Traffic Control Devices Pooled Fund Study

Countdown Pedestrian Signals Legibility and Comprehension without Flashing Hand

Phase I Final Report

To:

Federal Highway Administration
1200 New Jersey Avenue, S.E.
Washington, DC 20590

By:

Ron Van Houten
University of Western Michigan
Kalamazoo, Michigan

August 2014

Forward

The objective of the Transportation Pooled Fund Program's Traffic Control Device (TCD) Consortium is to assemble a consortium of regional, State, local entities, appropriate organizations and the FHWA to 1) establish a systematic procedure to select, test, and evaluate approaches to novel TCD concepts as well as incorporation of results into the MUTCD; 2) select novel TCD approaches to test and evaluate; 3) determine methods of evaluation for novel TCD approaches; 4) initiate and monitor projects intended to address evaluation of the novel TCDs; 5) disseminate results; and 6) assist MUTCD incorporation and implementation of results.

This report documents the first phase of an FHWA project to examine the differences in comprehension between the inclusion and elimination of the flashing don't walk (FDW) hand on the pedestrian signal during the countdown phase. The project focused on 1) evaluating pedestrian comprehension of the Countdown Pedestrian Signals (CPS) alone compared to the CPS plus the FDW, 2) examining how well pedestrians are able to determine how much time they need to cross during the pedestrian change interval, and 3) assessing whether or not the removal of the FDW from the pedestrian clearance interval would affect the ability of low-vision pedestrians to discriminate the pedestrian signal phase.

This report is of interest to engineers, planners, and other researchers and practitioners who are concerned with the implementation of effective pedestrian signals. Information on the potential effects of these signal modifications may be of interest to local, regional, and State authorities as they evaluate their existing and planned pedestrian management strategies.

Monique R. Evans
Director, Office of Safety
Research and Development

Notice

Quality Assurance Statement

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Countdown Pedestrian Signals Legibility and Comprehension without Flashing Hand: Phase I Final Report		5. Report Date July 2014
		6. Performing Organization Code
7. Author(s) Ron Van Houten		8. Performing Organization Report No.
9. Performing Organization Name and Address Western Michigan University Psychology Department 3700 Wood Hall Kalamazoo, MI 49008-5439		10. Work Unit No.
		11. Contract or Grant No. DTF61-08-D-00032-T-13010
12. Sponsoring Agency Name and Address Office of Safety Research and Development Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296		13. Type of Report and Period Covered Phase I Final Report, July 2013 – July 2014
		14. Sponsoring Agency Code HRDS-30

15. Supplementary Notes: This study was conducted as part of the FHWA Traffic Control Devices Pooled Fund Study. Jim Shurbutt is the Technical Manager of the FHWA TCD Pooled Fund Study.

16. Abstract

The purpose of this study was to examine the comprehension of the countdown pedestrian signal with and without the flashing Don't WALK (FDW) indication, and the effect of removing the FDW on pedestrians with low vision. Three studies were conducted. The results of the first study indicated that pedestrians were more likely to consider crossing if they judged they had enough time with the CPS alone than with the CPS plus the FDW and that this effect held for male and female participants, and across young adult, adult, and senior age categories. The results of the second study found participants had little difficult judging the time required for distances of approximately 12 m, 18 m, and 24 m (40 ft, 60 ft, and 80 ft, respectively), and that most pedestrians could discriminate the time without making significant changes in the walking speed. The results of the third study found that pedestrians with low vision often have difficulty discriminating the signal phase with longer crossings, but that the removal of the FDW from the CPS plus FDW display had no negative impact on their decision to cross during the pedestrian clearance phase.

17. Key Words	18. Distribution Statement
Pedestrian Safety, Pedestrian Countdown Timers, PCT, Low vision pedestrians, walking speed	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	58	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AASHTO ....American Association of State Highway and Transportation Officials

CPS ....Countdown Pedestrian Signal

DOT ....Department of Transportation

FDOT .... Florida Department of Transportation

FDW..Flashing Don’t Walk

FHWA...Federal Highway Administration

FW...Flashing Walk

ITE ....Institute of Transportation Engineers

ITS...Intelligent Transportation System

LED……………………………………………………….………Light Emitting Diode

MUTCD .... Manual on Uniform Traffic Control Devices

SDW………………………………………………………..…………..Steady Don’t WALK

TCD...Traffic Control Device

UVC ....Uniform Vehicle Code

EXECUTIVE SUMMARY

BACKGROUND

Countdown Pedestrian Signals (CPS) have been shown to be more intuitive for users in communicating the amount of available crossing time at intersections, which may result in better levels of service for pedestrians at signalized intersections. Survey research has shown that the traditional Flashing Don't Walk (FDW) signal is poorly understood with low levels of comprehension.[1,2] In contrast, comprehension for CPS tends to be much higher: between 86 percent[3] and 100 percent.[2]

Field research has also shown that the traditional FDW signal was associated with pedestrians being more likely to start crossing during the (FDW) phase, run out of time while crossing, return to the starting side of the crossing, or even stop in the roadway when the light changed.[4] Crash data suggests that when countdown timers are added to existing pedestrian signals, crashes decrease by 25 percent.[5] One field study has shown that pedestrians are more likely to judge whether they have time to cross when the CPS is used alone.[6] However, little is known about how well pedestrians discriminate how much time they need to cross.

Before the use of countdown timers, the FDW signaled pedestrians not start crossing because there was no way for them to determine if there was adequate time to finish crossing. It was fine to finish crossing, however, if one had already started to cross before the FDW appeared. Because pedestrians cross at different speeds, the timing of the FDW needed to be set at a value that would allow slower pedestrians to safely cross. The addition of the CPS allowed pedestrians to directly determine whether they have time to cross once they arrived at the crosswalk.

Technically, it is a violation of the Uniform Vehicle Code and Model Traffic Ordinance—commonly referred to as the UVC[7]—to cross when the FDW is present. Work is currently underway to revise the UVC. One option being considered is removing the FDW and replacing it with a statement that pedestrians who start to cross after the start of the countdown must finish crossing before the solid hand appears. However, a change in the Manual on Uniform Traffic Control Devices (MUTCD)[8] must precede this change. The recent trend toward calculating crossing time based on slower pedestrians has exacerbated this issue because it traps more pedestrians on the sidewalk who can easily cross successfully in the time allotted during the early portion of the crossing signal.

PHASE I RESEARCH

The Traffic Control Devices Pooled Fund Study (TCD PFS) is a continual effort that focuses on addressing human factors and operations issues in a systematic evaluation of novel TCDs. As part of this effort, the FHWA Human Factors Team is evaluating CPSs. The purpose of this Phase I research was to conduct research examining differences in comprehension between the inclusion and elimination of the flashing hand on the pedestrian signal during the countdown phase. This will: 1) provide additional data on the pedestrian comprehension of the CPS alone compared to the CPS plus the FDW, 2) provide information on how well pedestrians are able to discriminate how much time they need to cross during the pedestrian change interval, and 3) provide data on whether the removal of the FDW from the pedestrian clearance interval would affect the ability of low-vision pedestrians to discriminate the pedestrian signal phase and effect their safety.

In Experiment 1A, 300 people were shown a digital video display of the walk symbol, the don't walk symbol, the PCS plus FDW, and the PCS alone on a tablet display. The results indicated that pedestrians were more likely to consider crossing if they judged they had enough time with the CPS alone than with the CPS plus the FDW and that this effect held for male and female participants, and across young adult, adult, and senior age categories.

Experiment 1B examined how well pedestrians could determine how much time they needed to cross. Participants viewed a CPS and were told to start crossing when they felt they had just enough time to cross the street. Participants had little difficult judging the time required for 12 m, 18 m, and 24 m (40 ft, 60 ft, and 80 ft, respectively) crossings. Most pedestrians could discriminate the time without making significant changes in the walking speed. Another interesting finding was that pedestrians walked faster than typical in most studies where they were timed starting at the onset of the walk. This is likely because pedestrians may walk more slowly when they know they have more than enough time to cross.

Experiment 1C examined how well low-vision pedestrians could determine how to respond and when to cross when comparing the CPS alone and the CPS plus FDW for a 12 m (40 ft) and 30.5 m (100 ft) crossing. The results of this experiment showed that low vision pedestrians often have difficulty discriminating the signal phase with longer crossings but that the removal of the FDW from CPS plus FDW display had no negative impact on their decision to cross during the pedestrian clearance phase. At 12 m (40 ft) all participants identified the color and 17 out of 20 identified the shape of the FDW symbol, 16 could identify the countdown and 14 could read all or some of the numbers. Only 6 chose to cross. All 6 participants could identify numbers and based the decision on the numbers identified. For the 30.5 m (100 ft) crossing, 13 out of 20 participants identified the color of the FDW plus CPS while 15 identified the color of the CPS alone, but only one could read the numbers. Only four people said they would cross with the FDW plus CPS display even thought they could not read the numbers. Two of these participants said they could see the countdown was present. One said he would be careful because he did not know how much time he had to cross. Only one person in the CPS alone condition said they would cross and they could see the countdown and based their decision on the time left to cross.

INTRODUCTION

BACKGROUND

In an increasingly complex pedestrian environment, where pedestrian signal phases may not be concurrent with vehicular green, use of pedestrian signal indications is necessary. Safe initiation of crossings requires that pedestrians be able to locate, see, and accurately interpret information provided by pedestrian signals. Research indicates that countdown pedestrian signals are widely desired by pedestrians. In general, countdown pedestrian signals are interpreted correctly or more correctly than conventional pedestrian signals, and that they do not adversely affect crossing safety. There is also the possibility that correct interpretation of pedestrian signals having countdown indications could be further increased by a simpler set of displays, i.e. walking person, countdown (without flashing hand), and steady hand indications.

Many questions remain, however, regarding the legibility and interpretability of countdown indications by the full spectrum of persons who make crossing judgments on the basis of visual information. Size and brightness of countdown signals have not been investigated. Human factors research is urgently needed to ensure that pedestrian countdown signal displays will be maximally usable by pedestrians with a full range of vision, and that provision of audible countdown information for blind pedestrians does not have adverse consequences.

There are also questions about how low-vision pedestrians will utilize these displays. Estimates derived from the National Health Interview Survey[9] found 21.2 million adult Americans who reported trouble seeing, even when wearing glasses or contact lenses, 15.2 million of whom were over 65 years of age. The required size of pedestrian signals, in relation to crossing distance, may not be adequate to ensure that countdown information is highly legible even to pedestrians who have unimpaired vision.

Technically, it is a violation of the Uniform Vehicle Code and Model Traffic Ordinance—commonly referred to as the UVC[7]—to cross when the FDW is present. Work is currently underway to revise the UVC. This work proposes to drop the current meaning of FDW and instead state that pedestrians must finish crossing before the solid hand appears. However, a change in the Manual on Uniform Traffic Control Devices[8] must precede this change.

The Traffic Control Devices Pooled Fund Study (TCD PFS) is a continual effort that focuses on a systematic evaluation of novel TCDs. These evaluations examine the human factors and operations issues associated with each novel TCD. As part of this effort, the FHWA Human Factors Team is evaluating CPSs. This report summarizes the results of a Phase I evaluation of CPS, examines some of the potential pedestrian comprehension and performance issues associated with these signals, and provides some recommendations for future research.

OBJECTIVES

The objectives of this project are to determine both the comprehension of the pedestrian countdown signal (focusing on the inclusion and elimination of the flashing hand during the countdown) as well as the legibility of these signals using the full spectrum of persons who make crossing judgments on the basis of visual information.

The main goals of this study are to test the comprehension of pedestrian countdown signals and understanding how pedestrians respond to various countdown signal scenarios in the field. Within these broader goals, the following specific goals are part of this Phase I effort:

1. Identify previous research in the area and determine current state of the practice.
2. Conduct a study to focus on differences in understanding between the inclusion and elimination of the flashing hand of the pedestrian signal during the countdown phase.
3. Produce a report describing the study results (this Phase I report).

REPORT OVERVIEW

This report provides a description of the methods, results, and conclusions from Phase I research. The body of this report contains the following topic sections:

- *Signal Information from FHWA Traffic Control Devices (TCD) Pooled Fund Study States:* Data was collected from members of the FHWA TCD Pooled Fund States to understand what types and sizes of pedestrian heads were in use.
- *Experiment 1A:* An experiment that examined pedestrian comprehension of different pedestrian signals.
- *Experiment 1B:* An experiment that examined pedestrian performance in determining the amount of time required to cross.
- *Experiment 1C:* An experiment that examined low-vision pedestrian comprehension of different pedestrian signals.
- *Conclusions:* Provides an overview of the Phase I research.
- *Appendices:*
  - Appendix A: Question Protocol for Experiment 1A.
  - Appendix B: Crossing Times for Experiment 1B.
  - Appendix C: Individual Responses from Experiment 1C.

LITERATURE AND STATE OF THE PRACTICE

Countdown Pedestrian Signals (CPS) display the available crossing time in seconds to complement the conventional Flashing Don't Walk (FDW) phase of pedestrian traffic signal cycle. The Manual on Uniform Traffic Control Devices for Streets and Highways[8] provides guidance for the use of the CPS and presents it as the standard signal configuration. Pedestrian countdown signals have been shown to be more intuitive for users in communicating the amount of available crossing time at intersections, which also may result in better levels of service for pedestrians at signalized intersections. The Florida Department of Transportation (FDOT), for example, conducted a study to determine pedestrians' comprehension of the traditional FDW sign versus the CPS. The study showed that the CPS was more intuitive than the traditional flashing FDW display, which contributed to pedestrians making better decisions about when to begin crossing and when to wait for the next walk signal. However, it is a violation of the UVC[7] to cross when the FDW is present.

When Countdown Pedestrian Signals (CPS) did not exist, the FDW signaled pedestrians not start crossing because there was not a way for them to discriminate whether there was adequate time to finish crossing. It was acceptable for a pedestrian to finish crossing, however, if one had already started to cross during the walk. Because pedestrians cross at different speeds, the timing of the FDW needed to be set at a value that would allow slower pedestrians to safely cross. The addition of the CPS allowed faster pedestrians to directly determine whether they have time to cross once they arrived at the crosswalk.

Survey research has shown that the traditional FDW signal is poorly understood with correct comprehension levels between 31 percent[2] and just below 50 percent[1] while comprehension for the CPS is between 86 percent[3] and 100 percent.[2] Field research has also shown that the traditional FDW signal was associated with pedestrians being more likely to start crossing during the FDW phase, run out of time while crossing, return to the starting side of the crossing, or even stop in the roadway when the light changed.[4] The recent trend toward calculating crossing time based on slower pedestrians has exacerbated this issue because it traps more pedestrians on the sidewalk who can easily cross successfully in the time allotted during the early portion of the crossing signal.

One reason why the FDW is poorly understood is that the meaning of flashing prohibitive signals is not standardized. For example, a flashing red traffic signal should be treated as a stop sign. Although most drivers know the meaning of the flashing red light indication at an intersection, this is only from training and experience. It would be unclear what behavior would be appropriate to a flashing a red arrow, a flashing do not enter sign or a flashing no right turn on red signal. A yellow walk indication would have been more intuitive based on the meaning of a yellow light. Also, as mentioned above, crossing when a FDW is present is a violation of the UVC. This increases the uncertainty associated with crossing and could contribute to the poor understanding of FDW.

A number of additional studies have documented safety advantages of countdown signals based on pedestrian behavior.[10,11] The Minnesota Department of Transportation (MnDOT) compared the FDW alone and the flashing FDW plus CPS by counting the number of pedestrians who successfully crossed an intersection before the FDW phase ended. Their research showed an average 12 percent increase in successful pedestrian crossings with the implementation of CPSs.[12] In addition, pedestrians were less likely to cross near the end of a pedestrian walk phase if it appeared that there was insufficient time. Similarly, pedestrians who were crossing during the FDW phase increased their walking speed in an attempt to finish the crossing within the amount of time shown on the countdown signal.[12] A number of other studies have also documented an increase in successful crossings.[13,14]

A summary report of various crash reduction methods and their effectiveness was prepared by the FHWA in 2007; this report included countdown pedestrian signals. The evidence summarized in this report suggests that when countdown timers are added to existing pedestrian signals, crashes decrease by 25 percent.[5] It is often the case that benefits can vary dependent on context and pedestrian and driving culture. Other studies have shown that, relative to traditional FDW signals, the addition of the CPS is associated with reduced crashes.[15,16] A large study conducted by Van Houten, LaPlante, & Gustafson examined crashes following the installation of pedestrian countdown signals at 362 intersections in the city of Detroit.[17] The results of the analysis showed a 70 percent reduction in pedestrian crashes. These signals were installed in phases with control sites. Crash reductions paralleled the installation schedule, and did not occur at control sites.

Logically, the behavioral and safety changes that took place when the countdown signal was added to the FDW walk display must be a consequence of the addition of the countdown signal. These results imply that most pedestrians can see and comprehend the meaning of the CPS. This is further supported by their regulating crossing speeds as a function of the time remaining to cross.[4]

One study funded by FHWA focused on the issue of whether it would be desirable to delete the FDW display from the pedestrian change interval.[6] These researchers directly compared the CPS alone and the CPS with the FDW. The authors pointed out the poor comprehension of the FDW and that the legal meaning of the FDW is relatively poor. It was speculated that removing the FDW from the CPS might “actually improve pedestrian comprehension and crossing decisions by eliminating the source of confusion.”

In the first study, Singer and Lerner investigated pedestrian comprehension of the CPS alone, the CPS with the FDW, and the FDW alone.[6] Forty-five participants were shown pictures of the crossing scenarios. Each scenario was presented three times: once with each of the key pedestrian signal configurations. Pedestrians were asked to describe the correct pedestrian crossing behavior for each scenario. The CPS alone produced the fewest errors, the CPS with the FDW performed nearly as well and the FDW alone had the most errors. Participants were most likely to believe that they were permitted to start a crossing during the pedestrian change interval when shown the CPS alone. A second study examined the field application of the CPS alone with the CPS plus the FDW at two sites. They found that pedestrians started crossing later with the CPS alone but there was no increase in the percentage of pedestrian crossing during the steady don’t walk phase although those who finished during the SDW tended to finish somewhat later. However these shifts toward later starts and finishes did not necessarily indicate an increase in unsafe behavior because of the presence of the five-second buffer time between the start of the SDW and the release of conflicting traffic and there were no pedestrian/vehicle conflicts during the CPS alone and the CPS plus FDW display. Singer and Learner also reported a slight but statistically significant decrease in the frequency of pedestrians running in the crossing during the CPS alone condition. There were several limitations to the Singer and Lerner study. First, the curb-to-curb walking distance on both streets was only 12 m (40 ft). Second, the pedestrian change interval was relatively short, 10 and 11 s respectively. Third, no data were collected on the impact of removing the FDW display on low-vision pedestrians.

We could not find data on the recognition distance for the countdown display by low-vision pedestrians. The recent Institute of Traffic Engineers (ITE) performance specification standard recommends only one size (approximately 23 cm, or 9 in.) for the pedestrian countdown display.(18) The number of individuals experiencing vision loss and other disabilities is expected to grow in coming decades,(19,20,21) in tandem with the anticipated increases in the numbers of older persons in society. Desai, Pratt, Lentzer and Robinson(22) estimate that 14 percent of persons 70-74 years of age have serious difficulty seeing, even with their glasses, and this increases to 32 percent among persons 85 or older. Unfortunately, there has been limited research in comparing and examining the effectiveness of different size pedestrian signals and countdown signals with partially sighted individuals. Available data then suggest that removing the FDW from the CPS may improve decision-making by allowing pedestrians to focus on relevant information without the presence of ambiguous information.

Two studies have examined recognition distance for pedestrians with low vision.(23,24) Williams et al. found that low-vision pedestrians could identify the walk signal at a distance of 33 m (108 ft) with a standard deviation of 12.9 m (42.4 ft) and the steady don’t walk (SDW) at a distance of 28.1 m (92.2 ft) with a standard deviation of 12.9 m (42.3 ft).(23) Van Houten et al. found that low-vision pedestrians could identify the walk signal at 18.6 m (61 ft).(24) In both these studies, the man icon and hand icon were 28.4 cm (11.2 in.) high.

In summary, studies show increases in comprehension and crossing success when CPS are added to the FDW indication. A number of studies also report reductions in vehicle pedestrian conflicts and pedestrian crashes. Data also show that the FDW is still not well understood by pedestrians and limited data from one study shows that crossing success is somewhat better when the CPS is used without the FDW. However, little is known about how well pedestrians are able to discriminate how much time they require to cross and no data is available for the recognition distance of the CPS with and without the FDW for low-vision pedestrians.

The purpose of this study is to provide additional data on the possible advantages of using the CPS alone, how well pedestrians are able to discriminate how much time they need to cross during the pedestrian change interval, and the effects the CPS has on the ability of low-vision pedestrians to discriminate the pedestrian signal phase. Previous research on the comprehension of the CPS with and without the FDW, and field comparisons of their relative efficacy, was only completed one part of the country. This study will extend the generality of these findings by replicating it in another region. This study will also increase the generality of these findings by determining how well pedestrians can discriminate the time needed to cross various width roads and examining the impact of removing the FDW would have on people with low vision.

SIGNAL INFORMATION FROM FHWA TCD POOLED FUND STATES

This section describes data collected from FHWA TCD Pooled Fund states that was conducted in support of Experiments 1A, 1B, and 1C.

INTRODUCTION

ITE specifies three sizes for pedestrian signal heads.[25] For crosswalk lengths of less than 18.3 m (60 ft), the walking person and upraised hand icons are 15.2 by 8.9 cm (6 by 3.5 in.), and the countdown display 22.9 by 17.8 cm (9 by 7 in.); for crosswalk length of over 18.3 m (60 ft) two dimensions are specified: the walking person and upraised hand icons are to be 22.9 by 13.3 cm (9 by 5.25 in.), or 27.9 by 17.8 cm (11 x 7 in.). In both cases, the countdown display should be 22.9 by 17.8 cm (9 by 7 in.). Each digit in the countdown display in all cases should be 22.9 cm (9 in.) high by 8.23 cm (3.25 in.) wide. The MUTCD specifies that the height of the walking person icon, the upraised hand icon and the numbers in the countdown display should be 22.9 cm (9 in.) in height for crosswalks where the pedestrian enters the crosswalk more than 30.5 m (100 ft.) from the pedestrian signal head indications.[8] A search of vendors on the approved list of several large states indicates that none produce a standard pedestrian countdown display with digits larger than 22.9 cm (9 in.).

In order to understand how these values are applied at the jurisdictional-level, information was requested from states participating in the FHWA TCD Pooled Fund program. The purpose of this activity was to understand the size of pedestrian heads used for crossing, as well as to gain information on the configuration of the head.

METHOD

Information was requested from states participating in the pooled fund research program. This request asked them to identify the state and: 1) provide the size pedestrian heads used for crossings less than and greater than 30.5 m (100 ft) in length, and 2) provide the size of the digits used in countdown timers for crossings with a crossings width of less than or greater than 30.5 m (100 ft) in length.

RESULTS AND DISCUSSION

We received feedback from the city of Los Angeles and the following 13 states: Florida, Kansas, Minnesota, Mississippi, Missouri, Nebraska, Nevada, North Carolina, Oregon, Pennsylvania, South Carolina, Texas, and Wisconsin.

Use of the walking person and upraised hand icon displays was common. Thirteen of the fourteen locations (approximately 93 percent) responding that they used the 27.9 by 17.8 cm (11 x 7 in.) walking person and upraised hand icons 40.6 by 45.7 cm (16 by 18 in.) message bearing surface for all crosswalk lengths. Only the state of Nevada used a smaller size 22.9 cm by 13.3 cm (9 in. by 5.25 in.) walking person and upraised hand icons, 30.5 by 30.5 cm (12 by 12 in.) housing for crosswalks less than 30.5 m (100 ft) length.

Use of the countdown display was also common. Almost all respondents reported using the 22.9 by 17.8 cm (9 by 7 in.) countdown display for crosswalk both under and over 30.5 m (100 ft) in length. The state of Kansas reported using countdown displays with a 15.2 cm (6 in.) height for crosswalks less than 30.5 m (100 ft), and 22.9 cm (9 in.) height for crosswalks of more than 30.5 m (100 ft) in length. The city of Los Angeles specified the 22.9 cm (9 in.) height as a minimum but did not specify any other sizes.

The results of this information-gathering exercise suggest the most commonly used configuration is the 40.6 by 45.7 cm (16 by 18 in.) pedestrian signal head housing with the 22.9 cm (9 in.) countdown digit size for all crosswalk lengths. The community appears to have reached a consensus on size of pedestrian signals, and signal vendors are not offering larger sizes for sale. Based on these results, further research was conducted using the 40.6 by 45.7 cm (16 by 18 in.) pedestrian signal housing with the 22.9 cm (9 in.) countdown displays.

EXPERIMENT 1A: PEDESTRIAN COMPREHENSION OF SIGNALS

The purpose of this experiment was to examine comprehension of the CPS alone and the CPS with the FDW in order to determine whether the removal of the FDW component would improve clarity.

INTRODUCTION

This experiment examined pedestrian comprehension of various pedestrian countdown scenarios, including the inclusion and exclusion of the flashing hand in the countdown phase. The participant sample was drawn from a diverse population of both genders representing different ages in two geographically different locations.

METHOD

The method for Experiment 1A is described, below.

Participants and Experiment Venue

Participants in this study were 100 adults from the Naples, Florida, metropolitan area, and 200 adults from the Kalamazoo, Michigan, metropolitan area, for a total sample size of 300 adults. Data collection in Naples, Florida, was completed before data collection in Kalamazoo, Michigan, commenced. Testing for this study was conducted between 8:00 AM and 4:30 PM. Potential participants were sampled at mall locations (Naples, FL) or at a downtown location (Kalamazoo, MI). All participants self-reported either corrected or uncorrected visual acuity of 20/40 or better. A summary of participants by location is provided in Table 1.

Table 1. Participant demographics, Experiment 1A.

Location	n, Males (all ages)	n, Young Adult Males	n, Adults Males	n, Seniors Males	n, Females (all ages)	n, Young Adult Females	n, Adults Females	n, Seniors Females
Kalamazoo, MI	111	29	68	14	89	22	53	14
Naples, FL	53	10	37	6	47	7	29	11
Total	164	39	105	20	136	29	82	25

Apparatus

A video was produced for each of the following signal configurations and phases: walk, don’t walk, FDW plus CPS, CPS alone, and CPS plus flashing walk. Each video was recorded in clear daylight conditions, and had a duration of approximately 10 s. Displays that included the CPS began with the countdown timer displaying 17 s and counted down for 10 s. Videos were displayed to participants on a tablet computer with a 24.6 cm (9.7 in.; diagonally-measured) display.

Although the Florida data showed clear differences between the CPS alone and CPS plus FDW display, it was hypothesized that the CPS plus a flashing walk display would be the most intuitive option. Therefore, an additional video was included for the later data collection effort in the Michigan location. Michigan participants were shown same videos employed in Florida, with the addition of a video showing the CPS plus FW. The videos used for each location are described in Table 2.

Table 2. Videos used in Experiment 1A.

Location	**Videos Used**
Kalamazoo, MI	Walk, don’t walk, FDW plus CPS, CPS alone, CPS plus FW
Naples, FL	Walk, don’t walk, FDW plus CPS, CPS alone

Procedure

After providing informed consent, participants were shown each of the videos in a counterbalanced order. Following each video presentation, participants were asked a series of questions (see Appendix A for the question protocol) to determine their beliefs as to the display’s meaning, as well as what they should do in response to the display.

For every signal head, people were asked: “Imagine yourself at a crosswalk, about to cross the street, and you see this display. They were then shown the video segment of the relevant video display in a randomized order and asked the following open-ended questions: What does this display mean? And what should you do if you see this display?” Follow-up questions were asked when required to ensure clarity. The decision tree followed in asking these questions is described in Appendix A. Opened ended questions were asked to avoid leading the pedestrians. Follow-up questions were only asked to clarify ambiguous answers.

Analysis

Similar to the method used by Singer and Lerner(6), responses were categorized into decisions of walk, make a decision, or don’t walk for each signal configuration. Make a decision represents any response that indicated that they would need to judge how much time they had left to cross the street of various lengths. Participants indicating they would walk (cross the street) considered 17 s as adequate to cross a typical street walking at a speed of 1.5 or 1.8 m/min (5 or 6 ft/min).

For the walking person symbol, correct answers included participants who indicated that they could/would cross, while incorrect answers included participants who indicated that they could/would not cross. For the solid hand display, correct answers included participants who indicated that they could/should not cross, while incorrect answers included participants who indicated that they could/should cross.

For the clearance phase display, responses were coded by responses indicating that there was sufficient time to cross (17 s was displayed on the countdown; coded as “walk”) or that the participant would have to decide if there was enough time to cross depending on distance and time remaining (coded as “make a decision”).

Responses that indicated that the person should not cross fell into two categories. One response was that they should not cross or start to cross because the hand was present. The second was they should not cross because the hand was counting down the time to the next walk. These responses were coded as “Don’t Walk.” Technically, the choice to not start to cross is correct in reference to the Universal Vehicle Code. This definition made sense before the countdown signal was implemented because a pedestrian had no idea how much time was left to cross when the FDW was presented alone. However, after the introduction of CPS it was possible for pedestrians to determine how much time remained to finish a crossing as well as information on how to adjust walking speed if they found there was sufficient time to cross at the original crossing speed.

RESULTS

Participant responses, by indication, are presented in Table 3 (for Kalamazoo, MI) and Table 4 (for Naples, FL). Note that these results illustrate participants’ understanding of the signal and does not necessarily represent what they would do. The trends in these data are similar to those obtained in the Singer and Lerner study.[6] The present findings suggest that individuals understand that they can cross during the walk interval and should not cross during the don’t walk interval when the solid hand is displayed.

Table 3. Kalamazoo, MI, participant responses by indication, Experiment 1A.

Indication	Walk (Percent)	Make a Decision (Percent)	Don’t Walk (Percent)
Walk	200 (100)	0 (0)	0 (0)
Don’t Walk	0 (0)	0 (0)	200 (100)
CPS + FDW	67 (33.5)	53 (26.5)	80 (40)
CPS	88 (44)	62 (31)	50 (25)
CPS + FW	133 (66.5)	47 (23.5)	20 (10)

Table 4. Naples, FL, participant responses by location and indication, Experiment 1A.

Indication	Walk (Percent)	Make a Decision (Percent)	Don’t Walk (Percent)
Walk	100 (100)	0 (0)	0 (0)
Don’t Walk	0 (0)	1 (1)	99 (99)
CPS + FDW	42 (42)	16 (16)	42 (42)
CPS	61 (61)	23 (23)	16 (16)

In regard to the three clearance intervals (CPS alone, CPS + FDW, and CPS + FW) tested at the Michigan location, more people understood that they should not start to cross during the clearance interval with the FDW present (40 percent vs. 25 percent for the CPS alone, and 10 percent for the CPS plus FW). However more participants understood they could cross or make a decision with a countdown showing a countdown with 17 s. with the CPS alone

(75 percent), and the most participants thought they could cross or make a decision to cross when presented with the CPS plus flashing walk (90 percent).

Figure 1, Figure 2, and Figure 3 display the results for Michigan participant responses to the CPS plus the FDW, CPS alone, and the CPS plus flashing walk (FW) displays, respectively. As shown in the figures, the two response categories for a decision to cross were "walk" and "make a decision." The CPS alone has a large effect on pedestrian response to the clearance interval. For the CPS plus FDW only 60 percent thought they could walk or make a decision to begin crossing. However, this increased to 75 percent with the CPS alone and increased further to 90 percent for the CPS plus FW display. This finding indicates a perceived shift in decision making when the countdown timer is present that places less emphasis on signal compliance and more emphasis on pedestrian choice. Also shown in the figures are both types of participant responses to don't walk: "don't walk" and "countdown (CD) displays the time until the walk appears". As shown in these figures, approximately 10 percent of the people erroneously thought the CPS plus FDW and CPS alone were timing the amount of time until the walk indication appeared. This error only occurred in 3 percent of the participants with the CPS and FW display. More participants responded "make a decision" with the CPS alone than with the CPS with FDW, or with CPS with flashing walk.

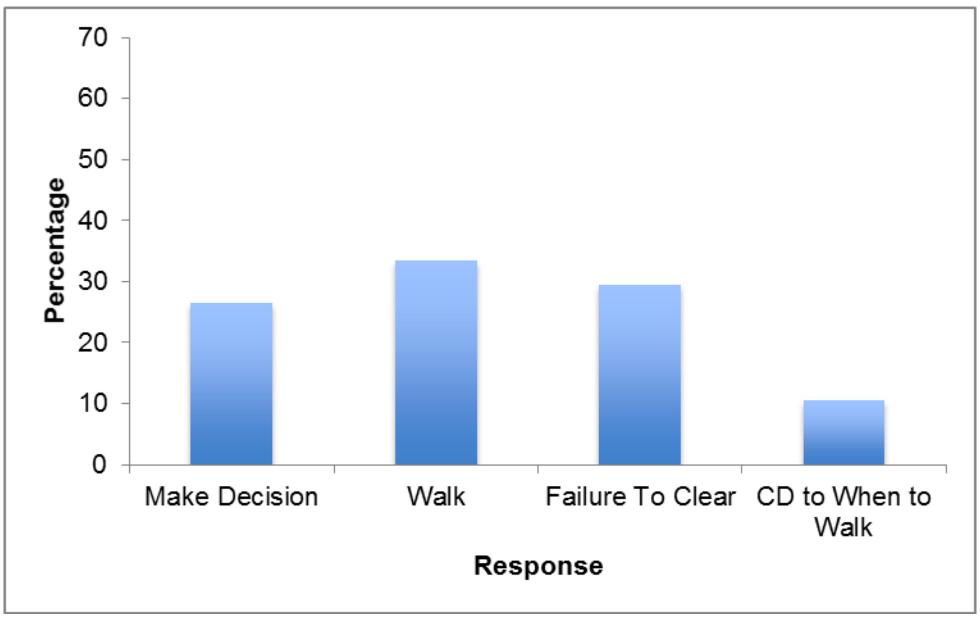

Figure 1. Chart. Percentage of Michigan participant responses to CPS + FDW.

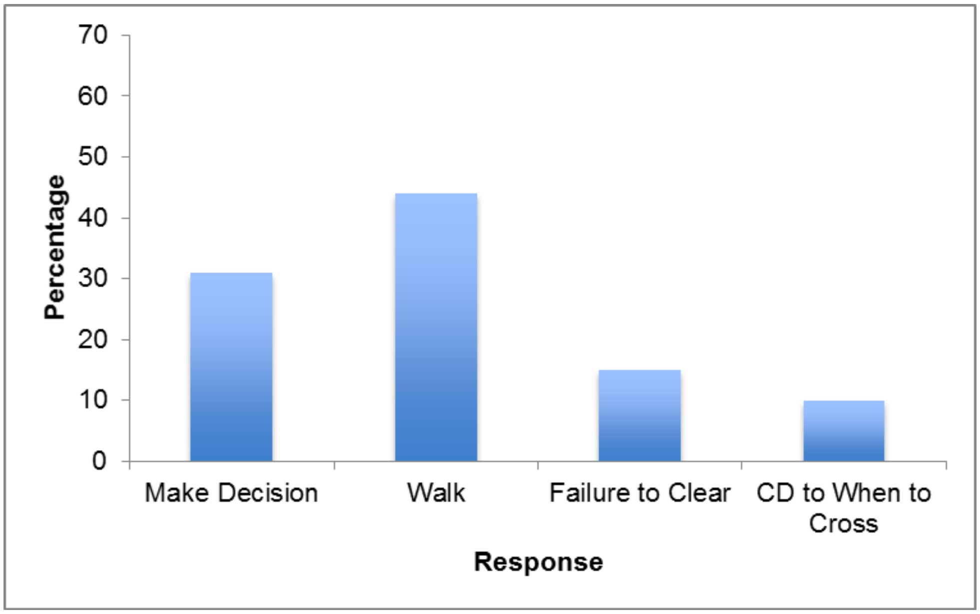

Figure 2. Chart. Percentage of Michigan participant responses to CPS alone.

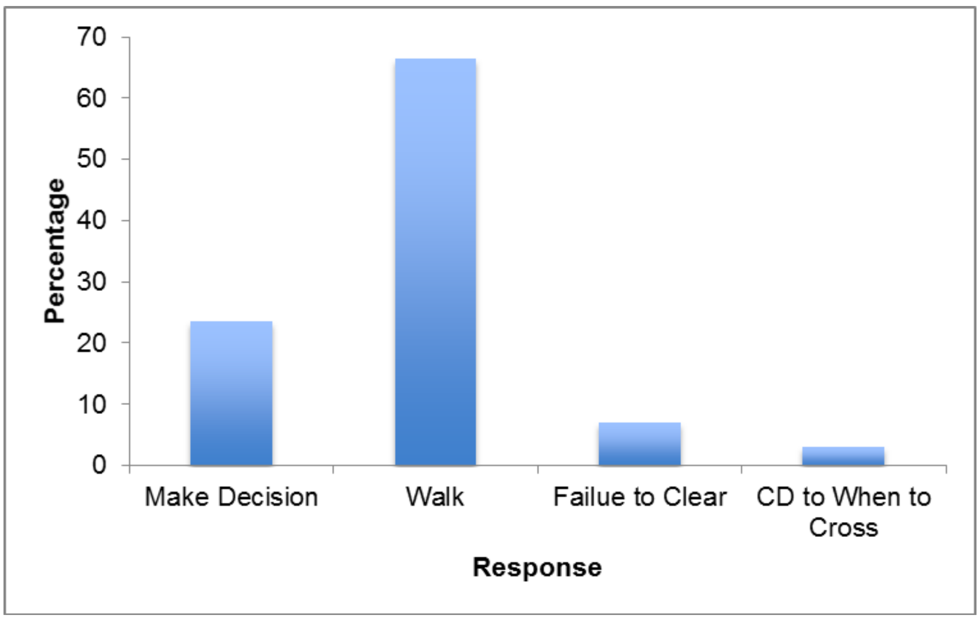

Figure 3. Chart. Percentage of Michigan participant responses to CPS plus FW.

Table 5 shows the pooled data for the Michigan and Florida samples. Those who choose walk or make a decision were pooled and a *z*-score test for dependent groups was used to test for significance. The proportions of the 300 sample who choose to walk or make a decision was 0.78 for the CPS alone and 0.59 for the CPS plus FDW condition. This difference was significant at the $p = 0.01$ level. These results demonstrate that more people believe they can cross or consider crossing when shown a countdown starting at 17 s when the FDW is absent then when it is present.

Table 5. Pooled data for Michigan and Florida samples.

Indication	Walk (Percent)	Make Decision (Percent)	Don't Walk (Percent)
Walk	300 (100)	0 (0)	0 (0)
Don't Walk	1 (0.3)	0 (0)	299 (99.7)
CPS + FDW	109 (36)	69 (23)	122 (41)
CPS	150 (50)	84 (28)	66 (22)

Table 6 shows the break down by sex and age for the pooled samples. Because the walk alone and don't walk alone were understood by all but one participant, these indications are not presented in this table.

Table 6. Responses by demographic category and indication.

Category/Indication	Walk (Percent)	Make a Decision (Percent)	Don't Walk (Percent)
Males/CPS + FDW	58 (35)	31 (19)	75 (46)
Males/CPS	79 (48)	44 (27)	41 (25)
Females/CPS + FDW	51 (38)	38 (28)	47 (35)
Females/CPS	70 (51)	41 (30)	25 (18)
Young Adults/CPS + FDW	22 (32)	15 (22)	31 (46)
Young Adults/CPS	42 (62)	10 (15)	16 (24)
Adults/CPS + FDW	77 (41)	41 (22)	69 (37)
Adults/CPS	80 (43)	62 (33)	45 (24)
Seniors/CPS + FDW	10 (22)	13 (29)	22 (49)
Seniors/CPS	27 (60)	13 (29)	5 (11)

DISCUSSION

Few differences were observed between the Florida and Michigan data for the walk and don't walk responses. This indicates that these signal displays are intuitive and generally-understood. Responses to the CPS with the FDW and CPS alone were similar between the Michigan and Florida sites, with more participants responding to cross with the CPS alone than the CPS plus FDW, and fewer choosing not to cross with the CPS plus FDW than with the CPS alone. The percentage choosing pedestrian decision was higher with the CPS alone.

It is also likely the case that many participants choosing to cross did so because they judged the 17 s displayed adequate time to cross. The largest difference between the Michigan and Florida data was the higher proportion of participants choosing to walk or make a decision to walk for the CPS alone in the Florida data. If the goal is to allow pedestrians to choose whether to cross based on the time remaining on the CPS display the CPS alone is a better choice than the CPS with the FDW display.

Some interesting differences were observed in the clearance display data. First, a somewhat higher proportion of males than females indicated the signal meant don't walk, and a higher percentage of females in the CPS plus FDW indicated make a decision. It should be noted that this does not reflect what they would do, just what they thought the signal meant. It is possible that males could be more likely to cross when they think it is not permitted.

Second, in regard to age, young adults show the largest change in making the decision to walk the CPS alone, and they also were the only group showing a reduction in choosing to make a decision with the CPS. These results are not unexpected considering that average walking speed should be highest for this group and most thought they could cross with 17 s. The seniors had the highest proportion of choosing to make a decision for both the CPS and FDW and CPS alone.

EXPERIMENT 1B: TIME REQUIRED TO CROSS AN INTERSECTION

The MUTCD [8] specifies that the walking speed used to travel to the far side of the traveled way or to a median of sufficient width to allow a pedestrian to wait should be 1.07 m/s (3.5 ft/s). The manual also specifies that “Where pedestrians who walk slower than 1.07 m/s (3.5 ft/s), or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.07 m/s (3.5 ft/s) should be considered in determining the pedestrian clearance time. Clearly many pedestrians can walk faster than 1.07 m/s (3.5 ft/s) or less and could safely cross with less time than is provided. The purpose of this experiment was to determine how well pedestrians could discriminate how much time they required to cross a crosswalk length of approximately 12 m, 18 m, and 24 m (40 ft, 60 ft, and 80 ft, respectively) at a walking pace.

INTRODUCTION

Many pedestrians use the CPS to determine whether they have time to cross the intersection if they arrive during the pedestrian clearance interval. Pedestrians who start crossing during the walk can also monitor their progress during the pedestrian clearance phase and adjust their walking speed, allowing them to finish crossing before the don’t walk indication appears. Pedestrians with a relatively fast gait use the CPS for the former reason, while pedestrians with a slower than average gait use the CPS for the later reason. Using the CPS to determine whether there is sufficient time to cross allows more pedestrians to cross during each cycle. This study examined how well pedestrians could discriminate the amount of time required for them to cross the street.

METHOD

The method for Experiment 1B is described, below.

Participants and Experiment Venue

Participants in this study were 60 pedestrians drawn from University students and faculty. All pedestrians were capable of walking at a normal or faster than normal walking speed. Testing for this study was conducted between 8:00 AM and 4:30 PM (daylight hours), with ambient lighting conditions ranging from overcast to bright sunshine. All participants self-reported either corrected or uncorrected visual acuity of 20/40 or better. A summary of participant demographics is provided in Table 7.

Table 7. Participant demographics, Experiment 1B.

Gender	n	n, Young Adults	n, Adults	n, Seniors
Males	25	21	3	1
Females	35	33	2	0

Apparatus

A simulated crosswalk was created on the campus of a university. The simulated crosswalk was located in an area with no motor vehicle traffic, allowing for participant safety and controlling for the presence of vehicles. The simulated crosswalk was 3 m (10 ft) wide, with a total length of 24 m (80 ft). Distance markings at 3 m (10 ft) intervals were created using red tape.

The pedestrian signal was mounted at the simulated crosswalk 2.4 m (8 ft) above ground level. The signal head had 22.9 cm (9 in.) high walk and don't walk icons, and 15.2 cm (6 in.) high countdown numbers. The following four presentation modes were employed: walk sign alone, the don't walk sign alone, and the FDW sign plus the pedestrian countdown signal.

Procedure

Each of the 60 participants was asked to make three crossings, one for each length. Therefore data were collected for a total of 180 pedestrian crossings. The presentation order for each of the three crosswalk lengths was randomly counterbalanced across participants.

Participants were given the following instructions: "Imagine you are at a busy intersection, and want to cross the street. The pedestrian signal will begin by showing an orange hand; next it will show a white walking person. When the orange countdown begins I want you to begin to cross when you think you have just enough time to safely walk, not run, across the street. As you are crossing, try to finish your crossing before the countdown ends. If you see that you might not have enough time to finish crossing, you can adjust your speed walking faster, jogging or even running if necessary. If you needed less time than you thought, you can finish crossing before the end of the countdown. You don't have to slow down to finish just at the right time. If you feel you needed to increase your pace but see it is no longer necessary, you can also go back to a normal pace."

Analysis

Participant crossing times were measured for each 3 m (10 ft) segment, for all crosswalk lengths. A trained observer using a stopwatch recorded crossing times. If the participant finished crossing before the countdown was complete, the number of seconds left was recorded. If the participant finished after the countdown had timed out, the number of seconds that elapsed after the countdown finished was also was recorded.

A second trained observer scored the walking pace for each segment as a walk, a jog or a run. These three paces were selected as they are able to be reliably classified through operational definitions. Walking was defined as lifting and setting down each foot in turn, never having both feet off the ground at once. Running was defined as moving so swiftly that both feet leave the ground during each stride. Jogging was distinguished from running by having a wider lateral spacing of foot strikes, creating side to side movement at a low speed than running.

The following four measures were collected and evaluated:

1. The time required traversing each consecutive 3 m (10 ft) length of each of the three crosswalk lengths. This measure allowed us to calculate the segment average walking speed for each consecutive 3 m (10 ft) segment.
2. The time remaining before the end of the countdown, or the time elapsed after the end of the countdown, when the participant finished the crossing. This measure allowed us to determine the accuracy of participant's estimates.
3. Whether participants altered their gait by jogging or running in order to cross within the time they judged was adequate. This was a secondary measure of the adequacy of participant's estimates of the time required to traverse each length of crosswalk.

RESULTS

Analysis of crossing times indicated that participants had little or no difficulty discriminating how much time was required to traverse the approximately 12 m, 18 m, and 24 m (40 ft, 60 ft, and 80 ft, respectively) length crosswalks. For the 12 m (40 ft) crosswalk, only one participant failed to traverse the crosswalk in time, and this participant only exceeded the countdown timer by 1 s. Similar results were found for the 18 m (60 ft) crosswalk; only one participant misjudged the 18 m (60 ft) crossing, exceeding the countdown by 1 s. For the 24 m (80 ft) crosswalk, all participants were able to traverse the crosswalk before the countdown timer ended. No order effects were present. As shown in Figure 4, the average amount of time on the CPS signal when participants finished crossing was relatively similar between crosswalk lengths.

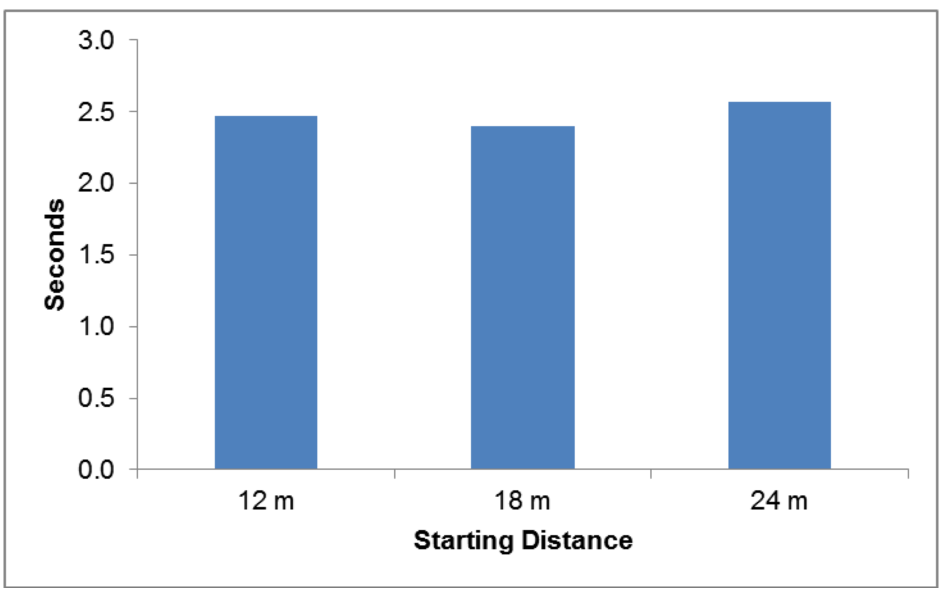

Figure 4. Chart. Average time remaining on the countdown when participants finished crossing.

Analysis of crossing gait indicated that some participants had to shift crossing paces during the crossing period. Eight participants (approximately 13 percent) had to shift from a walk to a jog for at least one 3 m (10 ft) segment. Four participants (approximately 6.7 percent) jogged for the last 3 m (10 ft) segment, and four (approximately 6.7 percent) jogged for the last two 3 m (10 ft) segments. No participant needed to run. Crossing data for each participant is provided in Appendix B. No order effects were present. Most participants were able to judge fairly closely with the average participant finishing the crossing with between 2 and 3 s remaining on the countdown timer for each crossing distance. Figure 5 shows the average crossing speed for all pedestrians crossing for each participant for crossing distance.

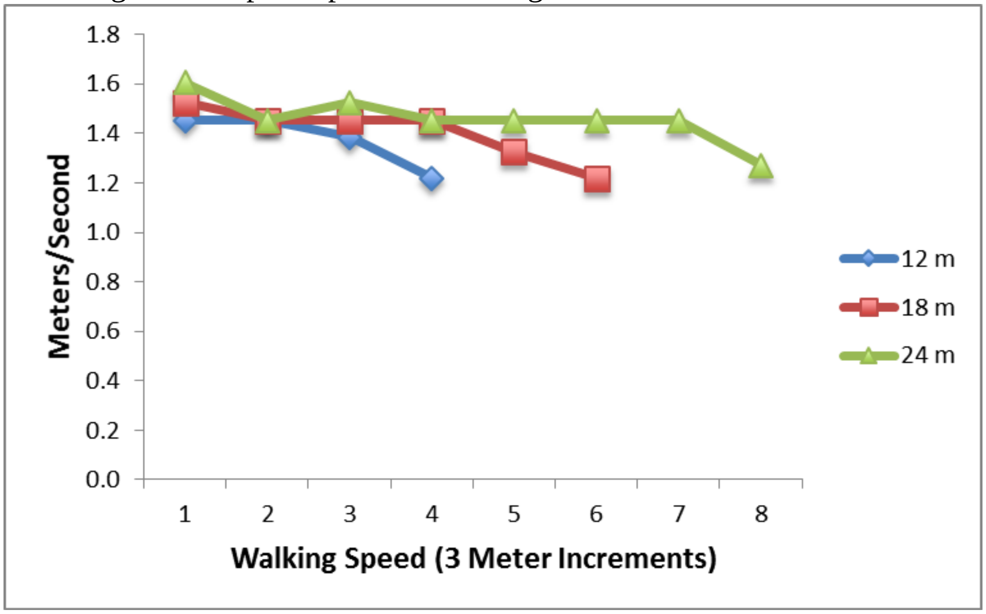

Figure 5. Chart. Average walking speed for each segment for each crosswalk length.

DISCUSSION

The results of this experiment suggest that many people have gained experience crossing with a countdown signal and appear to have learned to discriminate how much time is required to cross. An examination of these data shows a high degree of consistency in crossing speed over the entire crossing. Most participants were able to maintain a steady walking pace, and almost all were able to finish before the end of the countdown display. It is interesting to note that the two pedestrians who did not finish before the end of the countdown would have finished before the end of the yellow indication for the cross traffic (assuming standard signal timing).

One of the most interesting finding from this experiment was the high walking speeds observed in this study. Most participants walked at a brisk pace and, although most were between the ages of 18 and 24, some participants were over 65 years of age. It is possible that pedestrians walk slower when they know they have ample time to cross and faster when they know they have less time to cross. The individual data from Experiment 1B (shown in Appendix B) support this hypothesis, with 35 of the pedestrians decreasing their walking speed during the widest crossing during the last 3 to 6 m (10 to 20 ft). These data suggest that naturalistic crossing speed data collected only on pedestrians starting to cross at the onset of the walk indication may be slower than that obtained if they aware they had less time to cross. It is likely that data based on such naturalistic observation may reflect a slower walking speed than people actually require crossing.

Future research is needed to examine this issue with a random cross-section of adults to better determine pedestrian crossing time.

EXPERIMENT 1C: LOW-VISION PEDESTRIAN STUDY

The purpose of this experiment was to determine whether the elimination of the FDW from the CPS display would have an adverse effect on low-vision pedestrians.

INTRODUCTION

Low-vision individuals often have difficulty discriminating the pedestrian signals, especially with longer crossings. These individuals may utilize the additional information provided by the FDW to help determine whether they can cross. Therefore, the elimination of the FDW may result in these individuals having an increased likelihood of mistaking the display for the walk. It must be noted that although some low-vision pedestrians may not be able to see any of the pedestrian signal displays at some distances, they should not cross under these circumstances.

METHOD

The method for Experiment 1C is presented below.

Participants and Experiment Venue

Participants in this study were persons with a visual acuity between 20/70 (the criteria for low-vision) and 20/200 (the criteria for blindness). Participants ranged in age between 15 and 95 years of age and, in order to participate, needed to be ambulatory and use crosswalks. For younger participants, parental consent was obtained. Testing for this study was conducted between 8:00 AM and 4:30 PM (daylight hours), with ambient lighting conditions ranging from overcast to bright sunshine. A summary of participant demographics is provided in Table 8.

Table 8. Participant demographics, Experiment 1C.

Gender	n	n, Youth	n, Young Adults	n, Seniors
Males	6	1	1	4
Females	14	1	0	13

Apparatus

The apparatus described in Experiment 1B was employed in this experiment.

Procedure

After obtaining informed consent, participants were shown each of the pedestrian signal indications in a random order from a distance of 4.5 m (15 ft). Participants were asked to describe:

1. The color of the signal indication
2. The shape of the signal indication
3. The name of the signal indication

4. What they should do if they see this indication.

This was done to familiarize them with the display and to serve as a participant qualification for the study. Participant who could not see the indications at a distance of 15 ft. would be disqualified; no participant failed this test.

Participants were escorted to a distance of either 12 m (40 ft) or 30.5 m (100 ft) from the signal location. Participants were then shown the following five pedestrian display indications: walk, don’t walk, the CPS plus FDW, the CPS alone, and the transition from the don’t walk to the walk display. At the start of each trial they were instructed to turn around, look at the pedestrian signal, and state whether they see the color of the display, shape of the display, and (in the case of the presence of the countdown display) the amount of time indicated on the display. Participants were also instructed to indicate they would do if they wanted to cross the street and saw this display. If the countdown was displayed they were asked if they could read the numbers and read them back. The order of trials and the presentation of signal icons were randomized, with each of the signal options counterbalanced across participants.

Analysis

Participant responses were recorded for each of the stimulus condition. The experimenter recorded whether they could identify the color of the display, the shape of the display, and if they identified the countdown they were asked if they could identify the numbers on the display. The experimenter then asked what they would do if they saw this display.

RESULTS

The summary percent responding to each question for each of the pedestrian signals tested are presented in Table 9 (for 12 m) and Table 10 (for 30.5 m). Individual data are presented in Appendix C. For the 12 m (40 ft) crossing, results indicate that 95 percent of the participants were able to identify the color and 85 percent were able to identify shape of the walk indication. All participants who said they could identify the color said they would choose to cross. One participant (5 percent) could not identify the color or shape, and said they would not cross (this participant said they would ask for help in crossing). Participant responses for the walk symbol provided at a 12 m (40 ft) distance are provided in Appendix C. For the analysis of the walk signal at the 30.5 m (100 ft) crossing, 60 percent could identify the color and 45 percent could identify the shape of the walk indication. Three participants (15 percent) could only identify the color of the walk indication and not the shape; two of these participants said they would cross, and one said they would not. Eight participants (40 percent) could not identify the color or the shape, all of these participants said they would not cross, would ask for help or observe traffic cycles and use that information to cross.

All of the participants could identify the color and 85 percent could identify the shape of the don’t walk indication at the 12 m (40 ft) crossing. All participants said they would not cross. For the 30.5 m (100 ft) crossing, 75 percent of the participants could identify the color and 45 percent said they could identify the shape of the signal. None of the participants said they would cross.

Table 9. Summary results for each tested signal for 12 m (40 ft), Experiment 1C.

Condition	Percent Recognize Color	Percent Recognize Shape(s)	Percent That Could Read Number	Percent Choosing to Cross
WALK	95	85	NA	95
DON'T WALK	100	85	NA	0
DON'T WALK TO WALK	95	80	NA	90
PCS plus FDW	100	FDW 85 PCS 80	70	30
PCS alone	100	85	75	35

Table 10. Summary results for each tested signal for 30.5 m (100 ft), Experiment 1C.

Condition	Percent Recognize Color	Percent Recognize Shape(s)	Percent That Could Read Number	Percent Choosing to Cross
WALK	60	45	NA	55
DON'T WALK	75	45	NA	0
DON'T WALK TO WALK	70	25	NA	65
PCS plus FDW	65	FDW 30 PCS 35	0	20
PCS alone	75	40	5	5

Participants who could not identify the color or the shape said they would ask for help or observe traffic before attempting to cross.

For the 12 m (40 ft) crossing with the transition from don't walk to walk indication, 95 percent of the participants identified the color change and 80 percent identified change in the shape of the symbols. Only one participant who did not identify the color or shape of the indication said they would not cross; this participant said they would ask for help. For the 30.5 m (100 ft) crossing with the transition from don't walk to walk indication, 70 percent were able to identify the color change; all but one of these participants said they would cross. Five of the participants who were able to identify the color change were also able to identify the change in shape. Seven participants (35 percent) said they would not cross. These participants said they would ask for help, or watch and use traffic to cross.

For the 12 m (40 ft) crossing with FDW plus CPS indication, all participants identified the color and 85 percent identified the shape of the flashing don't walk display. Sixteen 80 percent could identify the countdown and 70 percent could read all or some of the numbers. Only six (30 percent) chose to cross; all of these participants could identify numbers and based the decision to cross on the numbers identified. For the 30.5 m (100 ft) crossing with FDW plus CPS indication, 65 percent identified the color, 30 percent identified the shape of the FDW, and 35 percent identified the countdown display, but none could read the numbers. Four participants (20 percent) said they would cross even though they could not read the numbers. Two of these participants said they could see the countdown was present, and one participant said he would be careful because he did not know how much time he had to cross.

For the 12 m (40 ft) crossing with the CPS alone, all participants were able to identify the color and 85 percent could identify the countdown was present while 75 percent of participants could read the numbers. Because sufficient time was left for the crossing, 7 participants (35 percent) elected to cross.

For the 30.5 m (100 ft) crossing with the CPS alone, 75 percent could identify the color of the countdown display, and 40 percent could identify there were numbers, however only one participant (5 percent) could read the numbers. Only the participant who could read the numbers elected to cross.

DISCUSSION

The results of this experiment show that persons with low-vision typically are cautious when making decisions on crossing. In all but one case the participants would not cross unless they could identify the walk symbol or read the numbers on the CPS that displayed sufficient time to cross. The only exceptions were four participants in the FDW plus CPS condition who choose to cross even though they could not read the numbers. One participant noted that he had to be careful because he did not know how much time was left. No participants in the CPS alone condition who could not read countdown elected to cross. It appears from these data that pedestrians with low-vision either wait for the walk symbol or are willing to use the CPS if they can read the numbers. The FDW plus CPS appeared no more effective than the CPS alone. Because of the relatively small sample size, it is not possible to conclude that the FDW plus CPS was less safe than the CPS alone. However, these findings do not mitigate against removing the FDW.

SUMMARY AND CONCLUSIONS

Information was requested from members of the FHWA TCD Pooled Fund states was conducted to determine the appropriate signal head configuration for testing. The results of this exercise indicated that most states reported the 40.6 by 45.7 cm (16 by 18 in.) pedestrian signal head housing with the 22.9 cm (9 in.) countdown digit size for all crosswalk lengths. Based on these results, we utilized the 40.6 by 45.7 cm (16 by 18 in.) pedestrian signal housing with the 22.9 cm (9 in.) countdown display in our testing.

Experiment 1A examined pedestrian comprehension of signals. Results indicated that participants understood that they should not start to cross during the clearance interval with the FDW present. However, more participants understood they could cross with a countdown showing a countdown with 17 s when the CPS was presented alone, and that most participants thought they could cross or choose to cross when presented with the CPS plus flashing walk. This finding indicates a perceived shift in decision making when the countdown timer is present that places less emphasis on signal compliance and more emphasis on pedestrian choice. This result is in agreement with field data showing that more pedestrians cross, but fewer are still in the intersection, after the countdown has finished.[(4)] More participants responded “make a decision” with the CPS alone than with the CPS with FDW or CPS with flashing walk. These results held for males and females and were consistent across age groups. These data are consistent with those reported by Singer and Lerner [(6)] in the North Eastern region of the country, and add data from a Midwest and Southern state, and increase the generality of the findings.

Experiment 1B examined how well pedestrians could determine how much time they needed to cross a crosswalk of approximately 12 m, 18 m, and 24 m (40 ft, 60 ft, and 80 ft, respectively), length. A total of 60 participants were instructed to start to cross only when they had sufficient time to finish their crossing. An examination of these data shows a high degree of consistency in crossing speed over the entire crossing. Most pedestrians were able to maintain a steady walking pace, and almost all were able to finish before the end of the countdown display. It is interesting to note that the two pedestrians who did not finish before the end of the countdown would have finished before the end of the yellow indication for the cross traffic (assuming standard signal timing). One of the most interesting findings was the high walking speeds observed in this study. Most observational data on walking speeds has based it on pedestrians starting during the walk indication. It is possible that pedestrians walk slower when they know they have a lot of time to cross and faster when they know they have less time to cross. An examination of the pedestrian walking speed data (provided in Appendix B) show that most pedestrians did not walk slower for shorter distances. These data support the hypothesis that pedestrians use the CPS time to determine the gait required to cross safely. This also implies that pedestrians “trust” the CPS to provide them with accurate information. A study of walking speeds based on the time the pedestrian think they need to cross facing a countdown timer is needed to better examine this issue.

Because these results provide evidence that pedestrians can use the countdown timer to ensure they can clear the crosswalk prior to cross traffic being released, there appears to be a safety benefit to the CPS. The results of Experiment 1A also indicate that the countdown used alone would help more pedestrians to cross during each cycle since some pedestrians feel they cannot cross when the FDW is present. Although pedestrian clearance appears to be exclusively a level of service issue, it also impacts safety because reducing the number of people who would need to wait during the FDW and don't walk in order to cross during the next walk. This reduces the number of pedestrians who have an opportunity to violate the SDW signal by attempting to cross during a perceived gap in the cross traffic. Field data should provide more information on this issue.

Experiment 1C examined whether the elimination of the FDW from the CPS display would have an adverse effect on low-vision pedestrians. An adverse effect would be an increased likelihood of crossing during the pedestrian countdown if they could not read the numbers, mistaking the display for the walk. It must be noted that although some low-vision pedestrians may not be able to see any of the pedestrian signal displays at some distances, they should not cross under these circumstances. The results of this study show that persons with low-vision typically are cautious crossing the street. In all but one case the participants would not cross unless they could identify the walk symbol or read the number on a countdown that displayed sufficient time to cross. The one exception was four participants in the FDW plus CPS condition who choose to cross even though they could not read the numbers. One even mentioned that he had to be careful because he did not know how much time was left. No participants in the CPS alone condition who could not read countdown elected to cross. Because of the sample size it is not possible to conclude that the FDW plus CPS was less safe than the CPS alone, but these data do not mitigate against removing the FDW.

It is interesting to note that the countdown signals are significantly smaller than the walking person and hand symbols. Because many of the pedestrians with low-vision did successfully use the countdown signal at shorter length crossings, it is possible to recommend that the size of the countdown display be increased to the same height at the other indications. This would improve recognition distance and would allow low-vision pedestrians to read the numbers sooner if they started after they saw the end of the walk. The results also show that pedestrians with low vision are relying on color for crossings of 30.5 m (100 ft), without being able to identify the shape of the symbol. These results support the need for accessible signals for wider crossings.

The overall results of this Phase I research support dropping the FDW from the pedestrian clearance interval. This change would increase the percentage of pedestrians who can walk at a higher speed than the slower speed the clearance display is calculated to support to cross safely. By clearing more pedestrians each cycle, the number left who might choose to violate the signal decreases. This change would also require a change to the UVC to not count pedestrians as violators if they begin to cross during the countdown, provided they finish crossing before the countdown ends. Another option would be to leave the FDW in place, but change the MUTCD and the UVC to not count pedestrians who start to cross during countdown with flashing hand as violators, provided they finish before countdown times out. One disadvantage of the former option is that many pedestrians who could cross would continue not to cross because they understand the FDW to mean they can't start to cross.

REFERENCES

1. City of Chicago Department of Transportation. (2002). *Countdown pedestrian signal study final report*. Retrieved October 16, 2003 from American Traffic Safety Services Association website: http://www.atssa.com/pubinfo/downloads/11-15-02a.PDF
2. Mahach, K., Nedzesky, A.J., Atwater, L., & Saunders, R. (2002). A comparison of pedestrian signal heads. *ITE Annual Meeting Compendium.*
3. Farraher, B. A. B. (2000). Pedestrian countdown indication – Market research and evaluation. *ITE 2000 Annual Meeting and Exhibit.*
4. Huang, H., & Zegeer, C. (2000). *The effects of pedestrian countdown signals in Lake Buena Vista*. Florida Department of Transportation.
5. Federal Highway Administration (FHWA). (2007). *Desktop reference for crash reduction factors*. Washington, DC: Author.
6. Singer, J. P., & Lerner, N. (2005). *Countdown pedestrian signals: A comparison of alternative pedestrian change interval displays: Final report* (Prepared for the Federal Highway Administration). Rockville, MD: Westat. Retrieved from http://www.atssa.com/galleries/default-file/Ped_Countdown_Report.pdf
7. National Committee on Uniform Traffic Laws and Ordinances. (2002). *Uniform vehicle code and model traffic ordinance*. Alexandria, VA: Author.
8. Federal Highway Administration (FHWA). (2012). *Manual on uniform traffic control devices for streets and highways* (2009 Ed., Including Revision 1 and 2). Washington, DC: Author.
9. Centers for Disease Control and Prevention National Center for Health Statistics. (2006). *National Health Interview Survey* (ICPSR20681-v3). Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor]. http://doi.org/10.3886/ICPSR20681.v3.
10. Eccles, K. A., Tao, R., & Mangum, B. C. (2007). Evaluation of pedestrian signals in Montgomery County, Maryland. *Transportation Research Record, 1878,* 36-41.
11. Schattler, K. L. Wakim, J. G., Datta, T. K., & McAvoy, D. (2007). Evaluation of pedestrian and driver behaviors at countdown pedestrian signals in Peoria, Illinois, *Transportation Research Record*, *2002*, 98-109.
12. Institute of Transportation Engineers (ITE). (2007). *Pedestrian signal safety for older persons*. Washington, DC: Author.
13. DKS Associates. (2001). *San Francisco pedestrian countdown signals: Preliminary evaluation summary*. San Francisco, CA: San Francisco Department of Parking and Traffic.
14. Leonard, J., Juckes, M., & Clement, B. (1999). *Safety & behavior: Behavioral evaluation of pedestrians and motorists towards pedestrian countdown signals* (Prepared for the City of Monterey, California). Laval, Quebec: Dessau-Soprin Inc.
15. Markowitz, F., Sciortino, S., Fleck, J. L. & Yee, B. M. (2006) Pedestrian countdown timers: experience with an extensive pilot installation. *ITE Journal*, *76*, 43-48.

16. Pulugurtha, S. S., Desai, A., & Pulugurtha, N. M. (2010). Are pedestrian countdown signals effective in reducing crashes? *Traffic Injury Prevention, 11*, 632-641.

17. Van Houten, R., LaPlante, J., & Gustafson, T. (2012). *Evaluating pedestrian safety improvements* (Report No. RC-1585). Lansing, MI: Michigan Department of Transportation.

18. Institute of Transportation Engineers (ITE). (2010). *Pedestrian traffic control signal indicators: Light emitting diode (LED) signal modules*. Washington, DC: Author.

19. Crews, J. E. (1991). Measuring rehabilitation outcomes and the public policies of aging and blindness. In N. D. Weber (Ed.), *Vision and Aging: Issues in Social Work Practice*. New York: Hawthorn.

20. Manton, Kenneth G., Corder, L.S., & Stallard, E. (1993). Estimates of change in chronic disability and institutional incidence and prevalence rates in the U.S. elderly population form the 1982, 1984, and 1989 National Long Term Care Survey. *Journal of Gerontology: Social Sciences, 48,* S153-166.

21. De l'Aune, W., Williams, M., Watson, G., Schuckers, P., & Ventimiglia, G. (2007). Clinical application of rehabilitation outcomes. *Journal of Visual Impairment and Blindness, 98,* 197-211.

22. Desai, M., Pratt, L., Lentzner, H., & Robinson, K. (2001, March). Trends in vision and hearing among older Americans. *Aging Trends, 2*. Hyattsville, MD: Centers for Disease Control and Prevention National Center for Health Statistics.

23. Williams, M. D., Van Houten, R., & Blasch, B. B. (2006). Recognition distance of pedestrian traffic signals by individuals with low vision. *Journal of Rehabilitation Research and Development*.

24. Van Houten, R., Blasch, B., & Malenfant, J. E. L. (2001). Use of animated eyes in pedestrian signals increases WALK sign recognition distance of low vision pedestrians. *Journal of Rehabilitation Research and Development, 38,* 443-448.

25. Institute of Transportation Engineers (ITE). (2004). *Pedestrian traffic control signal indicators* (Performance Specification). Washington, DC: Author.

APPENDIX A. QUESTION PROTOCOL FOR EXPERIMENT 1A

1. **General question for all signal heads**
    a. For every signal head, people were asked: "Imagine yourself at a crosswalk, about to cross the street, and you see this display. What does this display mean? And what should you do"
2. **Walk alone**
    a. If they responded: "I could cross."; "I could walk."; or any variant of these with the same meaning, their response was scored as correct.
    b. Any other response was coded as incorrect.
    c. There were no follow-up questions as all respondents made the correct response.
3. **Don't Walk alone**
    a. If they responded: "I would wait for the walk."; or "I can't cross the street."; or any variant with the same meaning, their response was scored as correct.
    b. Any other response was coded as incorrect.
    c. There were no follow-up questions as all respondents made the correct response.
4. **Countdown Pedestrian Signal plus FDW, the Countdown Pedestrian Signal alone, and the Countdown Pedestrian Signal plus the Flashing Walk (this option was only presented to the 200 participants in MI). These three options are always presented with 17 s displayed.**
    a. If they responded: "Walk across the street."; "Cross the street."; "Make a decision on whether to cross or not cross."; "'17' seconds left to cross the street, therefore I can cross."; or any other way of saying that they can cross the street, they were marked as correct.
    b. If they only responded: "'17' seconds to cross the street." they were asked: "What should you do?"
        i. If they responded: "I can cross the street." they were scored as correct. Any other response was coded as incorrect.
    c. If they responded: "I must stay at the crosswalk." they were asked: "Why?"
        i. If they responded: "There is not enough time to cross." they were also asked how much time they would need to cross. They were then asked: "What should you do if the display showed that amount of time?" If they answered: "Cross the street." their response was scored as correct. Any other response was marked as indicating they are not permitted to start crossing the street.
        ii. If they answered: "It did not matter how much time was displayed, I would not cross." they were asked what about the sign is telling them to stay. At this point, the response was recorded and their response was scored as prohibited from starting to cross the street.

d. If they responded: “I can’t walk.”; or “I can’t cross the street.”; or any variant of this, they were asked what about the sign is telling them they can’t walk. If they responded: “The flashing hand.”; “The flashing hand.”; “The color of the sign.”; or “The sign is broken and means the same thing as the flashing man.”; or any variant of these with the same meaning, their response was recorded and they were scored as being prohibited from starting to cross the street.
e. If they responded: “‘17’ seconds until I can cross the street. Therefore I need wait until the end of the countdown then begin to cross the street.”; or any variant with the same meaning, they were marked as incorrect.

APPENDIX B. CROSSING TIMES FOR EXPERIMENT 1B

The crossing times for each of the 60 participants from Experiment 1B is provided in this appendix. Note that the order of crossings was counterbalanced. For clarity of presentation, crossings are provided in a consistent order within the table.

Table 11. Participant crossing times, Experiment 1B.

Participant	Crossing	3 m (10 ft)	6 m (20 ft)	9 m (30 ft)	12 m (40 ft)	15 m (50 ft)	18 m (60 ft)	21 m (70 ft)	24 m (80 ft)
1	**12 m**	1.62	1.46	1.37	1.31	NA	NA	NA	NA
1	**18 m**	1.62	1.52	1.31	1.52	1.31	1.13	NA	NA
1	**24 m**	1.92	1.37	1.71	1.71	1.37	1.37	1.46	1.22
2	**12 m**	1.62	1.37	1.71	1.71	NA	NA	NA	NA
2	**18 m**	1.71	1.31	1.37	1.71	1.31	1.28	NA	NA
2	**24 m**	1.37	1.52	1.52	1.62	1.31	1.37	1.46	1.13
3	**12 m**	1.52	1.28	1.52	1.31	NA	NA	NA	NA
3	**18 m**	1.62	1.52	1.37	1.28	1.37	1.22	NA	NA
3	**24 m**	2.04	1.52	1.37	1.46	1.37	1.52	1.46	1.62
4	**12 m**	1.31	1.10	1.04	NA	NA	NA	NA	NA
4	**18 m**	1.46	1.16	1.28	1.16	1.16	0.91	NA	NA
4	**24 m**	1.31	1.28	1.28	1.16	1.28	1.04	1.28	0.94
5	**12 m**	1.52	1.28	1.62	1.13	NA	NA	NA	NA
5	**18 m**	1.52	1.31	1.71	1.37	1.52	1.13	NA	NA
5	**24 m**	1.46	1.62	1.37	1.62	1.37	1.71	1.28	1.13
6	**12 m**	1.62	1.80	1.52	1.22	NA	NA	NA	NA
6	**18 m**	1.80	1.31	1.52	1.37	1.37	1.37	NA	NA
6	**24 m**	1.92	1.71	1.71	1.71	1.71	1.46	1.46	1.04
7	**12 m**	1.71	1.31	1.62	1.16	NA	NA	NA	NA
7	**18 m**	1.37	1.52	1.10	1.37	1.31	1.16	NA	NA
7	**24 m**	1.62	1.52	1.46	1.31	1.52	1.37	1.52	1.31
8	**12 m**	1.62	1.52	2.04	1.80	NA	NA	NA	NA
8	**18 m**	1.52	1.46	1.52	1.37	1.52	1.28	NA	NA
8	**24 m**	1.46	1.52	1.62	2.53	1.52	1.62	1.52	1.31
9	**12 m**	2.53	1.62	1.37	1.16	NA	NA	NA	NA
9	**18 m**	2.04	1.62	1.62	1.46	1.16	NA	NA	NA
9	**24 m**	3.38	1.80	1.71	1.71	1.52	1.80	1.52	1.37
10	**12 m**	1.52	1.16	1.10	1.10	NA	NA	NA	NA
10	**18 m**	1.31	1.13	1.31	1.13	1.28	0.98	NA	NA
10	**24 m**	1.52	1.37	1.62	1.71	1.37	1.37	1.46	1.04
11	**12 m**	1.46	1.31	1.52	1.22	NA	NA	NA	NA

Participant	Crossing	3 m (10 ft)	6 m (20 ft)	9 m (30 ft)	12 m (40 ft)	15 m (50 ft)	18 m (60 ft)	21 m (70 ft)	24 m (80 ft)
11	**18 m**	1.52	1.71	1.52	1.62	1.28	1.22	NA	NA
11	**24 m**	1.31	1.80	1.52	1.22	1.31	1.37	1.13	1.13
12	**12 m**	1.31	1.37	1.52	1.28	NA	NA	NA	NA
12	**18 m**	1.92	1.52	1.71	1.28	1.52	1.52	NA	NA
12	**24 m**	1.62	1.52	1.46	1.62	1.62	1.62	1.52	1.28
13	**12 m**	1.04	1.52	1.37	1.16	NA	NA	NA	NA
13	**18 m**	1.28	1.10	1.28	1.46	1.62	1.16	NA	NA
13	**24 m**	1.52	1.71	1.62	1.37	1.37	1.80	1.28	1.37
14	**12 m**	1.52	1.52	1.62	1.46	NA	NA	NA	NA
14	**18 m**	1.52	1.52	1.62	1.52	1.52	1.28	NA	NA
14	**24 m**	1.52	1.37	1.31	1.46	1.46	1.52	1.37	1.22
15	**12 m**	1.46	1.28	1.52	1.04	NA	NA	NA	NA
15	**18 m**	1.31	1.28	13.11	1.71	1.46	1.13	NA	NA
15	**24 m**	1.46	1.52	1.62	1.62	1.52	1.52	1.52	1.62
16	**12 m**	1.80	2.35	2.04	2.35	NA	NA	NA	NA
16	**18 m**	1.46	1.62	1.71	1.46	1.52	1.37	NA	NA
16	**24 m**	1.52	1.52	2.04	1.71	1.71	1.52	1.46	1.31
17	**12 m**	1.31	1.46	1.62	1.37	NA	NA	NA	NA
17	**18 m**	1.28	1.80	1.71	1.71	1.71	1.46	NA	NA
17	**24 m**	1.80	1.80	2.04	1.71	1.71	1.71	3.05	2.77
18	**12 m**	1.80	1.31	1.31	1.13	NA	NA	NA	NA
18	**18 m**	1.37	1.52	1.31	1.37	1.31	1.28	NA	NA
18	**24 m**	1.31	1.52	1.46	1.52	1.37	1.37	1.37	1.46
19	**12 m**	1.16	1.31	1.22	1.28	NA	NA	NA	NA
19	**18 m**	1.52	1.37	1.28	1.31	1.28	NA	NA	NA
19	**24 m**	1.31	1.52	1.46	1.46	1.10	1.37	1.46	1.13
20	**12 m**	1.46	1.52	1.46	1.37	NA	NA	NA	NA
20	**18 m**	2.53	1.62	1.80	1.52	1.71	1.28	NA	NA
20	**24 m**	1.80	1.80	1.46	1.71	1.52	1.46	1.31	1.22
21	**12 m**	1.46	1.52	1.46	1.37	NA	NA	NA	NA
21	**18 m**	2.53	1.62	1.80	1.52	1.71	1.28	NA	NA
21	**24 m**	1.80	1.80	1.46	1.71	1.52	1.46	1.31	1.22
22	**12 m**	1.46	1.71	1.46	1.22	NA	NA	NA	NA
22	**18 m**	1.52	1.71	1.52	1.52	1.28	1.28	NA	NA
22	**24 m**	2.16	2.16	1.80	1.80	1.52	1.71	1.46	1.31
23	**12 m**	1.22	1.31	1.37	1.13	NA	NA	NA	NA
23	**18 m**	1.31	1.52	1.31	1.46	1.52	1.01	NA	NA
23	**24 m**	1.46	1.31	1.37	1.52	1.52	1.37	1.46	1.10

Participant	Crossing	3 m (10 ft)	6 m (20 ft)	9 m (30 ft)	12 m (40 ft)	15 m (50 ft)	18 m (60 ft)	21 m (70 ft)	24 m (80 ft)
24	**12 m**	1.92	1.62	1.62	1.28	NA	NA	NA	NA
24	**18 m**	1.52	1.92	1.92	1.52	1.52	1.52	NA	NA
24	**24 m**	1.71	1.62	1.80	1.71	1.62	1.71	1.52	1.52
25	**12 m**	1.31	1.31	1.16	0.79	NA	NA	NA	NA
25	**18 m**	1.37	1.62	1.46	1.46	1.37	1.28	NA	NA
25	**24 m**	1.16	1.62	1.71	1.31	1.46	1.62	1.37	1.52
26	**12 m**	1.62	1.52	1.37	1.28	NA	NA	NA	NA
26	**18 m**	1.37	1.37	1.28	1.31	1.31	0.73	NA	NA
26	**24 m**	1.71	2.04	1.71	1.62	1.71	1.62	1.62	1.31
27	**12 m**	1.71	1.52	1.37	1.28	NA	NA	NA	NA
27	**18 m**	1.52	1.52	1.52	1.46	1.46	1.16	NA	NA
27	**24 m**	1.46	1.37	1.31	1.22	1.37	1.37	1.31	1.16
28	**12 m**	1.52	1.37	1.16	1.28	NA	NA	NA	NA
28	**18 m**	1.62	1.31	1.31	1.46	1.31	1.31	NA	NA
28	**24 m**	1.37	1.80	1.22	1.28	1.46	1.37	1.37	1.13
29	**12 m**	1.22	1.28	1.37	1.31	NA	NA	NA	NA
29	**18 m**	1.31	1.52	1.37	1.52	1.37	1.13	NA	NA
29	**24 m**	1.52	1.28	1.31	1.37	1.52	1.52	1.92	1.22
30	**12 m**	1.22	1.28	1.16	1.16	NA	NA	NA	NA
30	**18 m**	1.13	1.28	1.28	1.16	1.31	1.31	NA	NA
30	**24 m**	1.71	1.52	1.37	1.37	1.46	1.31	1.37	1.10
31	**12 m**	1.28	1.10	1.62	0.88	NA	NA	NA	NA
31	**18 m**	1.04	1.13	1.46	1.31	1.28	1.28	NA	NA
31	**24 m**	1.22	1.22	1.46	1.37	1.37	1.22	1.16	1.37
32	**12 m**	2.35	1.46	1.31	1.28	NA	NA	NA	NA
32	**18 m**	2.04	1.71	1.37	1.46	1.31	1.52	NA	NA
32	**24 m**	1.80	1.52	1.31	1.31	1.52	1.37	1.31	1.31
33	**12 m**	2.04	2.35	1.92	1.62	NA	NA	NA	NA
33	**18 m**	3.05	1.92	2.26	1.80	1.80	1.71	NA	NA
33	**24 m**	2.04	2.04	1.80	1.71	1.92	1.92	1.92	1.92
34	**12 m**	2.53	1.80	1.62	1.62	NA	NA	NA	NA
34	**18 m**	1.62	1.52	1.62	1.62	1.37	1.31	NA	NA
34	**24 m**	1.92	1.52	1.62	1.80	1.52	1.52	1.46	1.31
35	**12 m**	1.04	1.52	1.46	1.31	NA	NA	NA	NA
35	**18 m**	2.26	1.31	1.31	1.31	1.46	1.31	NA	NA
35	**24 m**	1.92	1.13	1.31	1.37	1.46	1.71	1.92	1.37
36	**12 m**	2.35	1.37	1.28	1.22	NA	NA	NA	NA
36	**18 m**	1.52	1.31	1.52	1.31	1.52	1.22	NA	NA

Participant	Crossing	3 m (10 ft)	6 m (20 ft)	9 m (30 ft)	12 m (40 ft)	15 m (50 ft)	18 m (60 ft)	21 m (70 ft)	24 m (80 ft)
36	**24 m**	1.46	1.37	1.62	1.62	1.13	1.52	1.62	1.22
37	**12 m**	1.46	1.62	1.62	1.37	NA	NA	NA	NA
37	**18 m**	2.26	1.37	1.62	1.52	1.37	1.31	NA	NA
37	**24 m**	1.80	1.62	1.71	1.52	1.62	1.62	1.46	1.46
38	**12 m**	1.62	1.01	1.16	0.94	NA	NA	NA	NA
38	**18 m**	1.92	1.16	1.28	1.16	1.10	0.98	NA	NA
38	**24 m**	1.13	1.10	1.16	1.22	1.28	1.13	1.10	1.16
39	**12 m**	1.62	1.10	1.13	1.04	NA	NA	NA	NA
39	**18 m**	1.52	1.22	1.10	1.28	0.88	1.10	NA	NA
39	**24 m**	3.05	1.04	1.31	1.22	1.28	1.46	1.62	1.10
40	**12 m**	2.04	1.04	1.16	1.01	NA	NA	NA	NA
40	**18 m**	1.62	1.22	1.31	1.28	1.52	1.16	NA	NA
40	**24 m**	1.52	1.16	1.22	1.31	1.37	1.46	1.52	1.37
41	**12 m**	1.71	1.71	1.71	1.28	NA	NA	NA	NA
41	**18 m**	1.80	1.52	1.71	1.28	1.62	1.16	NA	NA
41	**24 m**	1.71	1.37	1.52	1.62	1.46	1.46	1.62	1.22
42	**12 m**	1.31	1.37	1.28	1.13	NA	NA	NA	NA
42	**18 m**	1.46	1.10	1.28	1.22	1.31	0.98	NA	NA
42	**24 m**	1.80	1.22	1.16	1.31	1.13	1.28	1.22	0.91
43	**12 m**	1.80	1.16	1.31	1.10	NA	NA	NA	NA
43	**18 m**	1.52	1.62	1.37	1.62	1.62	1.28	NA	NA
43	**24 m**	2.04	1.13	1.28	1.31	1.37	1.28	1.37	1.13
44	**12 m**	1.62	1.46	1.52	1.31	NA	NA	NA	NA
44	**18 m**	2.04	1.37	1.71	1.37	1.37	1.22	NA	NA
44	**24 m**	2.04	1.52	1.62	1.31	1.31	1.37	1.37	1.13
45	**12 m**	1.46	1.28	1.28	1.01	NA	NA	NA	NA
45	**18 m**	1.46	1.52	1.37	1.52	1.37	1.37	NA	NA
45	**24 m**	1.71	2.53	1.46	1.28	1.31	1.52	1.37	1.31
46	**12 m**	1.22	1.71	1.71	1.92	NA	NA	NA	NA
46	**18 m**	1.10	1.80	1.80	1.71	1.80	1.62	NA	NA
46	**24 m**	1.13	1.62	1.71	1.71	1.92	1.80	1.71	1.71
47	**12 m**	1.04	1.28	1.37	1.22	NA	NA	NA	NA
47	**18 m**	1.37	1.31	1.37	1.31	1.28	1.16	NA	NA
47	**24 m**	1.16	1.37	1.46	1.52	1.46	1.46	1.37	1.46
48	**12 m**	1.04	1.46	1.31	1.28	NA	NA	NA	NA
48	**18 m**	1.28	1.31	1.31	1.22	1.13	1.13	NA	NA
48	**24 m**	1.28	1.22	1.37	1.37	1.31	1.31	1.37	1.16
49	**12 m**	1.01	1.31	1.10	0.98	NA	NA	NA	NA

Participant	Crossing	3 m (10 ft)	6 m (20 ft)	9 m (30 ft)	12 m (40 ft)	15 m (50 ft)	18 m (60 ft)	21 m (70 ft)	24 m (80 ft)
49	**18 m**	1.28	1.28	1.28	1.62	1.46	1.31	NA	NA
49	**24 m**	1.04	1.31	1.31	1.31	1.37	1.46	1.37	1.37
50	**12 m**	1.71	1.62	1.37	1.46	NA	NA	NA	NA
50	**18 m**	1.52	1.62	1.52	1.52	1.52	1.46	NA	NA
50	**24 m**	2.04	1.71	1.62	1.62	1.31	1.80	1.71	1.28
51	**12 m**	1.92	1.71	1.80	1.46	NA	NA	NA	NA
51	**18 m**	1.37	1.71	1.80	1.46	1.80	2.26	NA	NA
51	**24 m**	1.31	1.80	1.92	1.80	1.92	1.52	1.80	1.31
52	**12 m**	1.62	1.52	1.46	1.16	NA	NA	NA	NA
52	**18 m**	1.37	2.26	1.52	1.71	1.46	1.37	NA	NA
52	**24 m**	1.37	1.62	1.71	1.71	1.71	2.26	2.53	1.92
53	**12 m**	1.37	1.71	1.52	1.31	NA	NA	NA	NA
53	**18 m**	1.62	1.52	1.46	1.37	1.31	1.16	NA	NA
53	**24 m**	1.46	1.37	1.46	1.37	1.28	1.31	1.22	0.98
54	**12 m**	1.80	2.26	2.04	1.37	NA	NA	NA	NA
54	**18 m**	1.92	1.62	1.16	1.04	1.01	1.37	NA	NA
54	**24 m**	2.26	1.92	1.80	1.62	1.62	1.80	2.35	1.46
55	**12 m**	1.31	1.37	1.46	1.22	NA	NA	NA	NA
55	**18 m**	1.80	1.71	1.80	1.71	1.62	1.31	NA	NA
55	**24 m**	1.92	1.80	1.46	1.46	1.28	1.52	1.46	1.13
56	**12 m**	1.37	1.37	1.13	1.13	NA	NA	NA	NA
56	**18 m**	1.52	1.62	1.52	1.46	1.62	1.52	NA	NA
56	**24 m**	1.71	1.46	1.37	1.46	1.46	1.37	1.71	1.22
57	**12 m**	1.16	1.10	0.98	1.01	NA	NA	NA	NA
57	**18 m**	1.31	1.28	1.28	1.37	1.16	1.22	NA	NA
57	**24 m**	1.22	1.04	1.01	1.13	1.01	1.13	1.31	1.52
58	**12 m**	1.28	1.52	1.52	1.22	NA	NA	NA	NA
58	**18 m**	1.46	1.62	1.46	1.52	1.46	1.16	NA	NA
58	**24 m**	1.92	1.46	1.62	1.46	1.37	1.28	1.31	1.04
59	**12 m**	1.28	1.28	1.10	0.82	NA	NA	NA	NA
59	**18 m**	1.37	1.28	1.16	1.62	1.37	1.04	NA	NA
59	**24 m**	1.31	1.52	1.80	1.52	1.52	1.22	1.22	1.16
60	**12 m**	2.26	1.92	2.53	2.35	NA	NA	NA	NA
60	**18 m**	1.62	1.46	1.37	1.52	1.92	1.62	NA	NA
60	**24 m**	1.62	1.52	1.46	1.52	1.37	1.52	1.46	1.52

APPENDIX C. INDIVIDUAL RESPONSES FROM EXPERIMENT 1C

The individual participant responses to the different signal indications in Experiment 1C are provided within this appendix.

Table 12. Participant responses to the Walk indication at a 12 m (40 ft) distance.

Participant Number	Identified Color	Identified Shape	Crossing Action
1	No	No	Not cross
2	Yes	No	Cross
3	Yes	Yes	Cross
4	Yes	Yes	Cross
5	Yes	Yes	Cross
6	Yes	Yes	Cross
7	Yes	No	Cross
8	Yes	Yes	Cross
9	Yes	Yes	Cross
10	Yes	Yes	Cross
11	Yes	Yes	Cross
12	Yes	Yes	Cross
13	Yes	Yes	Cross
14	Yes	Yes	Cross
15	Yes	Yes	Cross
16	Yes	Yes	Cross
17	Yes	Yes	Cross
18	Yes	Yes	Cross
19	Yes	Yes	Cross
20	Yes	Yes	Cross

Table 13. Participant responses to the Walk indication at a 30.5 m (100 ft) distance.

Participant Number	Identified Color	Identified Shape	Crossing Action
Participant 1	No	No	Not cross
Participant 2	Yes	No	Cross
Participant 3	No	No	Not cross
Participant 4	No	No	Not cross
Participant 5	Yes	Yes	Cross
Participant 6	Yes	Yes	Cross
Participant 7	No	No	Not cross
Participant 8	No	No	Not cross
Participant 9	Yes	Yes	Cross
Participant 10	Yes	Yes	Cross
Participant 11	Yes	Yes	Cross
Participant 12	Yes	No	Cross
Participant 13	Yes	No	Not cross
Participant 14	No	No	Not cross
Participant 15	No	No	Not cross
Participant 16	Yes	Yes	Cross
Participant 17	Yes	Yes	Cross
Participant 18	No	No	Not cross
Participant 19	Yes	Yes	Cross
Participant 20	Yes	Yes	Cross

Table 14. Participant responses to the Don't Walk indication at a 12 m (40 ft) distance.

Participant Number	Identified Color	Identified Shape	Crossing Action
1	Yes	No	Not cross
2	Yes	Yes	Not cross
3	Yes	Yes	Not cross
4	Yes	Yes	Not cross
5	Yes	Yes	Not cross
6	Yes	Yes	Not cross
7	Yes	No	Not cross
8	Yes	Yes	Not cross
9	Yes	Yes	Not cross
10	Yes	Yes	Not cross
11	Yes	Yes	Not cross
12	Yes	Yes	Not cross
13	Yes	Yes	Not cross
14	Yes	Yes	Not cross
15	Yes	Yes	Not cross
16	Yes	Yes	Not cross
17	Yes	No	Not cross
18	Yes	Yes	Not cross
19	Yes	Yes	Not cross
20	Yes	Yes	Not cross

Table 15. Participant responses to the Don't Walk indication at a 30.5 m (100 ft) distance.

Participant Number	Identified Color	Identified Shape	Crossing Action
1	No	No	Not cross
2	No	No	Not cross
3	Yes	Yes	Not cross
4	Yes	Yes	Not cross
5	Yes	Yes	Not cross
6	Yes	Yes	Not cross
7	No	No	Not cross
8	No	No	Not cross
9	Yes	No	Not cross
10	Yes	Yes	Not cross
11	Yes	No	Not cross
12	Yes	Yes	Not cross
13	Yes	Yes	Not cross
14	Yes	No	Not cross
15	Yes	No	Not cross
16	Yes	No	Not cross
17	Yes	No	Not cross
18	No	No	Not cross
19	Yes	Yes	Not cross
20	Yes	Yes	Not cross

Table 16. Participant responses to the Don't Walk to Walk transition at a 12 m (40 ft) distance.

Participant Number	Identified Color	Identified Shape	Crossing Action
Participant 1	No	No	Not cross
Participant 2	Yes	No	Cross
Participant 3	Yes	Yes	Cross
Participant 4	Yes	Yes	Cross
Participant 5	Yes	Yes	Cross
Participant 6	Yes	Yes	Cross
Participant 7	Yes	No	Cross
Participant 8	Yes	Yes	Cross
Participant 9	Yes	Yes	Cross
Participant 10	Yes	Yes	Cross
Participant 11	Yes	Yes	Cross
Participant 12	Yes	Yes	Cross
Participant 13	Yes	Yes	Cross
Participant 14	Yes	Yes	Cross
Participant 15	Yes	Yes	Cross
Participant 16	Yes	Yes	Cross
Participant 17	Yes	No	Cross
Participant 18	Yes	Yes	Not cross
Participant 19	Yes	Yes	Cross
Participant 20	Yes	Yes	Cross

Table 17. Participant responses to the Don't Walk to Walk transition at a 30.5 m (100 ft) distance.

Participant Number	Identified Color	Identified Shape	Crossing Action
1	No	No	Not cross
2	Yes	No	Cross
3	No	No	Not cross
4	Yes	No	Cross
5	Yes	No	Cross
6	Yes	No	Not cross
7	No	No	Not cross
8	No	No	Not cross
9	Yes	No	Cross
10	Yes	Yes	Cross
11	Yes	Yes	Cross
12	Yes	Yes	Cross
13	Yes	No	Cross
14	Yes	No	Cross
15	No	No	Not cross
16	Yes	No	Cross
17	Yes	No	Cross
18	No	No	Not Cross
19	Yes	Yes	Cross
20	Yes	Yes	Cross

Table 18. Participant responses to the CPS plus FDW at a 12 m (40 ft) distance.

Participant Number	Identified Color	Identified Shape	Read Numbers	Crossing Action
1	Yes	No/No	No	Not cross
2	Yes	Yes/No	No	Not cross
3	Yes	Yes/Yes	Some	Not cross
4	Yes	Yes/Yes	Yes	Not cross
5	Yes	Yes/Yes	Yes	Not cross
6	Yes	Yes/Yes	Yes	Not cross
7	Yes	No/No	No	Not cross
8	Yes	Yes/Yes	Yes	Not cross
9	Yes	Yes/Yes	Yes	Cross
10	Yes	Yes/Yes	Yes	Cross
11	Yes	Yes/Yes	Yes	Not cross
12	Yes	Yes/No	No	Not cross
13	Yes	Yes/Yes	Some	Cross
14	Yes	Yes/Yes	No	Not cross
15	Yes	Yes/Yes	Some	Cross
16	Yes	Yes/Yes	Some	Not cross
17	Yes	No/Yes	No	Not cross
18	Yes	Yes/Yes	Yes	Cross
19	Yes	Yes/Yes	Yes	Not cross
20	Yes	Yes/Yes	Yes	Cross

Table 19. Participant responses to the CPS plus FDW at a 30.5 m (100 ft) distance.

Participant Number	Identified Color	Identified Shape	Read Numbers	Crossing Action
1	No	No/No	No	Not cross
2	No	No/No	No	Not cross
3	No	No/No	No	Not cross
4	Yes	Yes/Yes	No	Not cross
5	Yes	No/No	No	Not cross
6	Yes	Yes/Yes	No	Not cross
7	No	No/No	No	Not cross
8	No	No/No	No	Cross
9	Yes	Yes/Yes	No	Cross
10	Yes	Yes/Yes	No	Cross
11	Yes	Yes/Yes	No	Not cross
12	Yes	No/No	No	Not cross
13	Yes	No/No	No	Not cross
14	No	No/No	No	Not cross
15	Yes	No/No	No	Not cross
16	Yes	No/No	No	Not cross
17	Yes	No/No	No	Cross
18	No	No/No	No	Not cross
19	Yes	No/Yes	No	Not cross
20	Yes	Yes/Yes	No	Not cross

Table 20. Participant responses to the CPS alone at a 12 m (40 ft) distance.

Participant Number	Identified Color	Identified Shape	Read Numbers	Crossing Action
1	Yes	No	No	Not cross
2	Yes	Yes	No	Not cross
3	Yes	Yes	Some	Not cross
4	Yes	Yes	Some	Not cross
5	Yes	Yes	Yes	Not cross
6	Yes	Yes	Yes	Cross
7	Yes	No	No	Not cross
8	Yes	Yes	Yes	Not cross
9	Yes	Yes	Yes	Cross
10	Yes	Yes	Yes	Cross
11	Yes	Yes	Yes	Not cross
12	Yes	Yes	Yes	Not cross
13	Yes	Yes	Some	Cross
14	Yes	No	No	Not cross
15	Yes	Yes	Some	Cross
16	Yes	Yes	Some	Not cross
17	Yes	Yes	No	Not cross
18	Yes	Yes	Yes	Not cross
19	Yes	Yes	Yes	Cross
20	Yes	Yes	Yes	Cross

Table 21. Participant responses to the CPS alone at a 30.5 m (100 ft) distance.

Participant Number	Identified Color	Identified Shape	Read Numbers	Crossing Action
1	No	No	No	Not cross
2	Yes	No	No	Not cross
3	Yes	No	No	Not cross
4	Yes	Yes	No	Not cross
5	Yes	No	No	Not cross
6	Yes	Yes	No	Not cross
7	No	No	No	Not cross
8	No	No	No	Not cross
9	Yes	No	No	Not cross
10	Yes	Yes	No	Not cross
11	Yes	Yes	No	Not cross
12	Yes	Yes	No	Not cross
13	Yes	No	No	Not cross
14	Yes	No	No	Not cross
15	No	No	No	Not cross
16	Yes	No	No	Not cross
17	Yes	Yes	No	Not cross
18	No	No	No	Not cross
19	Yes	Yes	Some	Cross
20	Yes	Yes	No	Not cross