B. The arrow on the pushbutton vibrated when the walk signal came on. Also, in response to an extended button press, the WALK signal and subsequent locator tone increased in volume for that pedestrian phase to provide beaconing. The housing of the device was slightly different in Charlotte than the Tucson devices.

APS D

APS D had a clicking locator tone. The entire flat smooth front panel of the rectangular box-like device was the electronic pushbutton. The tactile arrow was on top of the pushbutton device. There was a short beep to indicate that the button had been pushed to request a WALK signal. When the pushbutton was held in for three or more seconds, a pushbutton information message was heard. In Tucson, the pushbutton information message did not use the same format as the others. The message was "We want to help you cross the street." In Charlotte, the information message followed the format described in description of APS B. The WALK signal was a rapid ticking sound and the arrow on top of the device vibrated during the WALK. There was a tactile crosswalk map made up of raised symbols, on the side panel of the device, on the side away from the street.

APS Installation and Sound Adjustment

General Description

Although an attempt was made to find four intersections in each city with comparable features, it was impossible to find four that were truly identical, even within one city. Because APS were being installed at existing intersections, there were slight differences in location in relation to the crosswalk, curb ramps and sidewalk configuration at each intersection. APSs were installed on poles that were present at the intersection where possible. In general, Tucson uses mast arms for signal installation, while Charlotte typically uses span wire installations. This results in differences in pole and APS location. Tucson already had two pushbuttons on each corner, mounted on poles separated by at least 10 feet, usually beyond the outside crosswalk lines. Most poles were behind the sidewalk, although some were on the curb side of the sidewalk. In Charlotte, 15 additional poles were installed to locate the APS so the pushbuttons (and APS speakers) were separated by at least 10 feet on all corners on which participants began their crossings (two target corners had two APS on same pole). This separation was created in order to follow the Guidance in *MUTCD* 4E.09 (*1*). Most APSs were in line with the crosswalk lines and between one foot and 10 feet from the curb line.

Signal technicians were not familiar with all the devices to be installed. There was a learning curve in understanding the installation specifications and other requirements. Adjustments were also made after researchers arrived in each city to ensure all devices were installed and operating as designed. Particular attention was paid to alignment of arrows and speakers and adjustment of volume of the WALK messages and locator tones.

Sound Levels

There are two criteria for sound level. One addresses the distance from which sounds should be audible, and the other addresses the difference in sound between ambient sound and signals. *MUTCD* 4E.06 Guidance reads "The accessible walk signal tone should be no louder than the locator tone, except when there is optional activation to provide a louder signal tone for a single pedestrian phase." *MUTCD* 4E.09 Guidance reads "Pushbutton locator tones should be intensity responsive to ambient sound, and be audible 1.8 to 3.7 m (6 to 12 ft) from the pushbutton, or to the building line, whichever is less. Pushbutton locator tones should be no more than 5 dBA louder than ambient sound" (*1*) There are several problems with implementation of this guidance, although, in practice, when attended to, it works fairly well.

The distance at which a signal is audible cannot be objectively measured. This is always a subjective measure, so the distance at which signals are heard is always subject to individual differences in perception by the individual who installs or adjusts the volume on any APS. Furthermore, audible distance is influenced by humidity, atmospheric pressure, and reflective surfaces such as buildings or controller boxes nearby. Therefore, it is never a constant even for the same individual. A locator tone that can be heard no more than 6 feet away by one person on a still day, may be heard more than 20 feet away by the same individual on a windy day.

Humidity, reflective surfaces nearby, and obstacles between the APS and the pedestrian can also affect the ability to hear the locator tone or signal from particular positions.

Another difficulty is that the automatic volume adjustment response is not very precise and varies among the devices because manufacturers use different algorithms. The rate of response to changes in ambient sound can greatly affect differences in perceived loudness. For example, if a loud truck passes by and there is a slight delay in the response to this loud ambient sound, the signal will still be heard as loud after the truck is well away from the intersection and the ambient sound level is lower.

In addition, the amount by which ambient sound and signal volume differ is not capable of easy measurement in the field because the individual bursts of signal sound are too short to be accurately measured by normal sound level meters. Optimal volume adjustment has not yet been adequately researched. An informal survey of jurisdictions having experience installing APS, as well as of APS manufacturers, indicates that in practice, technicians typically adjust the volume by listening to it in the relevant environment (*35*).

An APS may need to be carefully adjusted before the volume is perceived as loud enough by most users who are blind or who have low vision, but not too loud to be tolerated within the neighborhood. After installation of devices, researchers went to each intersection with the traffic signal technicians to check and adjust the volume on all devices. In general the volume was adjusted downward in an attempt to meet the recommendations of the *MUTCD*. Standing at each crosswalk departure location, researchers listened to each device while the signal technician adjusted the volume and consensus was reached on the volume level. APS A and APS B require adjustments at the pedestrian signal head; at times the volume would seem to change after the pedestrian signal head was reassembled. APS C and APS D are adjusted with handheld PDA type devices from the ground.

Manufacturers were available during the installation and final adjustments and provided invaluable assistance in getting devices adequately adjusted. In Tucson, all were in contact by phone or email. In Charlotte, three manufacturers sent representatives to work with the signal technicians and researchers on final adjustments. Despite every effort, there were differences in perceived loudness between devices, between intersections, and between cities.

Device Functioning

Tucson

APS A did not seem to respond well to ambient sound, although the manufacturer's representative suggested that their adjustments were so subtle that it was imperceptible to individuals listening to the signal.

The adjustment for ambient sound also did not seem satisfactory in APS B. The locator tones seemed quite loud at all times, audible as much as 50 feet away from the devices, despite a great deal of time spent attempting to adjust the devices.

There were some variations in the functioning of APS C, which were not completely diagnosed and were inconsistent. The devices installed in Tucson were prototypes of the new model and that may have caused some problems. Automatic volume adjustment seemed to work well. However, at times, the locator tone seemed to shut off at one of the devices. There was also a slight delay in the beginning of the speech walk message after the visual WALK signal was displayed. The WALK and green ball for vehicles would be displayed for approximately a second before the speech walk message began; the reason for this could not be determined although a controller or wiring issue was suspected. Near the end of the experimental trials, it was determined that the beaconing function was not working because the devices were not wired correctly for it to function.

It was necessary to change some of the settings of APS D so the locator tone would sound during flashing DONT WALK. Some devices were not functioning properly, but the experimental trials could be conducted with the devices available. The automatic volume adjustment seemed to work well.

Charlotte

Even after numerous adjustments with the manufacturer's representative, APS A didn't seem to respond to ambient sound but was quite loud all the time. The locator tone could be heard from 50 feet away.

APS B was really adjusted to be too quiet due to complaints from an office/residence on one corner. Baffles were installed to block sound traveling back toward the residential neighborhood. It was very hard to hear the locator tone when approaching the intersection along the sidewalk, although it could be heard when standing at the street waiting to cross. The APS did adjust to ambient sound within a narrow range (low maximum volume).

The locator tone of APS C seemed somewhat louder than other devices. It did vary with ambient sound but could be heard from 50 feet away as the intersection was approached. There was a building on one corner and controller on same corner that reflected the sound.

APS D needed some changes in the settings but seemed to respond well to ambient sound.

Procedure

Participants were tested in individual sessions lasting approximately four hours. Much of the time was used in traveling between intersections in an air-conditioned vehicle, so the session was not excessively strenuous or stressful. Each block of trials consisted of the following:

- Participant and three researchers traveled by passenger car to the first intersection.
- After parking about ½ block from the intersection, participant and researchers walked to the starting point for each crossing (a randomized distance of 50-100 feet from the corner), where instructions were given to the participant.
- Participant made one street crossing with O&M specialist monitoring for safety, using typical O&M procedures.
- Participant and O&M specialist returned across the street.
- All returned to the car and proceeded to the second intersection.
- While riding to the next intersection, O&M specialist obtained subjective data about the participant's experience with the previous crossing.
- The same process was repeated at each of the four intersections.

A minimum of a half-hour refreshment break was taken between the general information and the specific information conditions. During the break, participants were familiarized with demonstration units of each type of APS.

At each intersection, participants made one crossing of the major street in a counterclockwise direction (with the street and parallel traffic on the left), and one crossing of the major street in a clockwise direction. In the no information condition, participants in Tucson made one crossing of the minor street in a counter-clockwise direction. (The no information condition crossing was always a minor street crossing.) Order of intersections and approach (clockwise or counterclockwise) were counterbalanced so each participant made two clockwise and two counterclockwise crossings in each block of trials, and crossed the major street clockwise and counterclockwise with each type of APS. No two crossings were identical.

Before beginning the experimental trials, after review of the consent form, the following information was provided to participants:

> *We're going to be traveling to different intersections. At each intersection, you will make one street crossing; then we'll go on to another intersection.*

This was followed by the following instructions, according to the information condition. For the no information condition, participants were given the following instructions before each crossing:

> *There is a street in front of you. When you come to the street, cross it the way that you usually do. If you think you don't have enough information to make the crossing please ask me for assistance. You may request assistance for any part of the street crossing task. For instance you might like to have help locating the crosswalk, aligning to cross, or knowing when the walk interval begins, or you may request to be guided for the entire task. If you think you'd ask another pedestrian for assistance, just ask me. I will intervene only if necessary for your safety.*
>
> *Researchers (names of those on site provided) will be recording information about the traffic at the intersection, your use of the pushbutton, where you begin crossing from, when you begin your crossing and where you end your crossing. We will ask you about what information you used to cross the street after you complete the crossing.*

Before the general information condition, a description of the features of the pushbutton-integrated APS used in the study was read. The script for this description was as follows:

> *At each of these intersections, new types of Accessible Pedestrian Signals or APS are installed. These APS have some features that you might not have experienced before.*
>
> *First, all of them have what is called a locator tone. Locator tones are intended to notify you that there is a pushbutton at the intersection and to help you in finding the pushbutton. Some individuals have found that they are able to hear the locator tone while crossing, as they approach the other side of the street, and use it for directional assistance. The locator tones on these APS are different tones, but have one quality that is standardized: they repeat at a repetition rate of once per second.*

> *The WALK indication on these APS may be provided by a speech message, or a rapidly repeating tone that is just a faster version of the locator tone, or a cuckoo or chirp. Both the walk indication and the locator tone may get louder or softer, depending on the sound of traffic. Each device also has an arrow that points toward the crosswalk it controls and in the direction of travel on the crosswalk. That arrow vibrates when that crossing has the WALK signal. That may be useful when you are having trouble hearing the WALK indication.*
>
> *There are some other features that these APS may have; not all of them have all of these. They may provide a tone or a speech message to let you know that the button has been pushed. There may be a tactile map of the crosswalk on the side of the device.*
>
> *They may have a feature called extended button press that calls additional features when the button is pressed for three seconds or more. If you hold the button in, you may get a louder signal and/or a speech message that provides additional information about the crossing.*

The whole description, or any part of it, was read again if participants had questions, or requested a review.

Before each crossing in the general information condition, the following instructions were provided to each participant:

> *There is a street in front of you. At all of these crossings, it is necessary to push the pedestrian pushbutton to get the walk signal. There is an accessible pedestrian signal for the crosswalk. Do your best to figure it out and use its information to help you make your crossing.*
>
> *If you think you don't have enough information to make the crossing, please ask me for assistance. You may request assistance for any part of the street crossing task. For instance you might like help locating the crosswalk, aligning to cross, or knowing when the walk interval begins, or you may request to be guided for the entire task. If you think you'd ask another pedestrian for assistance, just ask me. I won't tell you how to use the Accessible Pedestrian Signal, but will help you with other aspects of the crossing if you ask. I will intervene only if necessary for your safety.*
>
> *Researchers (Barlow and Huang or Barlow and Carter) will be recording information about the traffic at the intersection, your use of the pushbutton, where you begin crossing from, when you begin your crossing and where you end your crossing. We will ask you about what you used to cross the street after you complete the crossing and ask questions about your perception of the APS at this intersection.*

Before beginning the crossings in the specific information condition, participants and researchers took a break in a quiet room with refreshments. During this time, each participant was familiarized with functioning demonstration units of each APS installed for the research. A description of the pushbutton, rather than device labels or manufacturers' names, was used in discussing the devices. APS A was referred to as the one with the round plastic pushbutton; APS B was the one with the round metal pushbutton in Tucson and one with the plastic pushbutton with the arrow on it in Charlotte; APS C was the one with the flat metal pushbutton with the arrow on it and APS D was the one with the flat panel pushbutton. Participants were allowed to examine each device, and they were shown the pushbutton, the tactile arrow, and the tactile map of the crosswalk (if available). They could hear the actuation indicator tone or message, the pushbutton locator tone, the walk indication, and the pushbutton information message (if available). The ambient sound response of the devices was explained and demonstrated. The researcher also confirmed participants' understanding of the tactile arrow, by asking each person to point in the direction the arrow was pointing. Those who were incorrect were shown the correct orientation of the arrow and demonstrated their understanding. They were encouraged to ask questions about the devices and their features.

Before each crossing in the specific information condition, each participant was told which type of APS was installed at that crossing, and the features of that type of APS were reviewed.

> *There is a street in front of you. There is an Accessible Pedestrian Signal for the crosswalk. You've now been introduced to the various signals and I'll just review briefly some of the features of this one. As at previous crossings, if you need assistance with any part of the task, just ask me. I will intervene only if necessary for your safety. We will ask you about what you used to cross the street after you complete the crossing and ask questions about your perception of the APS at this intersection. I'll briefly review the features of the device installed here: (followed by appropriate description from script).*

Each description was different to fit the device installed at that intersection. For example:

- *This is the one with the flat panel pushbutton*
- *It has a tapping or clicking locator tone.*
- *The entire flat front panel is the pushbutton. The raised part at the bottom is a light that lights up when the button has been pushed. You will hear a short beep to indicate that you have pushed the button.*
- *There is an arrow on top of the pushbutton device that indicates the direction of the street that it controls and vibrates during the walk phase.*
- *There is a tactile crosswalk map on the side panel of the device, on the side away from the street.*
- *If you hold the pushbutton in for more than three seconds, you will hear a speech pushbutton information message.*
- *When the walk signal comes on, you will hear a rapid ticking sound.*

Following completion of all crossings, participants were asked to use a Likert scale to rate the extent of their agreement with four questions. These subjective data allowed for comparing the four APS types in terms of interface issues, special features, and beaconing.

In Tucson, in the no information condition, all crossings were of the minor street. Traffic on the major street was relatively steady even in off-peak hour conditions. In Charlotte, it became clear during piloting that the distance and travel time between intersections was too great to complete crossings in all three conditions in less than five hours. The no information condition was dropped due to these time constraints.

RESULTS AND DISCUSSION

Results have been organized according to: 1) use of the pushbutton, 2) results most closely associated with crossing timing, 3) results most closely associated with wayfinding, and 4) subjective results. Within the first three sections, results are also broken down by information condition and city, and by device and city.

As previously discussed, there were differences between Tucson and Charlotte in intersection characteristics such as the volume of traffic, width of streets, location of pedestrian pushbuttons, as well as minor differences in some of the devices installed in the two cities. There were also differences in the procedure followed. Therefore, data were analyzed separately for each city, and not combined. Any statistical comparison between cities would be confounded by these differences; therefore no inferential analyses of differences between cities were conducted.

Inferential analysis of all measures of all levels of all factors was made difficult by a large amount of systematically missing data. For example, if 16 of 20 participants searched for the pushbutton at a given intersection, and 10 found it, there were data on use of the pushbutton features for the 10 participants who found the pushbutton. If 4 participants asked for assistance in finding the pushbutton (i.e., did not find it independently), there was information on the use of the tactile arrow and use of the extended button press for 14 participants, those 4 in addition to the 10 participants who found the pushbutton independently. For the 2 who searched and did not find a pushbutton or request assistance finding one, and for the other 4 participants who did not search for the pushbutton, there is no pushbutton related data available.

The data were analyzed in three primary ways. For those variables that provided interval level data (e.g., latencies), median replacement was used to replace missing data. Appropriate inclusion criteria were then determined for investigating each question of interest. For example, in order to ask which of the various devices allowed for more rapid onsets of crossing following the audible signal, it was statistically appropriate to include only those participants who had used all of the pushbuttons in a given information condition and thus had audible WALK information to use at each intersection in that information condition. Listwise deletion was used to eliminate those individuals from the analysis who did not meet the inclusion criteria, and paired-samples t-tests or repeated-measures ANOVAs were conducted.

A second method was used to analyze data pertaining to information condition (ignoring device differences) or device differences (ignoring information condition). In order to determine whether observed differences were statistically significant, it was necessary first to transform the data into interval level. The following is an example of how this was done. In order to investigate whether or not participants were more likely to use the tactile arrow feature on one device than another, a new variable was calculated for each device type. Imagine that for a given device type a participant did not use the feature in the 'no information condition,' but did in the 'general' and 'specific information' conditions. This individual thus used the feature two-thirds (67%) of the time for this device. Percentages were calculated in this way for each device and for each participant. The data could thus be treated as interval level, and either a repeated-measures ANOVA or a paired-samples t-test could be used to look for differences between the devices.

Finally, basic descriptive statistics are provided for many of the categorical level variables. Once again inclusion criteria were established for each category (e.g., only those participants who searched for the pushbutton) and then percentages were calculated for the number of those participants who used a certain feature or performed in a given way.

Interpretation of data across information conditions is always confounded somewhat by the possibility of learning about the particular intersections. The no information, general information and specific information trials could logically only take place in that order; that is, order could not be randomized or counterbalanced. However, procedures were used that minimized the likelihood that participants learned specific crosswalk or intersection characteristics, or the locations of APS at particular corners. Therefore significant differences across information conditions are most likely due to the effect of the level of information with APS devices unless otherwise noted. In the general information condition, those participants (most of them) who used the APS at most of the crossings, gained some hands-on familiarity with the APS. In the specific information condition, this was supplemented by participants' use of demonstration devices of each APS, as well as by knowing which APS would be present at each crossing, as they prepared to make that crossing. The additional information was consistent with the intent of that condition, which was to represent the common situation in which pedestrians who are blind or visually impaired know what kind of an APS they will find at a crossing, and know its features. While many pedestrians who are blind or who have low vision travel novel routes at least occasionally, most travel by these pedestrians, like travel of pedestrians who have unimpaired vision, is on familiar routes. Also, many jurisdictions prefer to work with certain manufacturers and may have installed a number of devices with similar or 'standard' features in their jurisdiction, so it is not unusual for pedestrians who are blind to have had experience with the type or types of devices installed in their area.

Use of the Pushbutton

Finding and Using Pushbutton

Data were collected on searching for the pushbutton, time to find and use the pushbutton, using the wrong pushbutton, correctly rejecting or incorrectly using the wrong pushbutton, use of the tactile arrow, use of the tactile map, use of the extended button press feature, and listening to the intersection information message resulting from the extended button press. Results are reported for only the most informative measures, including searching for the pushbutton, finding the pushbutton, using the wrong pushbutton, use of the tactile arrow, use of the extended button press feature and use of the tactile map.

In Tucson, at many intersections throughout the city, signals are installed on mast arms and each corner has two pushbuttons on poles that are separated, and located near the end of each crosswalk. Use of a pushbutton is required to actuate the WALK signal for both the major and minor streets at most signalized intersections. Thus, participants should have had prior experience crossing at intersections where pushbuttons were installed in predictable locations. However, participants were asked, at the end of all trials, whether they usually use pushbuttons when they are present. Nine of 20 said they usually do not use pushbuttons, while six said that they usually do, and the other five said they use pushbuttons only when they know that the pushbuttons are there or it is a particularly difficult intersection.

In Charlotte, which has many curving streets resulting in skewed intersections, it is very common to have two pushbuttons on the same pole, or to require pushbutton actuation for only the major street at an intersection. Two pushbuttons on one corner are occasionally mounted on two separate poles, one at the end of each crosswalk, but that is not common. Therefore participants may not have had experience with consistent pushbutton placement, and may have been familiar with situations where pushbutton actuation was not necessary for all crossings. Because no data was collected in the no-information condition in Charlotte, we have no data indicating use of pushbuttons. However, following all experimental trials, participants were asked whether they typically used pushbuttons when crossing streets. Seven out of 20 said they usually do not use pushbuttons, six said that they usually do, and the other seven said they do only when they know that the pushbuttons are there. Also, in related research in Charlotte, (NEI) sixteen blind participants crossing at complex, unfamiliar signalized crossings, without APS, did not look for pushbuttons on any of the 64 crossings at which pushbutton actuation was necessary.

Information Condition

Tucson – Based upon participants' reports of their typical pushbutton use, it is not surprising that in the no-information condition in Tucson, only five participants looked for the pushbutton on every crossing, and at each of three intersections, one additional person (different people) looked for the pushbutton. Of the 28.8% of 80 trials on which participants looked for the pushbutton, the correct pushbutton was found and used on 83% of trials, while the incorrect pushbutton was used on 13% of trials (*see Table 3-1*). A few participants requested assistance in finding the pushbutton, and then pushed it. So the button was pushed on more trials than it was found independently.

Information condition appears to have had a significant effect on participants' choosing to search for the pushbuttons. In trials following general information, participants searched on 97.5% of trials, and participants searched on 100% of trials following specific information. The overall analysis is significant ($F(2,38) = 51.37$, $p<.001$), as is the comparison between no information and general information conditions ($F(1,19) = 49.76$, $p<.001$)

There are several likely explanations for the large increase in looking for pushbuttons between the no information and general information conditions. First, a possible cause of the low incidence of looking for the pushbutton in the no information condition may have been that all crossings in this condition were across the minor street. Because pedestrian timing was concurrent, and because there was always adequate traffic on the parallel street, there was sufficient information from vehicular flow for participants to cross without using the pushbutton.

TABLE 3-1 Pushbutton measures by information condition – Tucson

	No information	General information	Specific information	F or t
Looked for Pb	28.8	97.5	100.0	F(2,38) = 51.370**
Found Correct PB		80.6	79.2	t(17) = 0.223
Used Tactile Arrow		68.8	72.9	t(11) = 0.432
Used Wrong PB		18.8	14.1	t(15) = 0.764
Used Extended Push		38.8	77.8	t(11) = 2.759*

* Significant at $p < 0.05$

** Significant at $p < 0.001$

Second, prior to the general information trials, participants were told that pushbuttons were needed to actuate the WALK signal and its associated timing at every crossing. Finally, prior to the general information trials, participants were told that all pushbuttons would have a locator tone coming from the pushbutton, so they knew they could use the sound of the locator tone to help them find the pushbutton. Therefore, the increase in looking for the pushbutton (as well as in use of the pushbutton—see below) was likely attributable to several factors, most of which are amenable to increased training in the function of signalized intersections, with emphasis on the use of a pushbutton, which is often required to actuate a pedestrian timing of adequate length. The presence of a locator tone to inform pedestrians of the presence of a pushbutton and its location may also influence the use of pushbuttons, since five participants in Tucson and seven in Charlotte said they only used pushbuttons if they knew they were there and where to find them.

The looking for the pushbutton variable was used as an inclusion variable for analysis of the use of the wrong pushbutton, and the interaction with the pushbutton variable (i.e., those who found the pushbutton with or without assistance) was used as an inclusion variable for the analyses of specific pushbutton features (i.e., use of arrow, extended push). Where these criteria were applied across all three levels of information, the result was too few participants to provide sufficient power. This is the result of having so few participants look for the pushbutton in the no information condition. Using the same inclusion criteria but restricting the analysis to the general information and specific information conditions where the number of participants who searched for the pushbuttons is much higher, there was no significant difference in participants' looking for the pushbutton, finding the pushbutton, using the wrong pushbutton, or using the tactile arrow. However, the increase in use of the extended button press, from 38.8% to 77.8% was significant ($t(11) = 2.759$, $p<.05$).

Although there was no significant difference between the general and specific information conditions with regard to the number of participants who pushed the wrong pushbutton, it is nonetheless interesting to consider the implication of the use of the wrong pushbutton. The primary reason for inclusion of the tactile arrow on APS is to enable pedestrians who are blind or who have low vision to accurately determine which pushbutton controls which crosswalk. In Tucson, across the general and specific information conditions, participants looked at the arrow on the incorrect pushbutton on 28 trials. However, on 100% of these trials they correctly rejected the incorrect pushbutton (*see Table 3-2*).

Charlotte – In Charlotte, where no data was collected in the no-information condition, increasing familiarity from general information to specific information condition had no effect on participants' looking for the pushbutton. With one exception, every participant searched for the pushbutton on every trial. This was similar to the result from Tucson. However, increasing information between the general information and specific information conditions did lead to participants finding the pushbutton on a greater percentage of trials, which was not the case in

TABLE 3-2 Percentage and proportion of trials on which participants correctly rejected the incorrect pushbutton (i.e., checked the tactile arrow on the incorrect pushbutton, and then chose not to push that button), by information condition

City	General Information	Specific Information
Tucson	100% (12/12)	100% (16/16)
Charlotte	52% (17/33)	80% (24/30)

Tucson. As shown in Table 2-3, 19 participants searched for the pushbutton on every trial, and participants found the button on average 67.1% of the time following general information, while the same participants found the button on average 84.2% of the time following specific information ($t(18) = 2.233$, $p<.05$).

There was a trend towards increasing information leading to lower use of the incorrect pushbutton. Following general description, participants used the wrong pushbutton on average 25% of the time. Following specific information, participants used the wrong pushbutton only 10.3% of the time. This difference approaches significance ($t(16) = 1.975$, $p = .066$).

Use of the incorrect pushbutton presented a very different picture in Charlotte than in Tucson (*see Table 3-2*). In Tucson, participants looked at the arrow on the incorrect pushbutton on 28 trials, but they always correctly rejected the incorrect pushbutton. However, in Charlotte, participants looked at the arrow on the incorrect pushbutton on 63 trials, and correctly rejected it on only 41 trials (65%). While the improvement in overall use of the wrong pushbutton from the general to the specific information condition approached significance, participants still failed to reject the incorrect pushbutton on 20% of trials (6/30) following specific information. To observers, participants in Charlotte seemed less skilled, particularly in orientation, which may have related to the generally curving and hilly streets of the area as contrasted to Tucson's square flat grid pattern. The confusion of pushbuttons seemed to be related to the participants' lack of strategies to maintain their orientation; some would completely turn to face the street parallel to their travel path, while examining the arrow on the device and then push the button and line up to cross the parallel street.

The increased information also led to significantly greater use of the tactile arrows from 86.7% of trials following general information, to 100% of trials following specific familiarization ($t(14) = 2.48$, $p<.05$). Increased information also resulted in a significant increase in use of the extended button press feature from 17.7% to 71.1% ($t(14) = 6.804$, $p<.001$).

Devices

Tucson – When considering APS devices with regard to locating and using pushbuttons, and when collapsing across information conditions, there is a slight trend such that the percentages of participants finding the correct pushbutton was higher for APS A and B than for

TABLE 3-3 Pushbutton measures by information condition – Charlotte

	General Information	Specific Information	T
Looked for pushbutton	95.0	100	T(19) = 1.00
Found Correct PB	67.1	84.2	T(18) = 2.233*
Used Arrow	86.7	100	T(14) = 2.477*
Used Wrong PB	25.0	10.3	T(16) = 1.975
Used Extended Push	17.7	71.1	T(14) = 6.804**

* Significant at $p < 0.05$

** Significant at $p < 0.001$

Example: On average, each participant used the arrow on 86.7% of crossings in the general information condition.

APS C and D. This difference did not appear following the specific information condition (*see Table 3-4*). Additionally, a slight trend in Charlotte was in a different direction.

APS D resulted in the highest rates of using the wrong pushbutton in the specific information condition; however there were not large differences in this regard, and there were no trials on which participants failed to reject the incorrect pushbutton after checking the arrow, so the arrow was apparently well-understood. These results may suggest that it was more difficult to locate the arrow on APS D than on the other APS, but not more difficult to "read" the arrow. The arrow was on top of the APS, while it was on the front surface of all the other APS. The high rate of using the wrong pushbutton, attributable entirely to participants who did not reference the arrow, may also reflect the location of one APS D device in Tucson, for the parallel (incorrect) street, which was on a pole that was within the approach sidewalk rather than at the back of the sidewalk as most others were.

A fairly clear trend emerges when examining the data for use of the tactile arrow on the correct device. In the general information condition, participants used the tactile arrow 76% and 89% of the time on APS A and APS C, respectively. On APS B and APS D, the equivalent rates were 61% and 56%, respectively. In the specific information condition, this trend continued. APS A and C both resulted in 89% using the tactile arrow, while APS B and D resulted in 68% and 56% using the tactile arrow. This trend does not appear in the Charlotte data, suggesting that arrow use is therefore unlikely to be due to differences in device characteristics. However, the arrow position on APS B was different between the two cities and may help explain the much higher rates of use in Charlotte. Furthermore, although arrow use for APS D was higher in Charlotte than in Tucson, it remained to lowest between devices within Charlotte.

It was possible to use the data on use of the tactile arrow to compute inferential statistics regarding device differences by collapsing across the general and specific information conditions, as described near the beginning of the results section. This required using only those participants who interacted with all four pushbuttons in both conditions, providing a sample of 12 participants. The resulting analysis is significant ($F(3,33) = 4.64$, $p<.01$). The average percentages match the frequency analysis from above quite well; APS A 83.3%, APS C 87.5%, APS B 66.7%, and APS D 50.0%. A comparison of the two devices with the greatest difference, APS C and APS D, is significant ($F(1,11) = 9.00$, $p<.05$). APS C was only marginally better than APS B ($F(1,11) = 4.66$, $p = .054$). However, it is unclear if there is a meaningful difference between device characteristics, as an identical pattern of results did not appear in the Charlotte data.

There is no clear picture with regard to the use of the extended pushbutton features of the three devices in which they were present.

On the whole, the Tucson data associating devices with use of the pushbutton does not present a very clear picture. There were not large differences in the numbers of participants finding the various APS devices under the general or specific information conditions. The one clear conclusion is that the tactile arrow was more likely to be used on the APS C devices than on APS B, and the trend suggests more so on both APS C and A devices than on APS B and D.

TABLE 3-4 Pedestrian interaction by device and information condition – Tucson

	APS A	APS B	APS C	APS D
No information condition				
% that searched for PB*	**25%** (5/20)	**30%** (6/20)	**30%** (6/20)	**30%** (6/20)
Of the # that searched for the PB				
% that found the PB**	**100%** (5/5)	**100%** (6/6)	**67%** (4/6)	**67%** (4/6)
% used wrong PB	**0%** (0/5)	**17%** (1/6)	**17%** (1/6)	**17%** (1/6)
Of the # that interacted with the correct PB				
% that used tactile arrow***	**40%** (2/5)	**0%** (0/6)	**50%** (2/4)	**25%** (1/4)
% that used extended push	NA	**0%** (0/6)	**25%** (1/4)	**0%** (0/4)
% that used tactile map	NA	NA	NA	**0%** (0/4)
General information condition				
% that searched for PB*	**90%** (18/20)	**100%** (20/20)	**100%** (20/20)	**100%** (20/20)
Of the # that searched for the PB				
% that found the PB	**83%** (15/18)	**85%** (17/20)	**75%** (15/20)	**70%** (14/20)
% that used wrong PB	**17%** (3/18)	**10%** (2/20)	**20%** (4/20)	**21%** (4/19)****
Of the # that interacted with the correct PB				
% that used tactile arrow	**76%** (13/17)	**61%** (11/18)	**89%** (16/18)	**56%** (9/16)
% that used extended push	NA	**50%** (9/18)	**39%** (7/18)	**38%** (6/16)
% that used tactile map	NA	NA	NA	**13%** (2/16)
Specific information condition				
% that searched for PB*	**100%** (20/20)	**100%** (20/20)	**100%** (20/20)	**100%** (20/20)
Of the # who searched for the PB				
% that found the PB	**85%** (17/20)	**75%** (15/20)	**75%** (15/20)	**70%** (14/20)
% that used wrong PB	**5%** (1/20)	**l0%** (2/20)	**12%** (2/17)****	**25%** (5/20)
Of the # that interacted with the correct PB				
% that used tactile arrow	**89%** (17/19)	**68%** (13/19)	**89%** (16/18)	**56%** (10/18)
% that used extended push	NA	**79%** (15/19)	**89%** (16/18)	**78%** (14/18)
% that used tactile map	NA	NA	NA	**17%** (3/18)

* PB = pushbutton
** Of the 25% who looked for the pushbutton in the No information condition, 100% found the pushbutton (5 of 5)
*** Of the 100% who found the pushbutton in the No information condition, 40% used the tactile arrow (2 of 5)
**** Missing data
NA Feature not available on device

The arrow on APS C was on the pushbutton and the arrow on A was large and the main feature on the front of the device.

Charlotte – In Charlotte, it is also difficult to say anything about differences in rates of finding the pushbutton attributable to device (*see Table 3-5*). By the time participants were familiarized with the devices, the rates were fairly similar. In the general information condition, APS C led to the highest rates of finding the pushbutton (79%), while APS A resulted in the lowest (53%). These differences may be attributable to the large numbers of participants who found and used the incorrect pushbutton at APS A and quit looking for a pushbutton, even when they checked the arrow and it pointed the wrong way. In the specific information condition, all devices resulted in rates of finding the correct pushbutton between 80% and 90%. There were unavoidable differences in volume setting between devices in Charlotte. The locator tones of APS A and C were louder than the others, and several participants complained about the sound of APS C echoing off of a nearby building.

In the general information condition, about 20% of participants used the wrong pushbutton when at intersections with APS D, B and C, and 42% of the time when using APS A. The intersection with APS A was also the one with the lowest rates of use of the correct pushbutton. This may have been due to an idiosyncrasy in locations of APS A devices at this intersection; one was close to the controller, making the sound echo, and the other was behind the sidewalk.

However, by the time the participants had received specific information, no more than two participants used the wrong pushbutton at any given intersection. The most noteworthy thing that appears from the data following the specific information is that some participants who checked the tactile arrow nonetheless pushed the incorrect button. The fundamental problem here may be a lack of understanding of arrows, even with the demonstration of arrows that was provided. It could also be because the demonstration was in a room, not on a corner, and no information was provided regarding the usual geometric relationships between corner, crosswalk, and pushbutton. Some participants seemed to decide that the correct pushbutton was always on the right, or always on the left, when, in fact, the side of the pedestrian on which the pushbutton was located was determined by whether the parallel street was to participants' left or right and varied depending on whether the pedestrians was making a clockwise or counterclockwise crossing (part of the counterbalancing scheme).

Possibly of more interest is the difference in occurrence of situations in which participants checked the wrong pushbutton and then decided it was incorrect (correct rejection). Following general information, the APS D devices led to an 80% correct rejection rate, APS B a 57% rate, and the APS C and A devices around 30%. Following specific information, the results did not closely match those following general information. Although APS C had the lowest rate of correct rejection, there were only 3 participants who ever checked the wrong pushbutton and thus this is not a stable measure. For the other three devices, the rates were at or above 75%, with APS A leading the category with 90% correct rejections.

It should be noted, in examining these results and comparing to Tucson, that APS B had been significantly redesigned and the arrow was actually on the pushbutton rather than above the pushbutton in Charlotte. This seems to have affected the use of the tactile arrow on the device. With regard to tactile arrow use following general description, APS A, B, and C resulted in 88% or higher rates of use. Only 65% of participants used the feature on APS D. Following specific

TABLE 3-5 Pedestrian interaction by device and information condition – Charlotte

	APS A	APS B	APS C	APS D
General information condition				
% that searched for PB*	**95%** (19/20)	**95%** (19/20)	**95%** (19/20)	**100%** (20/20)
Of the # that searched for the PB				
% that found the PB	**53%** (10/19)	**68%** (13/19)	**79%** (15/19)	**65%** (13/20)
% that used wrong PB	**42%** (8/19)	**21%** (4/19)	**21%** (4/19)	**15%** (3/20)
Of the # that interacted with the correct PB				
% that used tactile arrow	**88%** (15/17)****	**100%** (19/19)	**89%** (16/18)****	**65%** (11/17)
% that used extended push	NA	**22%** (4/18)****	**26%** (5/19)	**6%** (1/17)
% that used tactile map	NA	NA	Na	**0%** (0/17)
Specific information condition				
% that searched for PB*	**100%** (20/20)	**100%** (20/20)	**100%** (20/20)	**100%** (20/20)
Of the # who searched for the PB				
% that found the PB	**80%** (16/20)	**80%** (16/20)	**90%** (18/20)	**90%** (18/20)
% that used wrong PB	**5%** (1/20)	**l0%** (2/20)	**5%** (1/19)****	**11%** (2/18)****
Of the # that interacted with the correct PB				
% that used tactile arrow	**100%** (18/18)	**100%** (20/20)	**100%** (20/20)	**95%** (19/20)
% that used extended push	NA	**65%** (13/20)	**80%** (16/20)	**65%** (13/20)
% that used tactile map	NA	NA	Na	**28%** (5/18)*****

* PB = pushbutton
** Of the 95% who looked for the pushbutton in the general information condition, 53% found the pushbutton (10 of 19)
*** Of the 53% who found the pushbutton in the general information condition, 88% used the tactile arrow (15/17)
**** Missing data—1 participant
***** Missing data—2 participants
NA Feature not available on device

familiarization, the rate on APS D was up to 95% and all other devices resulted in 100% usage rates. This may indicate that when pedestrians who are blind or visually impaired know what kind of arrow they will encounter, they are quite likely to use it at unfamiliar crossings, or it may simply be that following specific information, they understood arrows better and were more inclined to check them out. The rate of arrow usage in Charlotte appears to be somewhat higher than that for Tucson, but pushbutton location was fairly consistent in Tucson. In Tucson, some participants may have decided that they could be sure which crosswalk was controlled by the pushbutton solely on the basis of location of the pushbutton. However, even with the higher rate of arrow usage in Charlotte, participants pushed the wrong button, after using the arrow, on more trials in Charlotte than in Tucson (*see Table 3-3 above*).

The rates of use for the extended pushbutton feature look similar to those for the tactile arrow. In the general information condition, 6% of participants (1 participant) used the extended press feature on APS D, while 22% and 26% used the feature on APS B and C, respectively. Following specific information, the rates of use were equivalent for APS B and D(65%), but were used slightly more on APS C (80%).

Latency to Find and Use Correct Pushbutton (Pushbutton Latency)

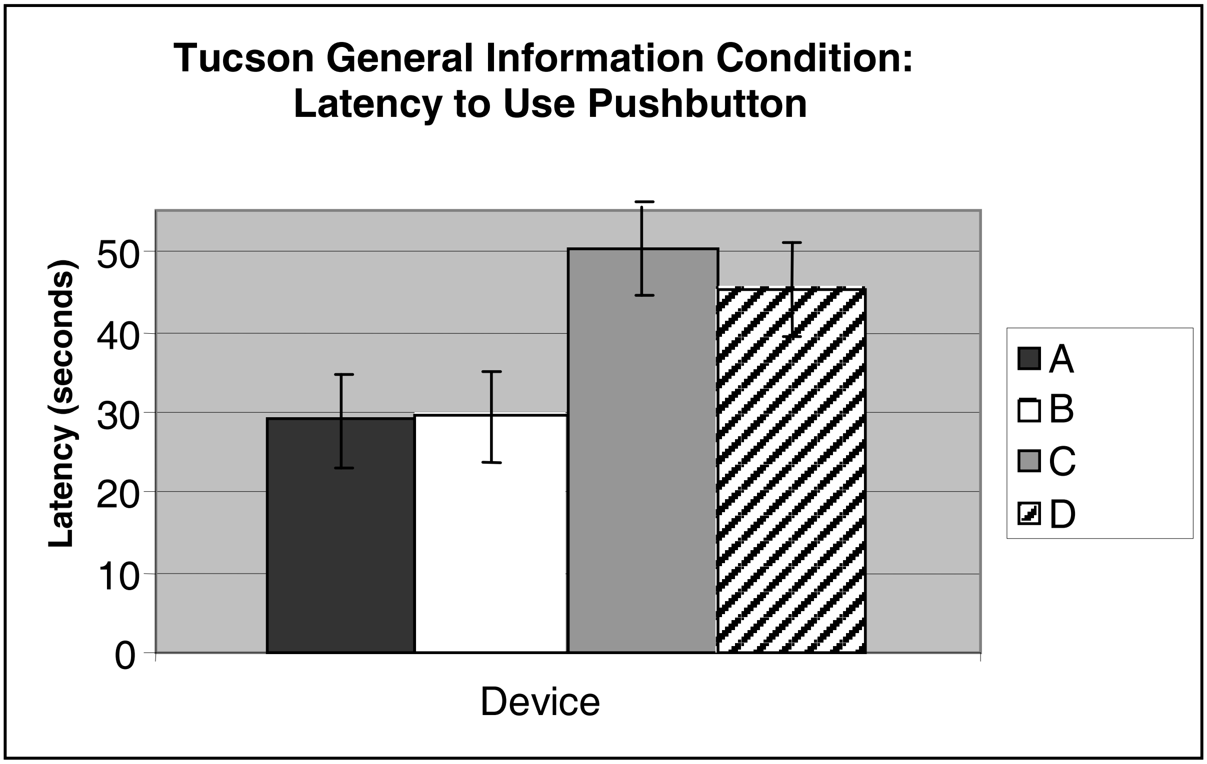
Tucson

With regard to time to locate the pushbutton in Tucson, there were so few participants who looked for and found the pushbutton in the no information condition, that no statistical tests could be done for either information condition or device.

In the general information condition, median replacement resulted in the replacement of four to six data points for each device. (Since all analyses were conducted using paired-samples or repeated-measures methods, the estimates of error used in the t-tests and ANOVAs are not a matter of variability around the mean but rather a measure of covariability across conditions. Therefore, this method of data replacement does not artificially inflate power.) The subsequent ANOVA revealed significant differences attributable to device. The mean amount of time to locate and use the correct pushbutton varied between 29 and 50 seconds, with the times for APS A and B being similar 28.95 and 29.55 seconds, and those for APS C and D being longer, 50.30 and 45.50 seconds. The overall analysis was significant ($F(3,57) = 3.56$, $p<.05$). A comparison between the averaged latencies on APS A and B devices, and the averaged latencies on APS C and D revealed a significant difference, ($F(1,19) = 11.12$, $p<.01$). Finally, no statistically significant difference was found between APS C and APS D (s*ee Figure 3-5*). The difference between these two pairs of devices, in time to locate and push the correct pushbutton, may be that APS A and APS B had very typical, rounded, pushbuttons, while the pushbuttons of APS C and APS D were unique. Although it is impossible to differentiate, it is possible that participants found all devices in approximately equal amounts of time, but it then took longer to find the actual button for APS C and D.

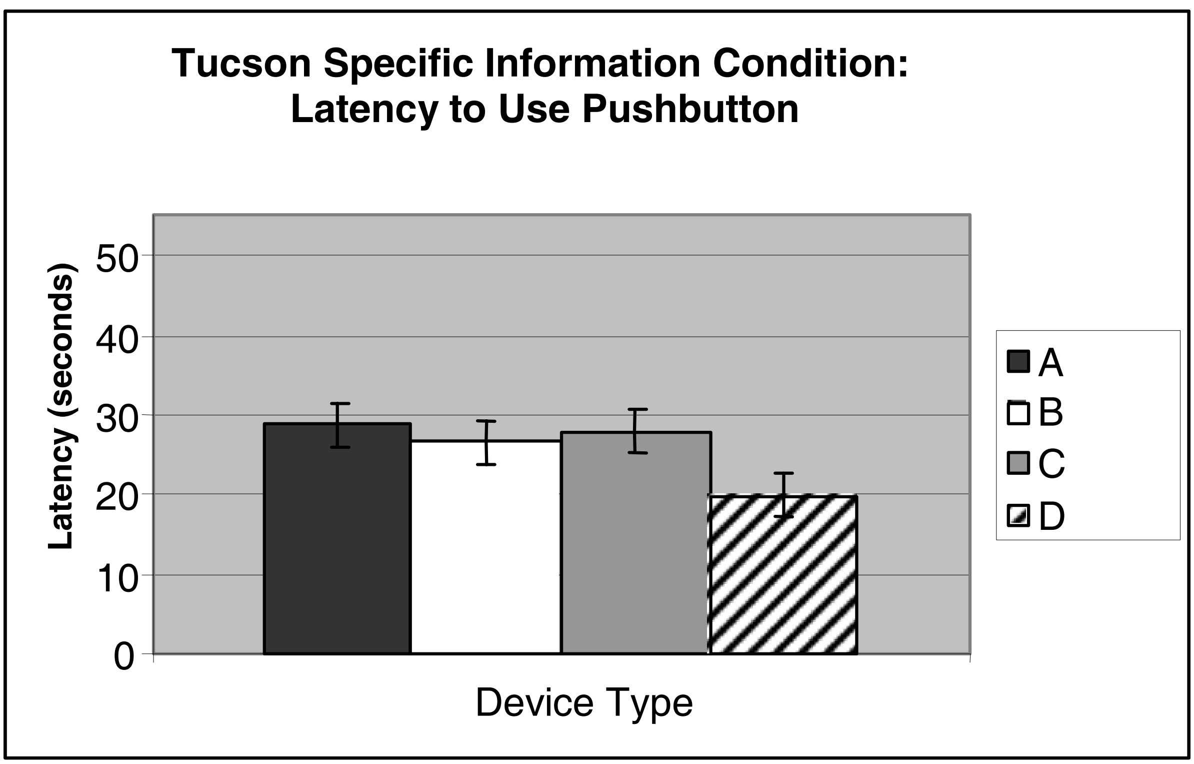
In the specific information condition, the use of median replacement resulted in the replacement of between three and six data points per device, and the ANOVA revealed no significant differences between latencies ($F(3,57) = 2.106$, $p>.05$). The lack of significance clearly differs from the analysis in the general information condition, and furthermore, a closer look at the means reveals a different pattern than was present in the general information condition as well. With specific information, the means for the APS A, B, and C are very similar, and APS D had a trend towards faster latencies (*see Figure 3-6*).

Looking from one Tucson figure to the other, it appears that there is a considerable improvement for the APS C and D buttons between the general information and specific information conditions. For the APS C and D, this does represent a significant improvement ($t(19) = 2.32$, $p<.05$, and $t(19) = 4.85$, $p<.001$, respectively). Furthermore, it appears that the average latency to find the pushbutton has decreased between the general information and specific information blocks. This is statistically confirmed ($t(19) = 4.147$, $p<.001$) and reveals



F(3,57) = 3.560, p<.05, N=20

Figure 3-5. Latency to use the pushbutton: general information condition – Tucson.



F(3,57) = 2.106, p>.05, N=20

Figure 3-6. Latency to use pushbutton: specific information condition – Tucson.

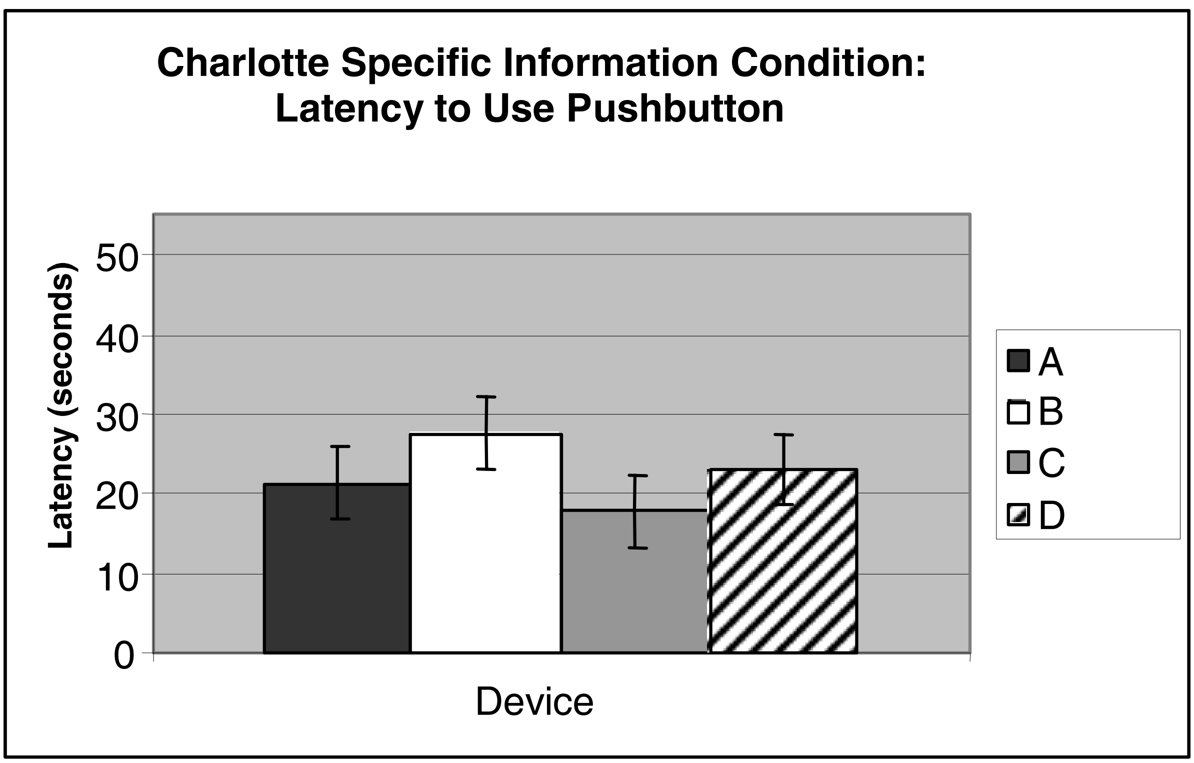
that the average amount of time to use the pushbutton in the specific information condition (25.70 sec) is faster than that in the general information condition (38.58 sec).

The measure of latency to find and push the correct pushbuttons includes any time taken to use the tactile arrow on the incorrect APS and to reject it and to find and push the pushbutton on the device. Therefore the improvement in latency for APS C and D may not indicate a decrease in latency for finding the pushbutton pole and the device, but a decrease in time taken to actually locate and push the button on the device. APS C and D both had unique pushbuttons, so until participants had specific hands-on familiarization, and knew what sort of pushbutton they would encounter at each intersection, they took some time in deciding what part of the device to actually push. This was particularly evident to researchers in the case of the flat-panel pushbutton of APS D.

Charlotte

With regard to time to locate the pushbutton in Charlotte, although more than 50% of participants found each pushbutton individually, only four participants found all four pushbuttons. Thus, the limited amount of latency data available in the general information condition makes running any within subjects statistical tests inappropriate.

Analysis of data from the specific information condition required median replacement of up to four missing values per device and revealed no significant differences attributable to device ($F(3,57) < 1.00$) – (*see Figure 3-7*). The average amount of time to use the pushbutton following



$F(3,57) < 1.00$, N=20

Figure 3-7. Latency to use pushbutton: specific information condition – Charlotte.

the specific information was similar between the two cities (22.4 seconds in Charlotte and 25.7 seconds in Tucson).

In comparing the specific information results across the two cities, both analyses are non-significant, and the trends are not the same, but the average amount of time to find the pushbuttons is rather similar. One reason for the difference in trend may be that pushbutton-integrated APS were more familiar to the Charlotte participants; there are a number of pushbutton-integrated APS in Charlotte, and none in Tucson.

Crossing Timing

Measures associated with crossing timing included time to begin crossing (Starting Latency), interval during which participants began crossing (Start Interval), interval during which participants finished crossing (Finish Interval), and whether participants finished crossing before the onset of perpendicular traffic (Finish Before Perpendicular). The longer participants delayed starting to cross, the greater was the likelihood that they would still be in the crosswalk when perpendicular traffic received a green signal.

Information Condition

Tucson – There was only one participant who began each crossing without assistance and who had the audible WALK signal for all 12 crossings. Furthermore, there were only four participants who had the audible WALK and crossed independently at each of the eight crossings in the general and specific information blocks. Therefore, analyses of starting latency were undertaken with all 20 participants while keeping in mind the potential confounds. There are differences in measures of crossing timing across information conditions; these significant differences are exclusively between the no information condition and both the general information and specific information conditions, which did not differ from one another on any of these measures.

The overall analysis of differences in starting latency across information conditions, using 19 participants (one instance of missing data), is significant ($F(2,38) = 11.580$, $p<.001$). No information differs from both general information ($F(1,19) = 9.699$, $p<.01$), and specific information ($F(1,19) = 16.701$, $p<.001$), which are not significantly different from one another (*see Table 3-6*).

TABLE 3-6 Measures of crossing timing by information condition – Tucson (N = 19)

	No Information	General Information	Specific Information	F (2,36)
Starting latency in sec. **	5.36	3.53	3.21	11.580*
Started during WALK ^	18.42%	64.05%	72.84%	21.297*
Completed during WALK or FDW ^	7.89%	31.58%	42.11%	10.926*
Completed before perpendicular Green ^	97.37%	93.84%	94.74%	< 1.00

* Significant at p < 0.001

** Latency in seconds measured from the onset of WALK.

^ Each value represents the average percentage of trials within the given block in which each participant performed accordingly.

There are no significant differences on measures of crossing timing between the general and specific information conditions, and the improvement in all measures of crossing timing between the no information and the general and specific information conditions is likely attributable to increasing use of the pushbutton and thus presence of the audible WALK signal. In the no information condition, in 80 possible trials, participants used the pushbutton on only 16 trials. By the general information condition this had increased to 66 of 80 trials. However, in the no information condition, participants were always crossing a minor street and had good traffic cues indicating the onset of vehicular green, which was concurrent with the WALK signal if it had been present. In the absence of the WALK signal, the length of the parallel vehicular green nonetheless allowed ample time for most participants to complete their crossings before the onset of perpendicular green. The picture might have been different if participants were crossing a major street instead of a minor street on crossings in the no information condition. Note, however, that latency in the no information condition was more than five seconds, even though participants were crossing the minor street in the presence of good vehicular cues. If greater use of the pushbutton, and consequent presence of the WALK signal, accounts for increased starting during the WALK interval, starting during the WALK interval may be increased by participants knowing there is a pushbutton and being able to find the pushbutton and the same training as suggested under Use of the Pushbutton.

Of concern to the researchers in the no information condition were comments of some participants who seemed to be trying to use the locator tone changes in volume (in response to ambient sound) as a walk indication. These participants generally did not look for or push the button, but heard the audible pushbutton locator tone, and without knowledge of locator tones and their function, made an assumption that it was some kind of walk indication. This misunderstanding of the ambient sound adjustment and of the locator tone could lead to dangerous crossings. Where pushbutton-integrated devices with locator tones are installed, a concerted effort should be made to provide information about the devices to individuals in the community.

Charlotte – In Charlotte, there were nine participants who crossed independently and had audible WALK signals at every crossing. Analysis of crossing timing measures with these nine individuals revealed no significant differences attributable to level of information (*see Table 3-7*).

TABLE 3-7 Measures of crossing timing by information condition – Charlotte (N=9)

	General information	**Specific information**	**t(8)**
Starting latency in sec. **	3.19	2.81	1.214
Started during WALK ^	86.11%	94.44%	1.155
Completed during WALK or FDW ^	63.89%	77.78%	1.170
Completed before perpendicular Green ^	91.67%	97.22%	1.512

* Significant at $p < 0.05$

** Latency in seconds measured from the onset of WALK.

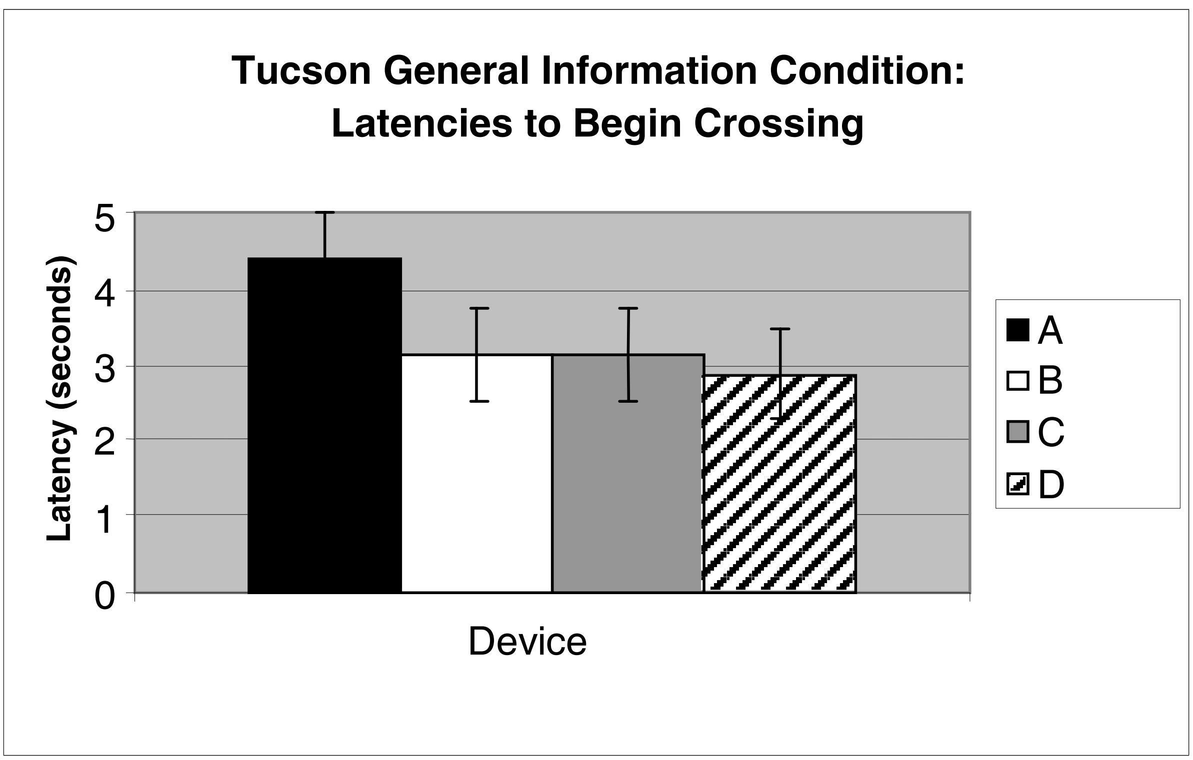
^ Each value represents the average percentage of trials within the given information condition in which each participant performed accordingly.

When analyzing measures of crossing timing, including all 20 participants, as was done with the Tucson data, keeping in mind the possible confounds, all measures showed significant differences (results not presented here). This lends support to the hypothesis that significant differences present in the Tucson analysis were the result of participants' increasing use of the pushbuttons and thus higher rates of audible WALK signals, rather than increasing understanding of the APS features.

Device

Tucson – Data were not analyzed by device for the no information condition, as there was little use of APS. However, data for the general information condition was analyzed using the presence of audible WALK information at each intersection as the inclusion criterion, which resulted in only seven participants. The overall analysis failed to achieve significance (F(3,18) = 1.390, p>.05) – (*see Figure 3-8*).

In order for comparisons between devices to be meaningful, it is important that the conditions be as similar as possible in every other respect. Therefore, participants who were included in the analyses of measures of crossing timing entered all four streets independent of assistance in determining crossing timing and had the audible WALK signal from each of the four devices during the given information condition. This resulted in an analysis of data from 7 participants in the general information condition and 17 participants in the specific information



F(3,18) = 1.390, p>.05, N = 7

Figure 3-8. Latency to begin crossing by device: general information condition – Tucson.

condition. Occasionally, one of these individuals would be missing a piece of data, and descriptive statistics were calculated from the remaining individuals (*see Table 2-8*).

The numbers above represent those who had APS at all four intersections and entered all four without assistance. But consider for a moment if we just look at the assistance with crossing timing variable (one of two inclusion criterion variables). In the general information block the number of participants who began crossings without assistance for APS A, B, C, and D were 18, 20, 18, and 13 respectively. In the specific information block, they were 20, 20, 20, and 19. When we consider the numbers of participants who had the APS and entered independently, they are 14, 18, 16, and 10 in the general information condition, and 19, 19, 18, and 18 in the specific information condition. The fewer number of participants included in the above calculations (7 and 17) is a result of the specific effects of the listwise deletion procedure necessary for meaningful comparisons.

Although most participants did perform the majority of their crossings independently and with audible WALK information, the relatively low number of participants who did so at the intersection with APS D in the general information condition (n=10) greatly limited the number of participants included in the full analysis. Participants had a great deal of difficulty locating and pushing the pushbutton on APS D in the general information condition and some were observed to be quite frustrated and requested assistance with starting crossing. In addition, some seemed confused on hearing the rapid tick walk indication and asked for confirmation from the orientation and mobility specialist (which was recorded as a request for assistance on the crossing). Interestingly considering the trouble discussed here, starting latencies were faster for APS D than for the other three APS in both information conditions (statistically confirmed in the specific information condition only; see below).

Following specific familiarization, the majority of participants were using the APS devices and thus the sample size for the analysis of latency following listwise deletion is 17. In this case, the analysis of latency to begin crossing by device is significant ($F(3,48) = 3.466$, $p<.05$). The means look rather similar between APS A, B and C; 3.35, 3.59, and 3.71 seconds, respectively. The mean amount of time to begin crossing with the APS D was 2.24 seconds. A

TABLE 3-8 Measures of crossing timing by device and information condition – Tucson

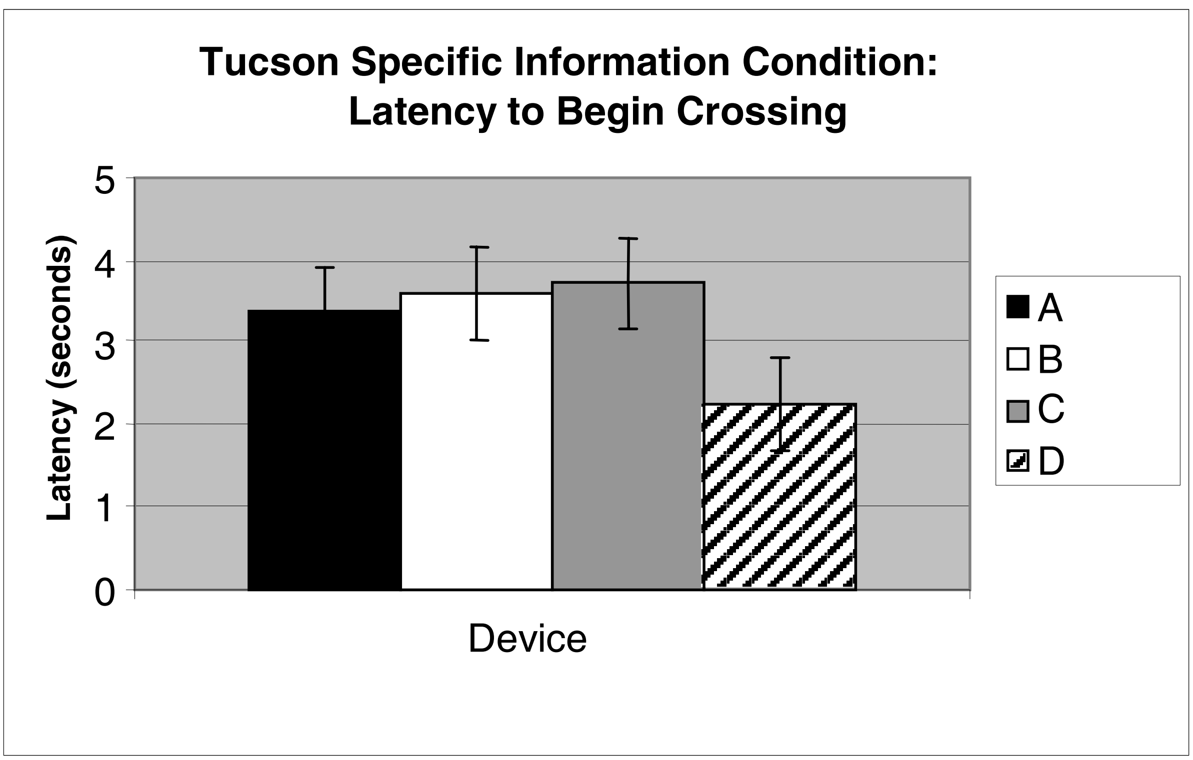
Measure	**A**		**B**		**C**		**D**	
Information Condition	**G**	**S**	**G**	**S**	**G**	**S**	**G*** **	**S*** **
Starting latency in sec.*	4.43	3.35	3.14	3.59	3.14	3.71	2.86	2.24
Started during WALK**	57%	88%	71%	65%	86%	59%	71%	94%
Completed during WALK or FDW**	14%	53%	29%	41%	29%	29%	43%	75%
Completed before perpendicular green**	100%	100%	100%	94%	100%	88%	100%	94%

General information: n = 7
Specific information: n = 17
* latency in seconds after the onset of WALK. Latency was measured from the onset of WALK.
** % of participants who started or ended their crossings under the listed parameters.
*** G = general information; S = specific information

comparison between the averaged latencies for APS A, B and C, and APS D, shows that the average amount of time to begin crossing for these three APS was significantly slower than for APS D (F(1,16) = 41.86, p<.001), and the various devices each produced slower responses than APS D when compared directly (*see Figure 3-9*), confirming the results of our previous research finding that the fastest response to the correct WALK signal was when it consisted of rapid ticks.(5,6)

Looking back at general information (*see Figure 3-8*), there was a similar trend amongst the means even though there were not significant differences. APS D resulted in the fastest latencies (but keep in mind the large amount of missing data), APS C and B had identical latencies (to a hundredth of a second). The exception was that APS A resulted in the slowest latencies following general information. APS A was the device with pedhead-mounted walk indications and participants may have been momentarily confused by the fact that the WALK signal was coming from a different place than the locator tone. On the other hand, participants in Tucson were somewhat more familiar with cuckoo/cheep pedhead-mounted APS than they were with the other types, since APS having cuckoo/cheep WALK signals are commonly installed there.

It should be expected that the faster starts in response to the APS D devices will result in other positive consequences related to the crossings. An analysis of the frequencies for a number of other measures of crossing timing following specific information supports this notion. Participants at the intersection with APS D devices were equivalently or more likely to begin



F(3,48) = 3.466, p<0.05, N=17

Figure 3-9. Latency to begin crossing by device: specific information condition – Tucson.

crossing during the WALK signal than at other intersections. These individuals finished their crossings during the WALK or flashing DON'T WALK 75% of the time versus 53% for APS A, 41% for APS B, and 29% for APS C. There was very little variability between devices in the number of participants failing to complete crossings before the onset of perpendicular traffic, with no more than 2 participants remaining in the crosswalk at the end of the WALK phase for any device. APS A also faired well in this analysis, with 88% of participants entering during the WALK signal, and 53% completing during the WALK or flashing DON'T WALK. There was no one left in the crossing when opposing traffic began to flow at intersections where APS A were installed. APS C resulted in the worst scores on all measures, however the poor performance may have been caused by irregularities in the functioning of APS C that were observed by the researchers in Tucson (see discussion of devices in Method). Following specific familiarization, participants were slowest to respond to APS B and C, the two devices with speech walk messages. Participants were fastest with the walk signal of APS D. Furthermore, this analysis matches up well with the frequency analysis such that the faster responses lead to more starting during walk interval, and higher rates of crossing completion before the end of the flashing don't walk interval.

Charlotte – Conducting analysis of starting latency, by device, following general information was based on a sample size of only 10 participants who were presented with WALK signals for each device, and who independently initiated all four crossings. The overall analysis failed to achieve significance, $F < 1.00$. (*see Figure 3-10 and Table 3-9*)

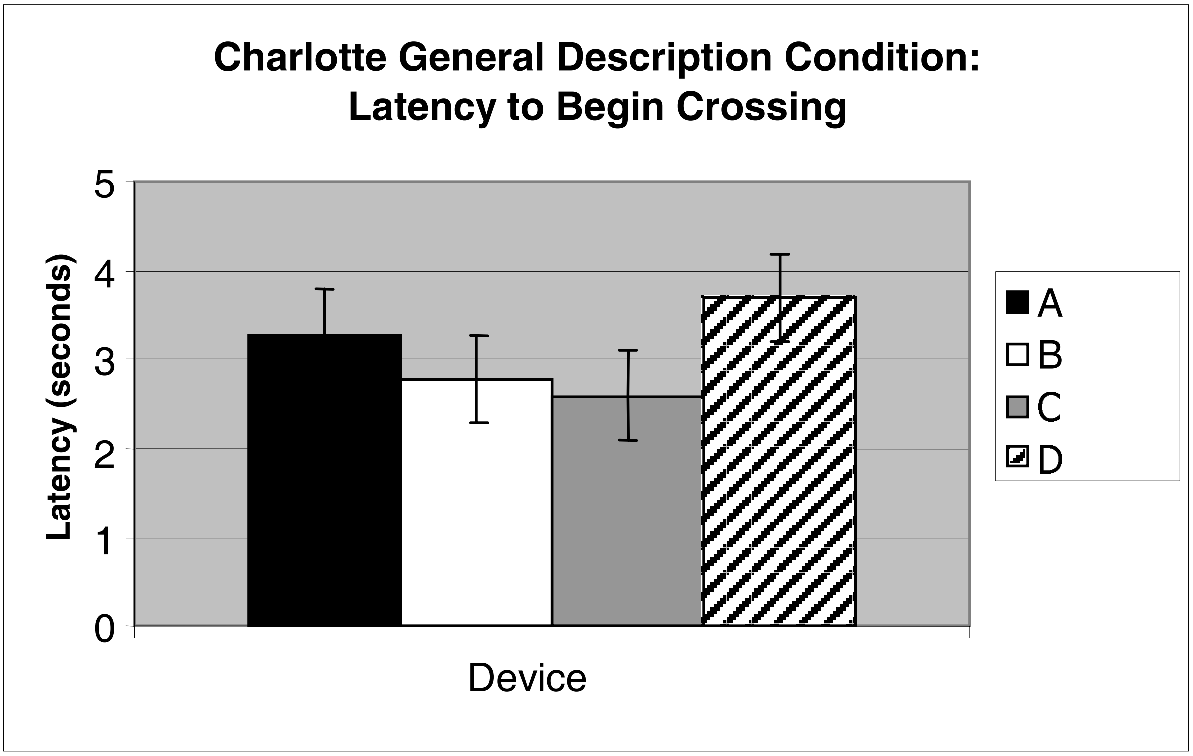
Following specific information, the majority of participants were using the APS and thus the sample size improved to 18. However, the analysis of latency to begin crossing was once again non-significant (*see Figure 3-11*).

In addition to having mean latencies in each information condition which were not significantly different from one another, the relative orders from fastest to slowest between the two information conditions was not the same. For example, following general information, the slowest mean response latency was at the intersection with the APS D (3.70 seconds), but in the

TABLE 3-9 Measures of safety by device and information condition – Charlotte

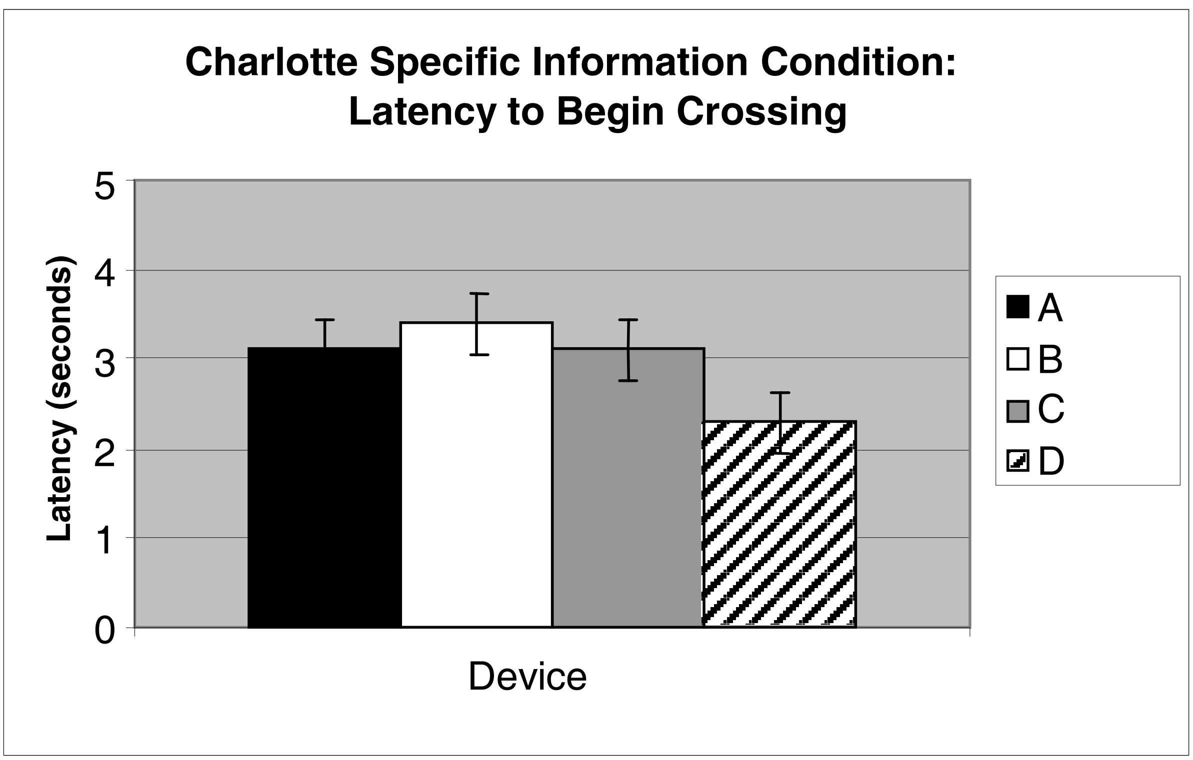
Measure	**A**		**B**		**C**		**D**	
Information Cond.	**G***	**S***	**G**	**S**	**G**	**S**	**G**	**S**
Starting latency in sec.*	3.30	3.11	2.80	3.39	2.60	3.11	3.70	2.28
Started during WALK**	80%	89%	80%	94%	90%	94%	80%	89%
Completed during WALK or FDW**	70%	72%	50%	59%	70%	65%	60%	88%
Completed before perpendicular green**	90%	100%	90%	94%	80%	100%	100%	94%

General information: n = 10
Specific information: n = 18
* latency in seconds after the onset of WALK. Latency was measured from either the onset of WALK, or the onset of parallel through traffic when there was no WALK signal.
** % of trials on which participants started or ended their crossings under each condition
*** G = general information; S = specific information



$F(3,27) < 1.00$, N=10

Figure 3-10. Latency to begin crossing by device: general description condition – Charlotte.



$F(3,51) < 1.00$, N=18

Figure 3-11. Latency to begin crossing by device: specific information condition – Charlotte.

specific information condition, this intersection had the fastest mean latency (2.28 seconds). In the general information condition, participants in Charlotte were observed to hesitate more on first hearing the rapid tick WALK signal at APS D, possibly to decide if what they were hearing was really the WALK signal. However, in the specific information condition, the pattern in Charlotte is very similar to that in Tucson; that is, the fastest responses were for APS D while responses to the other APS were similar to one another.

There was very little variability in the percentage of individuals who began crossing during the WALK signal (80-90%--general information, and 89-94%--specific information), or the percentage of participants who completed their crossings before the onset of perpendicular green (80-100%--general information, and 94-100%--specific information). There was slightly more variability in the percentage of individuals who finished during the WALK or flashing DON'T WALK (50-70%--general information, and 59-88%--specific information).

In comparing performance on latency to cross in the general information condition, the patterns between Tucson and Charlotte are not the same. In Tucson, the speech messages and rapid tick signal all produced equally fast starts (~3 seconds), while in Charlotte the rapid tick resulted in the slowest mean start, and the two speech messages provided the most rapid starts. Recall that within each city, these were not significant differences and no statistical tests were computed between the cities.

WAYFINDING

Measures associated with wayfinding were whether participants 1) were within the width of the crosswalk when they began crossing (Began Within), 2) were correctly aligned so that they were facing directly parallel to the crosswalk when they began crossing (Correctly Aligned), 3) traveled within the crosswalk lines at all points in the crossing between the beginning and ending (Crossed Within), and 4) ended the crossing within the crosswalk lines (Ended Within).

Information Condition

Tucson

Table 3-10 shows the percentages of all participants who performed in the given way on each measure, divided out by both device type and information condition, without concern for whether or how each participant used each device. There is no systematic difference attributable to information condition that is apparent in the data. Between general and specific conditions, performance for some devices improved slightly for one or two measures, but declined for other measures. Inferential analysis was conducted to reveal any significant differences attributable to device or an interaction between device and information condition (see below under Device).

Charlotte

Again, there are no systematic differences attributable to information condition that are apparent from the data. Between general and specific conditions, performance for some devices improved for one or two measures, but declined for another measure or two (*see Table 3-11*).

Because of observations in Tucson, it was noted in Charlotte if participants were standing immediately beside the pushbutton to begin their crossing, this sometimes resulted in their being outside the crosswalk lines when beginning. Therefore this table includes percent of participants who either began within the crosswalk or at the pushbutton. When that is considered, almost all participants began at one of those locations. This behavior has some implications for placement of pushbuttons closer to, or within, the extension of the crosswalk lines.

TABLE 3-10 Measures of wayfinding by device and information condition – Tucson

Measure	**APS A**		**APS B**		**APS C**		**APS D**	
Information Condition	**G**	**S**	**G**	**S**	**G**	**S**	**G**	**S**
Began within	83%	84%	78%	78%	75%	65%	72%	82%
Correctly aligned	79%	78%	70%	79%	84%	85%	63%	74%
Crossed within	69%	58%	53%	58%	53%	79%	80%	79%
Ended within	69%	74%	42%	58%	37%	68%	80%	68%

G = general information; S = specific information
N = 20

TABLE 3-11 Measures of wayfinding by device and information condition – Charlotte

Measure	**APS A**		**APS B**		**APS C**		**APS D**	
Information Condition	**G**	**S**	**G**	**S**	**G**	**S**	**G**	**S**
Began within *	84%	67%	90%	79%	77%	74%	88%	70%
Began within or at PB *	100%	94%	100 %	100%	100 %	100 %	100 %	95%
Correctly aligned	79%	77%	95%	80%	78%	79%	88%	100 %
Crossed within	84%	79%	95%	100%	85%	95%	69%	80%
Ended within	80%	74%	84%	95%	78%	84%	56%	65%

* In many cases, participants stayed near the pushbutton to either use the vibratory signal or to better be able to hear the signal. More lining up at the pushbutton occurred in the specific information condition than general information condition shown by the reduction in participants who began within the crosswalk.
G = general information; S = specific information
N = 20

Device

The measures of wayfinding are all categorical. To enable statistical analysis with regard to device, the categorical level variables were transformed into interval level variables (percentages) collapsing across familiarization level using the method outlined near the beginning of the results section.

Tucson

Table 3-12 shows the average percentage of trials on which each participant performed accordingly for a given APS in Tucson.

Collapsing across information conditions, it doesn't appear that any APS reliably provided more useful information than any other with respect to wayfinding. Furthermore, no specific type of interaction (general interaction, use of tactile arrow, or use of extended message; not presented in these tables) shows reliable improvement or impoverishment of ability to find and align to the crossing. One can also look at a given APS following general information and compare it with the same APS following specific information to see if type of information has specific effects on measures of wayfinding. There are no significant differences here, either.

One-way ANOVAs were computed in order to investigate whether the various devices produced differences in the percentage of trials participants began within the crosswalk, collapsing across information conditions, and no significant differences were found ($F(3,57) < 1.00$) , correctly aligned with the crosswalk ($F(3,57) = 1.53$, $p > 0.05$), traveled within the crosswalk ($F(3,57) = 1.86$, $p > 0.05$), or ended within the crosswalk ($F(3,57) = 1.67$, $p > 0.05$).

Charlotte

Table 3-13 shows the average percentage of trials on which each participant performed accordingly for a given APS in Charlotte.

Device did not result in differences between the percentage of trials in which participants began their crossing within the crosswalk ($F(3,57) < 1.00$). Some participants lined up at the pushbutton, with their hand on the tactile arrow as shown in Table 11, probably to use the vibration to confirm the WALK. In many cases, because of the location of the pushbuttons, this meant participants were not within the crosswalk when starting to cross.

An analysis of alignment by device was significant ($F(3,57) = 2.79$, $p < 0.05$). Participants aligned themselves correctly more often at the intersection with APS D than those with APS C ($F(1,19) = 5.63$, $p < 0.05$) and APS A ($F(1,19) = 7.107$, $p < 0.05$). Better alignment at the intersection with APS D is probably attributable to the sidewalk and ramp configuration at

TABLE 3-12 Participant performance by device – Tucson

Measure	APS A	APS B	APS C	APS D	F (3,57)
Began within	86.65%	79.10%	77.55%	81.70%	< 1.00
Correctly aligned	83.40%	69.20%	81.75%	76.00%	1.53
Crossed within	61.65%	56.70%	70.10%	71.75%	1.86
Ended within	68.35%	51.70%	61.85%	63.30%	1.67

$p < 0.05$

that intersection, rather than to a specific device feature since APS D had the lowest use of the tactile arrow (*see page 26*). At that intersection, the approach to the crosswalk was straight, and confined by landscape strips, and pushbuttons were near the street.

The analysis for travel within the crosswalk in Charlotte was also significant ($F(3,57) = 5.19$, $p < 0.01$). Comparisons revealed that the percentage of trials the participants traveled within the crosswalk at APS D intersection was significantly lower than that for APS C, ($F(1,19) = 7.027$, $p < 0.05$), and APS B, ($F(1,19) = 12.67$, $p < 0.01$). This may seem surprising, given that alignment was very good at the intersection having APS D, however, that intersection had the widest crossing. Furthermore, the percentage of the trials that participants traveled within the crosswalk for APS A was significantly lower than that for APS B ($F(1,19) = 5.63$, $p < 0.05$). The clockwise crossing at APS A had one diagonal curb ramp rather than two perpendicular ramps, which may have affected maintaining alignment as participants stepped off the curb.

The analysis of percentage of crossings in which participants ended their crossing within the crosswalk was also significant, ($F(3,57) = 3.95$, $p < 0.05$). For crossings having APS D, participants ended their crossing within the crosswalk on 57.7% of trials, but in this case it was only significantly lower than crossings at APS B (85.0%, $F(1,19) = 10.50$, $p < 0.01$). A very small deviation, especially one occurring early in a crossing, can easily take the traveler outside the crosswalk at a wide crossing, or participants who had traveled within the crosswalk for most of the crossing and felt they should have completed their crossing (who thought the road was narrower than it was) might correct by turning away from their parallel street looking for the curb and thus veer out of the crosswalk. The crossings at APS D were the widest (79 ft and 83 ft) and one of the crossings at APS B was the narrowest in Charlotte (49 ft). The other crossing at APS B was in the middle (58 ft).

The results regarding wayfinding in Charlotte are quite different from those in Tucson, where there were no significant differences attributable to device. It should be noted that almost all traffic in Charlotte turned right or left at the intersections, so there were few traffic cues for alignment or for correcting crossing alignment during crossing, while straight-through traffic was more plentiful in Tucson. Because of these differences in vehicular flow across cities, it is difficult to argue that specific information was being used to guide participants across the street. In Tucson, analyses of where participants traveled and where they ended their crossings were both non-significant, and the lowest percentages were both recorded at the intersection with the APS B. However, that intersection had the steadiest traffic on the minor roadway. These analyses seem to tell us little more than which intersections were particularly difficult with respect to

TABLE 3-13 Participant performance by device – Charlotte

Measure	APS A	APS B	APS C	APS D	F(3,57)
Began within	77.50%	85.00%	75.00%	80.00%	< 1.00
Correctly aligned	77.50%	87.50%	75.00%	95.00%	2.79*
Crossed within	77.50%	97.50%	90.00%	67.50%	5.19**
Ended within	75.00%	85.00%	75.00%	57.50%	3.95*

* $p < 0.05$
** $p < 0.01$

crossing within the crosswalk, and do not directly address the usefulness of the signals for guidance across the street.

It was the observation of the orientation and mobility specialists involved in data collection that most participants did not use any type of consistent strategy to maintain their alignment when having to interact with a pushbutton, then realign to cross. Most deviated on their approach to the street to check any pushbutton and locator tone they heard, and some became completely disoriented and lined up to cross the wrong street. The most common techniques taught for aligning to cross streets involve maintaining initial approach alignment and utilizing traffic traveling through the intersection to align. Where pushbuttons are used, the individual often must turn off the approach path to push the button, and the crossing must be made on the next through traffic phase without waiting through a cycle to align, which prevents the use of those techniques.

SUBJECTIVE RESULTS

Likert Ratings

In both cities and following each street crossing in all information conditions, participants were asked to rate their level of agreement with four statements using a 5-point Likert scale (1=strongly disagree; 5=strongly agree). Also in both cities, responses to an additional 11 statements were recorded following completion of all crossings in the specific information condition only.

Questions Asked after Every Trial in Every Condition

The four statements rated after all crossings in both cities were the following:

1. It was easy to find the pushbutton
2. I was sure I pushed the button for the street I wanted to cross.
3. I was certain the signal was for the crosswalk I wanted.
4. I used the signal to help me find the opposite corner.

Questions 1 and 2 were not asked if participants had not used the pushbutton. Question 3 was not asked if there was no WALK signal. Question 4 was asked after all crossings since the participant could possibly have used the pushbutton locator tone to find the opposite corner, even when there was no audible walk signal.

In the no information condition in Tucson (not conducted in Charlotte), so few participants interacted with the pushbutton that results are not informative. In the general and specific information conditions, results by device and by city are quite similar, while across information conditions they vary (*see Table 3-14 and Figure 3-11*). For all but one statement, ratings were as favorable or more favorable following specific information than following general information. In both information conditions in Tucson, 78% of participants replied agree or strongly agree in response to the statement, “It was easy to find the pushbutton.”

Although there was little improvement in objective measures between the general and specific information conditions, participants rated statements regarding their ability to use the APS more positively following specific information. Thus, even though participants were not familiar with a specific intersection, having specific information and experience with the APS at that intersection, and knowing which APS they would encounter, increased participants' perception of ease and confidence in interacting with the APS.

Following specific information, more than three fourths of participants generally felt that finding pushbuttons was easy, and most of the participants (approx. 90%) were confident that they pushed the correct button and started crossing with the correct WALK signal. Not nearly as many agreed that they used the signal to help them find the opposite corner. The lack of reported use of the signal to find the opposite corner is likely attributable to a number of factors. Participants who used dog guides (4 in each city) reported that they just followed their dog's guidance in the street. Others stated that they were using vehicles for their alignment cues or that they couldn't hear the locator tone of the APS until they were within a step or two of the opposite curb, so they didn't really use it.

Two devices, APS C and A, were specifically designed to provide beaconing to the opposite corner. Beaconing by the APS C consisted of a louder WALK, followed by a louder

TABLE 3-14 Range of mean response ratings for the various APS by question, collapsed across devices

Questions	Tucson Range of Mean Response Ratings	Charlotte Range of Mean Response Ratings
5. The locator tone helped me find pushbutton.	**3.58 – 3.79**	**3.05 – 4.37****
6.[a] The vibration during walk was helpful.		
7. The tactile arrow helped me know the pushbutton was for the correct street	**3.83 – 4.17**	**4.42 – 4.47**
8. The tactile arrow helped me align for crossing.	**2.00 – 2.57**	**3.38 – 4.00**
9. The tone or message helpful in letting me know the button had been activated.	**3.58 – 4.58***	**4.28 – 4.61**
10. The speech walk message easy to understand.	**3.95 – 4.25**	**4.00 – 4.68***
11. The pushbutton message easy to understand.	**4.42 – 4.67**	**4.38 – 4.75**
12.[b] The crossing map useful and easy to understand.	**4.00**	**4.17**
13.[c] The louder signal feature was helpful.	**3.86**	**4.00**

[a] Insufficient data for statistical analysis
[b] Only APS D had this feature, and only 3 (Tucson) and 6 (Charlotte) participants used it.
[c] Only APS C had this feature.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

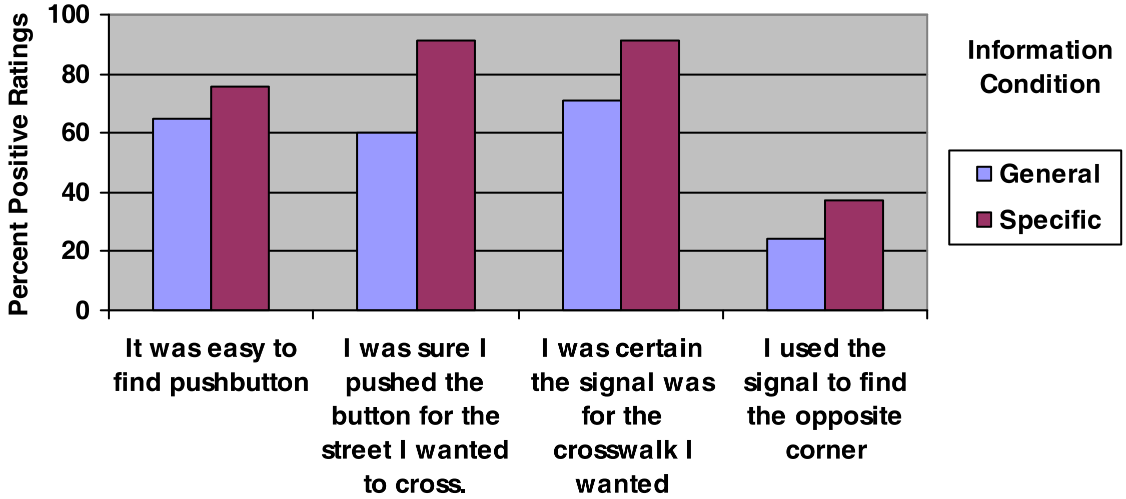


Figure 3-11. Percent of positive ratings (agree or strongly agree with statements) by information condition and statement, collapsing across devices and cities.

locator tone for the duration of the pedestrian phase, a strategy that was expected to be beneficial based on the laboratory findings in related research (*36*). The beaconing feature on the APS C was available only after an extended button press. This feature was not working correctly on APS C in Tucson, due to some wiring problems that were not discovered until the end of data collection, however, it was functioning in Charlotte. APS A provided beaconing from overhead speakers aimed at the center of the crosswalk during the WALK signal only. Other research had not found this system to be very useful for the alignment task (*22, 5*). For most trials in which participants reported that they used APS signals to help them find the opposite corner, the signal available would have been the relatively quiet locator tone.

The most interesting finding here is that, for each city and each information condition, the numbers of participants who reported using the APS to help them find the opposite corner are very similar for all devices. That is, even though the locator tone from only one device (APS C) became louder when the user used the extended button press (80% of participants used this feature in the specific information condition), there is no clear pattern that participants reported using the beaconing of APS C more than other devices. Researchers observed some participants altering their path to travel straight toward the pushbutton (and louder locator tone) of APS C in Charlotte, but participants did not seem to realize that they had done so.

In the general information condition, with regard to these first four measures, participants in Charlotte did not rate their experience using APS as highly as participants in Tucson for three of the four devices. This could have been attributable to having less experience with the experimental task than participants in Tucson, who had already had one block (no information condition) of testing (*see Figure 3-12*).

The poorer ratings for the APS B in Charlotte, following general information, were probably because the volume of both the locator tone and the speech walk message were lower than those for any other device, with baffles preventing sound traveling back down the sidewalk. These volume restrictions were in response to a neighbor's objection. Nonetheless, following specific information and despite the low volume, its ratings increased to essentially equal the ratings in Tucson. With the exception of APS B, ratings following specific information were higher in Charlotte than in Tucson.

The poor ratings for APS D in the general information condition in Charlotte may have been because the crossings at the intersection in Charlotte where APS D were installed were wider than those in Tucson, and there was initial confusion for some participants about whether the WALK indication was really the WALK indication. Following specific information, ratings for the APS D, like those for the APS B, increased markedly, to be even higher than comparable ratings in Tucson.

Questions Asked During the Specific Information Condition Only

After each crossing in the specific information condition only, participants were asked to state the extent to which they agreed with an additional nine statements (statements 5 – 13) using a 5-point Likert scale (1=strongly disagree; 5=strongly agree).

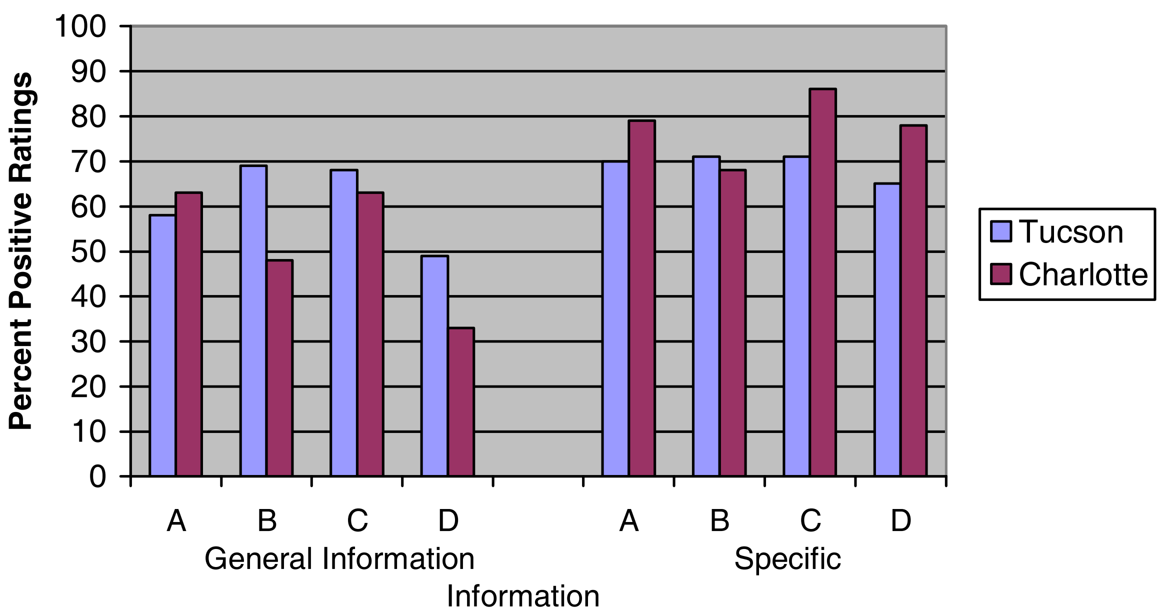


Figure 3-12. Percentage of positive ratings (agree or strongly agree with statements) by information condition and device.

In order to be included in repeated-measures ANOVA testing for significant differences between devices within a given city, each participant had to have a valid response on the question of interest for each device. Questions were not asked if they were non-applicable (i.e., a participant who did not use the tactile arrow would not be asked if the tactile arrow was helpful in aligning to cross). Thus, for analysis of subjective evaluations of device differences in the usefulness of the tactile arrows for aligning to cross, only those participants who used the tactile arrow on each of the four devices were included. Similar inclusion criteria were used for each of the questions, thus resulting in varying sample sizes for the analyses of responses to statements 5 – 13. Overall, there were few significant differences between the various APS for any question in either city (*see Table 3-14*).

Regarding helpfulness of the locator tone for finding the pushbutton (Question 5), there was a significant difference only in Charlotte ($F(3,54)=4.88$, $p<0.01$). The mean rating for APS B (3.05), was significantly worse than for APS C (4.37; $F(1,18)=7.58$, $p<0.05$) and for APS A (4.32; $F(1,18)=13.75$, $p<0.01$). This was undoubtedly because of the low volume setting of APS B in Charlotte, which was also rated as having the volume too low (see question 14 below). The range of all other mean ratings across both cities was 3.21 to 3.79, indicating a generally positive view of the information provided by a locator tone.

Participants in Charlotte may have had greater exposure to locator tones due to a fair number of APS C devices installed elsewhere around the city, and the most positive ratings were obtained for APS C in Charlotte. When asked, 11 participants reported having used locator tones before, however other ratings of the usefulness of the locator tone for finding the pushbutton were fairly equivalent between the two cities. After completing crossings in which the participants located the pushbutton independently, participants were asked how they knew where to find the pushbutton. Collapsing across all device types and information conditions, participants in Tucson reported using the locator tone 95% of the time, while the rate was at 83% in Charlotte. The lower percentage in Charlotte is largely the result of low rates of locator tone use on APS B. As discussed below, there were some considerable volume concerns for the locator tone on APS B which may have been the primary cause of diminished reliance on the feature in Charlotte.

Regarding helpfulness of the vibratory walk signal (Question 6), across both cities, only 2 participants used the feature at each of the four intersections, and thus no statistical analysis could be computed. Overall, the feature was used 11 times in Tucson and resulted in a mean response rating of 4.36, and it was used 27 times in Charlotte with a mean response rating of 4.37. Use of the vibratory feature may have been by participants who wanted to be sure they knew which APS was providing the WALK signal or some participants may have been just trying out the vibratory feature.

The mean rating for whether the tactile arrow was useful for knowing the pushbutton was for the street to be crossed (Question 7), collapsing across devices in both cities, was 4.34. There were no significant differences between the devices for either city. The high mean rating, however, indicates that participants regarded the tactile arrow as being very useful in determining which pushbutton was for which street.

The mean rating for whether the tactile arrow was useful for crossing alignment (Question 8), also showed no significant differences between devices within each city, but the mean ratings were all on the positive side of the scale in Charlotte and on the negative side of the scale in Tucson.

With regard to the helpfulness of the activation tone or message (Question 9), mean ratings for each city were strongly positive. There were no significant differences between devices in Charlotte, but in Tucson differences were significant ($F(3,54)=2.90$, $p<0.05$). APS C was rated significantly worse (3.58) than both APS B (4.58, $F(1,18)=6.33$, $p<0.05$) and APS D (4.26, $F(1,18)=6.64$, $p<0.05$) devices. However, APS C, which had the lowest mean in Tucson, had the highest mean in Charlotte (4.61), perhaps because some participants in Charlotte had prior experience with APS C. The most important conclusion that can be taken from ratings on this question is, therefore, that a good activation tone or message was very important to participants.

The speech walk message was available only on APS B and APS C (Question 10). The mean ratings, by city, indicate that participants found the speech messages quite understandable in both cities. In Tucson, there was no significant difference between devices, but in Charlotte, APS C (4.68) was rated significantly higher than the APS B (4.00; $t(18)=2.23$, $p<0.05$).

The pushbutton information message was available on APS B, C and D (Question 11). There was no significant difference between devices in either city, but mean ratings for each device in each city were all at or above 4.00, demonstrating participants' agreement that "The pushbutton information message was easy to understand,"

The tactile map was used by only 9 participants across both cities. The mean rating for the statement "The crossing map was useful and easy to understand," (Question 12) was 4.00 in Tucson and 4.17 in Charlotte, with all participants rating it 3.00 or above. There was insufficient data for further analysis. Researchers observed that many participants seemed to like the tactile map feature during the indoor demonstration, but most did not use it during experimental trials.

Regarding the helpfulness of the louder (beaconing) signal feature (Question 13), this feature was available only on APS C and only in response to an extended button press. Collapsing across both cities, 31 participants used the feature, giving it a mean response of 3.94 across cities, with only 4 participants rating it on the negative side of the scale.

Additionally, participants were asked to rate the volume of both the locator tone and the walk signal (items 14 & 15) on a 5-point scale (1=too quiet; 5=too loud). The means for the locator tone and WALK signal volumes in both cities were less than, but close to 3.00, halfway between too quiet and too loud (*see Table 3-15*). The two most extreme mean ratings regarding the volume of the locator tone were APS A (2.20--Tucson) and APS B (1.80--Charlotte). APS A did not seem to respond well to ambient sound, which might have contributed to the lower rating in Tucson, where traffic was quite noisy much of the time. In addition, one APS A device was installed several feet behind the stop line, so it was somewhat farther away from the approach sidewalk. The volume of the locator tone of APS B was very quiet in Charlotte with baffles installed on the approach side of the device due to neighbor complaints, so most of its sound was directed at the curb area and into the street, which was not very helpful in hearing the locator tone when approaching on the sidewalk. The most extreme rating regarding the volume of the WALK signal was also on APS B (Charlotte), probably for the same reason; the speech message was very difficult to hear. On the whole, participants were comfortable with APS volumes, although they would have liked them slightly louder.

TABLE 3-15 Mean rating of satisfaction with the volume levels of devices by locator tone and WALK signal within each city – N = 20 (1=too quiet; 3=just right; 5=too loud)

	APS A	APS B	APS C	APS D	F(3,57)
14. Level of locator tone					
Tucson	2.20	3.05	2.75	3.00	4.23**
Charlotte	2.75	1.80	2.75	2.25	13.08***
15. Level of WALK signal					
Tucson	2.80	2.50	2.70	3.05	2.89*
Charlotte	2.70	2.20	2.95	2.90	5.89***

* p<0.05
** p<0.01
*** p<0.001

Despite the relative similarity in ratings, there were nonetheless significant differences by device for the locator tone and the WALK signal volume in both cities. In Tucson, the analysis of locator tone volume was significant (F(3,57)=4.23, p<0.01), with participants indicating that the volume was too quiet on APS A when compared to the nearly perfect ratings obtained on APS B (3.05; F(1,19)=8.99, p<0.01) and APS D (3.00; F(1,19)=8.94, p<0.01. The analysis of ratings for the WALK signal volume were also significant (F(3,57)=2.89, p<0.05). The mean rating for the APS D (3.05) indicated that it was considered about right, while APS B (2.50) was considered somewhat quiet in comparison (F(1,19)=8.88, p<0.01).

In Charlotte, mean ratings for both the locator tone and WALK signal indicate that participants considered them somewhat too quiet. The analysis of responses to the level of the locator tone was significant (F(3,57)=13.08, p<0.001). The mean rating for APS B (1.80) was significantly worse than for all others: APS D (2.25; F(1,19)=5.15, p<0.05); APS C (2.75; F(1,19)=31.32, p<0.001); APS A (2.75; F(1,19)=26.48, p<0.001). This was to be expected considering APS B was set to a lower volume. Furthermore, the rating on APS D was significantly worse than that on the APS C (F(1,19)=7.31, p<0.05), and that on APS A (F(1,19)=10.56, p<0.01). The analysis of responses to the level of the WALK signal was also significant (F(3,57)=5.89, p<0.01). The mean rating for APS B is significantly worse than all others: APS A, F(1,19)=4.52, p<0.05; APS D F(1,19)=13.11, p<0.01; APS C F(1,19)=12.04, p<0.01. Once more, this was to be expected and no other significant differences emerged.

Although there are significant differences in the ratings for locator tone and for WALK signal volumes in each city, the fact that the differences in rank order change order across cities and across locator tones vs. WALK signals, makes it difficult to draw any firm conclusion about volume. This variation probably is indicative of the difficulty of regulating the signals to have equivalent perceived loudness between each other, within each city, and of the fluctuation of volume of both locator tones and WALK signals according to ambient sound. Although the accommodation to ambient sound is intended to make locator tones and WALK signals detectable and understandable in an environment with changing sound, response time and decay both vary somewhat across devices. In addition, all devices were subject to a maximum permitted volume of 89dB. Perceived loudness is affected by several other factors in addition to volume setting of devices and their response to ambient sound. These include the comparative spectrum of the signal to the ambient sound at any time, wind, humidity, and reflective surfaces.

Subjective Responses

After completing each crossing in the final block of trials, and after responding to all of the above discussed statements, participants were asked what they liked most and liked least about the devices at the intersection they had just crossed. Participants were not limited in the number of features that they could list in either of these two categories.

In an attempt to quantify these responses, positive and negative comments for each device were categorized. By the time these questions were asked, most participants had had experience with pushbutton locator tones, the pushbuttons, the activation tones/messages, the tactile arrow, and the WALK signals. The vibrating arrow was present on all devices, but used by few participants, so it had few comments. Features such as the crossing map, the extended button press, and the louder (beaconing) signal feature were not present on every device and were not used by all participants even when present, so these features drew few comments.

Categories of positive comments were the following.

- Location and Type of Button
- Location and Type of Arrow
- Walk Signal Type (Speech vs. Other)
- Walk Signal Information Distinguishing Streets
- Locator Tone
- Pushbutton Activation Tone
- Vibrating Arrow
- Pushbutton Information Message (after extended push)
- Volume Increase Feature (beaconing)
- Tactile Map
- Responsiveness to Ambient Noise

Categories of negative comments included the following. Note that there is some overlap between positive and negative comments. Some feature some participants liked, other participants disliked.

- Location and Type of Button
- Location and Type of Arrow
- Walk signal type (speech vs. other)
- Walk Signal is Confusing
- Lack of Info. Distinguishing Streets
- Difficulty Understanding the Walk Signal
- Pushbutton Activation Tone or Volume
- Locator Tone

- General Volume Complaints (Locator or Walk Signal)
- Lack of Features (Info Message or Volume Increase)
- Crossing Map Difficult to Read

With one exception, in one city, all devices had more positive comments than negative comments. In Charlotte, the APS D had more negative responses. The number of total positive comments, by device, in Tucson was between 31 and 48, while in Charlotte, it was between 22 and 29. The number of total negative responses, by device, in Tucson was between 18 and 37, while in Charlotte, it was between 14 and 20. APS B and C had more positive comments in both cities than APS A and D.

Across both cities, APS A and B had the location and type of pushbutton that garnered the most positive comments. Both of these devices have large, rounded pushbuttons, more closely resembling typical pushbuttons than those of APS C and D. Also across both cities, the pushbutton of APS D had the most negative comments. It was a flat panel electronic pushbutton on the face of the device. During experimental trials, researchers observed considerable exploration of APS D before the button was actually pushed. In fact, in the general information condition, researchers observed a number of incidents when the button was pushed by accident while participants were exploring the device and trying to figure out where the pushbutton was located. The lack of anything that felt like a pushbutton was clearly confusing to many participants and they pushed on the light, map symbols, or the arrow while exploring the device, and often were not aware of what they pushed to get the confirmation tone.

In Tucson, APS D also received the most negative comments regarding the type of arrow. The arrow was only 1.5 inches long, with a stroke width of 3/4 inch, while the next smallest arrow was that of the APS C device, at 2 inches long, with a stroke width of 1 inch. Also, the arrow of APS D was the only one located on the top (horizontal) surface of the device. In the objective data, in the general information condition, the pushbutton and arrow of APS D appeared to be more problematic than the pushbuttons and arrows of the other devices. Following specific familiarization, this difference had largely disappeared, however. In Tucson, the location and type of arrow of APS C received more favorable comments than those of any other device. That arrow was the only one that was located on the pushbutton for the Tucson experiment; in Charlotte, APS B also had the arrow on the pushbutton.

There were many comments regarding the type of WALK signal (speech—APS B and C vs. bird calls—APS A vs. rapid tick—APS D). In Tucson, there were between 9 and 13 positive responses to the WALK signals of all devices, and no negative responses. The higher numbers of responses were for APS B (13) and APS C (11), which both had speech messages, although the difference in numbers may not be meaningful. However there were 7 (negative) comments categorized as "Walk signal is confusing," for both APS A and APS D, the two devices having tone signals. There was a similar pattern in Charlotte, for both positive and negative responses, although the number of responses was less. Therefore, the general trend is that participants preferred the speech messages to either type of tone signal. It should be recalled, however, that in objective measures of latency in starting to cross, there was some advantage to the rapid tick signals. This pattern, in which subjective preference favors speech signals, but objective performance favors tone signals, was also found in research on pushbutton location and WALK signal conducted as part of this project (*see Chapter 4*) (*37*).

There was a notable preference for devices providing speech information to distinguish between streets having the WALK signal, that is, APS B and C, and a smaller number of negative comments regarding the lack of this information from APS A and D. There were comments that the speech messages of APS B were difficult to understand, but no such comments for APS C.

Something as simple as having a clear and audible tone to indicate that the pushbutton had been activated appears to be particularly appreciated by pedestrians who are blind, as this feature was mentioned positively by many participants. Both APS A and D received positive comments in both cities, and APS B also received positive comments in Charlotte. Those who commented positively regarding APS B specifically commented that they liked the "Wait" message (the pushbutton actuation indicator) that they heard immediately when they pushed the button during the flashing or steady don't walk intervals. There were a few negative comments on the sound of the activation indicator, mentioning APS C and A. Over all, the actuation tone of APS A received the highest number of positive comments across both cities --12, and APS D next --7.

Regarding locator tones, all devices across both cities received an approximately equal number of positive and negative comments.

There were scattered positive comments about the pushbutton information message and beaconing that could be actuated by an extended button press, the vibrating button or arrow, the tactile map, and the responsiveness to ambient sound. Negative comments regarding these features were all with regard to APS A, which lacked the pushbutton information message and the tactile map. In Tucson and Charlotte, APS A also did not seem to respond to ambient sound, although it has that capability. There were five positive comments about the tactile map, but three comments that it was hard to read.

In addition to reporting which features they liked most and liked least for each device immediately following use of the device in the specific information condition, participants were also asked a series of questions after completing all crossings. These questions were:

1. Which locator tone did you like best?
2. Which locator tone was easiest to home in on?
3. Which pushbutton was easiest to find? (after finding the device)
4. Which walk signal gave you the best info for which street had the walk signal?
5. Which walk signal was easiest to hear?

Participants were not limited to one device in answering the questions and could also respond with a "none" response (*see Table 3-16*).

It appears that preference for locator tones was fairly well distributed, with a slight preference for the locator tone on APS C followed by APS D. Interestingly, APS A and C have use the same locator tone, which some participants noted. Ease of finding the pushbutton was not related to reports of usefulness of the locator tone, as participants reported APS A to be the easiest to find, followed by APS B. This seems related to the rounded shape of the pushbuttons on those devices, about which many participants commented favorably. The clearest picture emerges in reports of which WALK signal gave the best information. Participants believed that those devices with speech messages (APS B and APS C) provided the least ambiguous information regarding the WALK signal. Finally, participants showed no clear preference for which walk signal was easiest to hear. APS A (bird calls) received the most votes across both cities, while APS C (speech) received nearly as many.

Attempting to amass all of this subjective information, the most desirable APS would have the following features:

- A locator tone (any)
- A rounded pushbutton
- A clear pushbutton activation tone
- Responsiveness to ambient sound
- A tactile arrow that is incorporated into the pushbutton itself
- A speech walk signal that indicates the name of the street to be crossed

TABLE 3-16 Frequencies of responses to questions on preference questionnaire

	None	**APS A**	**APS B**	**APS C**	**APS D**
Which locator tone did you like the best?					
Tucson	2	7	6	8	10
Charlotte	1	4	2	10	5
Which locator tone was easiest to home in on?					
Tucson	4	3	3	8	8
Charlotte	1	5	3	10	5
Which pushbutton was easiest to find?					
Tucson	2	9	10	6	3
Charlotte	0	12	4	4	5
Which walk signal gave you the best info for which street had the walk signal?					
Tucson	2	4	14	15	1
Charlotte	0	1	10	14	5
Which walk signal was easiest to hear?					
Tucson	1	10	6	5	8
Charlotte	1	7	5	10	3

- Easily understood speech
- Beaconing in response to an extended button press
- A pushbutton information message

SUMMARY AND CONCLUSIONS

This research evaluated what features of pushbutton-integrated APS were useful to pedestrians who are blind and how much information or training was needed in order to enable them to make use of those features. The results do not present a focused picture of one device and set of features that will provide unambiguous information to pedestrians who are blind or who have low vision at a range of intersections. So many factors are involved in the street crossing tasks that it is difficult to determine what features affected performance. Among the devices, some features seemed more useful or to be used more frequently, but even this information seemed to vary between the two cities. The results seem to support that when pedestrians who are blind have used a device, and know what kind of APS they will use at an intersection, device characteristics or features, such as the physical design of the pushbutton or tactile arrow, do not make much difference.

A fact that became clear in this research was that pedestrians who are blind do not have adequate information about using pushbuttons and APS devices in crossing streets and many did not have good information about the complexity of modern intersection signalization. When participants had some general information about new types of APS, they performed better at locations with APS installed than they did when no information was given to them about the APS. Although there was little improvement in objective measures between the general and specific information conditions, participants' ratings regarding their ability to use the APS were more positive following after receiving specific information. Thus, even though participants were not familiar with a specific intersection, having specific information and experience with the APS at that intersection, and knowing which APS they would encounter, increased participants' perceptions of ease and confidence in interacting with the APS.

Device Adjustments and Volume

Despite all efforts by cities and researchers involved in this project, it was difficult to install devices within the existing infrastructure in locations that were truly comparable. Both cities made every effort to install the devices for this project in optimal locations, but slight differences in pole location, such as distance from the curb or sidewalk, or position in relation to the curb ramp, made some pushbuttons more difficult to find than others. Even when everyone was committed to good installations, it was impossible to locate all devices in accordance with current *MUTCD* guidance and the *Draft Guidelines (1, 2)*. On one corner this was due to the curb radius and a fire hydrant. On another, the sidewalk and curb ramp would have had to be completely rebuilt to locate a second pushbutton pole. Many poles, and consequently pushbuttons, in Tucson were more than 5 feet outside the extension of the crosswalk lines, which may have contributed to some participants crossing outside the crosswalk, or to crossing alignment problems. These locations are examples of the real-world conditions that will be faced by engineers at most intersections. Unless the intersection is new or being completely rebuilt, it will often be difficult to achieve the optimum placement of APS.

The adjustment of the volume of the APS is critical for neighborhood acceptance and for usability by pedestrians who are blind. Even with ambient sound response, this is a difficult balance to strike. While most blind pedestrians felt the volumes were slightly too quiet, researchers thought some of them were too loud for neighborhood acceptance, particularly if they had been in residential locations. At one intersection in this research, volume of devices was turned down and severely baffled in response to a neighbor's complaints. Part of the problem may have been that the device had been installed and left over the weekend with the locator tone volume much too loud, due to a misunderstanding of the volume adjustment. Community objections to APS and locator tones are likely to affect the installation of APS, so proper volume adjustment is critical. In this research, the sound levels and ambient sound response of APS C and D were adjustable with handheld PDA-type devices and they seemed to be much easier to install and adjust.

Development in placement of APS and refinements in techniques used by pedestrians who are blind may also change their expectations about the volume of locator tones. If pedestrians who are blind continue to the edge of the street, then listen for the locator tones, it may be easier to adjust the sounds to be heard in the street vicinity and not on the approach sidewalk. And location of pushbuttons closer to the street and crosswalk location allows the volume of the locator tone and walk indication to be lower.

Use of Pushbutton

The results regarding the use of pedestrian pushbuttons by pedestrians who are blind indicates that typically, pedestrians who are blind do not use pedestrian pushbuttons. In Charlotte, where it is common to require pushbutton actuation for only the major street crossing at an intersection, 7 out of 20 participants said they usually do not use pushbuttons, 6 said that they usually do, and the other 7 said they do only when they know that the pushbuttons are there. In related research in Charlotte, 16 blind participants crossing at complex, unfamiliar signalized crossings, without APS, did not look for pushbuttons on any of the 64 crossings at which pushbutton actuation was necessary (*36*). Even in Tucson, where use of a pushbutton is required to actuate the WALK signal for both the major and minor street crossings at most signalized intersections, 9 of 20 participants said they usually do not use pushbuttons, 6 said that they usually do, and the other 5 said they do only when they know that the pushbuttons are there or the intersection is particularly difficult. In the Tucson experimental trials under the no information condition, only five participants looked for the pushbutton on every crossing, and at each of three intersections, one additional person (different people) looked for the pushbutton.

Locating Pole/Device

In the general and specific information conditions in both cities, most participants (98%) searched for the pedestrian pushbuttons, probably because they had been told that the pushbutton had to be used to actuate the APS, and the locator tone had been explained. In the no information condition, some were observed to wonder out loud about the locator tones that they heard, but few had actually investigated the pushbuttons or tried to determine where the tones were coming from.

Two types of subjective data support the usefulness of locator tones. First, participants were asked, following each crossing for which they used the pushbutton, how they located the pushbutton. This was an open-ended question, permitting multiple responses. Participants said they used the locator tone on most trials, regardless of device (Tucson 95%, Charlotte 83%). The lower percentage in Charlotte is largely the result of low rates of locator tone use on one device, where the volume was too quiet. Furthermore, when asked following each trial on which they had specific familiarization and experience with the four APS devices, to rate their agreement with the statement "The locator tone helped me find the pushbutton." mean responses for each device in each city were all in the positive direction. All APS across both cities received an approximately equal number of positive and negative comments, and no particular APS locator tone resulted in a higher percentage of participants finding the pushbutton.

The presence of a locator tone to inform pedestrians of the presence of a pushbutton and its location may also influence the use of pushbuttons, since five participants in Tucson and seven participants in Charlotte said they used pushbuttons if they knew they were there and where to find them.

However, the presence of a locator tone does not guarantee that pedestrians who are blind will find the pushbutton, even with specific information about the type of APS. In the specific information condition when participants looked for the pushbutton on 100% of trials, they failed to find the correct pushbutton on 21% of trials in Tucson and 16 % of trials in Charlotte. Possible reasons for this failure are that participants were not experienced at the task of looking for a pushbutton and maintaining orientation, so some found and used the wrong pushbutton (recorded as did not find pushbutton) or participants may have had difficulty locating the pushbutton and requested assistance (also recorded as did not find pushbutton). When data are examined for finding both correct and incorrect pushbutton for a crossing, participants found a pushbutton on over 90% of trials in both the general and specific information conditions. In the specific information condition, participants found a pushbutton on 95% of trials in Tucson and 99% of trials in Charlotte. However, some still found and used the incorrect pushbutton while others found the incorrect pushbutton and identified it as such without activating it, but then did not proceed to find the correct pushbutton. This may indicate the need for additional training and techniques for locating pushbuttons and recognizing the correct pushbutton, along with the provision of APS with locator tones.

Of concern to the researchers in the no information condition were comments of some participants who seemed to be trying to use changes in the locator tone volume (in response to ambient sound) as a walk indication. These participants generally did not look for or push the button, but heard the audible locator tone, and without knowledge of locator tones and their function, made an assumption that it was some kind of walk indication. This misunderstanding of the ambient sound adjustment and of the locator tone could lead to dangerous crossings. Where pushbutton-integrated devices with locator tones are installed, it may be necessary to make a concerted effort to provide information about the devices to individuals in the community.

Pushbutton Design and Features

Pushbutton Style

Indirect evidence for difficulty in finding the two pushbuttons that were atypical, the flat-panel pushbutton, and the flat recessed circular pushbutton, was found in the latency to find and push the correct pushbutton. The time included both the time to find the pole and the device, and the time to locate and use the button on the device. In the condition in which participants only had a general description of APS features, the two unusual pushbuttons took significantly longer to locate and push than the two buttons that were typical. When participants had specific information about and experience with the various pushbuttons, all differences in latency disappeared.

Style of pushbutton was frequently mentioned when participants were asked what they like most and least regarding each APS. The two APS having two inch diameter rounded pushbuttons "that pushed" drew a number of positive comments to the open-ended question.

On the basis of the objective latency results and the subjective preferences, it is recommended that the APS have a clearly defined pushbutton that is tactually identifiable. While protruding buttons did receive positive comments from participants, there was not enough evidence to warrant such a recommendation. It is also important to remember that any pushbutton needs to be designed to deter vandalism. The greatest design in the world is useless if the button has become inoperable as a result of vandals.

Tactile Arrow

In Tucson, increased information did not significantly affect use of tactile arrows. Almost 69% of participants used the arrow in the general information condition and 73% used it in the specific information condition. However, in Charlotte, increased information also led to significantly greater use of the tactile arrows, from 87% of trials following general information to 100% of trials following specific familiarization.

In Tucson, the tactile arrow was more likely to be used on the APS C devices than on others. The tactile arrow was on the pushbutton of APS C. It was also on the pushbutton of APS B in Charlotte and may have contributed to more use of the arrow on APS B there. However, the increased usage of the arrow on the pushbutton was not enough evidence to support a recommendation along these lines. While the arrow may have been "identified" more often when located on the pushbutton, there was no evidence that it was used more often for wayfinding when compared to arrows located at other places on various APS.

One of the purposes of the tactile arrow is to identify which street the pushbutton controls. Use of the tactile arrow and the incorrect pushbutton presented a very different picture in Charlotte than in Tucson. In Tucson, while participants looked at the arrow on the incorrect pushbutton on 28 trials, they always correctly rejected the incorrect pushbutton. However, in Charlotte, participants found the arrow on the incorrect pushbutton on 63 trials, and correctly rejected it on only 41 trials (65%). While there was a decrease in overall use of the wrong pushbutton from the general to the specific information condition, participants still failed to reject the incorrect pushbutton on 20% of trials (6/30) following specific information. To observers, participants in Charlotte seemed less skilled, particularly in orientation. The confusion of pushbuttons seemed to be related to the participants' lack of strategies to maintain their orientation; some would completely turn to face the street parallel to their travel path, while examining the arrow on the device and then push the button and line up to cross the parallel street. See additional comments on this subject under wayfinding.

Extended Button Press

Additional optional features on pushbutton-integrated APS are activated by an extended button press. These features included street name information provided in the pushbutton information message and a louder signaling (beaconing) feature. Where speech messages are used for the walk indication, it may be necessary for pedestrians to know the street names in order to recognize which street is being signaled. This is particularly true at corners where two pushbuttons are mounted on the same pole, although that situation was not included in this research. In both cities, the increase in use of the extended button press following specific information was significant, from 38.8% to 77.8% in Tucson, from 17.7% to 71.1% in Charlotte. This may indicate that more specific information and training is necessary if use of the extended button press is expected.

Pushbutton Information Message

The pushbutton information message provided additional intersection information (street names) in response to an extended button press during the flashing or steady don't walk intervals. As mentioned above, in the general information condition, few participants used the extended button press that was required to actuate the message. However, following hands-on familiarization with each of the three APS having this feature, participants chose to use the feature on more than 70% of crossings in both cities. When asked to mention features they liked most or least on each APS, there were a number of positive comments regarding the pushbutton information message, and there were no negative comments. Mean ratings for the statement "The pushbutton information message was easy to understand" were all at or above 4.0 (4=agree).

Crossing Timing

WALK Signals

There was significant improvement in all measures of crossing timing between the no information and the general and specific information conditions in Tucson. The measures were latency (time to start crossing), starting during the walk interval, completing crossing during the flashing DONT WALK, completing crossing during the steady DONT WALK, and completing crossing before the onset of perpendicular green. This is likely attributable to increasing use of the pushbutton and thus presence of the audible WALK signal. If greater use of the pushbutton, and consequent presence of the WALK signal, accounts for increased starting during WALK, then starting during the walk interval may be increased by education and training of individuals who are blind about the use of pushbuttons and their effect on signal timing. In Tucson and Charlotte, there were no significant differences on measures of crossing timing between the general and specific information conditions.

There were three types of WALK indications used in the devices installed in this research – speech messages, bird calls (cuckoo-cheep) and the rapidly repeating tone indication (rapid tick). In Tucson, in the specific information condition, starting to cross was significantly faster at APS D (rapid tick) than at any of the other devices. The pattern was similar in Charlotte, but did not reach significance. It appears that once pedestrians understood the crossing signal, the rapid tick crossing signal provided the best cue in terms of starting to cross quickly in both cities. The bird call tones and speech messages were all quite similar in both cities. The faster response to the rapid tick signal is supported by results of research on pushbutton location and nature of WALK signal, conducted under this same project, in which responses were quicker to the rapid tick than to cuckoo/chirp tones or to speech messages (*see Chapter 4*) (*37*).

Beaconing/Louder Signal

One APS provided beaconing with a louder signal that was requested by the same extended button push that actuated the pushbutton information message when it was present. Therefore data on use of the extended button press does not clearly indicate whether the extended press was used to actuate the pushbutton information message, the louder signal, or both. When asked to rate the extent of their agreement with the sentence, "The louder signal feature was helpful," the mean rating was positive (3.94), with only four participants giving it a negative rating, possibly because they did not think the signal got loud enough.

Another APS provided a pedhead-mounted speaker that was aimed toward the middle of the street and possibly provided beaconing during the WALK interval. However, for all signals, collapsing across cities and information conditions, less than 35% agreed that they used the signal to help them find the opposite corner. The most interesting finding here is that, for each city and each information condition, the numbers of participants who reported using the APS to help them find the opposite corner are very similar for all devices. That is, even though APS C and A had beaconing features, there is no clear pattern that participants reported using those signals more than other devices to find the opposite corner. Researchers observed some participants altering their path to travel straight toward the pushbutton (and louder locator tone) of APS C in Charlotte, but participants did not seem to realize that they had done so.

The lack of reported use of the signal to guide the pedestrian to the opposite corner is likely attributable to a number of factors. Participants who used dog guides (4 in each city) reported that they just followed their dog's guidance in the street. Others stated that they were using vehicles for their alignment cues, or that they could not hear the locator tone of the APS until they were within a step or two of the opposite curb, so they did not really use it. Ongoing research in another project is investigating additional beaconing options and may provide more insight in this area (*36*).

Wayfinding

Collapsing across information conditions, it does not appear that any APS reliably provided more useful information than any other with respect to wayfinding. Furthermore, no specific type of interaction (general interaction, use of tactile arrow, or use of extended message) shows reliable improvement or impoverishment of ability to find and align to the crossing. Because of observations in Tucson, data were collected in Charlotte on whether participants were standing immediately beside the pushbutton to begin their crossing. This sometimes resulted in them being outside the crosswalk lines when beginning their crossing. Almost all (97%) were either at the pushbutton or within the crosswalk when beginning their crossing. This behavior indicates that APS pushbuttons should be placed close to, or within, the extension of the crosswalk lines.

It was the observation of the orientation and mobility specialists involved in data collection that most participants did not use any type of consistent strategy to maintain their alignment or to realign when having to interact with a pushbutton. Most deviated on their approach to the street to check any pushbutton and locator tone they heard, and some became completely disoriented and lined up to cross the wrong street. The most common techniques taught for aligning to cross streets involve maintaining initial approach alignment and utilizing traffic traveling through the intersection to align. Where pushbuttons are used, the individual often must depart from the approach path to push the button, and the crossing must be made on the next through traffic phase without waiting through a cycle to align, which prevents the use of those techniques. Additional techniques and strategies are needed by blind pedestrians where pushbuttons are used.

Recommended Features of Pushbutton-integrated APS

As noted at the beginning of this summary, the results do not present a completely focused picture of one device and set of features that will provide unambiguous information. However, they do provide insight into use of various features and the information needed by pedestrians who are blind to use the APS and their features efficiently. Based on the objective data recorded for the 40 participants who made crossings, as well as subjective information obtained from these individuals, the APS should have the following features at all installations:

- Pushbutton locator tone (any)
- Clearly defined pushbutton that is tactually identifiable
- Tactile arrow (exact location on APS unit is not defined)
- Audible WALK indication (see discussion below on speech vs. tones)
- Vibrotacticle WALK indication
- Responsive to ambient sound

Subjective preference for speech WALK signals was much greater than for tones. However, it is impossible to make speech WALK signals understandable to all users, including the large population having age-related upper frequency hearing loss in addition to visual impairment, under all ambient sound conditions. Furthermore, other research conducted in this study and described in the next chapter showed that understanding of which crosswalk has the WALK indication is significantly more accurate with rapid tick walk indicators located close to the crosswalk than with speech signals or two different tone signals. Finally, response to the correct WALK indication was faster with the rapid tick signal, leading to less delay in starting to cross the street, and increasing the likelihood that crossings would be completed during the flashing DONT WALK interval. So despite the subjective preference, rapid tick is recommended for the WALK signal. Nonetheless, where two pushbuttons must be installed on the same pole, speech message WALK indications are needed to resolve ambiguity in which crossing has the WALK interval (see Chapter 3).

Under certain circumstances, the following secondary APS features are also desirable:

- Pushbutton information message
- Louder signal (audible beaconing)
- Tactile map of crosswalk

The recommended guidelines in Chapter 7 provide more guidance on when these secondary features may be desired.

CHAPTER 4

Experimental Trials on Pushbutton Location and WALK Indicator

INTRODUCTION

It is critical that any APS system provide clear information as to which crosswalk has the walk interval. Presently, APSs in the United States are not located at intersections in any consistent pattern, nor do APSs use consistent sounds to convey the WALK indication. Pedestrian pushbutton location is also not standardized in the United States, which makes it difficult to provide unambiguous audible WALK indications when an APS is added to an existing pedestrian signal.

Many cities in the U.S install pedestrian pushbuttons for crosswalks in both directions on a corner on a single pole. There are various reasons for this practice:

- Many installations use a single pole on a corner for span wires or mast arms to support traffic signals; money is saved by placing both pushbutton units on the same pole rather than installing additional poles with associated wiring and conduit.
- Poles are sometimes installed at various locations on the corner due to limited right of way or infrastructure constraints (e.g., underground utilities).
- AASHTO design guidelines discourage poles near the curb for vehicular safety reasons and to prevent turning trucks from damaging poles.

The *Manual on Uniform Traffic Control Devices* (*MUTCD*) 4E.08 reads "Pedestrian pushbutton detectors should be capable of easy activation and conveniently located near each end of the crosswalks"(*1*).However, poles where pushbuttons are located vary greatly in distance from the crosswalk. *MUTCD* 4.E.09 provides that "At corners of signalized locations with accessible pedestrian signals where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 3 m (10 ft)", and pushbuttons for APS should be located "adjacent to a level all-weather surface to provide access from a wheelchair, and where there is an all-weather surface, wheelchair accessible route to the ramp; within 1.5 m (5 ft) of the crosswalk extended; within 3 m (10 ft) of the edge of the curb, shoulder, or pavement; and parallel to the crosswalk to be used"(*1*). The U.S. Access Board's *Draft Guidelines for Accessible Public Rights-of-Way*, applicable to new construction and alterations, would also require that accessible pedestrian signals (APSs) be separated by at least 10 ft (*2*).

This set of experiments was undertaken to build on the knowledge base of why APSs are needed and to understand the importance of appropriate installation techniques. The primary purpose of this study was to determine the effect of three factors on the ability of pedestrians with visual or cognitive impairments to determine which crosswalk at a corner had the WALK signal. The factors under investigation were as follows:

1) Whether there were significant advantages to installing two poles on a corner, each with its own pushbutton-integrated APS, over installing two pushbutton-integrated APSS on a single pole.

2) whether proximity of these poles to the curb influenced the ability of participants who had visual or cognitive impairments to push the correct pushbutton and to know when the WALK signal came on for the street in front of them.
3) Whether there were significant advantages to using the same sound, versus two different sounds, versus two speech messages to indicate the walk interval.

METHOD

Participants

Participants for this effort were selected with the goal of comprising groups that included persons with a wide age-range, balanced according to frequency of independent travel and frequency of crossing at unfamiliar intersections. Altogether, there were 90 adults who were visually or cognitively impaired and who, by self-report, independently traveled outdoors on at least one route and crossed signalized intersections. Half of the participants had some degree of visual impairment, and half of the participants were cognitively impaired.

Local recruiters having extensive knowledge of, and contacts within, agencies or organizations relevant to each group of participants were hired, and the participants were recruited by word of mouth, flyers, and distributed e-mails. Many participants were associated with one of the following agencies: the Oregon Commission for the Blind, the ARC (formerly Association for Retarded Citizens) of Multnomah and Clackamas Counties, Independent Living Resources, the Brain Injury Association of Oregon, Traumatic Brain Injury Club, Legacy Good Samaritan Hospital, and Medical Center Young Adult Support Group.

The following information was gathered during personal interviews with persons with visual impairments who had expressed an interest in participating: date of birth, highest level of education, amount of vision (including ability to see walk/don't walk signs, poles, and crosswalk lines), etiology, date of onset of disability, additional disabilities, type of travel aid used, self rating of travel ability, frequency of independent travel, and frequency of crossing at unfamiliar intersections. Interviews with participants who were cognitively impaired gathered similar information: date of birth, highest level of education, amount of vision, date of onset of disability, additional disabilities including seizures, living situation, street crossing practices, frequency of independent travel, and frequency of crossing at unfamiliar intersections.

Forty-five participants with visual impairments were divided into three subgroups, of 15 participants each, based on their ability to see pedestrian signals, crosswalk lines, and poles. The group that had the least vision (referred to as totally blind) reported that they were totally blind or had only light perception and could not see pedestrian signals, crosswalk lines, or poles. This group ranged in age from 21 to 78, with a mean age of 47.6 years. Another group (referred to as legally blind) reported they were legally blind; some of them could occasionally see pedestrian signals and either occasionally or usually could see crosswalk lines and poles. This group ranged in age from 22 to 85, with a mean age of 51.6 years. A third group (referred to as low visual acuity) had visual impairments, but they were not necessarily legally blind and could usually see pedestrian signals, crosswalk lines, and poles. This group ranged in age from 19 to 74, with a mean age of 48.6 years. Participants who normally used a long cane as a travel aid in all the subgroups used a long cane during the research. No participant used a guide dog as a travel aid.

Forty-five adults with cognitive disabilities were also divided into three subgroups of 15 participants. One group was composed of people who had had head injuries. This group ranged in age from 22 to 57, with a mean age of 45.9 years. Another group was composed of people who had had strokes and whose vision and hearing might have been affected, but who were not legally blind. This group ranged in age from 35 to78, with a mean age of 52.5 years. A third group was composed of people who were developmentally delayed. This group ranged in age from 19 to 85, with a mean age of 49.1 years. All participants were cognitively capable of personally consenting to participation, and all said they independently crossed streets at signalized intersections.

Location and APS Equipment

The intersection of NE 7th Avenue and NE Multnomah Street in Portland, Oregon was equipped with eight pushbutton-integrated APS units that were mounted on temporary poles, with pushbuttons located 42 inches from the ground. In pushbutton-integrated APS, audible signals come from the pushbutton housing, unlike pedhead-mounted APS, in which the audible signals come from a speaker mounted in or on the pedhead. The pushbutton-integrated APS units used in this study included a pushbutton locator tone, automatic volume adjustment in response to ambient noise level, a tactile arrow that vibrated during walk interval (aligned in the direction of travel on the associated crosswalk), an audible "click" sound and red LED to confirm that the button had been pressed, and an audible WALK indication that varied during the experimental conditions.

The pushbutton locator tone is intended to aid approaching pedestrians with locating the pushbutton and to inform them that they need to push a button to receive a pedestrian signal and the extended green time needed to cross the street. The tone repeated once per second and was adjusted to be audible only six to twelve feet from the pushbutton. The audible WALK indications varied during the experimental conditions and were changed by the researchers with the use of a handheld programming unit supplied by the manufacturer (Polara Engineering).

Two APSs mounted on a single pole were used on two corners, and APSs mounted on two separated poles were used on the other two corners. On corners A and D (the northwest and northeast corners), the two APSs for crossing both streets at each corner were mounted on a single pole; on corners B and C (the southwest and southeast corners), the two APSs on each corner were mounted on two poles separated by at least 10 feet (*see Figures 4-1 and 4-2*), meeting the guidelines of the *MUTCD* as previously described.

Distance of the poles from the street was also varied. On corner A, the pole was installed approximately 3 feet from each street, and on corner D, the pole was installed approximately 10 feet from each street. The same was true for the corners with two pushbutton poles: on corner C, each pole was installed approximately 3 feet from the street, and on corner B, each pole was installed approximately10 feet from the street.

The choice of tones and speech messages used in the experiment was based on current practice and on recent laboratory research (*38, 39*). The single tone used was a rapid tick, as this tone has been found to be more highly detectable than other tones in use or proposed for APS. When two tones were used, they were the rapid tick and cuckoo. The cuckoo sound was selected over the chirp sound (both are often used together at an intersection) because it is not the same as any birdcall in the U.S., it is not mimicked by any birds common to the U.S., and it is more

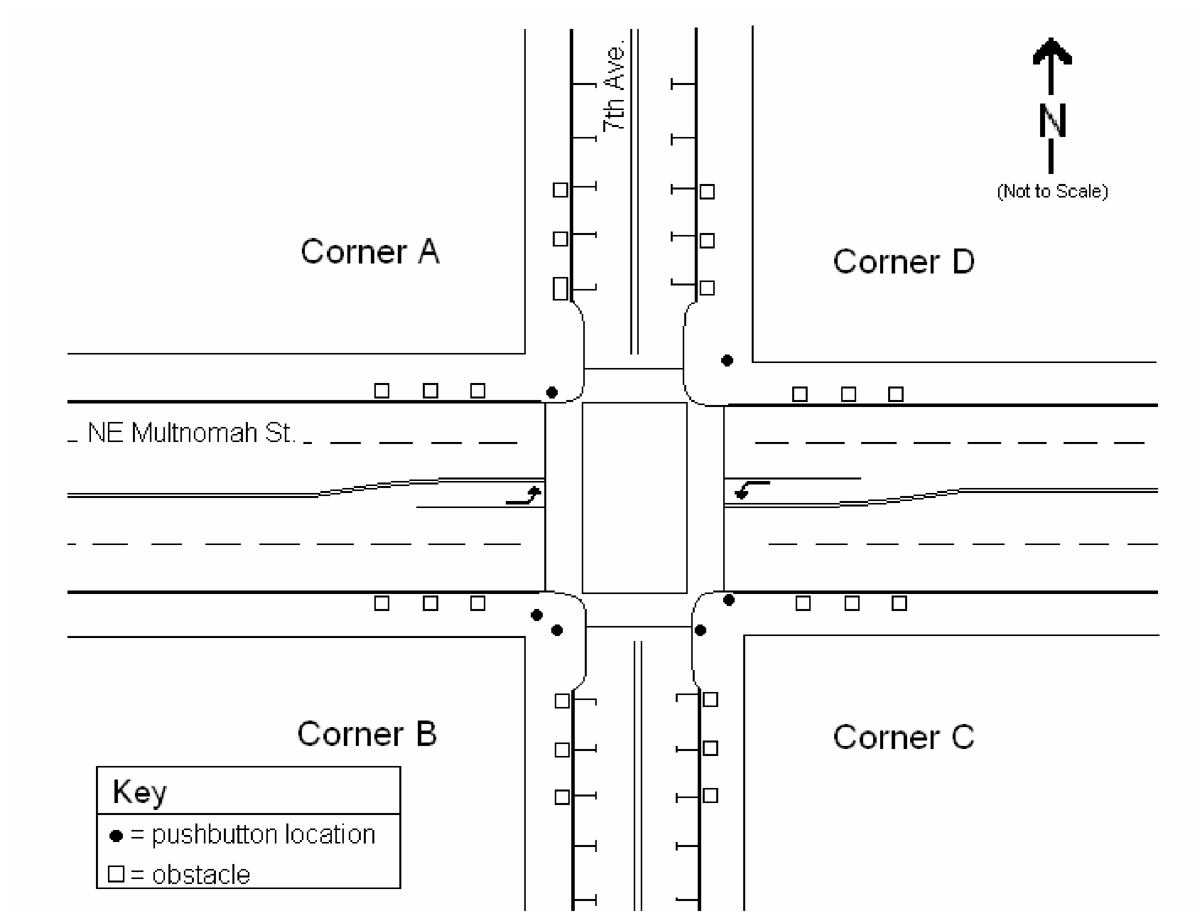


Figure 4-1. Intersection diagram for NE Multnomah Street and NE Seventh Avenue in Portland, OR.

detectable than the chirp sound. However, the cuckoo sound is not as detectable and localizable as the rapid tick.

There were two possible sound conditions on each corner. The audible WALK indication was set by the researchers for either: two different tones (cuckoo and rapid tick) or two same tones (rapid tick) on the corners having two poles. On the corners with just one pole (s*ee Table 4-1*), the audible WALK indication was either two different tones (cuckoo and rapid tick) or two speech messages ("7th, walk sign is on to cross 7th" or "Multnomah, walk sign is on to cross Multnomah)."

The total duration of all audible and visual WALK indications was seven seconds. There was a 0.5 second pause between repetitions for all sound conditions. Each speech message repeated twice during each WALK interval, and the cuckoo and rapid tick messages repeated three times during each WALK interval. This variability was due to the length of the messages. Each speech message was approximately 3 seconds, and each repetition of the cuckoo or rapid tick was approximately 2 seconds.

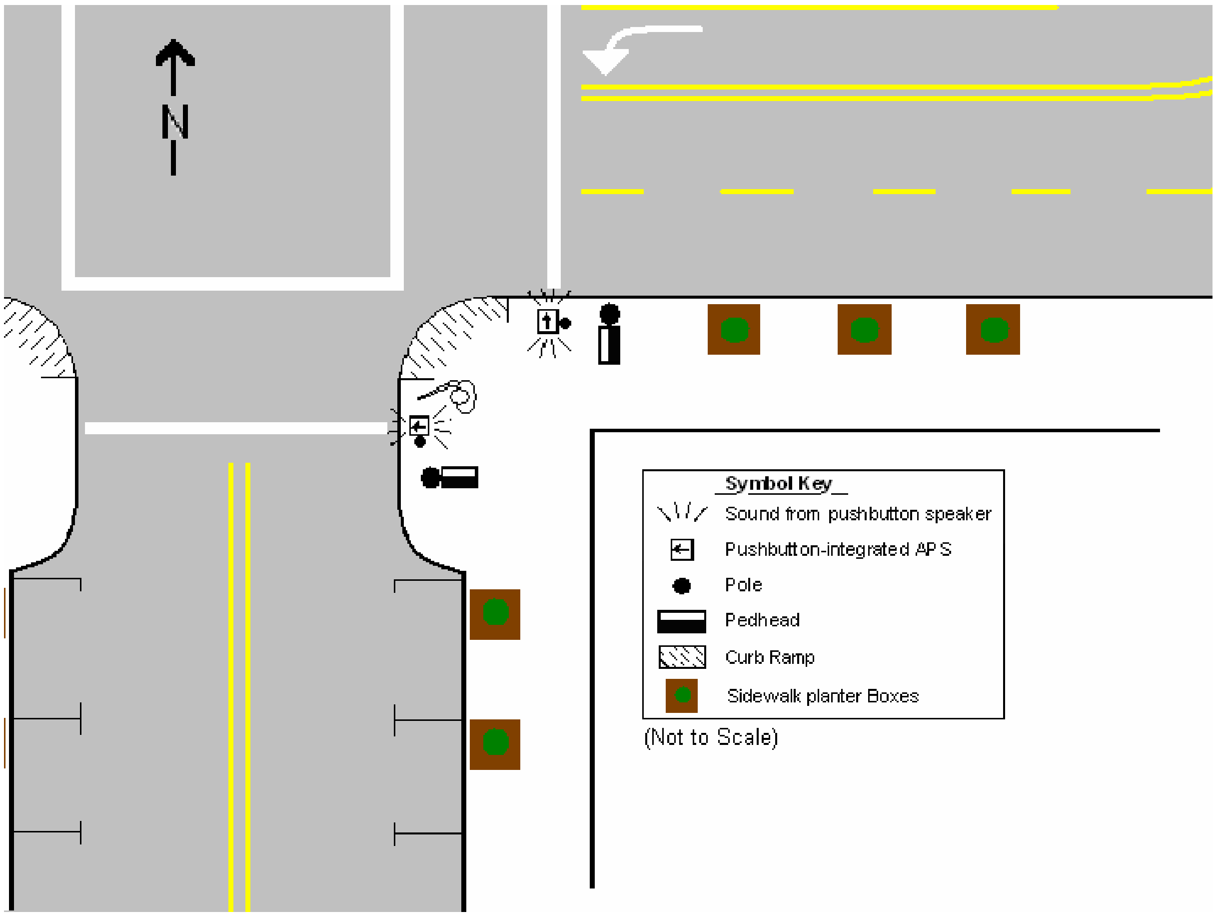


Figure 4-2. Diagram of Corner C (southeast corner of NE Multnomah Street and NE Seventh Avenue in Portland, OR).

To reiterate, two sound conditions (two tones or two speech messages) were assigned to corners having a single pole (corners A and D), and two sound conditions (two different tones or same tone) were assigned to corners having two poles (corners B and C). Testing every sound condition at every corner would have resulted in an experiment that required two sessions. Additionally, testing the same tone from each APS at corners having a single pole would have been noninformative. If both APSs have the same tone coming from the same location, there is no cue to indicate which crosswalk is being signaled. However, on corners having two pushbutton poles separated by at least 10 feet, it may be possible to hear which pushbutton is sounding. Researchers recognized that either two different tones or speech messages could have been used in APSs at corners having two poles; both would have provided information that was redundant to the cue that was provided by the location of the APS. A decision was made to use the most commonly used strategy in the U.S., which is the use of two different tones.

Procedure

All 90 participants were individually tested in approximately one-hour sessions. First the participants were familiarized with a nonfunctioning demonstration unit of the APS that included the tactile arrow indicating the direction of the associated crosswalk. Participants then listened to a tape recording of the various sounds that would come from the APS. The sounds included a locator tone and the three possible WALK indications. The participants were told that they were to identify the walk interval on the street in front of them by raising their hand. Participants were told that they could use the visual WALK signal if they could see it, the pushbutton sounds or messages, or the traffic. They were encouraged to use any information that they would normally use to determine when the WALK signal comes on. Then the participants were guided to the starting location for the first trial.

Before the participant arrived at the corner, the APS devices were configured to one set of the possible WALK indication sound conditions. The APS devices on corners having two poles were randomly set to either the same tone condition (rapid tick – condition 1) or two tones condition (cuckoo and rapid tick – condition 2). While the starting settings were determined randomly, the two corners with two poles were always set up for the same condition (#1 or #2) for each block of trials. The two APS units on each corner having a single pole were randomly set to either the two-tones condition or the speech message condition. Both APSs on the single pole corners were always set for the same condition within a block of trials. (*See Table 4-1.*)

Each participant completed 16 trials, which were conducted in two blocks of 8 trials with a short rest period (usually five to ten minutes) in between. For an intersection such as was used in this experiment, a pedestrian can approach each of the four corners from two different directions. Therefore, as shown in the Table 4-1, there are eight possible unique approaches/crossings at the intersection. Each participant completed all eight approaches in a randomly determined order both prior to and after the rest period. During the rest period, the

TABLE 4-1 Sound conditions and crossing direction

Corner A – one pole close to the curb	Sound condition A1: speech messages	Sound condition A2: two tones
APS for crossing southbound	Multnomah, walk sign is on to cross Multnomah	Cuckoo
APS for crossing eastbound	Seventh, Walk sign is on to cross seventh	Rapid tick
Corner B – two poles 10 feet from the curb	Sound condition B1: same tone	Sound condition B2: two tones
APS for crossing northbound	Rapid tick	Cuckoo
APS for crossing eastbound	Rapid tick	Rapid tick
Corner C – two poles close to the curb	Sound condition C1: same tones	Sound condition C2: two tones
APS for crossing northbound	Rapid tick	Cuckoo
APS for crossing westbound	Rapid tick	Rapid tick
Corner D – one pole 10 feet from the curb	Sound condition D1: speech messages	Sound condition D2: two tones
APS for crossing westbound	Seventh, WALK sign is on to cross Seventh	Rapid tick
APS for Crossing southbound	Multnomah, WALK sign is on to cross Multnomah	Cuckoo

APS devices at each corner were reconfigured to use the alternate sound condition.

For all trials, participants were positioned to start 30 feet from the pushbutton. For each trial, participants were instructed as follows:

> *"When I say Go, first, go push the button to cross the street in front of you. Then, stand where you would wait to cross the street. Raise your hand when the WALK comes on for the street in front of you, which is [street name]."*

When participants were 20 feet from the pushbutton, a stopwatch was started; it was stopped when participants pushed the correct pushbutton. If a participant pressed the incorrect pushbutton, but continued to search for the other APS, the time continued to run and was stopped if and when the participant pressed the correct pushbutton. On the other hand, when participants pressed the incorrect pushbutton and went and stood at the street demonstrating their belief that they had pressed the correct button, no time was recorded. In this instance, the experimenter would then press the correct pushbutton, and the remainder of the trial would be recorded. A stopwatch was also used to time the delay between the onset of the correct WALK signal and when participants raised a hand indicating their judgment that the WALK signal had come on for the street in front of them.

Once participants had pressed a pushbutton and taken up a position where they would normally wait to cross the street, one of the researchers always pressed the other pushbutton. By doing so, and in combination with beginning participants at certain times during the intersection phasing, the researchers attempted to ensure that on half of all trials, the first WALK signal to come on was that for the street in front of the participants while on the other half of the trials the first WALK signal was for the street beside participants. However, it was not entirely possible to achieve this balance given testing constraints.

For every trial, as soon as participants raised their hands to indicate their belief that the WALK signal for the street in front of them had come on, the trial ended, and the experimenter directed or guided them to the next starting point. A trial was also ended if, after pressing the pushbutton, a participant waited through four consecutive WALK intervals without responding.

Other information recorded on each trial included which pushbuttons the participants investigated and in which order, and which walk signal was the first to come on after the participants pressed the correct pushbutton. After the participants had completed all 16 trials, a short survey was administered to learn the attitudes and preferences of the participants towards the various pushbutton arrangements and sounds. The questionnaire addressed:

- which corner was the easiest and hardest,
- how easy it was to find and use the pushbuttons when the poles were near to or away from the curb and when the APS were on one pole or two poles,
- whether the participant used the arrow to determine which crosswalk the button controlled,
- which cues the participant used (i.e., visual signal, audible signal, or traffic) to decide when the WALK had come on, and
- which walk indication was the participant's favorite and least favorite.

Also included was the researcher's observation of what cue the participant seemed to be using during the trials.

RESULTS

The vast majority of significant findings, both practically and statistically, were found in the data collected from the two sub-groups having the least vision, referred to as totally blind and legally blind. Most of the results presented here will therefore focus upon these 30 participants. Relevant findings from the low visual acuity subgroup and the cognitively impaired group follow. Mean substitution was used to deal with all missing WALK signal response delays and pushbutton location times. For example, if a given totally blind subject was missing pushbutton location data on corner A-southbound approach-speech condition, the mean for the totally blind subjects on corner A-southbound approaches-speech condition was substituted).

Accuracy in Recognizing Correct Walk Signal

For the purposes of analysis and discussion, a correct response was one in which the hand raise occurred during one of the 7-second periods in which the visual pedestrian signal for the street in front of them was in WALK. It was possible for a correct response to occur following either a correct or an incorrect pushbutton activation. This resulted from the fact that an experimenter always pushed whichever pushbutton the participant had not. This allowed response data to be collected on trials in which an incorrect button push had occurred. An incorrect response was defined a bit more narrowly than a correct response. An incorrect response was recorded when the hand raise occurred during the first WALK interval for the side street. That is, after the participants pressed a pushbutton and took up a position to wait to cross the street, the visual and audible WALK signal to cross the street beside them came on first, and participants mistook this information to mean the WALK signal had come on for the street in front of them.

As explained in the procedure section, it was not possible to ensure that for each trial there would be an equal probability that the first WALK signal to come on would be for the street in front of the participant vs. the street beside the participant. Therefore, the number of trials in which an "error" was possible varies between corners and individual pushbutton position and sound conditions. The error rates presented in this section reflect the number of incorrect responses divided by the number of trials in which an error was possible (i.e., trials in which the first WALK signal after a pushbutton was pushed was for the street beside the participants). Error rates were calculated using a few different operational definitions of what constituted an error, and regardless of the method chosen the rank order of the corners remained the same. Therefore, this method for calculating error rates was chosen because the researchers felt that it best addressed the issue of whether or not the pole placements and sound conditions provided either ambiguous or unambiguous cues for the onset of the WALK signal.

One of the most striking findings of this study was the very low error rate at the two-pole near the curb configuration of corner C (4/53, 7.55%); *see table 4-2*. No other pushbutton configuration resulted in less than a 26.9% error rate. Also, the other two pole configuration (corner B) resulted in a lower error rate than both of the single pole corners. However, due to a lack of independence of the measures (i.e., repeated measures design), no statistical test could confirm whether or not the two pole configurations resulted in overall lower error rates than the

TABLE 4-2 Error in recognizing correct WALK signal, by corner

Corner	# of incorrect responses/total possible instances	error rate
A	17/56	30.36%
D	19/52	36.54%
C	4/53	7.55%
B	14/52	26.92%

corners with a single pole. Nevertheless, the actual differences between error rates in most of the situations discussed here are quite substantial.

For the corners with two poles, there were two possible audible signal conditions, same tone (sound condition 1) or two different tones (sound condition 2). In the same tone condition, a rapid tick indicated the onset of the WALK signal for both street crossings, while in the two different tone condition, a cuckoo signaled the northbound or southbound crossing and the rapid tick signaled the eastbound or westbound crossing. For the corners with a single pole, there were also two possible audible signal conditions, two different tones (condition 2) or two speech messages (condition 1). The two tone sound condition produced higher error rates on each corner than the corresponding same tone condition or speech message condition. (*see Table 4-3*). Overall, the two different tone/sound conditions resulted in a 36.27% error rate (37/102). For the two pole APS arrangements at corners B and C, the two different tone sound condition resulted in 12 errors on 52 possible trials (23.08%), while the same tone sound condition resulted in half as many errors (6/53, 11.32%). On corner C (two pole near the curb configuration), the error rate was a mere 3.57% (1/28) for same tone condition. For the single pole APS arrangements at corners A and D, the two tone sound condition was especially troublesome, causing errors on 50% of the possible trials (25/50). The speech message condition resulted in much reduced error rate of 18.97% (11/58).

Walk Signal Response Delay

For pedestrians to safely cross at signalized intersections, they should begin crossing during a walk interval for the street they wish to cross. It is also important that they begin crossing as soon after the onset of the WALK signal as possible to allow themselves adequate time

TABLE 4-3 Error in recognizing correct WALK signal, by corner and sound condition

Corner/sound condition	# of incorrect responses/ total possible instances	Error Rate (%)
A1 / Speech	7/33	21.21
A2 / 2 Tones	10/23	43.48
D1 / Speech	4/25	16.00
D2 / 2 Tones	15/27	55.56
C1 / Same Tones	1/28	3.57
C2 / 2 Tones	3/25	12.00
B1 / Same Tones	5/25	20.00
B2 / 2 Tones	9/27	33.33

to cross the street before the onset of perpendicular traffic.

WALK signal response delays (measured from the onset of the correct WALK interval) for totally blind and legally blind participants were both low and consistent for the two-pole, near the curb pushbutton arrangement at corner C. Regardless of the sound condition (same tone vs. two different tones) or approach direction, it took participants approximately 2.0 seconds to correctly respond to the onset of the WALK signal at corner C. Planned comparisons revealed significantly faster responses to the signals at corner C than those at corner A ($\underline{F}(1,29)=8.598$, $p<0.01$), corner B ($\underline{F}(1,29)=6.156$, $p<0.05$), and corner D ($\underline{F}(1,29)=31.459$, $p<0.001$), (*see Figure 4-3*).

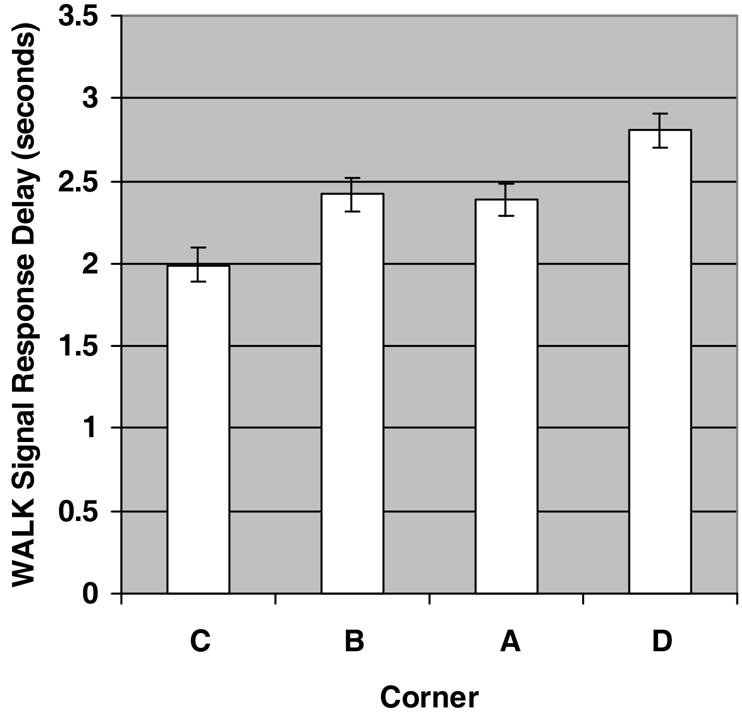


Figure 4-3. Mean WALK signal response delay by corner.

It was discussed earlier that for corners with a single pole, the two speech messages condition resulted in a much reduced error rate compared to the two different tone conditions. The effect of the speech messages on the walk signal response delay is not as clearly defined or, in most instances, as positive. At corner A, the speech message WALK indication resulted in significantly faster responses than did the rapid tick WALK signal ($\underline{F}(1,29)=8.333$, $p < 0.01$), however, the mean response delay for the speech condition (2.3 sec) was slower

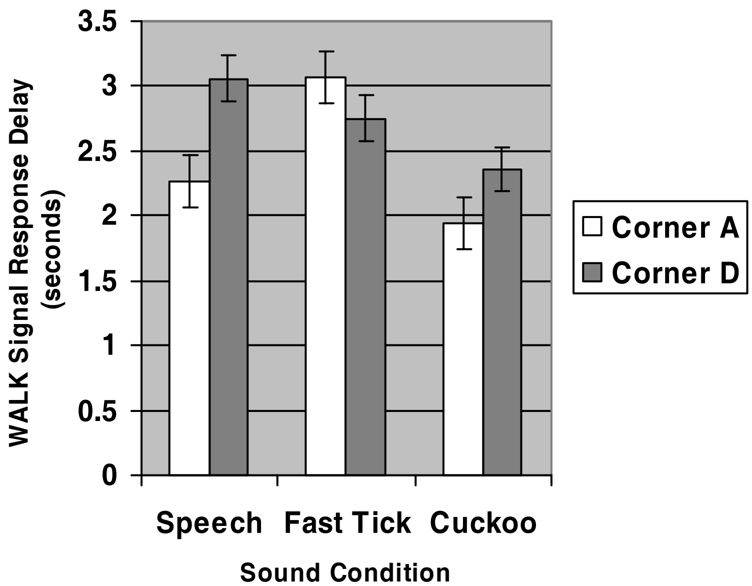


Figure 4-4. Effects of sound condition on WALK signal response delay at corners with two APS on one pole.

than that for the cuckoo WALK signal (1.9 sec, *see Figure 4-4*). This difference did not however achieve significance ($\underline{F}(1,29)=1.694$, $p > 0.05$). At corner D, the mean response delay for the speech message WALK signal was quite high (3.1 sec) and was slower than the mean response delays for the rapid tick WALK signal (2.7 sec) and for the cuckoo WALK signal (2.4 sec). The speech message WALK signal resulted in significantly slower responses than the cuckoo ($\underline{F}(1,29)=6.976$, $p < 0.05$), while the difference between response delays for the speech message and the rapid tick failed to reach significance ($\underline{F}(1,29)=2.407$, $p > 0.05$).

Pushbutton Location Times

Another factor of particular interest is how quickly blind participants were able to locate and press the appropriate pushbutton given the different APS arrangements at the four corners of the intersection. The pushbutton location times were measured from the time the participant crossed a line that was 20 feet away from the appropriate pushbutton to the time that they pressed the correct pushbutton. Again, when participants were unable to find the correct pushbutton or pressed the incorrect pushbutton and stopped searching for the correct button, no pushbutton location time was recorded. On average, pushbutton location times were fastest at corners D (13.6 seconds) and A (14.95 seconds, *see Figure 4-5*). While the difference between mean pushbutton location time at corners D and A was not statistically significant ($\underline{F}(1,29)=2.497$, $p>0.05$), the mean pushbutton location time at corner D was significantly faster than that at corners C ($\underline{F}(1,29)=4.838$, $p<0.05$) and B ($\underline{F}(1,29)=20.156$, $p<0.001$). The mean pushbutton location time at corner A was significantly faster that that at corner B ($\underline{F}(1,29)=13.049$, $p<.01$), but was not significantly faster than that at corner C ($\underline{F}(1,29)=1.395$, $p>0.05$).

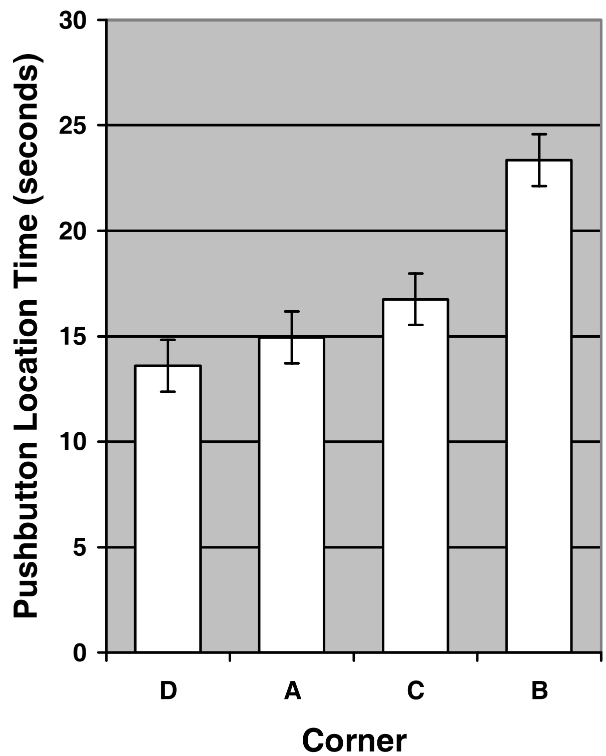


Figure 4-5. Pushbutton Location Time by Corner.

One result of interest was the very large discrepancy in pushbutton location times between northbound approaches to corner C (12.0 seconds), and westbound approaches to the same corner (21.6 seconds). Figure 4-6 clearly shows that the mean pushbutton location time for the northbound approaches to corner C was amongst the fastest across all approaches and corners. Also, the mean pushbutton location time for northbound approaches to corner C was significantly faster than the mean pushbutton location time for westbound approaches to the same corner ($\underline{F}(1,29)=81.968$, $p<0.001$). Possible reasons for this discrepancy will be addressed in the discussion.

Low Visual Acuity Subgroup

The analysis of the data collected from participants with low visual acuity (the subgroup with the most vision) demonstrated very few statistically significant differences; however, the majority of the trends in the data matched those for the totally blind and legally blind sub-groups. While the overall error rate for the low acuity group was only 5.36% (6/112), five of the six errors occurred on trials with the two different tone sound condition on corners A and D, the two most difficult conditions for the totally and legally blind participant sub-groups. Also similar to the analysis described above, mean WALK signal response delay at corner C (1.1 sec) was faster than those at all of the other corners (corner D, 1.2 sec; corner B, 1.3 sec; and corner A, 1.4 sec). The differences were moderately significant between mean WALK signal response delays at corners C and A (p=.066) and those at corners C and B (p=.077). It is of particular interest that although most members of this group of participants could see the visual walk signal, the same pattern of results as those obtained from participants with less vision emerges. This point will be addressed further in the discussion.

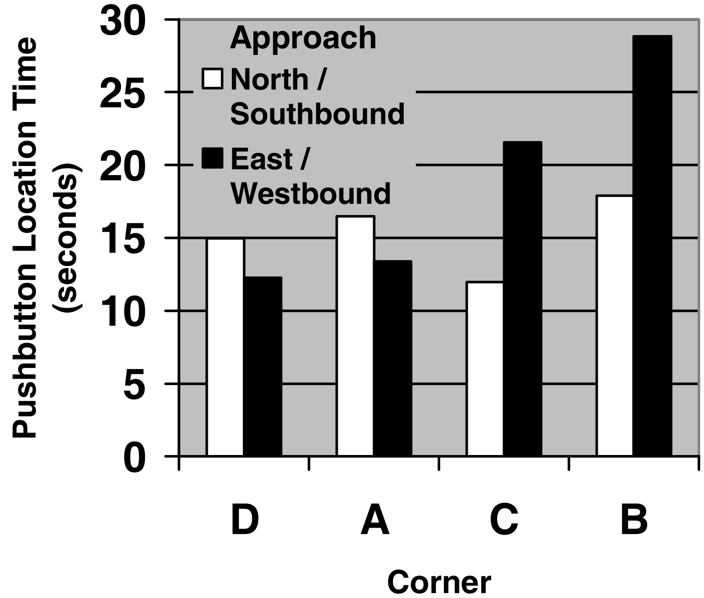


Figure 4-6. Pushbutton Location Time by Corner and Approach.

Although the speech condition resulted in no errors with this subgroup, it did result in the slowest response times at both corners A and D. At corner A, the speech message resulted in significantly slower responses than did the cuckoo ($\underline{F}(1,29)=16.230$, $p < 0.01$), but the mean WALK signal response delay for the speech message (1.6 sec) was not significantly slower than that for the rapid tick (1.4 sec). At corner D, no comparisons reached significance; however the mean WALK signal response delay for the speech message (1.3 sec) was slower than the delays for the cuckoo (1.1 sec) and the rapid tick (1.1 sec).

One difference from the participants who are totally blind or legally blind is in the ability of the participants with low visual acuity to efficiently find the correct pushbutton. The low visual acuity participants had little difficulty finding the correct pushbutton for the westbound approach to corner C. As a result, the fastest pushbutton location times for this subgroup were obtained at corner C (6.6 sec), although all pairwise comparisons failed to reach significance. Mean pushbutton location times at corners A and D were again similar to one another (both were

7.2 seconds due to rounding), and the slowest pushbutton location times were again recorded at corner B (7.7 sec).

Cognitively Impaired Group

The analysis of the data collected from the 45 participants with cognitive impairments similarly has few statistically significant differences; however the majority of trends in the data again matched those of the 30 totally blind or legally blind participants. The participants with cognitive impairments made very few errors (10/362) resulting in an overall error rate of 2.76%. The few errors committed did follow a pattern similar to those of the visually impaired participants. Only two of the ten errors occurred on corners with two poles (corners B and C), and more errors were committed in the two different tone conditions (6/10) than in the same tone or speech message conditions (4/10). Once again, the mean WALK signal response delay at corner C (0.9 sec) was faster than those at all of the other corners; however, there was no significant main effect for corner ($F < 1.0$) and all mean WALK signal response delays were less than 1.05 sec. Once more, all of these participants had sufficient vision to be able to see the visual walk signal, and yet the pattern of results is again similar to the visually impaired participants.

Mean pushbutton location times at corners D (6.19 sec) and C (6.22 sec) were both significantly faster than those at corners A (6.59 sec) and B (6.57 sec). The very small difference between the most extreme mean pushbutton location times (0.40 sec) does, however, qualify the importance of the significant differences. Once more, it is noted that for these participants the westbound approaches to corner C did not cause greater difficulty in finding the correct pushbutton than northbound approaches to the same corner.

Survey Results

The self-report questionnaire data is similar to the behavioral results in some ways and dissimilar in others. While corner C produced the most favorable behavioral results, the 45 participants with visual impairments gave the single-pole-close-to-the-curb configuration (Corner A) the most votes as the overall easiest corner (27/45, 60.0%), while the two-poles-near-the-curb configuration (Corner C) received the second most votes (13/45, 28.9%). Corner B (the two-poles-further-from-the-curb configuration), which produced some of the worst pushbutton location times and walk signal response delays, received the most votes as the most difficult pushbutton arrangement (34/45, 75.6%). The survey questions that most conflicted with behavioral results assessed participants favorite and least favorite sounds. Even though the rapid tick resulted in the best response accuracies and consistently fast walk signal response delays, it only received 17.8% of the vote as the favorite sound (8/45), and received the most votes as the least favorite sound (25/45, 56.6%). The speech message was the most popular of the sound messages (29/45, 64.4%), and also received the least votes as the least favorite sound (6/45, 13.3%).

DISCUSSION

Safe and legal pedestrian crossings at signalized intersections require that pedestrians correctly identify which crosswalk has the WALK indication. Positive information is provided by visual pedestrian signals and by APS (audible and vibrotactile) where they are available. Where pedestrian phasing is concurrent with vehicular phasing, the onset of the WALK signal can also be inferred by a surge of vehicular traffic going parallel to the crosswalk, from the lane/s closest to the pedestrian. In the absence of APS, pedestrians who are unable to see visual pedestrian signals typically attempt to begin crossing with this vehicular surge.

At complex, unfamiliar, signalized intersections without APS, pedestrians who are blind often fail to begin crossing within the WALK interval for the desired crosswalk (*36*). Even when APS are present, pedestrians who are blind sometimes find audible signal information ambiguous in terms of which crosswalk is being signaled (*5*). It is critical that any APS system provide unambiguous information. The results indicate that pushbutton location affects the ambiguity of WALK signal information.

Accuracy in Recognizing Correct Walk Signal

On the corner having pushbutton-integrated APS on two poles near the street, participants in the totally blind and legally blind sub-groups indicated that the street in front of them had the WALK signal, when, in fact, the WALK signal was to cross the street beside them, on only 7.55% of possible trials. This pole arrangement for APS devices corresponds to the arrangement that is required in some other countries, including Sweden, Denmark, and Australia (*40*). For all other pushbutton-integrated APS arrangements tested in this study, participants in the totally blind and legally blind sub-groups indicated that the street in front of them had the WALK signal, when it was actually the WALK signal to cross the street beside them, on at least 26.9% of trials. On those trials, if they had been crossing the street, they were likely to have started crossing at the onset of traffic on the street perpendicular to their direction of travel.

Use of the configuration with two pushbutton poles with APS near the curb, both having the same tone, resulted in excellent accuracy by participants who were unable to use visual pedestrian signals (totally and legally blind sub-groups). This pole configuration and use of same tone sound was also beneficial to participants having more vision (low visual acuity sub-group and cognitively impaired group), in determining which crosswalk had the WALK signal. This corresponds to the pushbutton pole arrangement plus WALK signal system that is common in countries using pushbutton-integrated APS (*40*).

Those participants who had vision sufficient to see visual pedestrian signals (i.e. the cognitively impaired participants and the low visual acuity participants) were recorded by experimenters as having typically used the visual pedestrian signals to determine the onset of the correct walk interval (and they also typically reported reliance on the visual pedestrian signals). It is therefore of interest that their results are in the same direction as those for the two sub-groups who were always or usually unable to see the visual pedestrian signals. It appears that, whether or not it was on a conscious level, or observable to experimenters, the participants who could see the visual pedestrian signal information were nonetheless influenced by both the pushbutton pole arrangement and the WALK signal sound. If they were not influenced by pole arrangement and the nature of the walk sound, accuracy would be expected to be the same under all pole arrangements and sounds.

Walk Signal Response Delay

Pedestrians who do not begin crossing promptly following the onset of the WALK interval may not complete their crossings before the onset of perpendicular traffic, at which time they are particularly at risk for crashes. Recent research on pedestrians who are blind making crossings at complex, unfamiliar, signalized intersections, found that on 51.4 % of trials, crossings were not initiated during the WALK interval, and on 26.9% of trials, crossings were completed after the onset of perpendicular traffic (*36*). Therefore, it was of interest to measure the delay in response to the onset of the WALK signal for the correct crosswalk.

In this study, for participants who were always or usually unable to see visual pedestrian signals (totally and legally blind sub-groups), responses to the onset of the WALK signal for the correct crosswalk were significantly fastest on the corner having two pushbutton poles with APS near the curb (corner C), and responses were uniformly fast at this corner regardless of sound condition. Although the overall mean walk signal response delay for this corner was approximately two seconds and well within the normal walk interval, delay would likely be longer if actually making crossings, as pedestrians who are blind typically require a little time to determine whether there are vehicles turning across the crosswalk. Mean WALK signal response delay for blind pedestrians crossing at complex, unfamiliar signalized intersections without APS has been found to be 6.4 seconds (*36*).

Responses to the correct WALK signal were also fastest at the corner having two pushbutton poles with APS near the curb for the participant groups who always or usually could see the visual pedestrian signal. Mean WALK signal response delays were lower for these groups than for the groups who were always or usually unable to see visual pedestrian signals.

It appears that, whether or not it was on a conscious level, or observable to experimenters, the response delay of participants who could see the visual pedestrian signal information was influenced by the pushbutton pole arrangement. Installing pushbuttons on two poles near the curb seems to promote fast reaction time to the onset of the WALK signal, and is thus likely to promote faster initiation of crossings for pedestrians with visual and cognitive disabilities.

Pushbutton Location

By comparing the time to press the correct pushbutton at corners having pushbuttons in different pole configurations, we are able to infer the participants' ability to easily locate the correct pushbutton. This task includes deciding which pushbutton controls the street they are preparing to cross. Nearly all participants were observed to visually or tactually use the tactile and/or visual arrows on APS to confirm which crosswalk was associated with the APS, and 82 of 90 participants (91%) reported that they used the arrows. The results of this research, therefore, would not necessarily be applicable to pushbuttons that did not have tactile and visual arrows that were carefully aligned with the direction of travel on the associated crosswalk.

For the participant sub-groups in this study who had the least amount of vision and who were rarely or never able to see visual pedestrian signals, time to press the correct pushbutton was marginally faster at the two corners having two pushbuttons on a single pole. The mean pushbutton location time for the corner having two pushbutton poles far from the curb was longest. However, any advantage in speed of pressing the correct push button is far outweighed in importance by the greater accuracy in identifying which crosswalk had the WALK signal. Errors in determining which crosswalk has the WALK signal may result in crashes, while delay in locating the correct pushbutton does not typically have negative consequences for life safety.

For the low visual acuity sub-group, unlike the sub-groups having even less vision, mean pushbutton location time was fastest for the corner having two pushbutton poles near the curb. However, as for the sub-groups having less vision, mean pushbutton location time was slowest for the corner having two pushbutton poles far from the curb. For the group having cognitive impairments, the corner having two pushbuttons near the curb resulted in one of the two fastest times, which were not statistically different from one another.

Therefore, although the results for time needed to find and press the correct pushbutton are not as clear-cut or definitive as for speed and accuracy in identifying the crosswalk being signaled, having two pushbutton poles near the curb generally appeared to promote speed (and by inference, ease) of locating the correct pushbutton.

Speed in locating the pushbutton appears to have been significantly influenced by the relationship between pushbutton location as designed to test the hypotheses of this experiment, and pushbutton location with relation to geometric idiosyncrasies at each corner. There may have been some difference attributable to slight differences in perceived loudness of each APS device as well. It was extremely difficult to make the perceived loudness of the APS signal the same from each device. Simply setting all devices the same for volume and ambient noise response is not sufficient because differences in the nature and distance of reflective surfaces at each corner also influence perceived loudness. At each corner, there was a significant difference in time to press the correct pushbutton depending on the direction from which the corner was approached.

For example, at the corner having two pushbutton poles near the curb, corner C (*see Figure 4-2*), mean time for pushing the correct pushbutton on westbound approaches was much longer than northbound approaches to the same corner. When approaching westbound, participants passed very close to the pushbutton to cross the street beside them (the parallel street) and the locator tone of that APS was usually very audible to participants. They may have been able to hear the locator tone for the pushbutton to cross the street in front of them (correct pushbutton) when they approached the incorrect pushbutton, but the loudness of the sound would have been much less. (Recall that locator tones are only intended to be heard 6 to 12 feet from the pushbutton, and the pushbuttons were approximately 10 feet apart.) Therefore it commonly occurred that participants would check the arrow on the APS for crossing the parallel street before finding and pressing the pushbutton for the street in front of them. When approaching the corner northbound, participants did not pass quite as close to the pushbutton for the parallel street because the pushbutton pole was on a bulb-out in the curb line, so they did not delay to check the arrow for the parallel street before finding and pushing the correct button.

Sound Condition

The two different tone condition may have produced more errors than the same tone condition at all corners because some participants with visual impairments had previous experience with cuckoo signals at other locations in the city and may thus have been primed to respond to the cuckoo, regardless of whether it was the correct signal. This could also explain why the cuckoo resulted in the fastest response rates at the single pole corners. Nonetheless, when pushbuttons were on two poles near the curb, accuracy was equally good with two tone and same tone conditions.

The two different tone condition may have had particularly high error rates on the single-pole corners because there was no redundant APS location information to indicate which crosswalk was associated with which sound. The speech message condition resulted in lower error rates than the two tone condition, but mean WALK signal response delays for the speech message WALK condition were slower. This may reflect greater cognitive demand for processing the speech messages than the tones, or may reflect the different lengths of the sounds and messages themselves. A single complete speech message lasted approximately three seconds, whereas a single cuckoo lasted somewhat over one second.

Comparison of Objective Measures and Subjective Judgments

Subjective judgments of participants, recorded on the survey, were variance with objective measures in three important ways. First, corner A (one pole close to the curb) had the most preferred pole arrangement with corner C (two poles far from the curb) a somewhat distance second choice. This is in contrast to objective measures in which corner C produced the fastest and most accurate responses to the walk indication. Because accuracy in responding to the walk indication is essential to safe street crossing at signalized intersections, despite the subjective preference, the arrangement at corner C is recommended.

Second, speech messages were used at the locations with two pushbuttons on a pole and resulted in better accuracy than two tones sound condition, but less accuracy than the rapid tick. Speech messages also resulted in slower response times than the rapid tick indication. When it is possible to separate the poles, the rapid tick WALK indication is recommended.

Third, the rapid tick was the least preferred WALK indicator, but it produced the fastest and most accurate responses to the walk indication. Because inaccuracy in responding to the WALK signal, that is, beginning the crossing when the wrong WALK signal comes on, has direct consequences for safety in crossing, the rapid tick is preferred over other WALK indications used in this research. Verbal messages may have been rated highly simply because participants were primarily native English speakers, because ambient sound was never excessively loud, and because it provided additional information, that is, the name of the street to be crossed. The cuckoo may have been rated more highly than the rapid tick simply because it was a more familiar walk indication to some participants. Therefore despite some dislike of the rapid tick WALK indication, it is the recommended sound because it results in fast and more accurate decisions regarding which crosswalk has the WALK.

RECOMMENDATIONS

The recommended location for two pushbutton-integrated APS on a single corner is consistent with Guidance in *MUTCD* 4E.09.

- Place each APS device on a separate pole, located as close as possible to the curb line.
- Place each APS as close as possible to the line of the associated crosswalk that is furthest from the center of the intersection.
- Place the two APS at least 10 feet apart.

The recommended WALK indication for APS that are located according to these recommendations is a rapid tick, or percussive sound, at 10 repetitions per second. Both APS should have the same WALK indication. Where it is technically infeasible to install two pushbuttons on a corner on two separate poles, it is recommended that verbal WALK messages following the model "*Multnomah. Walk sign is on to cross Multnomah*" be used. Two different tones to indicate which crosswalk has the WALK interval at an intersection where there are two pushbutton-integrated APS on a single pole provides ambiguous information and may result in pedestrians crossing with the wrong signal. Speech WALK indications should be used sparingly, however, as it is not possible to make them understandable under all ambient sound conditions, and to all pedestrians. In this experiment, speech messages were evaluated in a situation where all participants were told the name of the street that they were approaching. If the pedestrian is not familiar with the area or is confused about the street names, the speech message, which begins with the street name, will not clarify which crossing has the WALK. If speech messages are used, additional features may be needed on the device to provide street name information to the pedestrian who is unfamiliar with the intersection. These features would include a high-contrast tactile arrow oriented parallel to the direction of travel on the associated crosswalk, and a pushbutton information message that provides the name of the street controlled by the pushbutton. Braille street name information on the APS is also desirable.

Jurisdictions desiring to standardize the WALK indication should also standardize the location of APS so that they will provide unambiguous information regarding which crosswalk has the WALK interval. Where APS are installed in a variety of locations, engineering judgment is required to determine, for each intersection, whether the rapid tick or a speech WALK indication will provide the most unambiguous information to pedestrians.

CHAPTER 5

COLD WEATHER CASE STUDIES

INTRODUCTION

Cold weather case studies were conducted in order to ensure that this research covered a wide variety of climates in the evaluation of APS devices. Cities in cold weather climates could potentially face unique issues due to cold temperatures, snow, ice, and removal methods such as snowplowing and salting. The goal of these case studies was to find out what effects these cold weather characteristics had on the installation, operation, and maintenance of the APS devices, as well as the interaction with pedestrians who are visually impaired. The information acquired from these case studies will be used to develop additional recommendations for practitioners and will be part of the training materials to be developed later in this study.

Selection of cities for these case studies was based on several criteria. A study city needed to have a climate that experienced freezing temperatures and received precipitation (snow and ice) that warranted removal methods, including snowplowing and salting. The APS units employed by the city needed to be pushbutton-integrated devices. A study city needed to have multiple APS installations, not just an isolated occurrence. Since one of the goals was to find out the long-term effect of cold weather on the devices, cities with longer histories of APS use were preferred over those with shorter histories.

The research team used their knowledge of APS installation locations to draw up a list of cities that would be potential study sites. To add to this list, the team contacted distributors for the various manufacturers to learn of cities with APS installations. Of the 36 contact attempts made, two cities were selected for site visits. Another city provided written feedback but was not visited. Other cities were excluded due to lack of appropriate APS devices, short histories with devices (1 year or less), lack of sufficiently cold weather, and failure to establish contact with the appropriate individuals.

The two cities that were visited were Halifax, Nova Scotia and Waukesha, Wisconsin. These cities primarily use Novax and Polara equipment, respectively. Pushbutton-integrated APS have been in service in these cities for 1-2 years. Cities with long maintenance histories are difficult to find, due to the fact that pushbutton-integrated APS models have not been on the market for long. The city of Ann Arbor, Michigan provided written feedback but was not visited by the research team. Their APS devices, which had been in service for 5 years, had been sent to the manufacturer due to malfunction and it was unknown when they would be reinstalled at the intersections.

HALIFAX, NOVA SCOTIA

History and Background

Halifax has been using overhead-mounted Novax APS since 1998. Pushbutton-integrated units (Novax Vibrawalk) were introduced in 2003 and are now in operation at five intersections. The APS units were installed in response to requests from the Canadian National Institute for the

Blind (CNIB). All installations were retrofits to an existing signal and were performed by a contracted party.

Process and Procedure

Requests for APS installations come from the CNIB. They typically provide the city with a list of intersections where they would like APS installations. The city reviews the list and selects intersections for APS installations based on design of the intersection and available funding. If the intersection is suitable for pushbutton-integrated units, they install Novax Vibrawalks in addition to the overhead speaker APS units. Factors that affect the decision for pushbuttons include suitability of pole location and availability of wiring.

Funding

APS in Halifax were funded by the capital budget in a specified fund for pedestrian safety issues. There was also a federal 50-50 funding match in 2004 for APS installations.

APS Type and Features

Novax DS2000 Audible Pedestrian Signal for overhead speaker units

Novax Vibrawalk for pushbutton

APS features (pushbutton-integrated device installations):

- Locator tone
- Vibrotactile WALK indication
- Extended button press – when button is held for 3 seconds, the audible cuckoo will sound at the next WALK phase. Otherwise there will be no audible indication of the WALK phase.

Installation Issues

The APS unit is mounted on top of the pedestrian head and faces across the street. A typical configuration for a crossing in Halifax involves two APS units, one at each end of the crossing. The volume is set up so that the sound only reaches ¾ the way across the street. This enables the user to detect the second unit part way across the street and guide them in the proper direction. Setups with only one APS per crossing generated numerous noise complaints as the volume has to be higher to be heard across the street.

Most units are attached to aluminum poles but some locations have wooden poles, as shown in Figure 5-1. The APS units on wooden poles are clamped to the signal arm or pedestrian head. To access the pushbuttons, ½-inch PVC conduit is strapped to the wooden pole and an LB or liquid tight flex pipe provides access to the bottom of the pushbutton.

Figure 5-1. APS mounted on wooden pole.

The overhead speakers are typically mounted to the pedestrian signal head. Plastic (polycarbonate) signal heads gave problems with breaking when the APS speakers were mounted into them. Strong winds would push on the speaker and crack off the thin plastic of the signal head into which the speaker was mounted. In these cases, the speaker was mounted on the pole or some other metal or wood surface, as shown in Figure 5-2. Pedestrian signal heads made of aluminum did not have this issue. In areas with less of a problem with strong winds, this may not be a concern.

Availability of wiring at the pole is an important issue. If sufficient wiring is installed with the signal, installing an APS later is much easier. Pulling wire later can become prohibitively expensive.

Figure 5-2. APS overhead speaker mounted on signal head support arm.

Maintenance

The city handles the maintenance of the devices. The APS overhead speakers generally will start having problems at the 5-year mark. They usually last from 5 to 10 years. Damage is usually due to salt and moisture. The Vibrawalk devices have not shown any problems during the two years they have been in service. Halifax engineers have also noted that moisture and insects can cause pushbuttons to short out, thereby causing the APS to activate every cycle.

Cold Weather Issues

Snow is a constant problem in the Halifax climate. Snow banks can prevent access to the pushbuttons when not cleared properly. For intersections where pushbuttons are used, pole placement becomes an important issue so that the all pedestrians can reach the button. Poles with pushbuttons located to the immediate left or right of the crosswalk give a better chance of being reached by pedestrians and having the snow cleared properly. Halifax uses mini-plows for clearing sidewalks. They anticipate that this could be a problem with stub poles (i.e., knocking them over), so the use of stub poles is generally avoided.

Being near to the ocean, moisture and salt in the air is a problem for Halifax, as is salt on the roads for de-icing. Current Novax APS units (overhead-mounted speakers) last about five years before problems arise. There have been no problems or failures with the Vibrawalks yet.

Other issues are caused by freezing temperatures. Pulling additional wire for a retrofit installation cannot be done in the winter due to ice in the wire conduits. Extreme cold can cause some signals cabinets to fail and thus the APS to fail.

Evaluation

The initial installations of non-pushbutton-integrated APS installations were configured to give the audible WALK cuckoo at every cycle. The city received complaints about noise, especially in the summer months when people had their windows open. Due to concerns about noise, these units were set up to be off (give no audible indication) from 11:00 pm to 6:00 am. Pushbutton-integrated installations, however, can be accessed 24 hours per day, but the audible indication is given only when the button is held for three seconds. No feedback was reported on the pushbutton-integrated devices.

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WAUKESHA, WISCONSIN

History and Background

Waukesha has been using pushbutton-integrated APS with speech messages since 2002. Prior to that, they used overhead speaker units which gave a cuckoo or chirp but were not activated by pushbutton. There are approximately 84 Polara Navigator units in service in Waukesha, most of which were installed during summer 2004. The move to pushbutton-integrated devices was motivated by requests from the local blind community, the Sight Loss Network, who introduced the city to the speech message capability of the Polara Navigator.

Process and Procedure

The initial APS installations were performed in one large campaign in the summer of 2004. These installations were scattered about town, but mainly focused on center city intersections. There is another installation campaign planned that will involve approximately 100 units. This will focus on installing devices at the rest of the center city intersections and moving outwards from there. It is also current Waukesha policy that any new signal installation will be accompanied by an APS installation.

Funding

APS in Waukesha are currently fully funded by Waukesha County Community Development Block Grant Program up to a specified amount per year. This funding includes time and materials.

APS Type and Features

Polara Navigator for pushbutton-integrated devices (the model type mainly in use has four wires for installation and a separate control board that is configured remotely)

APS features:

- Pushbutton locator tone
- Vibrotactile WALK indication
- Extended button press
- Speech WALK indication
- Pushbutton information message by extended button press

Installation Issues

Installation of the devices is done by the city. If a signal to be retrofitted already has pushbuttons, this greatly facilitates APS installation. Even in these cases, however, the four-wire models still necessitate the pulling of extra wire.

Most of the signal poles are steel and accommodate the APS devices fairly easily. They try to have two poles per corner for every intersection. Sometimes stub poles are necessary if the signal poles are not close enough to the crosswalk. In one case, a lamp post was used successfully as a mount for an APS unit (*see Figure 5-3*), since aesthetics of the area placed restrictions on the number of poles that could be installed.

All but one of the existing APS installations were retrofits. However, all new signals in the future will have APS devices installed at the time of the signal installation.

Figure 5-3. APS mounted on lamp post.

Maintenance

There have been no maintenance issues for the APS units in their one year of service.

Cold Weather Issues

There were no significant issues related to APS units in cold weather during their one year of service. Previous pushbuttons (non-APS) had an estimated life of 10 years. The problems were mainly corrosion at the wire connections due to salt and moisture.

Waukesha uses mini-plows for removing snow from sidewalks. The manager of city snow plowing has expressed concern that stub poles may be damaged by these plows.

Evaluation

Devices in residential areas initially drew noise complaints. The city had been leaving the sound settings as the factory default. Once the volume was reduced, there were no complaints.

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ANN ARBOR, MICHIGAN

History and Background

Ann Arbor has been using pushbutton-integrated APS since 2001. Five Polara Navigators were installed that year and none have been added since.

Process and Procedure

APS units are installed on the basis of recommendations from the Ann Arbor Commission on Disability Issues.

Funding

Approval for APS funding comes through the City Council. The money is budgeted from the Major Street Fund, which is a transportation fund. Currently, $50,000 is designated for the purchase, installation and maintenance of five APS.

APS Type and Features

Polara Navigator (pushbutton-integrated unit)

APS features:

- Pushbutton locator tone
- Extended button press
- Speech WALK indication
- Pushbutton information message by extended button press

Installation Issues

All APS installations were retrofits to existing signals. All poles were steel poles, and existing wiring was sufficient to accommodate APS installation. Some units are installed on pedestrian signal poles and some are mounted on the vertical pole of a signal mast arm.

Maintenance

Many of the APS units began to malfunction in 2004 and the city sent them back to the manufacturer. The problem was observed to be rusting of the devices.

Vandalism was an issue. There were several instances where the unit was knocked off the pole. The attachment bolts were replaced with bigger diameter bolts.

Cold Weather Issues

Little direct effect was seen from cold weather conditions. However, the use of salt may have contributed to rust that was experienced. The city engineers do not believe that the winter conditions contributed much to the signal operation.

Evaluation

There were several complaints about the noise of the locator tones, especially in the summer when people keep windows open. The locator tone sound was lowered in response.

When there were two APS units on a single pole, the locator tone for one was switched off to control noise.

To explain how the APS devices work, the city publicized the devices through a newspaper article and local cable broadcast.

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CHAPTER **6**

ENGINEERING EVALUATION

INTRODUCTION

The engineering evaluation was conducted to acquire feedback on the physical installation, operation, and maintenance of APS devices in the two cities where the primary experiments were conducted – Tucson, Arizona and Charlotte, North Carolina. This section comprises the notes made by the city staffers on the installation of the APS and subsequent monitoring of the operation and maintenance performance. The information in this chapter may be helpful to engineers and signal technicians who have not worked with APS before. It covers the installation process for both cities as well as approximately one year of post-installation observation for the Charlotte sites and one and a half years of post-installation observation for the Tucson sites.

As with any technology, the design of APS is an ever-evolving field. Manufacturers of APS are constantly updating their products to address usability and design concerns. This engineering evaluation presents issues that were known at the time of this report and should be understood in that context.

INSTALLATION

Instructions

- Instructions provided by the manufacturer were generally very good and helpful for installers who had not previously dealt with APS. Manufacturers and their representatives were also very helpful in answering questions and making personal visits to the sites to solve installation problems.

Mounting

- In some cases, installers were able to use some or all of the pre-drilled mounting holes in the APS pushbutton unit. In cases where this was not possible, new holes had to be drilled.

Wiring

- Some APS types required four wires at the pushbutton; others required only two. If four wires were not available at locations where they were needed, extra wire needed to be pulled, making the installation more difficult.
- Some APS types had a central control board in the cabinet; others had individual control boards in the pushbutton or in the corresponding pedestrian signal head.
- Some APS types required wiring between the pushbutton unit and the pedestrian signal head. This added another level of difficulty to the installation. Sometimes this extra wire was not included from the manufacturer, or the included wire was not long enough.
- One APS type required the installation of a terminal block into each pedestrian signal head for the termination of wires.

Setup

- Setting up the timing on units that use remote controllers (specialized remote control or PDA with special software) was fairly easy and user-friendly. Other types of APS required the setup to be done inside the pushbutton or overhead unit, which was more difficult.
- One of the devices required a specialized screwdriver, which was sent later.

Volume adjustment

- For APS types that used remote control, adjusting the volume of the APS was fairly easy.
- However, some APS types required that the volume adjustment be done on the control board in the overhead pedestrian signal, which was much more difficult. This process required the installer to turn a volume adjustment screw while on top of a ladder, then climb down to evaluate the volume at street level. This proved to be a time-consuming process.
- The volume on most APS had to be adjusted after installation. The default settings from the manufacturer were typically too loud or no volume (silent).
- Upon activation, one installation had a locator tone that was extremely loud. The solution from the manufacturer's representative was to muffle the sound by placing foam inside the speaker unit.

OPERATION AND MAINTENANCE

Observed failures

- No response to ambient sound
- Weak or no vibration
- Malfunction of audible message or tone
- Delay between onset of walk interval and start of speech message
- Failure due to wire short going to the vibrator cover/pushbutton.
- Mechanical failure of pushbutton magnetic switch
- Failure of control board
- Faulty ped driver

Weather

- The pushbutton of some units operated intermittently since winter; possibly sensitive to temperature.

Damage

- One device was damaged by a turning vehicle but continued functioning.
- One unit was knocked off the pole.

Several of the directional arrow indicators came unglued and are missing.

CHAPTER 7

RECOMMENDED GUIDELINES

INTRODUCTION

The best approach to installing APS would be to ensure that all installations are standardized, i.e., have the same features and placed at the same locations on every corner of every intersection. This approach should still the ultimate goal. Unfortunately, increasing complexity in intersection geometry and signalization make a 'one-size-fits-all' approach to specifying APS features and installation difficult in the U.S. In particular, variations in pushbutton location, variations in location and direction of slope of curb ramps, the presence of islands and medians, the presence of very wide, sometimes skewed crossings, and the presence of yield-controlled right-turn lanes, mean that the use of the same features on all APS will result in some crossings that have adequate information for most users, but others that have insufficient information for many users, and still others that are made more dangerous by the installation of APS whose volume is not properly adjusted. Engineering judgment is needed at APS installations to determine the appropriate features for the APS and the best location for the installation. The recommendations included in this chapter are intended to provide practitioners with the information needed to choose the most appropriate APS features and make sound installation decisions.

Guidelines suggested in this chapter are supported by the results of two experiments conducted as part of this project. Research was conducted to determine what features of pushbutton-integrated APS best promote safe and independent street crossings by pedestrians who are blind. This research was conducted in Tucson, Arizona and Charlotte, North Carolina and is reported in full in Chapter 3. In addition, research was conducted to examine the effect of pushbutton location on the accuracy and speed of determining which crosswalk at a corner has the WALK signal. The research also examined the effect of type of WALK indication on accuracy and speed of determining which crosswalk had the WALK signal. This research involved groups of participants with varying levels of visual impairment and varying types of cognitive impairment. All significant results were for the group whose participants were totally blind; however the findings for all other groups were consistently in the same direction. This research was conducted in Portland, Oregon and is reported in full in Chapter 3.

Fortunately, all the pushbutton-integrated APS currently marketed in the U.S. have most of the features mentioned below as either standard or optional features. Often it is a simple matter of programming the APS to add, cancel, or change a feature. APS installed with default settings at all crossings do not always provide accessible and usable information to all pedestrians who are blind or who have low vision. Selection of features necessary at a particular crossing requires engineering judgment, and some intersections may require input from an orientation and mobility specialist and any individual who had requested installation of an APS at that crossing. While primary features are recommended on all APS, not all crossings at an intersection will need secondary features. For example, audible beaconing may be needed for the major street crossing, but unnecessary for the minor street crossing.

In countries such as Australia and Sweden, where the relationship between the crosswalk and the pushbutton is tightly controlled, and the curb ramp always slopes in the direction of the crosswalk, standard APS features and standard installation guidelines are very workable. This is not always the case in the U.S. The following sections on features and on installation guidelines will take into account the varied device and installation needs at crossings having different geometries and different signalization schemes.

FEATURES OF PUSHBUTTON-INTEGRATED APS

This section is divided into primary features and secondary features. Primary APS features are those that, on the basis of psychophysical research as well as subjective data, should be included in all pushbutton-integrated APS, regardless of intersection geometry or signalization. Secondary features are those that have been shown to facilitate crossings by some pedestrians who are blind, but which may 1) not be indicated for use at all intersections, 2) not be desired or needed by all pedestrians who are blind or who have low vision, or 3) have limited research support.

Primary APS features

Pushbutton Locator Tone

It is recommended that all pushbutton-integrated APS be required to have pushbutton locator tones that sound at one second intervals during flashing and steady DONT WALK intervals, as described in *MUTCD* 4E.09. No particular tone is recommended. Pushbutton locator tones are intended to notify pedestrians who are approaching a crosswalk of the need to press a button to get a WALK indication (and pedestrian timing); they also help users locate pushbuttons.

The strongest support for these recommendations is from two types of subjective data (*see Chapter 3*). First, participants were asked, following each crossing for which they used the pushbutton, how they located the pushbutton. This was an open-ended question, permitting multiple responses. Participants said they used the pushbutton locator tone on most trials, regardless of device (Tucson 95%, Charlotte 83%). Furthermore, when asked following each trial on which they had specific familiarization and experience with the four APS devices, to rate their agreement with the statement “The locator tone helped me find the pushbutton,” mean responses for each device in each city were all in the positive direction.

It is not possible to clearly measure the effect of locator tones on finding the pushbutton. In the condition in which participants had no information about the crossing other than that it would have an APS, and they did not know that the APS would be of the pushbutton-integrated type and may have been completely unfamiliar with this type of APS, participants searched for the pushbutton on very few trials. When they had general or specific information on the pushbutton-integrated APS, knew that there were pushbuttons at each crossing, and knew that each pushbutton had a locator tone, participants searched for pushbuttons on 98% of trials across both cities, suggesting that the locator tone was helpful in locating the pushbutton.

Among the four APS installed for this research, there were three different tones used as locator tones, one was a click tone, and one was an 880 Hz electronic tone, and two were a bright beep tone, all repeating at once per second. All APS across both cities received an approximately equal number of positive and negative comments, and no particular APS locator tone resulted in a higher percentage of participants finding the pushbutton. Participants said, after most trials, that they used the locator tone to help find the pushbutton, regardless of the nature of the locator tone.

Pushbutton Style

It is recommended that the APS have a clearly defined pushbutton that is tactually identifiable. Psychophysical tests provided no direct evidence of performance differences attributable to pushbutton style. However, style of the pushbutton was frequently mentioned when participants were asked what they liked most and least regarding each APS. The two APS having two inch diameter rounded buttons "that pushed" drew a number of positive comments to an open-ended question (s*ee Chapter 3*). It should be noted that APS with mechanical pushbuttons (providing the desired tactual feedback) may be more susceptible to vandalism than those with electronic (pressure-sensitive) pushbuttons.

Indirect evidence for difficulty in finding the two pushbuttons that were atypical, the flat-panel pushbutton, and the flat recessed circular pushbutton, is found in the latency to find and push the correct pushbutton. In the condition in which participants only had a general description of APS features, the two unusual pushbuttons took significantly longer to locate and push than the two buttons that were typical. The time included both the time to find the pole and the device and the time to locate and use the button on the device. However, when participants had specific information about and experience with the various pushbuttons, all differences in latency disappeared.

Tactile Arrow

It is recommended that tactile arrows be required on all pushbutton-integrated APS as indications of which crosswalk is controlled by which pushbutton. Tactile arrows are typically also used as an aid to alignment, however most users are unable to align with precision to tactile arrows. Style of arrow, within the range of the four APS tested, did not consistently make a difference. Therefore there is no recommendation for a specific type of arrow or location of the arrow, particularly since the *Draft Guidelines* include some specifications of arrow size and shape.

Results of subjective research (*see Chapter 3*) confirm that the tactile arrow is an important feature for helping APS users know which crosswalk is associated with a pushbutton. All mean ratings were positive for the question "The tactile arrow helped me know which pushbutton was for the correct street."

The performance measure that best indicates how effective the tactile arrows were at conveying which street was controlled by a pushbutton is the number of trials on which participants looked at the arrow on the incorrect pushbutton and correctly rejected it. In Tucson, although participants looked at the arrow on the incorrect pushbutton on 28 of 160 trials when general or specific information was provided, they correctly rejected the incorrect pushbutton on 100% of those trials. Participants in Charlotte looked at the arrow on the incorrect pushbutton on 63 of 160 trials, and rejected the incorrect pushbutton on 65% of those trials. (The difference between cities was probably due to the different levels of participant skill in independent travel, observed by researchers as inefficient or ineffective strategies for some tasks.) Participants in Charlotte were more successful in rejecting the incorrect pushbutton when they had specific information about the APS they were to encounter.

An additional subjective measure of the effectiveness of tactile arrows in communicating which crosswalk was controlled by a pushbutton was the ratings of agreement with the statement "I was sure I pushed the button for the street I wanted to cross." Participants responded positively to the statement on 60% of trials when they just had general information, and on 90% of trials when they had specific information. The increase in confidence, as well as in performance, following specific information was probably due to the brief training participants received interpreting arrow direction during their specific familiarization with demonstration devices.

Thus, the inclusion of a tactile arrow on APS quite successfully conveys which crosswalk is controlled by which pushbutton when users are accustomed to using arrows and understand their meaning. The arrow is also highly regarded for identifying which crosswalk is controlled by which pushbutton.

There were no significant differences attributable to style of arrow, with regard to correct rejection of the incorrect pushbutton. There were also no subjective differences related to the style of the arrow.

A different use of a tactile arrow is for aligning for crossing. However, mean ratings for the statement "The tactile arrow helped me align for crossing" were negative for all devices in Tucson, and slightly positive in Charlotte, showing no clear pattern of support for use of tactile arrows for this purpose. The data for alignment showed no differences attributable to style of arrow.

Precise alignment of tactile arrows with direction of travel on the associated crosswalk is nonetheless essential, because researchers observed that, at many crossings in Tucson and Charlotte, participants who used the arrow not only used it to confirm that the pushbutton was for the street they wanted to cross, but also used it as well as they could to align for crossing that street.

Actuation Indication

It is recommended that an audible actuation indication be required on pushbutton-integrated APS. This may be either a tone or a speech message. There is no support for specifying the nature of the actuation indication at this time.

The only data on the usefulness of the audible actuation indication is ratings of agreement with the statement "The tone or message was helpful in letting me know the button had been activated." Mean ratings were quite positive, ranging from 3.58 to 4.58 in Tucson and 4.28 to 4.61 in Charlotte, indicating a strong desire for an audible actuation indication (*see Chapter 3.*). There were no meaningful differences in ratings attributable to differences in actuation indications in either city. However, the indication message "Wait" received a number of positive comments on the open-ended question regarding most and least liked features. It received no negative comments.

Audible WALK Indication

The recommended WALK indication is a rapid tick signal, a signal that differs markedly from the locator tone in its repetition rate, and should be on for the duration of the walk interval except where the pedestrian signal rests in WALK, in which case it may be limited to approximately seven seconds. The WALK indication should repeat at ten times per second, while the locator tone repeats at once per second. However, accuracy in understanding which crossing is being signaled is dependent on excellent location of APS (*see below*) in which two APS at one corner are located on individual poles and spaced apart as described in *MUTCD* 4E.09.

In retrofit situations where it is necessary to place two APS on the same pole or closer than recommended, the WALK indication should be a speech message with the following format: "Oakdale, walk sign is on to cross Oakdale." The message should repeat for the duration of the walk interval (except where the pedestrian signal rests in WALK), and should be used in conjunction with a pushbutton information message.

Prompt initiation of crossing in response to the WALK indication contributes to the likelihood that crossings will be completed before steady DONT WALK, so the choice of WALK indication should be one which promotes fast starting to cross. Equally important is accuracy in understanding which crossing is being signaled. A fast start across the wrong street can be deadly. It is therefore even more important that the WALK indication result in accurate understanding of which crossing has the WALK signal. Research in this project addressed both of these issues, and concluded that the rapid tick WALK indication provides for both the fastest starts and the most accurate judgment regarding which crossing has the WALK signal—provided that the APS is located optimally. (*See General Installation Guidelines below.*)

There are three fundamental types of walk indications that are in use on pushbutton-integrated APS currently in use in the U.S.: cuckoo/chirp signals; rapid tick signals; and speech messages. All were included both in the research in Charlotte and Tucson (Chapter 3) and in research in Portland (Chapter 4). In Portland, all three kinds of indications were produced by the same APS. (The indications were switched by a hand-held controller during the course of the experiment.) Because there were no other device differences in Portland, the results are free from confounds with other device characteristics.

In Portland, both the location of pushbutton-integrated APS and APS WALK indications were explored. Cuckoo/rapid tick and rapid tick signals only were compared where two pushbuttons were located on two different poles at a corner, separated by approximately ten feet. Cuckoo/rapid tick and speech messages were compared where two pushbuttons were located on the same pole. Participants performed two tasks in preparation for crossings (but did not make crossings independently). They located the pushbutton to cross the perpendicular street, and they indicated when the WALK signal came on for that street. Measures that are meaningful in the context of specifying a WALK indication are speed and accuracy in indicating when the correct WALK indication appeared.

There were significant differences in response time and accuracy attributable to the nature of the WALK. The rapid tick used on the two-pole corners produced the fastest and most accurate responses to the WALK indication. When two pushbuttons were on the same pole, the fastest responses were to cuckoo/rapid tick signals, but responses were more accurate to speech messages.

Research in Tucson and Charlotte confirmed that when users knew the type of device they were going to be using, the fastest starts were for the APS having rapid ticks. In Tucson, initiation of crossings having the rapid tick WALK indication were significantly faster than crossings having other indications, the pattern was the same in Charlotte, although results were not statistically significant. There was no measure for accuracy in identifying the crossing being signaled by the WALK indication.

Vibrotactile WALK Indication

It is recommended that every pushbutton-integrated APS have a vibrating arrow to indicate the WALK interval to persons who have both vision and hearing impairments (deaf-blind). All the pushbutton-integrated APS currently marketed in the U.S. have this feature, and it is the accepted means of providing pedestrian signal information to deaf-blind pedestrians in the U.S.

It was the intent of this project to include a total of eight to ten participants who were deaf-blind and who traveled and crossed streets independently. However it was not possible to recruit this number of deaf-blind participants in the two cities involved. Nonetheless, there were seven participants who reported, or who were suspected of having, some degree of hearing loss in addition to blindness.

Participants used the vibrotactile arrow on a total of 38 trials in the experiment. Some of this use was likely to have been by persons with no hearing loss who wanted to confirm which APS was providing the WALK signal.

The mean subjective rating regarding the helpfulness of the vibratory WALK signal was 6.36 in Tucson and 4.37 in Charlotte, both strongly positive. There were positive comments regarding the vibrotactile arrow in response to an open-ended question asking participants to identify what APS features they liked most and least. There were no negative comments.

Response to Ambient Sound

All APS should be responsive to ambient sound. APS volume must be loud enough to be heard by users, but quiet enough to be tolerated by neighbors. Current Guidance provided in *MUTCD* 4E is the best that can be offered at this time.

All pushbutton-integrated APS currently marketed in the U.S. are responsive to ambient sound, according to guidance in *MUTCD* 2003 4E.

> 4E.06 – The accessible walk signal tone should be no louder than the locator tone, except when there is optional activation to provide a louder signal tone for a single pedestrian phase.
>
> Automatic volume adjustment in response to ambient sound should be provided up to a maximum volume of 89 dBA. Where automatic volume adjustment is used, tones should be no more than 5 dBA louder than ambient sound.
>
> 4E.09 – Pushbutton locator tones should be intensity responsive to ambient sound, and be audible 1.8 to 3.7 m (6 to 12 ft) from the pushbutton, or to the building line, whichever is less.

APS manufacturers differ in the ways in which they accomplish the automatic volume adjustment. First, the rates for sampling ambient sound vary. Second, the algorithm varies for how fast the signal responds to increases in ambient sound and in how fast the increased volume decays. Third, sensitivity of the automatic volume adjustment differs. In addition, the microphone and its housing also affect response to ambient sound.

It will never be possible to satisfy the volume requirements of all users, while causing minimal noise pollution. It was apparent in the research in Tucson and Charlotte that some participants found some sounds too loud, and others found them too quiet. The most common response was that they were too quiet. Nonetheless one neighbor strongly objected to the sound of the APS on the corner where he lives, and it had to be turned down. Differences in user need for APS volume make the possibility of individual actuation of a louder signal for one pedestrian phase appealing. APS can be adjusted to be very quiet, yet offer users the opportunity to elevate the volume when they desire it (*see Louder Signal below*).

Secondary APS Features

Pushbutton Information Message

A pushbutton information message is recommended, as it is particularly helpful to some users. A pushbutton information message is essential on APS where the WALK indication is a speech message. This is a message emitted from the APS when the button is pushed during flashing or steady DONT WALK intervals. The message should be "Wait, to cross Oakdale at North Avenue." (Emphasis and pause after Wait are intentional.) This message provides users with the name of the street controlled by that pushbutton and the name of the other street at the intersection. The message may come on with any button press during DONT WALK intervals, but it may also come on only in response to an extended button press. The message should sound immediately if the pushbutton is depressed for one second or longer (*34*).

In Tucson and Charlotte, during trials when they had only a general description of APS features, few participants used the extended button press that was required to actuate the pushbutton information message. However, following hands-on familiarization with each of the three APS having this feature, participants chose to use the feature on more than 70% of crossings in both cities. When asked to mention features they liked most or least on each APS, there were a number of positive comments regarding the pushbutton information message, and there were no negative comments. Mean ratings for the statement "The pushbutton information message was easy to understand." were all at or above 4.0.

Louder Signal (Beaconing Signal)

The inclusion of the opportunity to obtain louder signals during the pedestrian phase is recommended. This feature may assist some pedestrians who are blind or who have low vision, including those who have hearing loss, in locating the opposite corner. The louder signal is actuated by an extended button press, and operates only during the next pedestrian phase. It includes both the WALK signal and the subsequent locator tone for that pedestrian phase. Because it requires special actuation, and is operative for a single pedestrian phase, the louder signal is rarely obtrusive in the environment, while it is available to users when they have need for it.

Because the majority of pedestrians with blindness or low vision are over the age of 60, by which age they also have some upper frequency (age-related) hearing loss, and because the population of older pedestrians with vision impairments is increasing, the availability of louder signals on request, is potentially useful to a great many pedestrians who are blind or who have low vision. By 2010, it is estimated that there will be 20 million people in the U.S. over the age of 45 who are blind or who have low vision.

In the Tucson and Charlotte research, there was only one APS that had a louder signal available at the time of the experiment. The louder signal was requested by the same extended button push that actuated the pushbutton information message when it was present, so data on use of the extended button press does not clearly indicate whether the extended press was used to actuate the pushbutton information message, the louder signal, or both. Therefore the best demonstration regarding the usefulness and desirability of the louder beaconing feature, available on request, is from subjective data.

When asked to rate the extent of their agreement with the sentence, "The louder signal feature was helpful." the mean rating was positive (3.94), with only four participants giving it a negative rating.

Tactile Map of Crosswalk

A tactile map of what will be encountered in a crosswalk may be helpful to some pedestrians who are blind or who have low vision, at some crossings. Where used, it should have standard symbols. Refer to the *Guide* for recommended symbols for tactile crosswalk maps).

A tactile map of the associated crosswalk was available on only one APS used in this research, and it was a feature that was totally unfamiliar to all participants. Tactile maps, on the whole, are only moderately familiar to and are only occasionally used by people who are blind. Nonetheless, after participants were familiarized with this feature, 17% chose to use the map in Tucson, and 28% in Charlotte.

Participants were asked to rate the extent of their agreement with the statement: "The crossing map was useful and easy to understand." Mean ratings were 4.0 in Tucson, and 4.2 in Charlotte, indicating that the map was relatively desirable and easy to read. With additional experience with this particular map, it is possible that many people would find it easy to read and understand. We have no data to indicate with certainty what proportion of users would choose to use such a map at unfamiliar crossings, and it is unlikely that it would be used when making familiar crossings.

GENERAL INSTALLATION GUIDELINES

As for selection of APS features, a single standard for installation is not workable in the U.S., particularly for retrofit situations. Engineering judgment is required to determine the best way to install APS at a given intersection and crossing. Differences in curb radius, width of right-of-way, presence of parkway, curb ramp design and location, and existing infrastructure on corners make each installation different.

Described below are two different installation scenarios that will be applicable in most situations:

- <u>Two Pushbuttons on One Corner, Mounted on Two Poles – Rapid Tick Walk Indication</u> This design will apply most often in new construction and alterations, particularly when other alterations are being done on a corner, two poles should be installed for pushbutton-integrated APS, as described in detail below.
- <u>Two Pushbuttons on One Corner, Mounted on a Single Pole – Speech Walk Indication</u> This design will apply most often where it is technically infeasible because of limited right-of-way, topography, or locations of other essential equipment on corners, to install two pushbutton-integrated APS on a corner on separate poles. However, the APS features required for this situation are different than where each pushbutton-integrated APS is on its own pole.

Two Pushbuttons on One Corner, Mounted on Two Poles – Rapid Tick

Optimal location for pushbutton-integrated APS is between the edge of the crosswalk line (extended) furthest from the center of the intersection and the side of the curb ramp. APS should be between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement. The control face and tactile arrow should be carefully aligned with the direction of travel on the associated crosswalk. In order to provide wheelchair users with access to the pushbutton, all pushbuttons shall be located adjacent to a level all-weather surface.

Pushbutton-integrated APS shall be a maximum of 5 feet from the edge of the crosswalk line (extended) farthest from the center of the intersection. They shall be a maximum of 10 feet from the edge of the curb, shoulder, or pavement. At corners of signalized locations where two pedestrian pushbuttons are provided, the pushbuttons should be separated by a distance of at least 10 feet (*see Figure 7-2*).

A rapid tick WALK indication is recommended for installations following these guidelines for location and the use of two poles on a corner.

The research conducted in Portland (*see Chapter 4*) found that where pushbutton-integrated APS were mounted on separate poles, near the crosswalk line furthest from the center of the intersection (approximately 3 feet from the curb line and approximately 10 feet apart), speed and accuracy in judging when the correct crosswalk had the WALK signal was significantly better than when APS were located according to other criteria (*see corner C, Figure 7-3*). Moreover, accuracy in identifying the onset of the correct WALK signal was significantly greater when both APS on the same corner used the same tone (rapid tick) than when the two APS used two different tones (cuckoo and rapid tick).

When pushbuttons are precisely and consistently located in this way, identification of which crossing is being signaled can be based solely on which pushbutton the WALK signal comes from. There is no need to remember a code (such as cuckoo for a north/south crossing and rapid tick for an east/west crossing) or to understand speech messages. Figure 7-4 provides examples of pole arrangements that meet the requirements for corners having different geometries.

Two Pushbuttons on One Corner,

Mounted on a Single Pole – Speech

When it is necessary to mount two pushbuttons on one pole, it is recommended that they should be required to use speech message WALK signals rather than tone signals. Moreover, to be sure users know the street name to listen for in the WALK message,

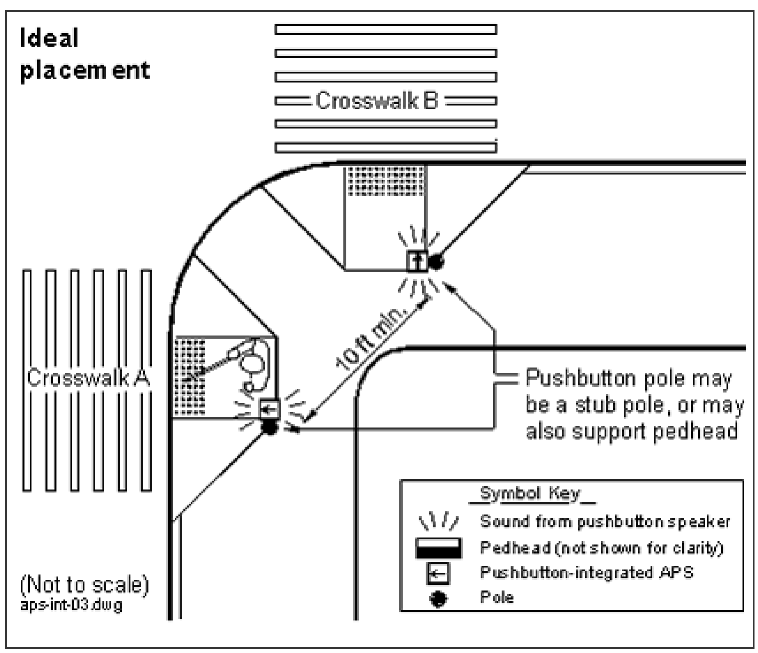

Figure 7-2. Optimal location of pushbutton-integrated APS.

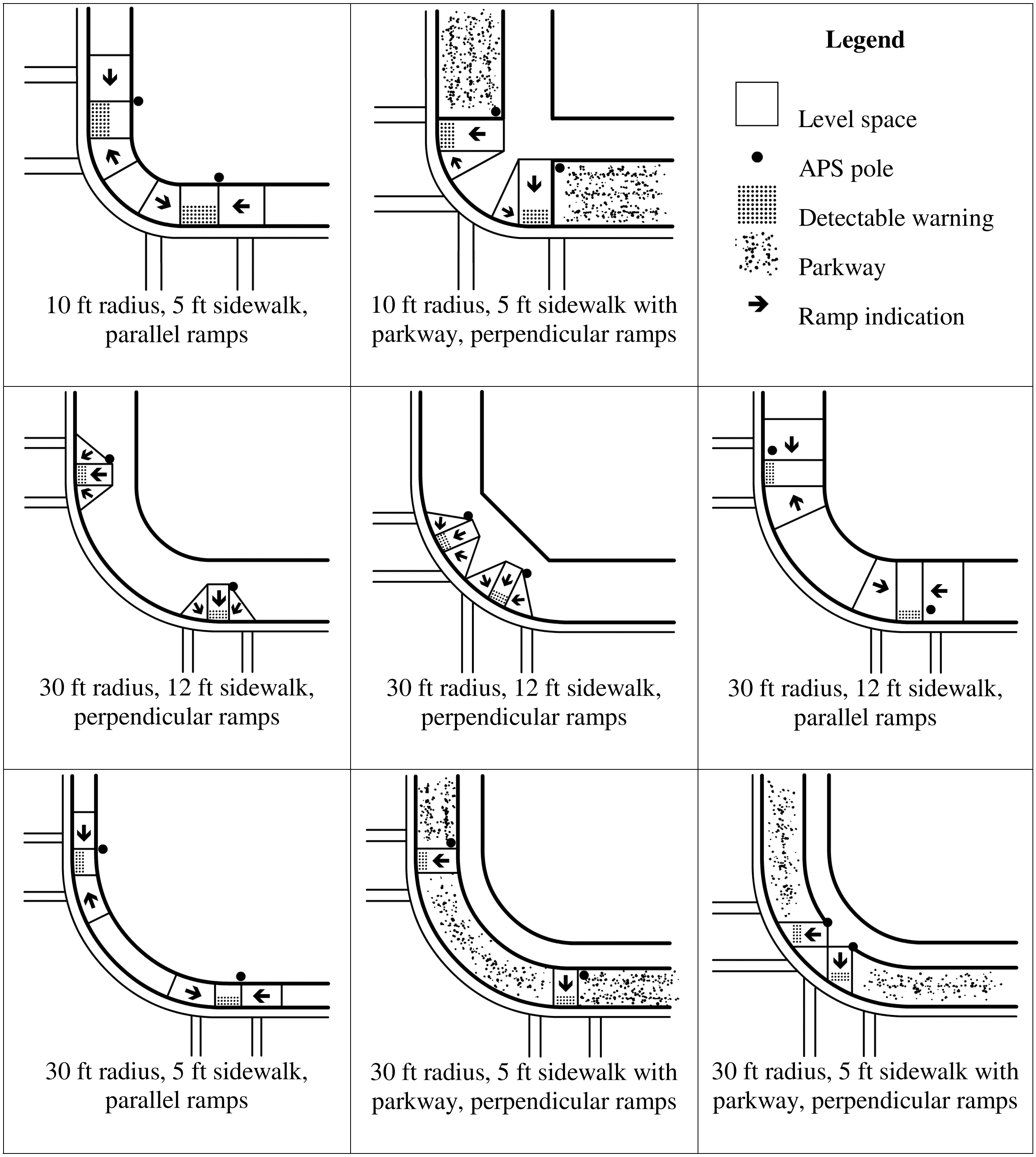

Figure 7-3. Examples of locations for pushbutton-integrated APS on corners having various geometries.

pushbutton information messages identifying the intersection and the street to be crossed should also be required.

Research in Portland demonstrated that response to identifying which crosswalk had the WALK signal was significantly more accurate when the APS provided speech WALK signals from both APS than when the APS used two tones – cuckoo and rapid tick (see Chapter 4). The same tone (rapid tick) system was not used in the research when there were two pushbuttons on one pole because there would be no way for users to know which pushbutton was signaling, other than use of the vibrating arrow. When two pushbuttons are on a single pole, and particularly when that pole is at the back of the sidewalk, it is not practical for the pedestrian who is blind or who has low vision to stand with a hand on the vibrating arrow while simultaneously preparing to cross.

CAREFUL VOLUME ADJUSTMENT

Volume adjustment of APS is both very important and somewhat difficult. The *MUTCD* provides guidance for APS (*see above under Response to Ambient Sound*). There is no evidence provided by this research that the current *MUTCD* guidance should be changed. But there was certainly evidence that sound level is closely related to such tasks as recognizing the presence and location of a locator tone, quickly responding to the onset of a WALK signal, and walking straight across the street.

MUTCD guidance discusses a maximum sound level that a locator tone or walk tone should exceed ambient sound (5 dBA), and an absolute maximum sound level in decibels on the A scale (89 dBA). While manufacturers can limit devices to a maximum of 89 dBA, setting an automatic sound level adjustment system to consistently provide a signal that is approximately 5 dBA above ambient sound is more art than science at the present time. Reasonably priced sound level meters, which are amenable to use in the field, are not capable of accurately measuring the sound levels of very short bursts of sound in comparison with more persistent, but still widely varying, sound levels of vehicles.

A more useful measure in the field is the guidance that APS sounds should be audible 6 to 12 feet from the APS, or to the building line, whichever is less. However, audible distance is a subjective measure that is inevitably influenced by each listener's own hearing, and by such influences on the audible distance of sounds as wind, humidity, and nearby reflective surfaces. Fine-tuning of sound levels in the field should be planned for in every APS installation. Visits may need to be made in both peak and off-peak hours to get a setting that is appropriate in both situations.

There are some intersection geometries that make careful attention to sound level settings critical. Where a signalized intersection has a right turn lane that is not signalized, it is very important that an APS on a splitter island not be audible from across the unsignalized turn lane. If it the APS is heard from the opposite side of the unsignalized turn lane, a pedestrian who is blind or who has low vision may mistakenly believe that the APS indicates a WALK interval for the unsignalized lane.

At intersections having split phasing, it is very important that APS signals not be audible across the street. For example, a northbound pedestrian who is blind or who has low vision is waiting to cross an east/west street, and the north/south street is to her left (she is at the east crosswalk). She hears the APS on the opposite side of the north/south street (for the west crosswalk) and assumes that there is a pedestrian phase for all pedestrians crossing the east/west street. She may cross directly into the path of southbound vehicles turning left across her path, which have a protected green left turn arrow.

SUMMARY

Experience with the installation and evaluation of APS indicates that particular attention is necessary in the installation process. Engineers and signal technicians need to take additional care in planning installations and making adjustments for the location of the pushbutton. For the devices to be effective for pedestrians with visual impairments, details matter. For example, the APS needs to be carefully positioned on the pole so that the tactile arrows are aligned with the intended crossing direction. There is also a need to become familiar with adjusting volume levels of the various tones and messages. It may be necessary to reevaluate the sound level of devices at peak and off-peak hours to assure that the volume is properly adjusted. It is also important to be aware of the effect of installing an APS and not completing sound level adjustments before leaving. In one installation during this research, an APS was installed and became operational on Friday. The volume adjustment was not done until Monday, which resulted in a very loud locator tone operating over the weekend. By Monday, nearby residents were quite negative about the APS, which could have been avoided by either leaving it off until the technician had time to adjust the volume correctly, or adjusting the volume at the time of installation.

CHAPTER **8**

INTERSECTION PRIORITIZATION TOOL

INTRODUCTION

One of the first questions that must be answered by local engineers and others responsible for the installation of APS devices is when and where is it appropriate to install such devices in other than new construction and alteration/reconstruction. In many cases, there is a need to prioritize intersections for APS installations. The *MUTCD* currently provides some guidance on this matter, but a more definitive approach is required to assist practitioners.

Several cities in the U.S. have highly structured rating scales that they have found useful in making decisions about which intersections or crosswalks should have APS (*40*). Factors that are typically included are:

- proximity to a facility for persons who are blind;
- proximity to alternate crossings;
- proximity to transit stops;
- proximity to key facilities used by all pedestrians;
- intersection geometry;
- vehicle speed;
- traffic volume (both heavy and light);
- number of vehicles per surge per crosswalk
- signal complexity
- pedestrian crash records;
- demonstrated need or user request;
- presence of pedestrian push buttons;
- surrounding land use and neighborhood acceptance; and
- existence of a signal which is susceptible to retrofitting (consideration should be given to both the physical infrastructure and the operational parameters, i.e., phasing, splits, and cycle length).

One of the weaknesses with the previous tools was a lack of validation with respect to the scoring system and the relative weights assigned to the different variables. In this project, an effort was made to develop a tool, have practitioners apply the tool, and then compare the objective ratings achieved with the tool to the subjective ratings of pedestrians with visual impairments and orientation and mobility (O&M) specialists. Provided in the remainder of this chapter is a discussion of the methodology used in the development of the tool. The tool itself, which includes a set of instructions for application, is provided in the companion document, *Accessible Pedestrian Signals: A Guide to Best Practice*, and is also available on the web at www.walkinginfo.org/aps.

FIELD DATA COLLECTION

TABLE 8-1 Number of crossings rated in each city

City	Number of Crossings
Charlotte, NC	33
Tucson, AZ	36
Cambridge, MA	40

In each of three cities (Cambridge, Tucson, and Charlotte), a project staff member and one or more local transportation engineers and/or planners applied the Intersection Prioritization Tool to rate crosswalks at ten intersections. The number of crossings in each city is shown in Table 8-1. These intersections were selected to capture the full range of crossing difficulty that may be experienced by a blind pedestrian, from very simple two-phase signals at relatively small intersections to large intersections with multiple phases and complex geometrics. The scores from the tool were used to rank-order the crossings from most difficult (and in need of an APS) to least difficult.

A local O&M specialist and two blind pedestrians who were skilled independent travelers and who were selected by organizations of blind persons in that locale used their expert judgment to review each crossing and also prioritize the crosswalks in terms of difficulty and in most need of an APS. Following the evaluation of all crossings in each city, the evaluators met to compare their results, discuss areas of agreement and disagreement with respect to what made each crossing easy or difficult, and to suggest ways in which the Intersection Prioritization Tool could be revised to yield results more consistent with the subjective scores of the blind travelers and O&M specialists.

CALIBRATION AND MODIFICATION

The objective scores from the practitioners and the subjective scores from the blind pedestrians and O&M specialists were used to calibrate and modify the tool. The goal of this task was to create a tool that could take observable characteristics of a pedestrian crossing and produce a score that would reflect the relative crossing difficulty and subsequent need for APS. Appropriately designed, the tool would include higher point values for characteristics that indicated a greater need for APS. The resulting scores could then be used to develop a prioritization of crossings based on need for APS.

The point values given to the various site characteristics included on the tool were initially drawn from the research team's knowledge of the relative importance of the characteristics and from the other similar tools that were previously mentioned. Starting with those initial point values, the calibration of the prioritization tool became an iterative process.

The characteristics of each crossing, which were captured in the field on paper, were entered into an electronic version (Excel workbook) of the prioritization tool. These data included intersection-wide characteristics, such as the type of signalization, and crosswalk-specific characteristics, such as crossing width and curb ramp configuration. Once all characteristics were entered, the prioritization tool calibration followed the iterative process explained below.

Step 1 – Use the Prioritization Tool to Calculate Scores for Each Crosswalk

The prioritization tool assigns point values based on the influence of a particular variable on a blind pedestrian's travel on the crossing. Higher point values indicate a greater difficulty for the blind individual and therefore a greater potential benefit from an APS installation. The score for a particular crosswalk is a sum of two scores – the score for the intersection at which the crosswalk is located and a score for the crosswalk itself. The variables included on each worksheet are as follows:

Intersection Worksheet Variables

- Configuration
- Signalization
- Proximity to transit facilities
- Proximity to facilities for the visually impaired
- Proximity to major pedestrian attractions

Crossing Worksheet Variables

- Crossing width
- Speed limit
- Approach/crossing geometrics
- Pedestrian signal control
- Vehicle signal control
- Off-peak traffic presence
- Proximity to alternative crossing with APS
- Pedestrian pushbutton location
- Requests for APS

Step 2 – Rank Crosswalks by Prioritization Tool Score

The crosswalks are ranked from greatest to least according to the score from the prioritization tool.

Step 3 – Compare Prioritization Tool Rankings to Rankings Given by Evaluators

It was then necessary to compare the prioritization tool rankings to the evaluator rankings to determine how well the tool was emulating the subjective rankings of the visually-impaired pedestrians and O&M specialists. The calibration of the tool was performed by looking at the top group of sites (greatest need for APS) and the bottom group of sites (least need for APS) in each set of rankings. Since each evaluator has a different priority ranking of sites, it cannot be expected that the tool would match the evaluator rankings place-for-place. Instead, the calibration process seeks to have as many sites as possible in the top group of the prioritization tool rankings also be found in the top groups of the evaluator rankings, and likewise for the bottom group.

The method used in this calibration took each site in the prioritization tool ranking and counted how many times the site appeared in the evaluator rankings. The sum of these counts reflected how well the prioritization tool rankings compared to the evaluator rankings. The goal of the calibration was to maximize this sum.

Step 4 – Adjust Point Values; Repeat Steps 1 through 3

To attempt to maximize the sum obtained at Step 3, the point value for a particular variable was sometimes adjusted. For instance, if the presence of islands or medians on a crosswalk was worth 3 points in the previous run, that value may have been increased to 4 to determine what effect the point value increase had on the overall fit of the prioritization tool. Once any point value was changed, Steps 1 through 3 were run again. Point values for different characteristics were increased and decreased until the sum produced at Step 3 could not be increased.

Adjustment of point values was guided in large part by the comments made by the evaluators on each crosswalk. For instance, if the evaluators made comments to the effect that the presence of a vehicular right-turn-only phase increased their concern about a particular crossing, then the point value for right-turn-only phase would be increased to better align the tool with the evaluator rankings. Point values for characteristics that were not mentioned by an evaluator were adjusted on an exploratory basis.

Other Point Value Adjustments

Some variables could not be included in the calibration process, due to lack of data or small sample size. In these cases, point values were assigned based on the team's assessment of the hazard of each variable with respect to other variables that had been calibrated.

Data were not available for the following variables:

- Proximity of transit facilities
- Distance to facilities for visually impaired
- Distance to major pedestrian attraction
- Leading pedestrian interval
- Distance to alternative APS crossing
- Requests for APS

There were too few crossings with the following characteristics to allow for point calibration:

- Non-concurrent WALK signal
- Channelized right turn lane under signal control

SUMMARY

The final, calibrated prioritization tool provides practitioners with a method for prioritizing locations for APS installation. The forms and instructions for the tool can be found in the companion document, *Accessible Pedestrian Signals: A Guide to Best Practice*.

CHAPTER 9

TRAINING AND RESOURCES

INTRODUCTION

As APSs are being installed in more and more cities, there is a need for guidance for decision-makers and practitioners. To this end, training materials were developed to provide guidance on when, where, and how APS devices should be installed. The materials consist of the companion resource document and a set of PowerPoint presentations that can be covered in a one-day course. These materials were organized to meet the needs of three specific audiences:

- Technicians, who are responsible for the installation, operation, and maintenance;
- Engineers/Administrators, who are involved in making decisions about when and where APS devices are needed and the features required; and
- Orientation and Mobility Specialists, who train pedestrians to use the devices and serve as advisors to the engineers.

The companion document, *Accessible Pedestrian Signals: A Guide to Best Practice*, is intended as a stand-alone document that contains all the training information developed in this project. It is also intended to be a resource document to accompany the one-day training course. While the course covers the basics of each topic area, the *Guide* contains more detail. In addition to the topics covered in the course (see below), the *Guide* also contains chapters on public education on APS, case studies in the U.S. and abroad, product-specific information, and an instruction manual for the APS Prioritization Tool.

The training course developed as part of this project is intended to be a one-day session that will cover the issues related to travel by those who are blind; traffic signalization; and when, where, and how APS devices should be installed. The course makes use of images, drawings, videos, and in-class demonstrations, as well as examples from real-world installations. The PowerPoint presentations contain scripts of the instructors' dialogue so that they may be read and understood outside of the course. Provided below is an outline of the modules covered in the training course and a brief description of the content of each module.

MODULE DESCRIPTIONS

Module A

Accessible Pedestrian Signals and Accessible Public Rights-of-Way (all audiences)

- Purpose and Description of APS – why APS are needed, scope of problems addressed, terminology
- History of Legislation and Current Guidance – TEA-21, *MUTCD*, 1973 Rehab Act, ADA, Draft PROWAG
- Resources – Federal agencies (FHWA, Access Board), consumer groups (ACB, NFB), professional organizations, local agencies

Module B

Travel Needs of Blind/Low-Vision Pedestrians (targeted at engineers)

- Blindness and Vision Loss – types of vision loss, definitions
- Travel Techniques and Aids – types of aids (dog guides, canes, etc.), O&M training
- Street crossings – analysis of situation, crossing techniques, crossing cues
- Challenges and Problems – examples (split phasing, mid-block signals, etc.)

Understanding Traffic Signals and Modern Intersection Design (targeted at O&M professionals)

- Terminology (e.g., cycles, phases, etc.)
- Signal Warrants (understanding why a signal may be installed)
- Type of Operation (pretimed, semi-actuated, full-actuated)
- Signal Timing (timing plans, walking speeds, understanding signal displays)

Module C

APS Features (all audiences)

- APS Features – locator tones, WALK interval tones and speech messages, vibrotactile feedback, tactile arrow, ambient noise adjustment, tactile maps, etc.
- Recommended Features – recommendations on type of WALK indication, etc (from project research)

Module D

When to Install APS (targeted at engineers)

- Where APS are required – current guidance
- Application of ADA – new construction, alteration projects, existing facilities (retrofit)

APS Prioritization Tool (targeted at engineers)

- Overview – intended use and audience for Prioritization Tool
- Development – brief overview of the development and validation process
- Intersection and Crosswalk Worksheets – walks through each variable that was included in the Tool
- Example of Prioritization Tool use

Module E

Designing Installations (targeted at engineers)

- General Considerations for Installations – pole location, intersection geometry
- Design Guidance for New Installations – Draft PROWAG, *MUTCD*
- Designing Installations in Retrofit Situations – how to conduct site evaluation and needs assessment; how to design in a non-ideal situation

Design Exercises

- Before/after photos of APS installations for group discussion

Module F

Installation, Operation, and Maintenance (targeted at technicians)

- Installation – infrastructure (poles, wiring, and other hardware), device mounting, adjustments (sound levels, ambient noise response, etc.)
- Adjusting Sound Settings – how to set volume for locator tone, WALK indication, etc.
- Post-Installation Checklist
- Maintenance – what to check and when

CHAPTER **10**

CONCLUSIONS

In 2000, two sections on APS were added to the *Manual on Uniform Traffic Control Devices (MUTCD)*, which became the first set of national standards for APS in the U.S. The *MUTCD* defines an APS as "…a device that communicates information about pedestrian timing in nonvisual format such as audible tones, verbal messages, and/or vibrating surfaces" (*1*). The rest of the *MUTCD* language provides standards, guidance and options, but does not specify walk messages or address many possible device features. In 2002, the U.S. Architectural and Transportation Barriers Compliance Board (Access Board) published draft recommendations and requirements for APS installation in *Draft Guidelines for Accessible Public Rights-of-Way (2).* The *Draft Guidelines* call for the use of pushbutton-integrated signals that provide audible **and** vibrotactile indications of the walk interval.

This research was the basis for more precise and well-supported standards and guidance on APS for inclusion in the *MUTCD* and the U.S. Access Board *Guidelines.* The research results have been forwarded to the Signals Technical Committee of the NCUTCD and to the Federal Highway Administration (FHWA) as background and support for changes in Part 4 of the *MUTCD*, as well as to the U.S. Access Board.

Two separate research experiments were undertaken in this project to develop the recommended guidelines for APS features and APS installation. The purpose of first study was to determine the effect of APS features, which are commonly found on most of the APS equipment marketed in the U.S., on the ability of pedestrians who are blind to locate and use pushbuttons, determine time to cross, determine appropriate heading for crossing, and maintain alignment while crossing. The second study was conducted to evaluate the effects of pole location, number of poles used in relation to number of APS devices, and type of WALK indication on the ability of pedestrians with visual or cognitive impairments to determine which crosswalk at a corner had the WALK signal. In addition to these two research studies, additional information about APS performance was gleaned from an engineering evaluation of the equipment installed during this research study, as well as from a series of cold weather case studies.

The result of these efforts is a set of recommended guidelines to help practitioners choose the most appropriate APS features to fit the needs of each application and make sound installation decisions. The recommendations are briefly summarized below; a more extensive description and justification for each can be found in Chapter 5.

Primary APS Features

Primary APS features are those that, on the basis of psychophysical research as well as subjective data, should be included in all pushbutton-integrated APS, regardless of intersection geometry or signalization.

Pushbutton Locator Tone – It is recommended that all pushbutton-integrated APS be required to have pushbutton locator tones that sound at one second intervals during flashing and steady DONT WALK intervals, as described in *MUTCD* 4E.09. No particular tone is recommended.

Pushbutton Style – Pushbuttons should be clearly defined and be tactually identifiable.

Tactile Arrow – It is recommended that tactile arrows be required on all pushbutton-integrated APS as indications of which crosswalk is controlled by which pushbutton. There is no recommendation for changes to arrow specifications currently provided in the *Draft Guidelines*.

Actuation Indication – It is recommended that an audible actuation indication be required on pushbutton-integrated APS. This may be either a tone or a speech message.

Audible WALK Indication – The recommended WALK indication is a rapid tick signal, a signal that differs markedly from the locator tone in its repetition rate, and should be on for the duration of the walk interval except where the pedestrian signal rests in WALK, in which case it may be limited to approximately seven seconds. The WALK indication should repeat at ten times per second, while the locator tone repeats at once per second. However, accuracy in understanding which crossing is being signaled is dependent on excellent location of APS (see below) in which two APS at one corner are located on individual poles and spaced apart as described in *MUTCD* 4E.09.

Vibrotactile WALK Indication – It is recommended that every pushbutton-integrated APS have a vibrating arrow to indicate the WALK interval to persons who have both vision and hearing impairments (deaf-blind).

Responsive to Ambient Sound – All APS should be responsive to ambient sound. APS volume must be loud enough to be heard by users, but quiet enough to be tolerated by neighbors. All pushbutton-integrated APS currently marketed in the U.S. are responsive to ambient sound, according to guidance in *MUTCD* 2003, Section 4E, which remains the best that can be offered at this time.

Secondary APS Features

Secondary features are those that have been shown to facilitate crossings by some pedestrians who are blind, but which may 1) not be indicated for use at all intersections, 2) not be desired or needed by all pedestrians who are blind or who have low vision, or 3) have limited research support.

Pushbutton Information Message – A pushbutton information message is recommended, as it is particularly helpful to some users. A pushbutton information message is essential on APS where the WALK indication is a speech message. This is a message emitted from the APS when the button is pushed during flashing or steady DONT WALK intervals. The message should be "Wait, to cross Oakdale at North Avenue." (Emphasis and pause after Wait are intentional.) This message provides users with the name of the street controlled by that pushbutton and the name of the other street at the intersection. The message is typically called with an extended button press, (pushbutton is depressed for one second or longer) during DONT WALK intervals (*34*).

Louder Signal (Audible Beaconing) – The inclusion of the opportunity to obtain louder signals during the pedestrian phase is recommended. This feature may assist some pedestrians who are blind or who have low vision, including those who have hearing loss, in locating the opposite corner. The louder signal is actuated by an extended button press, and operates only during the next pedestrian phase. It includes both the WALK signal and the subsequent locator tone for that pedestrian phase.

Tactile Map of Crosswalk – A tactile map of what will be encountered in a crosswalk may be helpful to some pedestrians who are blind or who have low vision, at some crossings. Where used, it should have standard symbols (*see Figure 5-1 for recommended symbols for tactile crosswalk maps*).

Installation Guidance

A single standard for installation is not workable in the U.S., particularly for retrofit situations. Engineering judgment is required to determine the best way to install APS at a given intersection and crossing. Differences in curb radius, width of right-of-way, presence of parkway, curb ramp design and location, and existing infrastructure on corners make each installation different. The recommendations summarized below apply to two types of installation scenarios and are intended to provide general guidance to the practitioner. For more details on and the justification for these recommendations, refer to Chapter 5.

Two Pushbuttons on One Corner, Mounted on Two Poles – Rapid Tick

This design will apply most often in new construction and major alterations that result in reconstruction of the corners of the intersection (e.g., new sidewalks, curb ramps, signal poles, etc.). In this case, two poles should be installed on each corner with pushbutton-integrated APS on each pole.

Optimal location for the pushbutton-integrated APS is between the edge of the crosswalk line (extended) furthest from the center of the intersection and the side of the curb ramp. APS should be between 1.5 feet and 6 feet from the edge of the curb, shoulder, or pavement. The control face and tactile arrow should be carefully aligned with the direction of travel on the associated crosswalk. In order to provide wheelchair users with access to the pushbutton, all pushbuttons shall be located adjacent to a level all-weather surface.

Pushbutton-integrated APS shall be a maximum of 5 feet from the edge of the crosswalk line (extended) farthest from the center of the intersection. They shall be a maximum of 10 feet from the edge of the curb, shoulder, or pavement. In this two-pole scenario, the pushbuttons should be separated by a distance of at least 10 feet.

A rapid tick WALK indication is recommended for installations following these guidelines. When pushbuttons are precisely and consistently located in this way, identification of which crossing is being signaled can be based solely on which pushbutton the WALK signal comes from. There is no need to understand speech messages or to remember a code (such as cuckoo for a north/south crossing and rapid tick for an east/west crossing).

Two Pushbuttons on One Corner, Mounted on a Single Pole – Speech

This design will apply most often where it is technically infeasible because of limited right-of-way, topography, or locations of other essential equipment on corners, to install two pushbutton-integrated APS on a corner on separate poles. However, the APS features required for this situation are different than where each pushbutton-integrated APS is on its own pole.

For this one-pole scenario, it is recommended that the APS be required to use speech message WALK signals rather than tone signals. Moreover, to be sure users know the street name to listen for in the WALK message, pushbutton information messages identifying the intersection and the street to be crossed are also necessary. Wording of speech WALK indications and pushbutton information messages should conform to recommended format (see Chapter 7: Recommended Guidelines).

Volume Adjustment

Volume adjustment of APS is both very important and somewhat difficult. The *MUTCD* Guidance discusses a maximum sound level by which a pushbutton locator tone or walk tone should exceed ambient sound (5 dBA), and an absolute maximum sound level in decibels on the A scale (89 dBA). While manufacturers can limit devices to a maximum of 89 dBA, setting an automatic sound level adjustment system to consistently provide a signal that is approximately 5 dBA above ambient sound is more art than science at the present time.

A more useful measure in the field is the guidance that APS sounds should be audible 6 to 12 feet from the APS, or to the building line, whichever is less. However, audible distance is a subjective measure that is inevitably influenced by each listener's own hearing, and by such influences on the audible distance of sounds as wind, humidity, and nearby reflective surfaces. Fine-tuning of sound levels in the field should be planned for in every APS installation. Visits may need to be made in both peak and off-peak hours to get a setting that is appropriate in both situations.

INTERSECTION PRIORITIZATION

One of the first questions that must be answered by local engineers and others responsible for the installation of APS devices is when and where is it appropriate to install such devices in other than new construction and alteration/reconstruction. In many cases, there is a need to prioritize intersections for APS installations. The *MUTCD* currently provides some guidance on this matter, but a more definitive approach is needed by practitioners.

As part of this research effort, a tool was developed, applied by practitioners, and then validated by comparing the objective ratings achieved with the tool to the subjective ratings of pedestrians with visual impairments and orientation and mobility (O&M) specialists. The tool itself, which includes a set of instructions for application, is provided in the companion document, *Accessible Pedestrian Signals: A Guide to Best Practice*, and is also available on the web at www.walkinginfo.org/aps.

TRAINING AND RESOURCES

Training materials were developed to provide guidance on where and how APS should be installed. The training is directed at three main audiences – traffic engineers, O&M instructors, and signal technicians. The materials consist of a set of PowerPoint presentations that comprise a one-day training course and a companion resource document, *Accessible Pedestrian Signals: A Guide to Best Practice*.

ADDITIONAL RESEARCH NEEDED

The results of this research have produced a set of recommended guidelines for APS installation and operation that will make it easier and safer for pedestrians with visual impairments to cross streets at signalized intersections. In time, the results will make their way into the *MUTCD* and other guides, which will lead to greater uniformity in the field. At the same time, this research discovered a number of issues requiring further investigation. Provided below is a list of topics to be considered for future research:

- Tone types (best accepted by nearby residents)
- Sound volume (best means of providing response to ambient sound, range and speed of response, range of decibel levels)
- Speech message clarity (consistency, programming and downloading messages, standardized library)
- Combining speech message and tones
- Audible message during flashing DON'T WALK (tone vs. speech, countdown)
- Use of APS to aid alignment before crossing and while crossing
- Beaconing (volume, duration after press)
- Guidance on the need for pushbutton APS on side streets.
- Location/size/color of tactile arrow
- Tactile map (consistency, availability, guidelines)
- Cold weather issues (future follow-up on case studies, comparison study)
- APS effect on general pedestrian population (use of pushbutton; latency to begin crossing)

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