Final Report:

Aging Road User Studies of Intersection Safety

BDV30 TWO 977-04

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Disclaimer

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation or the U. S. Department of Transportation.

Prepared in cooperation with the State of Florida Department of Transportation and the U. S. Department of Transportation.

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	pound force	4.45	newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa
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)				
^{o}C	Celsius	1.8C+32	Fahrenheit	^{o}F
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

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16. Abstract. Task 1.1 assessed younger (21-35 years), middle-aged (50-64 years), and older (65+) drivers' ability to quickly perceive the presence of marked/unmarked crosswalks and pedestrians within them in computer-based laboratory tasks that recorded response times and eye movements. There was an advantage for special emphasis markings in that they were detected more quickly and accurately compared to standard markings. However, there was no evidence that markings improved or reduced pedestrian conspicuity. In Task 1.2, pedestrians were observed at two signalized intersections (Monroe and Georgia, Monroe and Carolina) in Tallahassee to observe the effect of different crosswalk markings on pedestrian behavior. Special emphasis markings did not induce more pedestrians to cross at signalized crosswalk locations compared to crossing midblock at an unmarked location. A simulator experiment (Task 1.3) found that different crosswalk markings had no impact on driver behavior. Task 2.1 and Task 2.2 examined younger and older adults' perception-reaction times to yellow traffic signals in a driving situation. In Task 2.1, modeling was used to estimate this value for younger and older adults, while Task 2.2 provided this value through a driving simulator task. Both revealed that older adults needed substantially more time to react to a yellow signal compared to younger adults (Modeling: 767ms, Simulator Study: 803ms). Task 3.1 reviewed the Flashing Yellow Arrow (FYA) literature and suggested a need for further study, especially with older adults, and with respect to the effectiveness of FYA educational materials. A lab study (Task 3.2) found that participants of all ages infrequently misunderstood the meaning of a FYA signal in a way that would result in a crash. However, a simulator study (Task 3.3) found that behavioral measure of comprehension were higher for participants exposed to FDOT's FYA tip card. Recommendations for the implementation of each of these countermeasures are discussed.

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Crosswalk, pedestrian, older driver, older pedestrians age, aging road user, flashing yellow arrow, response time modeling	No restrictions

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Executive Summary

This document reports the results of projects BDK83 977-21 and BDV30 TWO 977-04.

The combined project investigated the effectiveness of safety countermeasures designed to protect drivers and pedestrians of all ages at intersections. Specifically, we examined 1) whether there is an advantage associated with special emphasis crosswalks compared to standard crosswalk markings, 2) whether estimates of perception-response time, which partially determine yellow signal phase duration, are sufficiently long to account for age-related changes, and 3) whether Flashing Yellow Arrow (FYA) protected/permissive left-turn (PPLT) displays are easily understood by older adults and whether current tip cards are effective at conveying the appropriate responses to these displays. These issues are especially relevant for the state of Florida, given its large and growing older adult population and the fact that Florida is one of the states with the highest pedestrian fatality rates in the United States. The Florida Department of Transportation (FDOT) will use study results to support the implementation of the Aging Road User Strategic Safety Plan through their Safe Mobility for Life Program.

Task 1: To ensure that countermeasures address the needs of all drivers and pedestrians, we included younger (ages 21 to 35), middle-aged (ages 50 to 64), and older adult (ages 65 and older) participants. In order to understand the potential advantage of special emphasis crosswalks, we examined both driver and pedestrian responses to standard and special emphasis markings. This included a laboratory study with eye tracking, an observation study to assess pedestrian and some driver behaviors, and a driving simulator study that evaluated the impact of standard and special emphasis crosswalk markings on drivers' responses to pedestrians entering the roadway and their allocation of attention. In laboratory tasks, a substantial advantage in recognizing the presence of a marked crosswalk was observed for special emphasis markings compared to standard markings. However, this did not translate to faster/more accurate detection of pedestrians within special emphasis markings in simulated roadway scenes. The observational study did not reveal that pedestrians were more likely to use a special emphasis crosswalk compared to a standard marked crosswalk, though some evidence from survey data collected suggested that pedestrians felt more comfortable within special emphasis crosswalks. Finally, the driving simulator study did not reveal that special emphasis crosswalks had a differential impact on drivers' behavior or attention compared to standard markings. In sum, special emphasis markings were easier to detect (especially for older adults, and especially at greater distance), but no observable impact on pedestrian or driver behavior was observed compared to standard crosswalk markings.

Task 2: Task 2 focused on estimating perception-response times to the onset of yellow traffic signals to ensure that perception-response times used in decisions such as setting yellow signal duration accurately account for age-related perceptual and cognitive declines. Goals, Operators, Methods, and Selection rules (GOMS) modeling was used to provide these estimates for younger and older adults, and these estimates were checked against data collected as younger and older drivers responded to yellow signals within a driving simulator. Modeling and experimental data were very consistent: the perception-response times of older adults were between 763 and 803ms longer than those of younger adults. Results suggest that estimates of perception-response time might need to be lengthened to account for age-related slowing.

Task 3: Task 3 focused on whether FYA PPLT displays are quickly and easily understood by drivers of all ages. A completed literature review suggested that FYA PPLT displays are effective at improving safety (compared to a circular green for the left turn movement), but these studies have generally included few older adult participants, and have not examined the potential benefit of educational materials to improve FYA comprehension. In a laboratory signal comprehension task it was found that in general, although there were errors in comprehension for all age groups, these errors would likely not be safety critical (i.e., participant assumes FYA indicates that the left-turning driver has right-of-way). Similar results were observed (few errors, no crashes) in a driving simulator study of FYA comprehension. However, an effect of FDOT's FYA tip card was observed. Consistent with uncertainty regarding what to do, participants who were not exposed to the tip card waited at the intersection significantly longer in response to a FYA signal compared to participants who read the tip card before the driving scenario. This effect was observed for both younger and older drives.

Based on these findings, we offer a number of recommendations:

1) At signalized intersections, the current study found no evidence of a significant advantage of special emphasis over standard crosswalk markings, however there could be specific situations not tested in the studies reported here in which special emphasis markings might be advantageous such as mid-block crossings or uncontrolled crossings at intersections.

2) Estimates of a perception reaction time (PRT) to a yellow signal, often assumed as 1 second, may not account for age-related changes adequately. To assist older drivers, this estimate should be increased. At a minimum, we recommend additional study to provide evidence that 1 second is sufficient.

3) Flashing Yellow Arrow (FYA) signals do not appear to be associated with safety-critical errors for younger or older adults. We can recommend their further implementation in the state of Florida as a safety countermeasure.

4) We recommend more active dissemination of FYA educational materials such as FDOT's FYA Tip Card. Tip cards were found to reduce confusion regarding the meaning of this signal and may increase traffic flow.

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Chapter 1. Introduction

Intersections make up a small proportion of the total roadway, yet are associated with a large proportion of traffic-related fatalities. In Florida in 2012, 32% of all traffic-related fatalities occurred at or near intersections (NHTSA, 2012). In this report we present the results of studies conducted to evaluate the effectiveness of three countermeasures designed to enhance the safety and mobility of Florida road users, with a focus on older adults (65+): Special emphasis crosswalks, extended yellow signal duration, and flashing yellow arrow protected/permissive left turn signals (FYA PPLT).

Special Emphasis Crosswalks. In 2010, Florida reported one of the highest rates of pedestrian fatalities in the United States: 2.58 per 100,000 residents (NHTSA, 2012). Although pedestrian fatalities represent a relatively small proportion of injuries and fatalities in traffic crashes (3% of injuries and 12% of fatalities), historically, this type of crash has been a difficult target for reduction because crashes are due to the interaction of a variety of factors, including the built environment and the behavior of both drivers and pedestrians. An important factor in pedestrian-vehicle crashes is that the driver fails to yield or fails to do so in sufficient time to avoid the crash. Considering this, crosswalks are intended to cue drivers that they are approaching a location where pedestrians may be crossing the roadway so that they exercise appropriate caution.

Yellow Signal Duration. Nationally, more than 900 people are killed and over 200,000 are injured each year in crashes involving running red signals, accounting for approximately 10 percent of all intersection fatalities (FHWA, 2010). While some red light running is reckless, caused by drivers trying to “beat the light,” other instances of red light running are misjudgments due to the driver not reacting quickly enough during the yellow signal phase. Increased enforcement, either through traffic stops or, more recently, through the use of red light running cameras (RLRC), target instances of reckless red light running. Other countermeasures, such as lengthening the yellow signal phase, installing vehicle detectors that prevent the onset of a yellow signal when a vehicle is in the “dilemma zone” (area within which it may be difficult for drivers to decide whether they should stop), or adjusting the all-red clearance interval, aim to reduce misjudgment-based red light running. Lengthening the yellow signal duration has been shown to be effective at reducing red light running (e.g. Bonneson & Zimmerman, 2004; Van der Horst, 1998). Studies have also found a combination of RLRC cameras and lengthening yellow signal duration to be effective at reducing red light running (Retting, Ferguson, & Farmer, 2008).

Countermeasures to Reduce Left-Turn Crashes: Flashing Yellow Arrow. Left-turn crashes are among the most common and severe intersection crashes (Wang & Abel-Aty, 2008). A left-turn crash involves a driver turning across a (typically fast-moving) stream of traffic and being struck by opposing traffic during the turn. As we will review later, older adults find making left turns especially challenging due to age-related changes to cognition and vision. Older adults have also been found to be at greater risk for intersection crashes in general (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998), and due to increased vulnerability to crash forces, older drivers are more likely than younger drivers to be seriously injured or killed when involved in a vehicle crash (e.g. ADOT, 1996; Li, Braver, & Chen, 2003). Countermeasures that successfully reduce left-turn crashes have the potential to substantially reduce the higher risk experienced by older drivers.

Potential causes of older adults' increased risk of crash involvement include perceptual and cognitive declines that accompany the aging process, which in turn impair the ability of older drivers to correctly judge the speed/distance of oncoming vehicles and the gaps between vehicles (Scialfa et al., 1991; Stamatiadis et al., 1991). One solution to reduce left-turn crashes has been to offset left-turn lanes so that drivers have a less obstructed view of oncoming traffic. Protected left turns, where there is an exclusive left-turn phase, have been shown to be the safest for left turning drivers. However, this benefit comes at the cost of reduced through volumes, which can also lead to delays (Yu, Qi, Yu, Guo, & Chen, 2008). The operation of a protected permissive left turn (PPLT) phasing has the benefit of increasing through volume but are also associated with higher crash rates compared to protected only phasing. A potential solution aimed at reducing the crash rate at PPLT intersections has been to implement a new traffic signal featuring a flashing yellow arrow, which received interim approval from FHWA in 2006. This signal configuration is intended to prevent the misconception that a circular green signal within a PPLT display guarantees right-of-way for the left-turning driver in a left-turn-only lane. In general, studies have found that drivers understand and react appropriately to the FYA signal. However, some studies have also noted lower comprehension rates for older drivers (Brehmer, Kacir, Noyce, & Manser, 2003), while other work has not included sufficient numbers of older participants to draw clear conclusions about potential age differences in signal comprehension (e.g. MoDOT, 2008).

The series of studies outlined in this report had the aim of understanding the effectiveness of various countermeasures designed to increase the safety of Florida road-users at intersections: special emphasis crosswalks, longer yellow signal phase durations, and FYA PPLT displays. Effective countermeasures are anticipated to be especially beneficial to Florida because 1) Florida has the highest pedestrian fatality rate in the nation, 2) Florida has one of the oldest populations in the U.S., with 18% of its population estimated to be age 65 or older, and the number of older citizens in Florida and throughout the nation is predicted to continue to grow (U.S. Census Bureau, 2011), and 3) research-based decision making is needed to support Florida's Aging Road User Strategic Safety Plan.

Objectives and Supporting Tasks

An objective of Florida's *Aging Road User Strategic Safety Plan* (FDOT, 2011; available: http://www.safeandmobileseniors.org/FloridaCoalition.htm#Strategic_Plan) is to "improve the transportation environment to better accommodate the safety, access, and mobility of aging road users" (Objective 5.2) through "research that enhances and validates safety and mobility countermeasures" (Strategy 5.2.4). The research reported here advances this objective by studying younger (18-35), middle-aged (50-64), and older (65+) drivers and pedestrians in their comprehension of and response to intersection signals and crosswalk markings. Task 1 focuses on issues related to crosswalk safety both from the perspective of the pedestrian and driver. Task 2 focuses on yellow signal time and whether current timing is sufficient for older adults given age-related declines in processing speed and reaction time (Salthouse, 1996). Finally, Task 3 focuses on Flashing Yellow Arrow (FYA) Protected/Permissive Left-Turn (PPLT) displays which have recently been introduced in Florida, with a particular focus on potential age-related differences and methods to boost comprehension across all ages.

Chapter 2. Task 1 - Evaluating the Impact of Standard and Special Emphasis Crosswalk Markings on Drivers' and Pedestrians' Behavior

Task 1.1. A Laboratory Investigation into Potential Perceptual Advantages of Special Emphasis Crosswalks

Task 1 consists of three studies designed to address the question of whether special emphasis crosswalk markings are more effective than standard crosswalk markings at enhancing pedestrian safety at signal-controlled intersections (see Figure 1). Because pedestrian-vehicle crashes are caused by the interaction of many factors, which include the speed at which drivers detect and yield to pedestrians crossing the roadway, as well as pedestrians' choices of crossing location and vigilance to approaching vehicles, our studies examined factors relevant to the behavior and performance of both drivers and pedestrians. To this end, we first conducted a laboratory study (Task 1.1) using eye tracking to assess potential perceptual advantages of special emphasis crosswalks over standard marked crosswalks. That is, are special emphasis crosswalks likely to be more quickly and accurately detected by drivers? An additional concern addressed by Task 1.1 is whether special emphasis crosswalks add visual clutter to the environment, which may decrease pedestrian conspicuity. To examine the effect marked crosswalks may have on pedestrian attitudes and behaviors, we conducted an observational study (Task 1.2) in which pedestrian behavior was compared between an intersection with standard crosswalk markings and an intersection with special emphasis markings. This task also included a survey of pedestrians regarding feelings of comfort and safety within crosswalks, and assessed knowledge of pedestrian laws. Finally, Task 1.3 examined the effect of different types of crosswalk markings on driver behavior. In this study, participants completed a simulated driving task in which they encountered pedestrians at signal-controlled intersections with either standard or special emphasis crosswalk markings. We compared drivers' responses to pedestrians entering the roadway, as well as drivers' allocation of visual attention.

Each of these studies included younger, middle-aged, and older drivers and pedestrians so that we could assess potential advantages of special emphasis crosswalk markings for road users of all ages. Given that older adults may require more time to react to driving events, the stronger visual cue provided by special emphasis crosswalk markings may be especially beneficial for older drivers. However, before we present the results of our completed studies, we begin with a review of previous research on the effectiveness of marked crosswalks in reducing pedestrian-vehicle crashes.

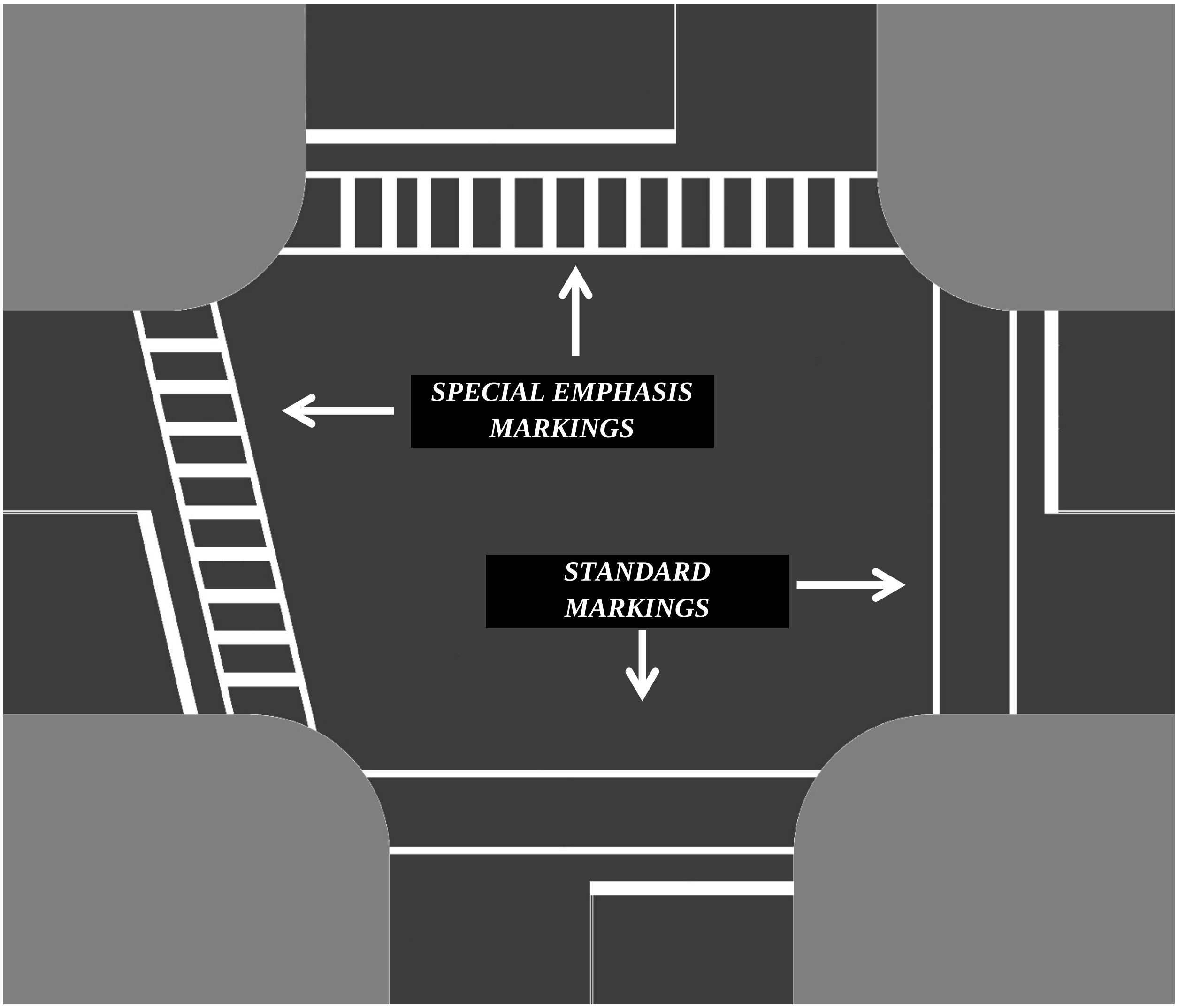

Figure 1. Example of standard and special emphasis crosswalks.

Review of Literature on the Effectiveness of Marked Crosswalks

A thorough evaluation of the efficacy of marked crosswalks in preventing pedestrian-motor vehicle crashes begins with a simple comparison of intersections with and without marked crosswalks. Interestingly, in some studies marked crosswalks appear to be associated with more motor vehicle pedestrian crashes than unmarked crosswalks (Herms, 1972; Zeeger, Esse, Stewart, Huang, & Lagerwey, Feaganes, & Campbell, 2005; Koepsell, McCloskey, Wolf, Moudon, Buchner, Kraus, & Patterson, 2002). In one of the earliest studies to examine the effects of marked crosswalks, Herms (1972) reported that the incidence of such crashes was two to four times higher when crosswalks were marked compared to when they are unmarked. Koepsell et al.'s (2002) analysis of crashes involving pedestrians over the age of 65 revealed that older pedestrians are twice as likely to be struck by a motor vehicle at marked crosswalks compared to unmarked crosswalks. In addition to evidence of a relationship between the presence of marked crosswalks and pedestrian-motor vehicle crashes, at least one study suggests that marked crosswalks may cause crashes. A before-after experimental design conducted by the Los Angeles County Road Department (1967) revealed a three- to four-fold increase in pedestrian motor vehicle crashes after marked crosswalks were installed at 89 intersections.

As Zegeer et al. (2005) caution, it is important to consider potential moderators before assuming that an effect generalizes across populations and conditions. It is possible that the association between presence of marked crosswalks and pedestrian-motor vehicle crashes depends on additional factors, for example, whether an intersection is signalized or not. Indeed, Koepsell et al. (2002) reported that the incidence of pedestrian-motor vehicle crashes was 3.6 times higher at marked crosswalks than at unmarked crosswalks, but only at intersections without stop signs or traffic signals. In the presence of stop signs and traffic signals, the odds of a pedestrian being struck at marked and unmarked crosswalks were roughly equal. In light of this finding, it is noteworthy that the 89 intersections manipulated by the Los Angeles County Road Department (1967) were unsignalized, and that the increase in crashes observed after marking crosswalks in these intersections may not have been observed had the manipulation been implemented at signalized intersections. Similarly, Zegeer et al. (2005) found that the relationship between presence of marked crosswalk and incidence of pedestrian-motor vehicle crashes depended on additional factors including density of traffic and number of lanes. Although marked crosswalks were associated with more crashes than unmarked crosswalks overall, the magnitude of this relationship was greater at busier intersections with more lanes of traffic. A study by Tobey, Shunamen, and Knoblauch (1983) suggests that the apparent association between the presence of marked crosswalks and pedestrian-motor vehicle crashes reflects the use of rates as dependent variables whose denominators are indifferent to pedestrian volume and traffic volume. Using the product of pedestrian volume and vehicle volume as a denominator, Tobey et al. (1983) reported that marked crosswalks were associated with *fewer* crashes than unmarked crosswalks. Besides the number of pedestrians and vehicles present, the demographic composition of pedestrians and drivers using a given intersection may also affect changes in observed pedestrian-vehicle crash rates after a crosswalk has been installed. Zegeer et al. (2005) note that older pedestrians' rate of involvement in crashes was high relative to their estimated crossing exposure. It may be that older adults, who are aware that they require more time to cross, are more likely than other age groups to choose to cross at a marked crosswalk when one is available, which can lead to elevated crash rates in an area that should not be interpreted as evidence that crosswalks increase pedestrian risk.

A satisfactory account of the relationship between presence of marked crosswalks and pedestrian-motor vehicle crashes, one that can accommodate the moderator effects described above, requires considering how crosswalks are perceived by both motorists and pedestrians. Herms (1972) proposed that marked crosswalks may instill a false confidence in pedestrians that motorists will yield. Similarly, Zegeer et al. (2005) suggested that installing crosswalk markings at non-intersection locations may increase the number of vulnerable individuals, such as children or older adults, who elect to use the crosswalk rather than cross at a signaled intersection. The idea in either case is that pedestrians assume motorists perceive marked crosswalks as readily as they do, which may not always be true. This raises an important possibility, namely, that alternative markings (i.e., special-emphasis) may actually reduce the incidence of pedestrian-motor vehicle crashes compared to standard markings. If special emphasis markings command more attention from motorists, then pedestrians' assumptions that motorists have heeded the crosswalk are more likely to be true. Thus, an important question to ask is whether motorists respond more quickly and appropriately to the presence of pedestrians when special emphasis markings are present compared to when standard markings or no markings are present. A before-after investigation of the effects of special emphasis crosswalks by Pulugurtha, Vasudevan, Nambisan, & Dangeti (2012) revealed that drivers were more likely to yield to pedestrians after special emphasis crosswalks were installed, and that drivers who did yield tended to yield earlier after special emphasis crosswalks were installed. However, it is unclear to what extent Pulugurtha et al.'s (2012) findings reflect special emphasis marking in particular as opposed to marking in general as they did not report whether modified intersections possessed standard markings prior to manipulation.

The literature on pedestrian use of crosswalks is compatible with the assumption that marked crosswalks increase pedestrians' perceptions of safety as studies suggest that pedestrians are more likely to use marked than unmarked crosswalks. Two studies which assessed pedestrian behavior at the same site before and after changes to crosswalk marking found that pedestrians were more likely to cross at a given location after crosswalk markings were installed (Harvard & Willis, 2012; Knoblauch et al., 2001) and felt safer while crossing after crosswalk markings were installed (Harvard & Willis, 2012). However, there is less evidence to inform the question of whether pedestrians are more likely to use special-emphasis crosswalks than standard crosswalks. The experimental research conducted by Pulugurtha et al. (2012) revealed that installation of special emphasis crosswalks did not increase diversion of pedestrians to crosswalks, but had the beneficial effect of increasing the proportion of pedestrians who scanned for traffic before beginning to cross as well as the proportion who scanned a second time after crossing halfway.

The purpose of Task 1.1 was to initially determine whether special emphasis crosswalks engendered any *perceptual* advantage. That is, do participants, when viewing driving scenes from the perspective of a driver, perceive special emphasis crosswalks (and pedestrians within it) more readily? To this end, we completed a laboratory study in which we assessed both how quickly younger, middle aged, and older participants were able to detect the presence of a marked crosswalk at an intersection in roadway scenes and how quickly participants detected the presence of a pedestrian in a marked (special emphasis or standard) crosswalk compared to when there was no marked crosswalk.

Method

Participants

A total of 63 younger (21 to 35 years), middle-aged (50 to 64 years), and older (65 and above years) participants were recruited from the Tallahassee, FL area. All were licensed drivers who drove at least once per week. We experienced some attrition, which is typical for an eye tracking study due to difficulty tracking through glasses. Our final sample included eye movement data from 18 younger adults (*M* = 21.8, *SD* = 1.1), 18 middle-aged adults (*M* = 60.4, *SD* = 3.8), and 19 older adults (*M* = 70.3, *SD* = 4.7).

Materials

A 3D model of an intersection was created in accordance with guidelines found in the Manual on Uniform Traffic Control Devices (MUTCD) and FDOT Design Standards, using SketchUp 8 Pro. The intersection had two lanes in each direction, in a commercial/residential setting. The model was designed in layers so that key elements, such as number and position of pedestrians and the type of crosswalk markings, could be varied systematically while the rest of the scene remained unchanged. Virtual cameras were placed at 50, 100, or 200 ft from the stop bars, at a height of 4.5 ft to approximate the eye height of a driver. Views from those cameras were exported into image files with a resolution of 1024 x 768 and displayed using the OpenSesame experiment software (Mathôt, Schreij, & Theeuwes, 2012) on a 19-inch CRT monitor. Eye movements were recorded using an EyeLink 1000 (SR Research) high-speed eye tracker at 1000 Hz.

Procedure

Participants were shown images containing standard (Figure 2), special emphasis (Figure 3), or unmarked crosswalks (Figure 4). Participants were educated and then tested on their ability to distinguish between marked (standard, special emphasis) and unmarked crosswalks. Once participants demonstrated knowledge of different crosswalk types, they were asked to perform a speeded identification task. An image was shown to the participant with a crosswalk 50, 100, or 200 ft away. Participants had to quickly and accurately determine whether or not a marked crosswalk was present or absent by pushing one of two buttons on the keyboard.

Figure 2. Example of a standard marked crosswalk at 50 ft.

Figure 3. Example of a special emphasis marked crosswalk at 50 ft.

Figure 4. Example of an unmarked crosswalk at 50 ft.

In a second task, participants judged whether a pedestrian was present in the roadway or not, again at three distances (50, 100, 200 ft). When a pedestrian was present, he or she was within either a standard, special emphasis, or unmarked crosswalk (see Figure 5 for an example). Images depicted a “worst-case-scenario” in that the pedestrian had not yet finished crossing or had just begun crossing when the signal turned green (however, given the nature of the task and the basic perception literature we did not anticipate that the status of the signal would have an influence on the detection task). We also manipulated the frequency at which pedestrians were present in the intersection. This was done because special emphasis crosswalks may be especially beneficial at locations where pedestrians are not frequently present, as drivers are not accustomed to searching for pedestrians and may benefit from the additional cue that pedestrians may be present. In one condition, participants were present on most trials (M = 82%, Range = 78% - 88%) and in another condition pedestrians were present on only on less than half of trials (M = 42%, Range = 34% - 48%).

Figure 5. Example of a special emphasis marked crosswalk marking at 50 ft with a pedestrian crossing (left).

Results

Response Time and Accuracy

<u>Crosswalk Detection Task</u>. Analyses of the accuracy and response time data from the crosswalk task indicated a clear perceptual advantage for special emphasis markings compared to standard markings, particularly for older participants. Participants detected the special emphasis crosswalk more quickly than the standard crosswalk at both near (50 ft), $t(54) = 7.75$, $p < .001$ (182 ms advantage) and far (100 ft) distances, $t(54) = 7.93$, $p < .001$ (318 ms advantage). The advantage for the special emphasis crosswalk compared to the standard crosswalk was significantly larger at greater distances, $t(54) = 4.03$, $p < .001$ (see Figure 6). These results suggest that the special emphasis markings may give drivers advanced warning to expect the presence of pedestrians. Accuracy was extremely low for the 200 ft standard marking crosswalk condition; thus, response times for marked versus unmarked conditions cannot be analyzed in this case.

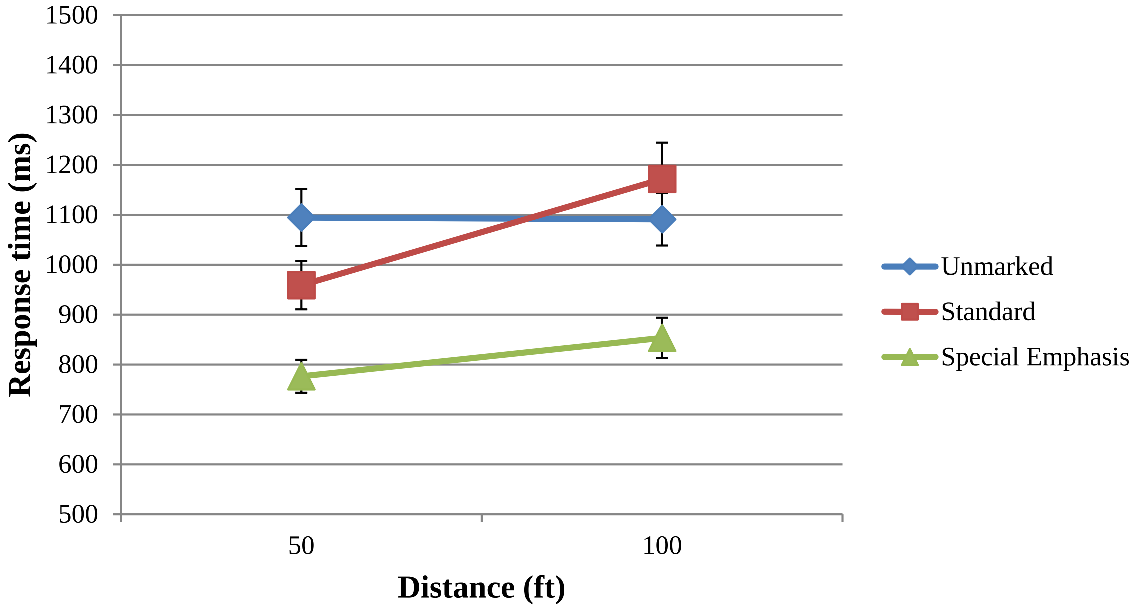

Figure 6. Response times for the judgment of whether or not a marked crosswalk was present. Participants were substantially faster at detecting special emphasis crosswalks compared to standard crosswalks. Error bars = +/- 1 SEM. See Appendix A for data broken down by age category.

In general, accuracy was high; with average accuracy across trials above 85% (see Figure 7). However, even though incorrect responses were fairly uncommon, participants were more accurate at detecting the presence of a marked crosswalk when the crosswalk on a given trial was a special emphasis crosswalk compared to when it was a standard crosswalk. At 200 ft, standard markings were imperceptible. Although special emphasis crosswalks were sometimes mistaken for unmarked crosswalks at 200 ft, they were still clearly visible the large majority of the time (85%). The very high accuracy of detecting an unmarked crosswalk, even at 200 feet, likely represents a bias to respond unmarked in the absence of clear evidence to the contrary.

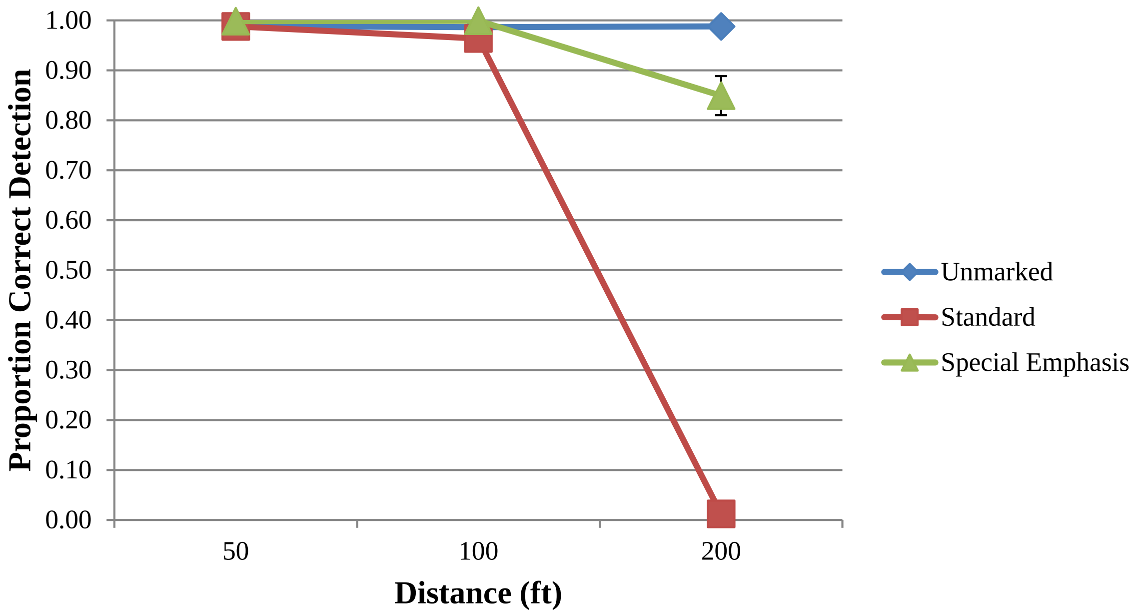

Figure 7. Accuracy for the judgment of whether or not a marked crosswalk was present. Error bars = +/- 1 SEM.

<u>Age Effects in Crosswalk Detection.</u> Given our focus on aging road users, we investigated whether older adults benefited as much from special emphasis crosswalks as younger adults. We calculated a “Special Emphasis Advantage” index, which represents how much more quickly participants detected a marked crosswalk when it was special emphasis compared to standard markings (Figure 8). All age groups benefited from special emphasis markings, but benefits were more pronounced for older adults. Statistically, this indicated a significant age effect ($F(2,52) = 3.65$, $p < .05$) of special emphasis markings. Response times and accuracy for each crosswalk type, broken down by age, is given in Appendix A.

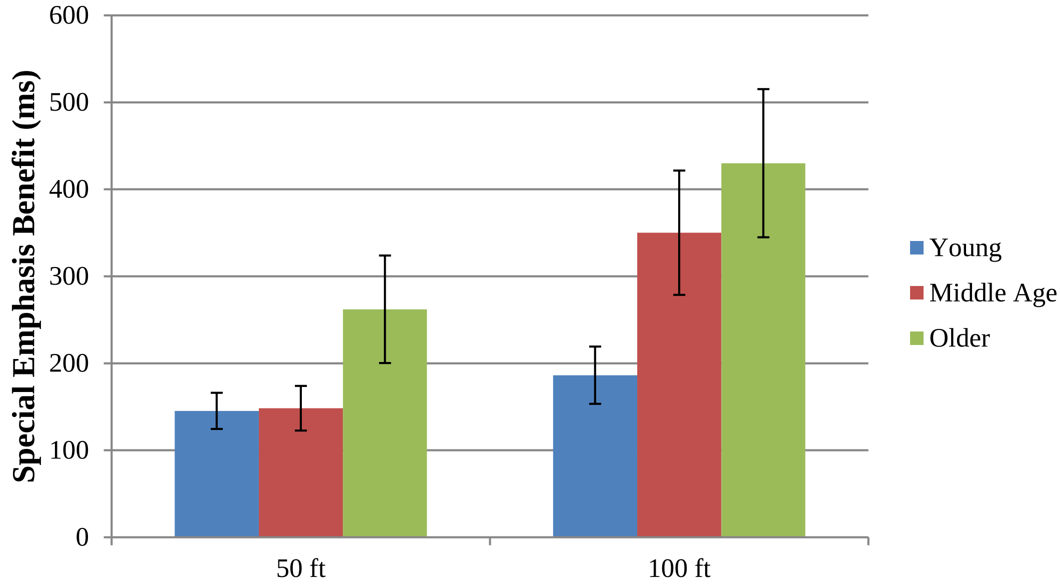

Figure 8. How much faster participants recognized special emphasis crosswalks compared to standard markings, as a function of age and crosswalk distance.
Note: The 200 ft distance was not included due to the low accuracy of the Standard condition at this distance. All age groups experienced a special emphasis advantage, with this advantage largest for older participants and for more distant crosswalks. Error bars = +/- 1 SEM.

Pedestrian Detection**.** One concern might be that the more salient special emphasis crosswalk markings might add to visual clutter and detract from the visibility of pedestrians. This was not the case in the current study. In the second part of the experiment, participants completed a pedestrian detection task where they were shown a picture of an intersection with either a standard or special emphasis crosswalk or no crosswalk and indicated, as quickly as possible, whether or not a pedestrian was present in the intersection. The frequency at which pedestrians were present was also varied between participants (approximately 80% of the time vs. approximately 40%). Participants were asked to push one of two buttons as quickly as possible depending on whether a pedestrian was present or absent.

Across conditions, pedestrian detection accuracy was quite high (about 95% even at the furthest distance). However, we did not find evidence that pedestrians were more quickly and accurately detected when they were within a special emphasis crosswalk compared to when they were within a standard crosswalk, or when no marked crosswalk was present (see Figure 9 & 10). Age did not interact significantly with crosswalk presence or any other variable of interest. However, response times and accuracy for each crosswalk type, broken down by age, is provided in Appendix A.

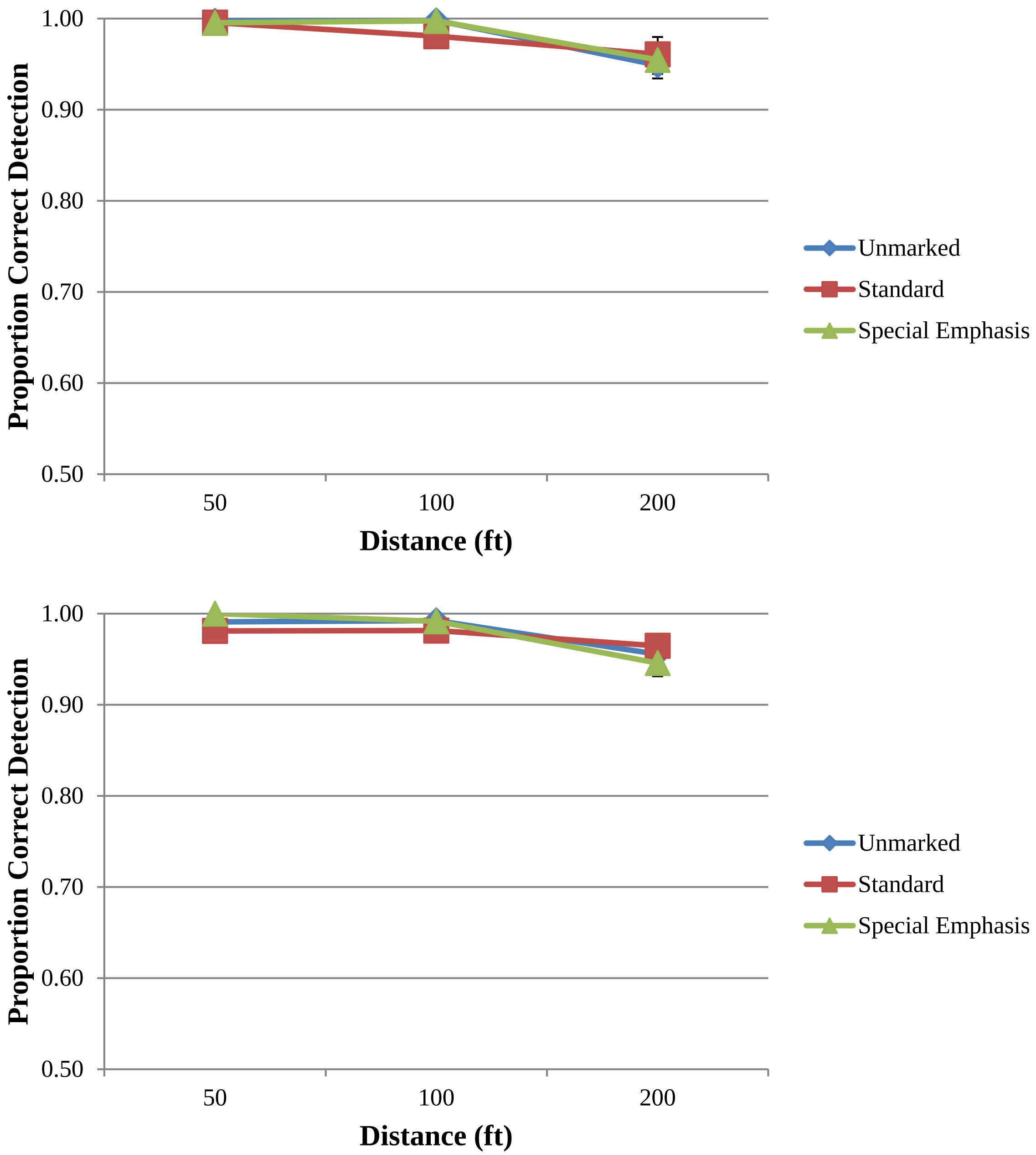

Figure 9. Accuracy for the pedestrian detection tasks. The top panel represents when the probability of a pedestrian was high, and the bottom when the probability of a pedestrian was low. Error bars = +/- 1 SEM.

There was a slight tendency for special emphasis crosswalks to lead to faster pedestrian detection at near distances, but this did not reach conventional significance (Crosswalk Type by Probability interaction; $F(2,1.23) = 3.28$, $p = .07$, after correction for lack of sphericity, see Figure 10). Again, age did not interact significantly with crosswalk presence or any other variable of interest. Taken together, these results suggest that the special emphasis markings may give drivers advanced warning to expect the presence of pedestrians, but do not seem to lead to slower detection of pedestrians due to increased visual clutter at intersections, or faster detection due to crosswalk markings cuing participants regarding where pedestrians might be located within the roadway.

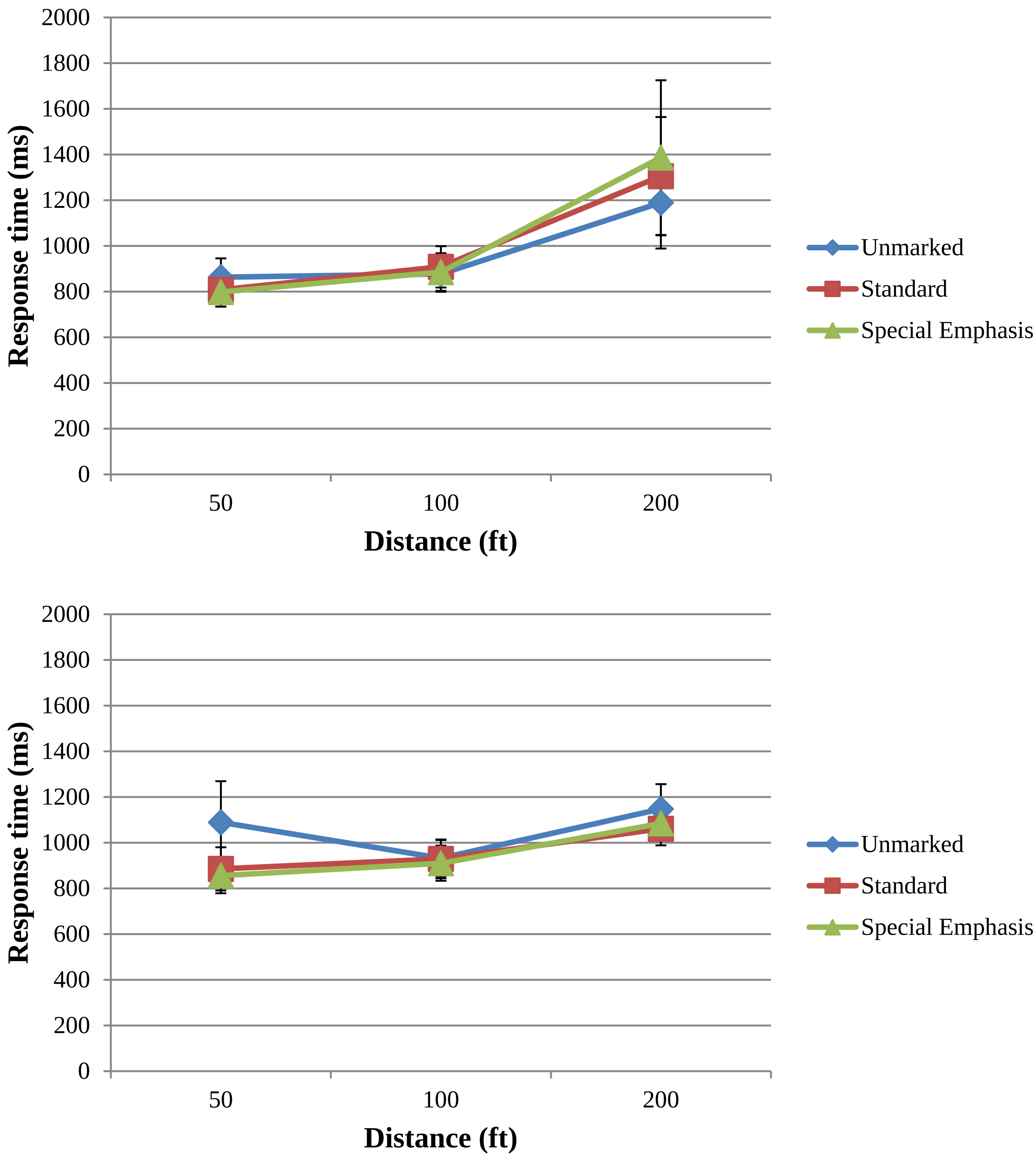

Figure 10. Response times for the pedestrian detection tasks. The top panel represents data from participants who were exposed to images in which there was a high probability a pedestrian could appear, and the bottom panel represents data from participants who were exposed to images in which there was a low probability of a pedestrian appearing. Error bars = +/- 1 SEM.

Eye Movement Analysis

Crosswalk Detection. In addition to examining response times to pedestrians, we were also interested in whether crosswalk markings might influence the allocation of attention. Of particular interest was whether eye scanning patterns were more efficient when special emphasis markings were present because they serve as a cue regarding where a pedestrian might be present. We predicted that the detection speed and accuracy advantage seen for special emphasis crosswalks in the crosswalk detection task would be associated with more efficient scan paths. In addition to requiring less time and fewer fixations to detect special emphasis crosswalks compared to standard crosswalks, we also expected participants' fixations to cover a smaller area.

First, we prepared concentric areas of interest which covered most of the visible area of the stimuli (see Figure 11). Because we found that standard crosswalks were more difficult (slower) to detect, in the crosswalk identification task we expected that participants would make more fixations over a larger area on trials when a standard crosswalk was presented compared to when a special emphasis crosswalk was displayed. This is because when an object is easy to perceive it is located quickly and visual search is terminated, requiring fewer fixations. When objects are more difficult to locate more extensive and wider scanning is necessary. We predicted that fixations in the outermost interest area would be more likely on trials where there was a standard crosswalk and less likely when there was a special emphasis crosswalk.

Figure 11. Interest areas for the crosswalk detection task. Fixations could fall in the center, middle, or outer-most ring, or outside of the three rings.

After excluding data from trials where the eye movement data was of poor quality, leaving a sample of 11,143 trials from 55 participants, we calculated a binary variable that indicated for a given trial whether any fixation fell in the outermost interest area. If any fixation fell in the outermost interest area, that trial would be coded as a 1. If no fixation fell in the outermost interest area, that trial would be coded as a 0.

Next, we conducted a multilevel logistic regression analysis to test whether the probability of a fixation occurring in the outermost interest area varied between crosswalk types. Consistent with predictions and with our findings of faster detection for special emphasis crosswalks, we found that participants were significantly less likely to have fixations in the outermost interest area on trials where there was a special emphasis crosswalk compared to those where there was either a standard crosswalk or no marked crosswalk. In other words, participants had to scan the roadway scene less to determine that a special emphasis crosswalk was present. For standard crosswalk trials, there was a 9.73% chance that a fixation would fall within the outermost interest area, compared to a 5.54% chance for trials where there was no marked crosswalk. However, and consistent with our finding of a quicker detection time for special emphasis crosswalks, this probability was significantly lower when special emphasis markings were present, with only a .96% chance of fixations in the outermost interest area on such trials (see Figure 12).

There was no evidence that older adults were more likely overall to have fixations over a wider area of the stimulus image, nor was there evidence that older adults' likelihood of having a fixation in the outermost interest area differed between crosswalk types. One important caveat, however, is that most of the trials that were excluded due to poor data quality came from older and middle aged adults. This is because older and middle aged adults' eyes are more difficult to track, both because of age-related changes in the eye and because older participants are more likely to wear glasses or bifocals, which can also lead to lower quality tracking data. Note that this analysis focused solely on the ability to detect and classify different types of crosswalks. *This does not suggest that when searching for pedestrians, we can expect that scanning would be less thorough in the presence of special emphasis crosswalks*. This issue is explored next.

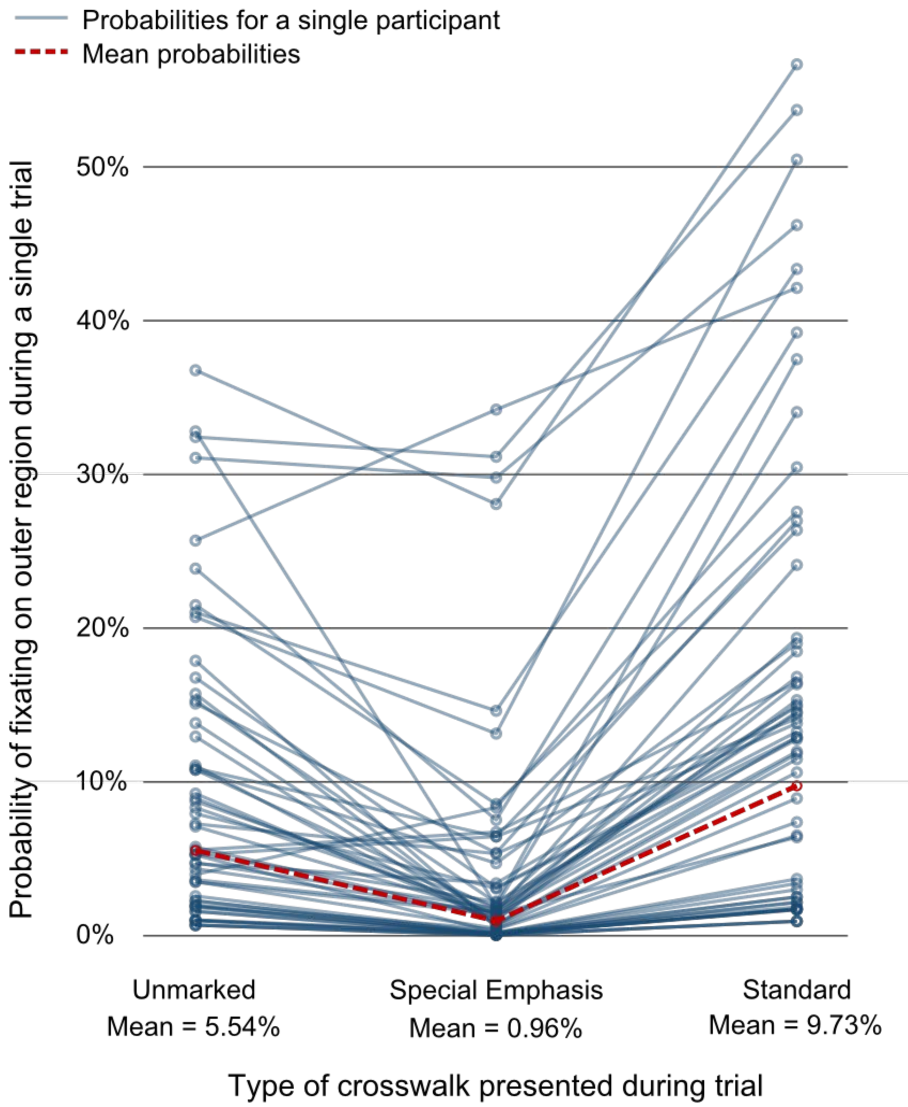

Figure 12. Probability that a fixation would fall within the outermost interest area for individual participants and averaged across participants by crosswalk type.

Pedestrian Detection. Because pedestrians could appear in one of three different locations (left, center, right), new interest areas were defined for the pedestrian detection task. For each distance (50,100, or 200 ft) and pedestrian lane position (left, center, or right), we defined one interest area for the pedestrian and another for the traffic signal (see Figure 13). The first step in analysis was to identify those trials and participants with high enough quality data to be included in the analysis. Any participants' trial with more than 3 blinks, very long blinks (2 seconds or longer), or more than 8 fixations were excluded from the analysis. Each of these is an indicator of poor tracking data for a trial.

The measure considered in the current analysis is the proportion of trials where the pedestrian was fixated. We also examine whether participants attend to the traffic signal, which showed a “worst case scenario” where the through signal is green but the pedestrian has not finished crossing, as well as whether attending to the signal was related to trial accuracy.

Figure 13. Interest areas used for the pedestrian detection task. This example shows the intersection from a simulated distance of 100 ft.

<u>Attention to Signal</u>*.* As we anticipated from the demands of the task, participants infrequently looked directly at the traffic signal. After filtering out trials with poor quality eye tracking data, across both conditions the signal was fixated on only 1% of trials (70 out of 10,836). The 70 trials in which the signal was fixated were all accurate trials; the signal was never fixated on an inaccurate trial. Taken together, these results suggest that the traffic signal was not an important source of information for participants. In addition, there was no evidence that the signal state distracted participants and prevented them from noticing the pedestrian.

Fixations on Pedestrians. Of interest in the current study was whether fixating the pedestrian was related to trial accuracy, as well as whether the pedestrian was more likely to be fixated when a special emphasis crosswalk was present. For the current analysis we considered only those trials where a pedestrian was present, as the probability of fixating the pedestrian is only meaningful if a pedestrian is present. This left a total of 6,722 observations from 58 participants (High Probability condition: $N = 26$, Low Probability condition: $N = 32$)

A multilevel logistic regression analysis (lme4 package for R; Bates, Maechler, Bolker, & Walker, 2013) was conducted to examine whether the likelihood of fixating the pedestrian on a given trial varied as a function of condition (high or low probability of a pedestrian), simulated viewing distance (50 ft, 100 ft, 200 ft), age group (younger, middle, older), crosswalk type (unmarked, standard, special emphasis), and trial accuracy. The probability of fixating the pedestrian was found to vary significantly as a function of each of the fixed factors included in the model (condition, distance, age group, trial accuracy, and crosswalk type).

On trials where a pedestrian was present, the probability of fixating the pedestrian decreased substantially as viewing distance increased, with the pedestrian being about 1.9 times more likely to be fixated on a 50 ft trial (85%) than on a 200 ft trial (46%) and 1.21 times more likely to be fixated on a 50 ft trial than on a 100 ft trial (70%). This factor had a stronger effect on the probability of fixating the pedestrian than any of the other factors in the model ($F = 442$). At the 50 ft viewing distance the pedestrian was a significantly larger target than on either the 100 or 200 foot trials, likely explaining more fixations on nearer pedestrians.

Condition also had a significant effect on the likelihood that the pedestrian would be fixated ($F = 13.36$). Compared to participants in the in the high probability condition, participants in the low probability condition were 1.3 times more likely to fixate the pedestrian on a given trial (78% vs. 61%). This difference was uniform across crosswalk types. It is likely, due to high exposure to pedestrian events, that partcipants in this condition developed the skill to detect pedestrians without having to overtly attend to them.

As expected, having fixated the pedestrian was significantly related to decision accuracy ($F = 9.08$). On trials where a pedestrian was present, participants were about 1.9 times more likely to have fixated the pedestrian on accurate (68%) than on inaccurate trials (36%).

The probability of fixating the pedestrian varied significantly between age groups ($F = 3.89$), with older adults being 1.35 times more likely to fixate the pedestrian on a given trial than were younger adults (77% vs 57%, see Figure 14). The magnitude of age differences were not found to vary significantly as a function of any of the other factors examined. Older adults' increased tendency to look directly at the pedestrian, regardless of location, may be an indication that they compensate for reduced field of view by scanning a larger portion of the visual field.

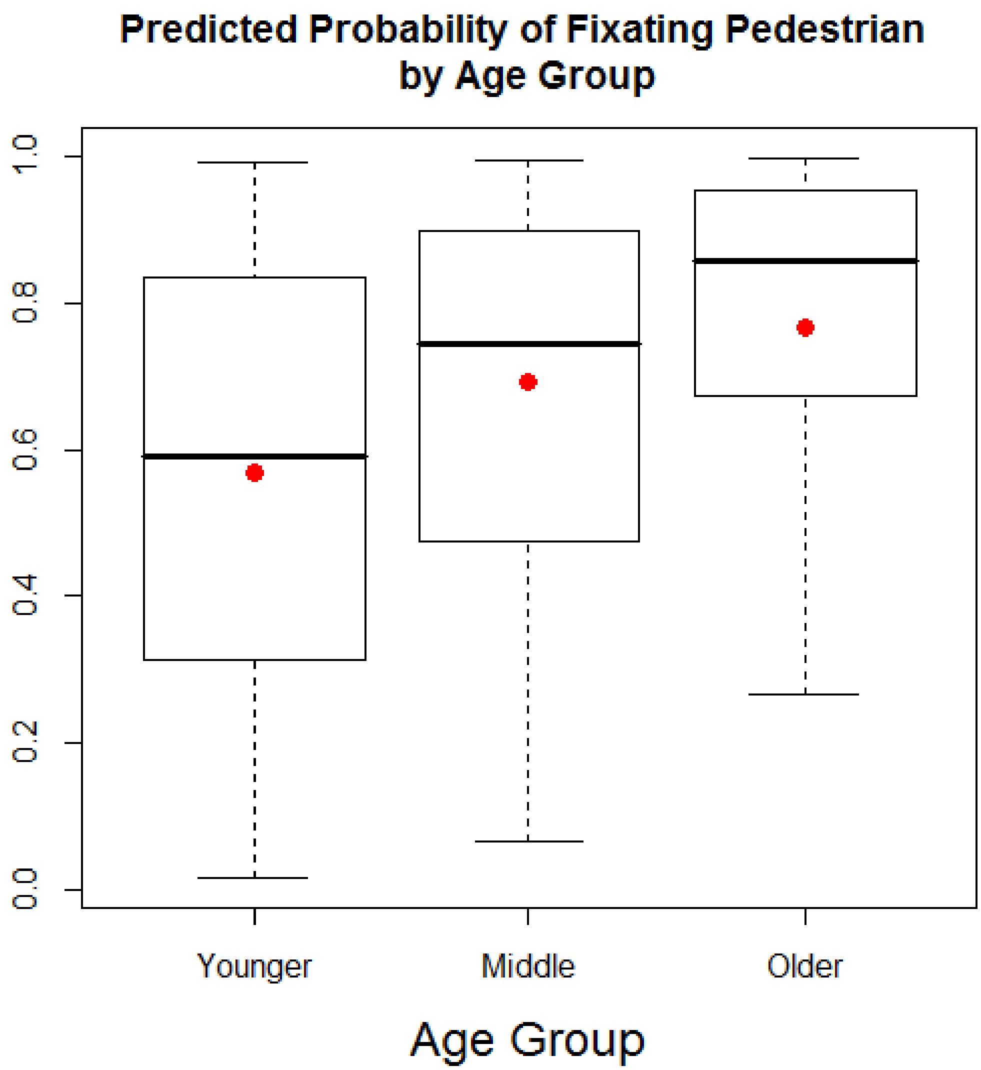

Figure 14. Boxplot showing model predicted probabilities of fixating the pedestrian on pedestrian present trials by age group. Black line indicates median and red dots show group means.

There was no evidence that crosswalk type was strongly related to the probability of fixating the pedestrian (F = 1.69), nor did the presence of a crosswalk interact with any other factor. Across all factors, the probability of the pedestrian being fixated was 67%. When the probability of fixating the pedestrian was compared between both types of marked crosswalk and unmarked crosswalks, the pedestrian was 1.04 times more likely to be fixated when they were within a marked crosswalk (68%) than when no markings were present (66%). However, the probability of the pedestrian being fixated was effectively identical between the two types of marked crosswalk (standard = 68%, special emphasis = .69%, see Figure 15). Out of all factors that influence pedestrian fixation, the effect of crosswalk type was minimal.

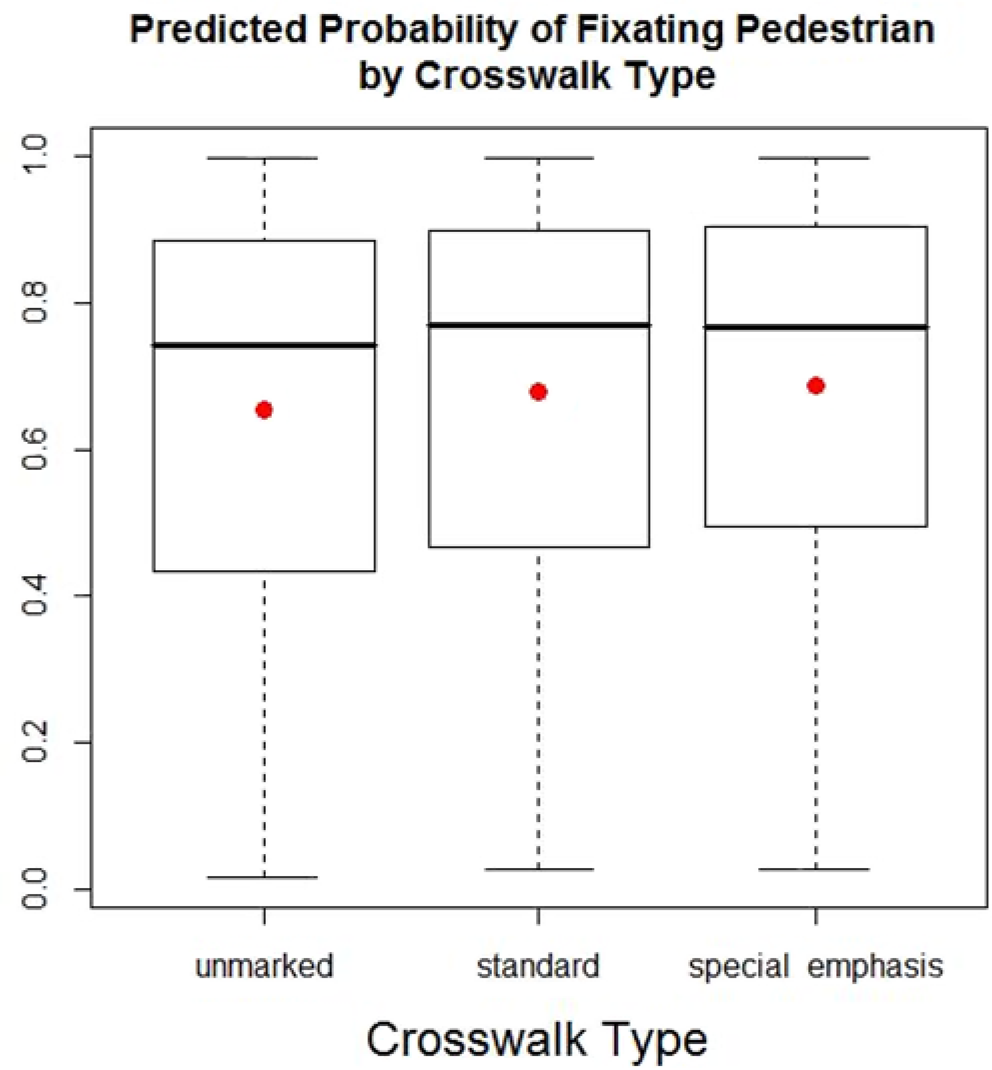

Figure 15. Boxplot showing model predicted probabilities of fixating the pedestrian on pedestrian present trials by crosswalk type. Black line indicates group median and red dots show group means.

Conclusions

In conclusion, recognition of a marked crosswalk occurs much more quickly when the crosswalk is marked with a special emphasis pattern. This is especially true for older adults who may be suffering from age-related changes in vision. The eye tracking data from the crosswalk task was generally consistent with the reaction time and accuracy results. We found that eye scanning patterns were more efficient when special emphasis markings were present.

There was not clear evidence that this marking pattern aided in the detection of pedestrians (though there were some non-significant trends to suggest this). However, response time, accuracy, and eye movement data provide compelling converging evidence that the greater salience of the special emphasis markings does not detract from pedestrian detection.

Task 1.2. A Survey/Observational Study of the Impact of Special Emphasis Crosswalks

Task 1.1 and 1.3 focus on the effects of the presence of special emphasis crosswalks on driver decision making and behavior. In Task 1.2 we focus largely on effects of special emphasis crosswalks on pedestrian behavior. Past research has yielded unclear and sometimes contradictory findings with respect to the efficacy of crosswalks in improving pedestrian safety. As noted in our earlier review of the literature, some studies have found that pedestrians are more likely to be struck by a vehicle when they are crossing within a marked crosswalk (e.g. Koepsell et al., 2008; Koepsell et al., 2012), though this is mostly accounted for by increased risk at midblock and uncontrolled intersections rather than at signalized intersection locations (Koepsell et al., 2002).

One potential explanation for these findings is that standard crosswalks are not sufficiently conspicuous and so do not provide a salient visual cue for drivers (Task 1.1). Special emphasis crosswalks, which are designed to have improved visibility compared to standard crosswalk markings, have been shown in at least one study (Pulugurtha et al., 2012) to be associated with an increased likelihood that drivers will yield to a pedestrian crossing within the crosswalk, as well as with earlier yielding.

However, another possible explanation for higher pedestrian crash rates at locations with a marked crosswalk could be that the presence of a marked crosswalk, though it may provide a strong visual cue for drivers, may have a negative effect on pedestrian behavior. Herms (1972) suggested that pedestrians crossing within a crosswalk may overestimate the likelihood that they are noticed by approaching drivers and that those drivers will yield. As a result, pedestrians crossing at locations with a marked crosswalk may cross with less caution than pedestrians crossing at locations without a marked crosswalk.

To assess the effect of special emphasis crosswalk markings on pedestrian behavior, relative to that of standard crosswalk markings, we observed pedestrian behavior at two signal-controlled intersections in the Tallahassee area. During an initial observation phase of 14 weeks, only standard crosswalk markings were present at the intersections (Figure 16). Special emphasis crosswalks were then installed at one intersection (Figure 17) while the other remained standard as a control. After a 25 week no-observation interval, a second observation phase began and had a total duration of 17 weeks. Of interest is whether pedestrian use of crosswalks varied between standard and special emphasis crosswalks.

Figure 16. On the left, the Monroe and Carolina intersection during the first observation phase. On the right, the Monroe and Georgia intersection during the same phase.

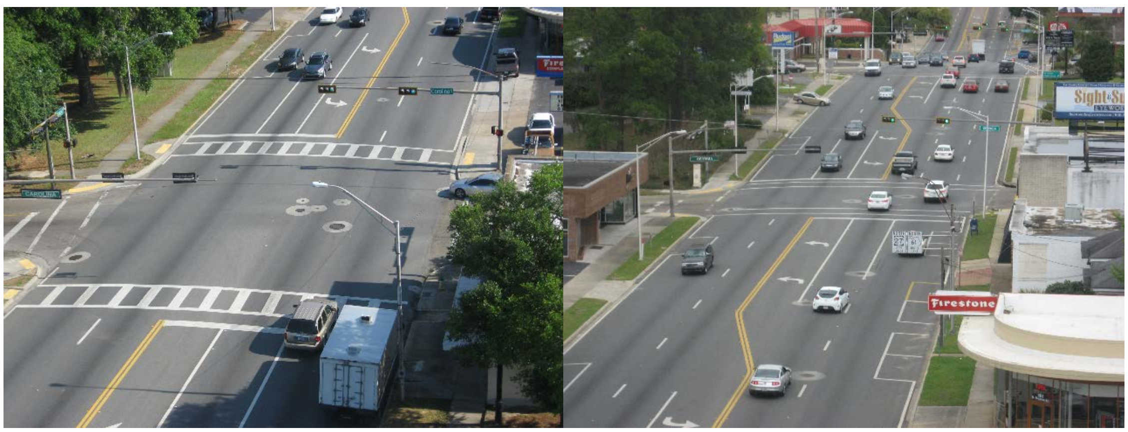

Figure 17. On the left, the Monroe and Carolina intersection during the second observation phase. On the right, the Monroe and Georgia intersection during the second phase.

To assess the relative effects of special emphasis and standard crosswalk markings on pedestrian feelings of confidence, comfort, and safety while crossing, a survey was developed (see Appendix B), using as a starting point the survey employed by Sisiopiku and Akin (2003).

Method

Experimenter training

This study depended crucially on observers being able to accurately classify pedestrians and their behaviors. To ensure that this was the case, observers received extensive training. This training program was developed to ensure consistency among observers, both within and between semesters.

Age Categorization Training Task. All observers completed a computerized age group categorization task. In this task pictures of faces (neutral expressions only) from the Center for Vital Longevity Face Database (Minear & Park, 2004) were shown one at a time, and the observer indicated via a key press whether the person shown should be classified as younger (18 to 35), middle aged (50 to 64), or older (65 and older). Average accuracy on the classification task across observers was 85%.

Example Videos. In the next stage of training observers watched videos of a pedestrian crossing at an intersection. These videos were developed by our research group to specifically demonstrate different types of pedestrian behaviors likely to be seen in the field, especially ones which might prove difficult for observers to rate. Observers watched each of the videos, rated crossing behaviors according to the observational definitions (Appendix C), then discussed their ratings with the project coordinator to be sure that they understood the rating categories. Rating accuracy for videos was not scored, because a single camera viewpoint could not provide all the visual information needed to create unambiguous stimuli. Instead, the videos provided a structured set of examples of pedestrian behaviors and the opportunity to discuss the rating categories prior to implementing them in practice observations.

Practice Observations. The final phase of training involved conducting practice observations at an actual intersection. Observers went in groups to an intersection with heavy pedestrian traffic to practice behavioral ratings in teams. Observation sessions were supervised by the project coordinator. Each team of observers chose one pedestrian to rate and compared results with other team members until ratings were consistently and correctly done and observers reported comfort with conducting the ratings. After observers were comfortable rating a single pedestrian, the number of pedestrians observed per signal phase was increased until observers could comfortably rate six pedestrians at once, with the project coordinator confirming inter-rater agreement. In addition, observers changed teams during practice sessions, with the project coordinator confirming that inter-rater agreement remained intact with varying practice partners. Observers who worked on the experiment across multiple semesters retrained each time to protect against drift, and were teamed with a blend of experienced and novice observers during practice.

The intersection at which practice observations were conducted had much heavier pedestrian traffic than the intersections that would be observed in the study. During our earlier pilot observations the highest number of independent pedestrians crossing at once at any potential study location was three.

Practice sessions were also conducted for situational variables. However, because there were fewer situational variables, practice sessions for this aspect of observations were less extensive.

Observation Sessions

Observations were conducted on Monroe Street at its adjacent intersections with Carolina and Georgia on Mondays, Wednesdays, and Fridays during mornings (7:30 - 9:30 am), midday (11 am – 1 pm), and late afternoon (4:00 – 6:00 pm), when pedestrian traffic was expected to be at its heaviest. During the initial phase of the study, January 1, 2013 to April 12, 2013, we collected observations from the beginning of the study until we were able to coordinate installation of special emphasis crosswalks at Carolina (see Figure 18).

This coordination involved FDOT and FSU PIs working with Ennis-Flint and Crown Technology, LLC, who volunteered materials and labor to modify crosswalk markings. This provided an opportunity for these vendors to test their materials while at the same time helping to advance the aims of the current project. During installation, Protection Services Inc. provided Maintenance of Traffic services, and Ameriseal Highway Striping, Inc. removed previous markings.

Georgia was left as a standard crosswalk as a control, but markings were refreshed. Observations began again after a 25 week hiatus to avoid the influence of a novelty effect. The second phase of observations spanned 17 weeks, excluding the interruption of the holidays and a training period at the beginning of the new semester, from October 11 2013 to December 6 2013 and from February 21 2014 to April 25 2014. Across all observation periods, no observations were collected on days when there was a 70% or greater predicted chance of rain for a given observation period or if it was raining at the time the observation session was scheduled to begin.

Figure 18. Installation of special emphasis crosswalk markings at Monroe and Carolina. Photos courtesy of Mary Anne Koos.

During observation sessions experimenters were stationed at each study intersection in pairs, with one observer recording situational data and the other recording behavioral data. This was done because the number of variables to be coded was judged to exceed what a single experimenter could record accurately and within the short time allotted for each observation. Experimenters were positioned near corners but not in a location that would potentially obstruct pedestrian traffic. Experimenters were intended to appear to be students so pedestrians would be less likely to suspect they were being observed. Experimenters carried notebooks, rather than clipboards, and were encouraged to have a backpack as well. If anyone approached the experimenters and asked why they were there, they were instructed to respond, “We’re doing research on traffic patterns.” Additionally, during training the experimenters had focused on being able to observe pedestrian behaviors while maintaining the appearance of being in a conversation with one another, and then writing down what they had observed once the pedestrian had completed crossing. This was intended to minimize observer effects.

One of the behavioral variables observers coded was whether pedestrians used the crosswalk. As it could be argued that a pedestrian crossing just outside of the crosswalk is still using the crosswalk, obtaining whatever advantages are conferred by the markings, such as greater driver expectation of pedestrian crossings at that location, we established a “crosswalk zone”. To determine the “crosswalk zone”, we measured the distance from the stop bar to the edge of the crosswalk markings on each side of each of the to-be-observed crosswalks. The average of these distances at these intersections was found to be 5 feet. At each intersection a small strip of neon green duct tape was placed on the curb or street 5 feet from either side of the marked crosswalks, delineating the crosswalk zone in a way that would be readily visible to the experimenters but not obtrusive to pedestrians (See Figure 19). During observations, if a pedestrian was either within the crosswalk markings or within the crosswalk zone, they were coded as “using the crosswalk”.

Figure 19. Bright green duct tape, which was visible from across the street, delineates the crosswalk zone. The duct tape was placed on the curb or street 5 feet from either side of the crosswalks. Red lines indicate tape locations in the image above.

As the intersections observed for the study were adjacent to one another, observers needed a way to determine consistently whether a pedestrian crossing at a midblock location should be considered to be crossing at their own intersection or at the next one. Cones were placed alongside the curbs at the midpoint between the intersections, and at an identical distance on the other side of each intersection. This ensured that each observer would be responsible for coding pedestrian behavior within approximately equal sections of the street (see Figure 20).

Figure 20. Orange dots show the locations of cones marking the area around each of the observed intersections.

Pedestrian Surveys

The survey questions can be found in Appendix B, and the full dataset for the survey will be included on the CD with the final report submission. During the final observation phase, pedestrians were approached for the survey after they had finished crossing. Because the primary object of the survey was to determine levels of confidence, comfort, and safety in the specific crosswalk they had just used, only pedestrians who had used a crosswalk were surveyed. To minimize any observer effect on ongoing observations, once a pedestrian was approached for a survey no further observations were collected until all pedestrians who might have seen the survey taking place had left.

For purposes of examining differences between age groups, it was critical that the survey be administered in a way that minimized the impact of any age-related perceptual or cognitive deficits. To that end, survey questions were read aloud to respondents, and when a question required a scale response, participants were handed a laminated sheet with the scale printed in large font. This was intended to alleviate any difficulties some participants may have had in reading smaller text as well as any difficulties in holding the response scale in working memory simultaneously with the question.

As survey data were only collected during the final, post-change observation phase and therefore no pre- vs. post- comparison could be made, once it became clear that there were not enough willing respondents at the study locations, additional surveys were collected at intersections physically similar to the study locations (see Table 1). At the supplemental locations, behavioral observations were only recorded for pedestrians whom the experimenters planned to approach for a survey. The categorization of age by observers was recorded for the sole purpose of determining accuracy of observers' pedestrian age categorizations in the field, participants' self-reported ages were used in analyses of survey data.

Table 1. Survey locations and number of surveys from each.

Intersection	Crosswalk Type	Surveys	Through Lanes	ADT*
Monroe / Carolina	Special Emphasis	31	4	29,734
Monroe / Georgia	Standard	7	4	29,734
Monroe / Gaines	Special Emphasis	30	4	21,914
Monroe / Sharer	Standard	7	4	42,754
Pensacola / Ausley	Standard	12	4**	30,512
Tennessee / Macomb	Standard	1	6	36,519

*ADT counts from: http://www.talgov.com/pubworks/pubworks-traffic-counts.aspx
**Monroe has raised median at this point.

Of the 83 surveys collected, 70 were able to be matched to corresponding observations, and 60 of those (85.7%) were accurately categorized, corresponding to the accuracy rate observed on the laboratory age categorization task observers completed during training.

Computer Surveys

There were additional questions of interest, such as knowledge of Florida law related to crosswalks and crossing roadways, which could not be included in the pedestrian surveys without lengthening them to the point where our response rate would become unacceptably low. Accordingly, these questions were administered via MediaLab to participants who were either visiting the lab for another study or were recruited and completed only this survey. A total of 38 younger adults (18 – 35) and 63 older adults (65+) were surveyed. Some questions were worded similarly to those in the pedestrian survey. The critical difference is that in the pedestrian survey, each participant was asked about their experience in the specific crosswalk they had just used, while in the computer survey participants were asked about their typical experience regarding a type of crosswalk, and were shown an overhead view of that type of crosswalk to refer to while they answered the questions. As such, the participants in the pedestrian survey only responded regarding one type of crosswalk marking, while the computer survey participants responded to both types of markings. The computer-based survey is included in Appendix B.

Results

R version 2.15.1, a statistical programming environment, was used to conduct the observational and pedestrian survey analyses (R Core Team, 2012. SPSS version 17, statistical analysis software, was used for the computer survey analyses (SPSS Inc., 2008).

Observational Data

Table 2 displays the percentage of participants who were observed using a crosswalk or crossing midblock, as a function of intersection location (Carolina vs. Georgia) and observation phase relative to the installation of the special emphasis crosswalk at Carolina (pre- vs. post-change). Each intersection saw a raw change in the percentage of crosswalk usage. In order to determine whether that change truly differed between intersections, a logistic regression controlling for weather conditions was employed. Predictors were intersection, observation phase, weather, and the interaction between intersection and observation time. Overall, intersection, observation phase, and their interaction together significantly predicted the probability of a pedestrian being observed using a crosswalk to an extent that was statistically significant at the .05 level. As shown in Table 2, the interaction was such that the difference in observed crosswalk use between pre- and post-change observation phases was greater for the Georgia intersection (22%) compared to the Carolina intersection (-10%). Contrary to predictions, from pre- to post-change, the proportion of pedestrians observed using the crosswalks was lower at the Carolina intersection where the change in crosswalk type to special emphasis was made ($p < .001$), but higher at the Georgia intersection where the crosswalks remained standard during the entire observation period ($p < .001$). Post-crosswalk conversion, the percentage of pedestrians using the crosswalk compared to crossing midblock was identical regardless of crosswalk marking type (83%). Figure 21 shows that the proportion of midblock crosses to crosswalk crosses was relatively stable within each time period (pre-change and post-change) for both intersections, suggesting that no single observation period had a substantial impact on the results.

Table 2. Percentage of pedestrians who were observed crossing the road using a crosswalk or at midblock as a function of intersection and observation phase

Intersection	Observation Phase	Crosswalk Type	Crossed at Crosswalk	Crossed at Midblock	Number of Observations
Carolina	Pre-Change	Standard	93%	7%	637
	Post-Change	Special Emphasis	83%	17%	640
Georgia	Pre-Change	Standard	61%	39%	196
	Post-Change	Standard	83%	17%	259

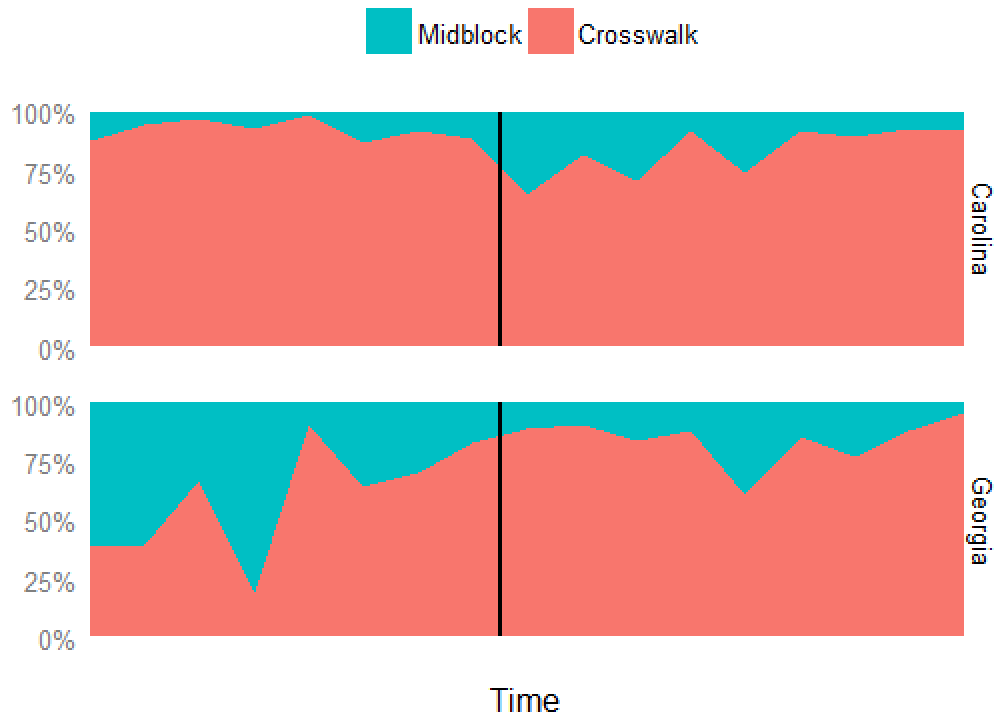

Figure 21. Proportion of midblock crosses to crosswalk crosses across the entire observation period. The line represents the point in time where the Carolina crosswalk was changed.

Motorist Behavior. Observers recorded whether the position of stopped vehicles at the intersection was behind the stop bar, past the stop bar but not encroaching on the crosswalk, intruding into but not blocking the crosswalk, or completely blocking the crosswalk such that the pedestrian would be forced to walk outside of the crosswalk while crossing (see Appendix C for coding sheet and definitions). For each observation where vehicles were present, a variable was coded 1 if a vehicle in either lane blocked the crosswalk, meaning that the pedestrian would have to walk outside of the crosswalk to be able to pass the vehicle, and 0 if no vehicle was blocking the crosswalk. Overall, across both the pre- and post-change period, it was very uncommon for vehicles in either through lane to completely block the crosswalk; there were only 32 instances out of 1738 total observations (includes only observations from Carolina and Georgia), which accounted for 1.8% of all observations and 3.6% of observations where vehicles were present (see Table 3).

Across all observations (including pre- and post-change), vehicles were about four times more likely to block the crosswalk at Carolina than at Georgia, though this difference was not statistically significant (p = .06). The difference in crosswalk blocking rates between the two intersections was similar during both the pre- and post-change period. When only the post-change period was examined, although the likelihood of a vehicle blocking the crosswalk was 28% greater at Carolina than at Georgia, this difference was not statistically significant (p = .73). Because it was more common for vehicles to block the crosswalk at Carolina, it is of interest whether the change in crosswalk markings at Carolina was associated with a reduction in the frequency at which vehicles blocked the crosswalk at that intersection. Looking only at observations from Monroe and Carolina, the frequency of crosswalk blocking declined by 50%, but the degree of change was not statistically significant (*p* = .08).

Table 3. Frequency at which vehicles blocked the crosswalk by intersection and observation period.

Intersection	Observation Period	Crosswalk Type	Total Observations	Vehicles Present*	Blocked
Carolina	Pre-change	Standard	637	333	20
Georgia		Standard	196	87	0
Carolina	Post-change	Special Emphasis	641	322	10
Georgia		Standard	264	84	2
Carolina	Combined	Std/SE	1278	655	30
Georgia		Standard	460	171	2

*Because some pedestrians crossed when no vehicles were stopped (e.g. during the Don't Walk phase) or at times when no vehicles were present, there are fewer cases where it was possible for a vehicle to block the crosswalk.

Because pedestrian traffic during the summer was very limited, vehicle-only observations were conducted during the post-change period from 5/24/2013 to 7/31/2013, yielding a total of 535 cases (see

Table 4 for a summary). Unlike the pedestrian observations, where observations of vehicles were only recorded if a pedestrian was present, each case in the vehicle-only observations represented the stop phase of a single signal cycle, and most observations were recorded over several concurrent traffic signal cycles, regardless of whether pedestrians were present at the time. Because the presence of pedestrians may influence driver behavior, these vehicle-only observations likely give a better estimate of the base rate at which drivers block the crosswalk at the observed intersections.

As was the case in the pedestrian observations, it was uncommon for stopped vehicles to block the crosswalk. Out of 486 observations where vehicles were present during the stop phase, there were 37 instances where a vehicle in any one of the through lanes blocked the crosswalk (8% of cases). The likelihood of a vehicle blocking the crosswalk in any one of the through lanes (north or southbound) on a given signal cycle was nearly four times greater at Carolina than at Georgia (p = .01).

Table 4. Frequency at which vehicles blocked the crosswalk by crosswalk type from vehicle-only observations.

Intersection	Crosswalk Type	Total Observations	Vehicles Present*	Blocked
Carolina	Special Emphasis	358	319	32
Georgia	Standard	177	167	5
Total	--	535	486	37

*Although vehicles were present during most signal cycles, this was not always the case.

Although there were not significant differences between intersections in the rate at which vehicles blocked the crosswalk, a similar trend was observed across two different data sets. Because motorists were more likely to block the crosswalk at Carolina in both the pre- and post-change observation period, this suggests that the difference may be due to factors other than the crosswalk markings. Figure 22 shows images of the northbound lanes of Monroe at Georgia and Carolina. The stop bar and crosswalk are placed further back from the corner at Carolina than at Georgia, and this is the case on both sides of the intersection. It may be that motorists tend to stop even with the corner, rather than the stop bar (the crosswalk blocking category would refer to only the through lanes), making motorists more likely to block the crosswalk at that location.

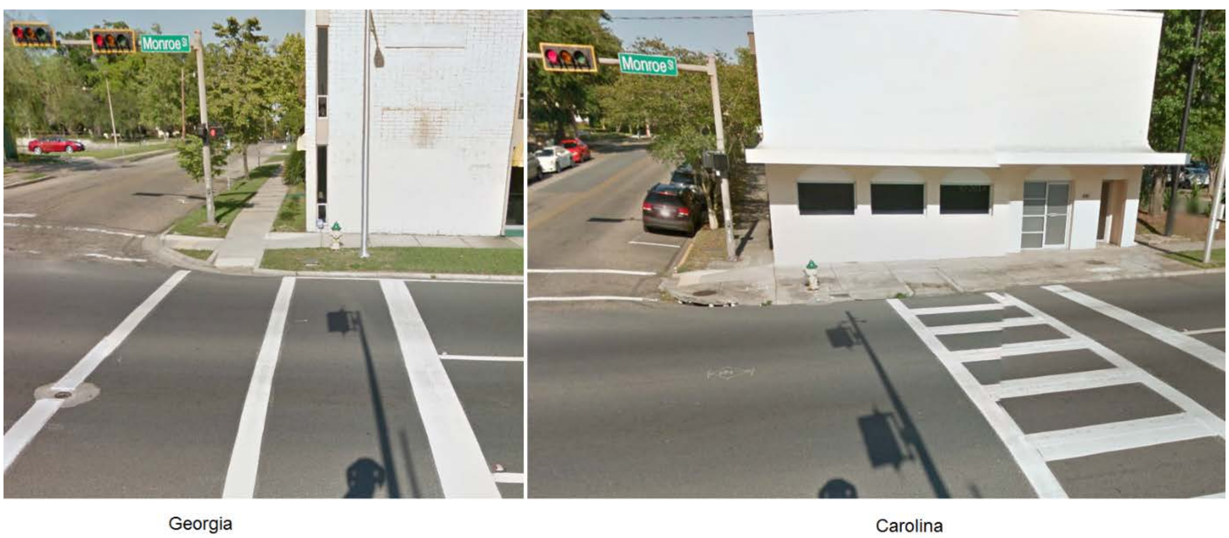

Figure 22. Comparison of crosswalk placement relative to the curb at Georgia and Carolina.

Pedestrian Survey

Descriptive statistics from the two most critical questions included in the pedestrian surveys are displayed below in Table 5. Table 6 displays the respondents' confidence that drivers will yield as a function of age group. In order to assess possible differences between the two crosswalk types, data for each question were submitted to a regression analysis using crosswalk type, age, and their interaction as predictors. In regards to how safe pedestrians felt while crossing the crosswalk, age was found to be predictive, b = -0.02, 95% CI [-0.035, < 0.001], $t(84)$ = -2.00, p = .049, such that increasing age was associated with lower levels of perceived safety.

However, crosswalk type, b = 0.38, 95% CI [-0.167, 0.927], $t(84)$ = 1.38, p = .171, and the interaction between crosswalk type and age, b = 0.03, 95% CI [-0.006, 0.057], $t(84)$ = 1.64, p = .105, were predictive to an extent that was statistically significant at the .05 level (model adjusted R^2 = .04, residual *SD* = 1.13).

In regards to pedestrians' confidence that motorists will yield to them at the crosswalk, both age, b = -0.02, 95% CI [-0.041, -0.007], $t(84)$ = -2.76, p = .007, and the interaction between age and crosswalk type, b = 0.04, 95% CI [0.013, 0.075], $t(84)$ = 2.85, p = .006, were predictive to an extent that was statistically significant at the .05 level (model adjusted R^2 = .09, residual *SD* = 1.11). For the special emphasis crosswalks, greater age was associated with less confidence that a motorist would yield, and for the standard crosswalks, greater age was associated with greater confidence. This effect is difficult to explain, but the small effect size (model adjusted R^2 = .09) indicates that the effect may overwhelmed by that of other factors, as this effect accounted for slightly less than 10% of the variation in confidence levels. More importantly, when controlling for age, the special emphasis and standard crosswalks did not differ in confidence to an extent that was statistically significant at the .05 level, b = 0.35, 95% CI [-0.19, 0.89], $t(84)$ = 1.31, p = .20. Thus overall, confidence that a driver would yield and perceptions of safety did not differ as a function of the crosswalk participants had just used. In fact, participant ratings for both confidence and safety averaged nearly neutral.

Table 5*. Descriptive statistics from the pedestrian survey data*

	Pedestrian age		Confidence that motorists will yield		How safe participants felt while crossing		
Crosswalk	*M*	*SD*	*M*	*SD*	*M*	*SD*	*N*
Special Emphasis	44.31	16.52	2.82	1.12	2.92	1.20	61
Standard	34.89	17.01	3.11	1.25	3.30	0.99	27

Note: Confidence and safety questions were rated on a scale of 1 (Not at all) to 5 (Completely).

Table 6. Confidence that motorists will yield as a function of age.

	Confidence that motorists will yield		
Age Group	*M*	*SD*	*N*
Young	3.10	1.15	40
Middle	2.65	1.16	37
Older	3.09	1.14	11

Perceived Slipperiness of Crosswalk. Pedestrians who completed surveys were asked to rate the slipperiness of crosswalks on a 1 to 5 scale (1 = Not at all, 5 = Completely). Because the slipperiness of the crosswalk marking material used at the Monroe locations were of special interest, crosswalk type was divided into three categories: Special Emphasis: Carolina, Special Emphasis: Gaines, and Standard. Because pedestrians generally do not walk on the painted surface when using a standard crosswalk, ratings from all four locations with standard crosswalks were combined (Georgia, Ausley, Sharer, and Macomb). A Kruskal-Wallis rank sum test revealed no significant differences in slipperiness ratings between the three types of crosswalks, χ^{2-} (2, N = 88) = 1.39, p = .50 (see Figure 23). Table 7 gives slipperiness ratings collapsed across all special emphasis and all standard crosswalks.

Although no differences in perceived slipperiness were observed, it is important to note that surveys were not collected when there was rain or when the predicted likelihood of rain was greater than 70% for a given shift (e.g. morning, midday). Although it is plausible that some surveys were collected following rain, when the crosswalk would still be wet, this is unlikely because many fewer surveys were collected on days when the weather was overcast. For the subset of 82 surveys where weather information was available from observations, 18 surveys were collected when the weather was overcast and 64 were collected when the weather was recorded as sunny. As a result, the slipperiness ratings reported here primarily reflect pedestrian perceptions of slipperiness when the crosswalk is dry.

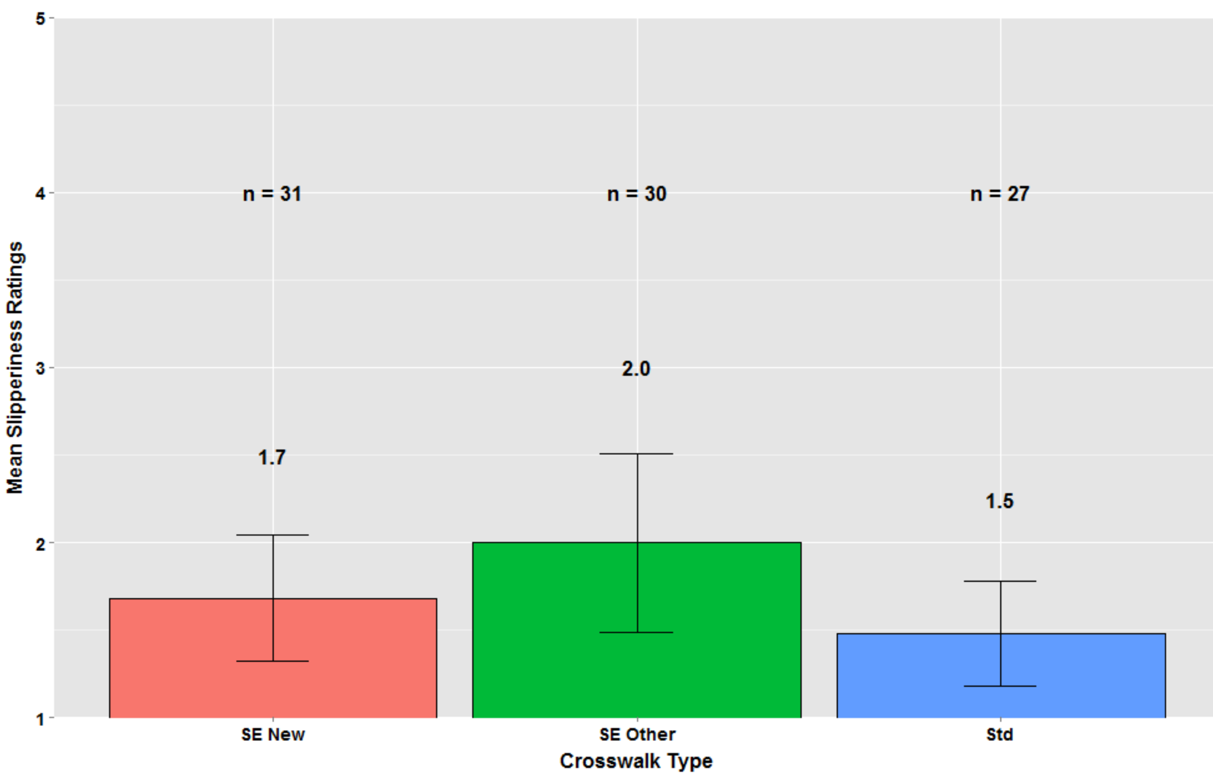

Figure 23. Perceived slipperiness of the crosswalk by crosswalk type. Mean rating is given in the base of each bar. Error bars show the 95% confidence interval.

Table 7. Perceived slipperiness of the crosswalk as a function of crosswalk type.

	Perceived Slipperiness		
Crosswalk	*M*	*SD*	*N*
Special Emphasis	1.84	1.19	61
Standard	1.48	0.75	27

Self-Reported Typical Use of Crosswalk. Participants were asked about their frequency of use and typical crossing behavior at the intersection where they were surveyed. Table 8 through Table 10 provide summary information for each of these items. Most pedestrians surveyed reported that they typically cross at the crosswalk, cross during the “walk” phase, and cross at that location five or more times each week.

Table 8. Survey responses to the question "Where do you typically cross at this location?"

Response Choice	**Number Selecting Response**
At the crosswalks	69
Near the crosswalk (but don’t use crosswalk)	7
At the middle of the block, away from the crosswalks	2
At any convenient location, don’t really have a preference	10
Total	88

Table 9. Survey responses to the question "Under which condition do you most typically cross at this location?"

Response Choice	**Number Selecting Response**
Only when the pedestrian signal indicates “walk”	58
Only when traffic clears completely	12
Anytime you feel a gap in traffic is big enough for you to cross safely	18
Total	88

Table 10. Survey responses to the question "How often do you cross at this location?"

Response Choice	**Number Selecting Response**
This is the first time	5
Less than one time a month	10
1 to 3 times a month	14
1 to 4 times a week	12
5 or more times a week	47
Total	88

Pedestrian Choice of Crossing Location. Question 11 was a three-part question where pedestrians were shown a picture showing the overhead view of the intersection (Figure 24, also see Appendix B) and asked to indicate whether they would choose to cross at the crosswalk or midblock from each of three different locations. As expected, proximity to the crosswalk was a strong predictor of whether pedestrians would indicate that they would choose to cross at the crosswalk. When the point indicated was near the intersection (Points A and C in Figure 24), more pedestrians indicated they would go to the intersection and cross at the crosswalk. When the point indicated was at midblock, about half of pedestrians at both locations said they would cross at midblock and half said they would cross at the crosswalk. Table 11 summarizes the proportion of participants at each location who indicated they would cross at each location.

Table 11. Number of participants indicating they would cross at the crosswalk or midblock as a function of starting location.

Location	**Intersection**	**Crosswalk**	**Midblock**
A	Carolina	21 (68%)	10 (32%)
	Georgia	5 (71%)	2 (29%)
B	Carolina	17 (55%)	14 (45%)
	Georgia	4 (57%)	3 (43%)
C	Carolina	23 (74%)	8 (26%)
	Georgia	6 (86%)	1 (14%)

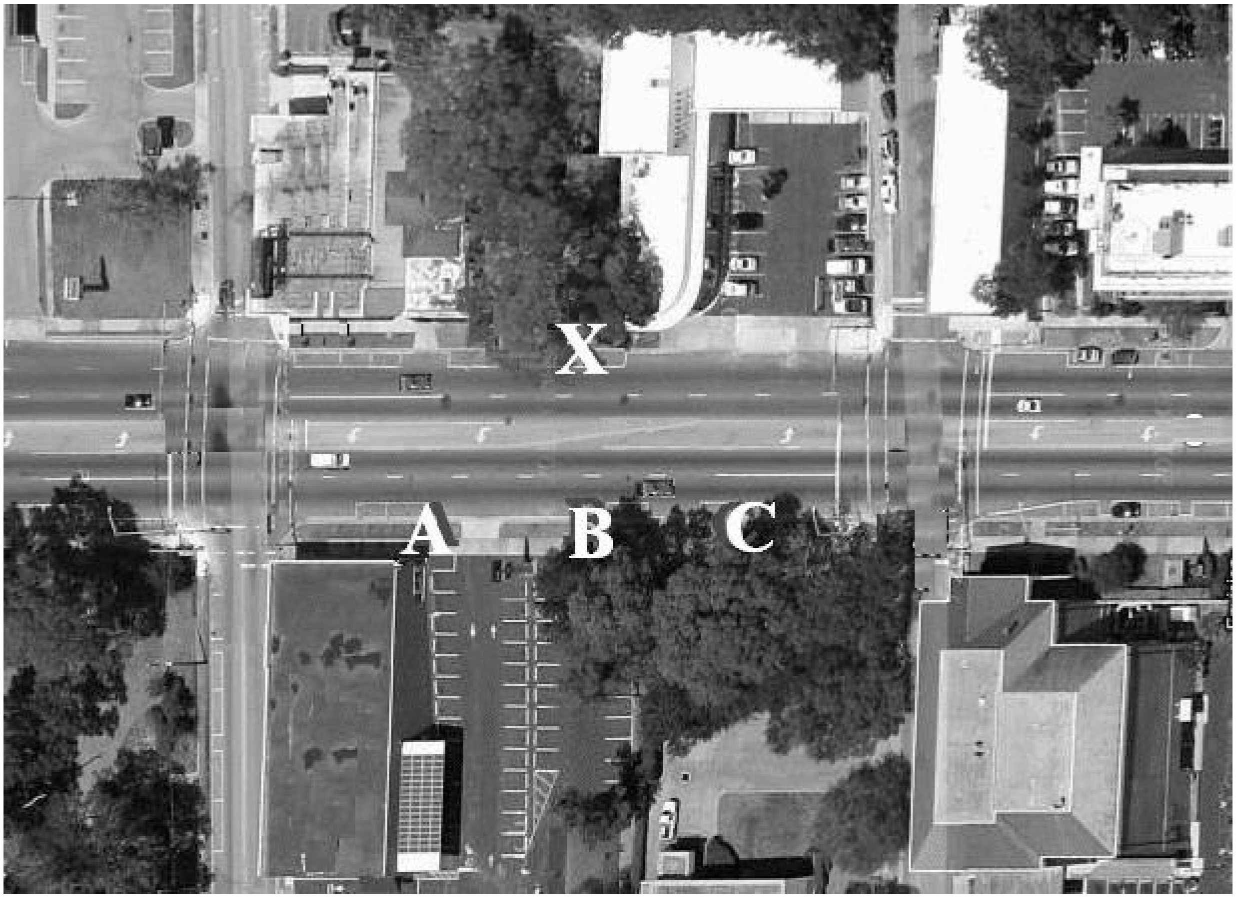

Figure 24. Map shown to pedestrians at Carolina and Monroe for question 11 on the survey. Pedestrians marked their chosen route on a printed copy of the map.

Pedestrian Origination and Destination Points. Questions 12 and 13 on the survey asked pedestrians about their origination and destination points. Overall, most origination and destination points were in the immediate area around the intersection, most often businesses or parking areas located on the same block. Appendix D provides tables of the most common origin and destination points for each survey location.

Note that several of the pedestrians surveyed were homeless (either self-reported or noted by the experimenter). The observation locations were near homeless shelters and other places where homeless people are known to frequent during daytime hours (e.g. library, unemployment office, downtown parks), so this population is likely over-represented in this sample.

Relationship between Motorist and Pedestrian Behavior. We collected a total of 88 surveys, and of these there were 83 surveys for which matching situational and behavioral observations were available. Of these, there were 59 surveys collected from pedestrians at special emphasis crosswalks and 24 collected at standard crosswalks.

Vehicles were present at the crosswalk during 78 of the 83 (94%) observation phases during which surveys were collected. Because it was so uncommon for vehicles to block the crosswalk; this subset of the data included only two observations (both at special emphasis crosswalks) where the crosswalk was blocked, so no statistical tests could be conducted comparing pedestrian feelings of safety or confidence that motorists would yield as a function of whether vehicles were blocking the crosswalk.

Computer Survey

Descriptive statistics from questions in the computer surveys which were worded similarly to those in the pedestrian surveys are displayed below in Table 12. Although similar in intent, these cannot be compared directly to the questions from the pedestrian survey, due to the questions being aimed at pedestrians' impressions of their typical crossing experiences rather than a concrete experience they had just acquired. Also, the fact that each participant saw both types of crosswalk might have introduced demand characteristics different from those in the pedestrian survey, which is another factor preventing direct comparison of the two surveys. On the other hand, this within-participant design that asked participants about both types of crosswalks may be more sensitive to participant's attitudes and preferences, and the more general questions are better suited to uncovering factors in decision-making processes involving crossing location choices.

Table 12. Descriptive statistics from the computer survey data.

Pedestrian age			Confidence that motorists will yield		How safe participants generally feel while crossing	
Younger n = 38	*Older N = 63*	Crosswalk	*Younger M [SD]*	*Older M [SD]*	*Younger M [SD]*	*Older M [SD]*
M = 23.76	M = 72.67	Special Emphasis	1.21 [0.28]	1.73 [0.9]	3.66 [0.63]	3.05 [0.58]
SD = 3.53	SD = 5.57	Standard	1.32 [0.62]	1.78 [0.73]	3.13 [0.58]	2.67 [0.67]

Note: Confidence and safety questions were rated on a scale of 1 (Not at all) to 5 (Completely).

It is reasonable to expect that, in participants who are shown both types of crosswalk markings, the strongest predictor of their responses to one type will be their response to the other type, so in order to investigate whether age effects were present, any effect of crosswalk type should be controlled for. Accordingly, a categorical regression analysis was conducted in SPSS for each survey question for each crosswalk type, using age group as a predictor and controlling for the individual's rating of the other crosswalk type. This type of analysis has the added benefit of making no assumptions about data distribution, which in the case of survey data is often highly skewed. Then, in order to test for differences between crosswalk types, a Bonferroni-corrected, repeated measures ANCOVA was used for each question with crosswalk type as a within-subjects factor and age group as a covariate if an age effect had been found. As the age groups were highly unequal, with 38 younger participants (ages 21 – 35) and 63 older participants (ages 65+), Cohen's *d* was used as a measure of effect size rather than partial eta squared. No interactions yielded significance values that warranted further investigation.

Confidence that a Motorist would Yield. Participants rated their levels of confidence that drivers would yield to them while in each type of crosswalk on a scale of 1 (Not at all) to 5 (Completely). Participants answered all questions regarding one type of crosswalk before being shown the other type of crosswalk and answering the same questions. There was no effect of age for standard crosswalks, but older participants tended to rate their confidence slightly higher than younger ones for special emphasis crosswalks, $b = .20$, $d = .43$, $t(98) = 2.09$, $p = .05$. Controlling for age, there was no effect of crosswalk type, $F(1,99) = 3.56$, $p = .06$, on confidence that motorists will yield.

Perception of Safety. Participants rated their levels of feeling safe while crossing within each type of crosswalk on a scale of 1 (Not at all) to 5 (Completely). There was no effect of age for standard crosswalks, but older participants tended to rate their feelings of safety slightly higher than younger participants for special emphasis crosswalks, $t(98) = 2.30$, $p = .02$, $b = .29$, $d = .62$. Controlling for age, all participants indicated greater feelings of safety with special emphasis markings, $F(1,99) = 8.37$, $p = .005$, $d = .40$ (Figure 25).

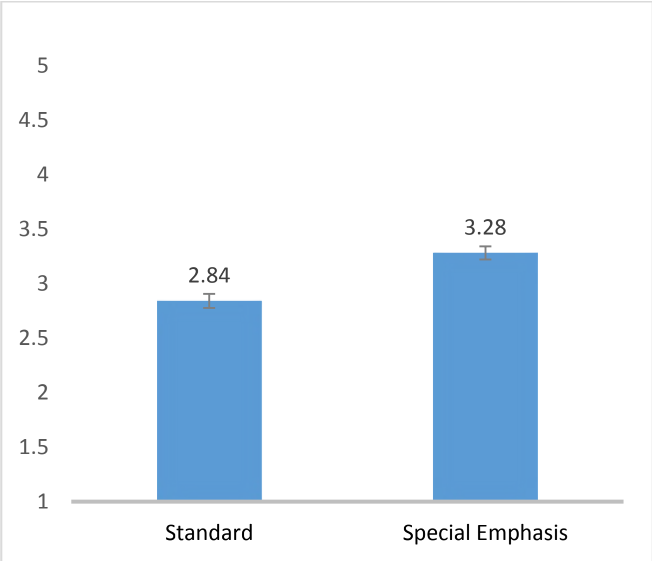

Figure 25. Ratings of general feeling of safety while crossing, by crosswalk type, controlling for age group. Responses ranged from 1 (Not at all) to 5 (Completely). The error bars represent standard error of the estimated marginal means.
Yielding Behavior of Typical Motorist

Participants were asked if they feel vehicles typically yield to pedestrians who were in each type of crosswalk and rated their responses on a scale from 1 (Not at all) to 5 (Completely). There was an effect of age for standard crosswalks, such that older participants tended to give a higher rating than younger ones, $t(98) = 2.59$, $p = .01$, $b = .25$, $d = .53$. There was no effect of age for special emphasis crosswalks. Controlling for age, there was no effect of crosswalk type, $F(1,99) = .29$, $p = .59$, on confidence that motorists will yield.

Yielding Behavior of Typical Turning Motorist. Participants were asked whether they feel that turning vehicles usually yield to pedestrians who are in each type of crosswalk and responded “Yes”, “No”, or “I don’t know”. For each question scored on this scale, data was recoded into an ordinal variable so that “No” would be the lowest value and “Yes” would be the highest value. There was no effect of age for either type of crosswalk. There was an effect of crosswalk type, such that participants indicated more belief that turning drivers would yield to pedestrians who were crossing in special emphasis crosswalks than standard crosswalks, $F(1,99) = 16.20$, $d = .40$, $p < .001$ (Figure 26).

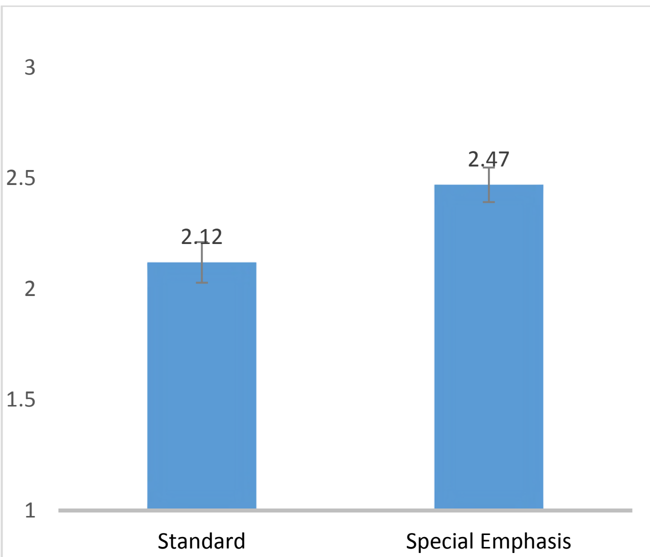

Figure 26. Ratings of general feeling of safety while crossing, by crosswalk type, controlling for age group. Responses were 1 – No, 2 – I don’t know, or 3 – Yes. The error bars represent standard error of the estimated marginal means.

Participants were asked whether, in general, pedestrians typically use each type of crosswalk when available, and responded “No”, “Yes”, or “I don’t know”. There was an effect of age for standard crosswalks, such that older participants indicated slightly higher levels of belief than younger ones that pedestrians typically use them, $t(98) = 2.19$, $p = .03$, $b = .13$, $d = .27$. Controlling for age, there was no effect of crosswalk type, $F(1,99) = .73$, $p = .39$.

Also among the computer survey questions were four items assessing knowledge of points of law. These questions were taken from the public survey/program evaluation questionnaire utilized by the FDOT’s Alert Today, Alive Tomorrow, Pedestrian/Bicyclist Safety program. The first item asks which side of the road a pedestrian should walk on when there is no sidewalk (the right side). The next item displays the four stages of a pedestrian signal (Figure 27) and asks during which one a pedestrian may begin crossing (the steady walking figure). The third item (see Appendix B) asks about the correct procedure when driving and making a permitted right turn at a red light (stop before entering near the crosswalk, then proceed if clear). The fourth item displays a depiction of four intersections (Figure 28) with three arrows marking crossing locations, and asks which of the three marked locations is not legal for pedestrians in Florida (location b, between two signalized intersections).

Figure 27. Depiction of pedestrian signal phases for the second point-of-law item in the computer survey.

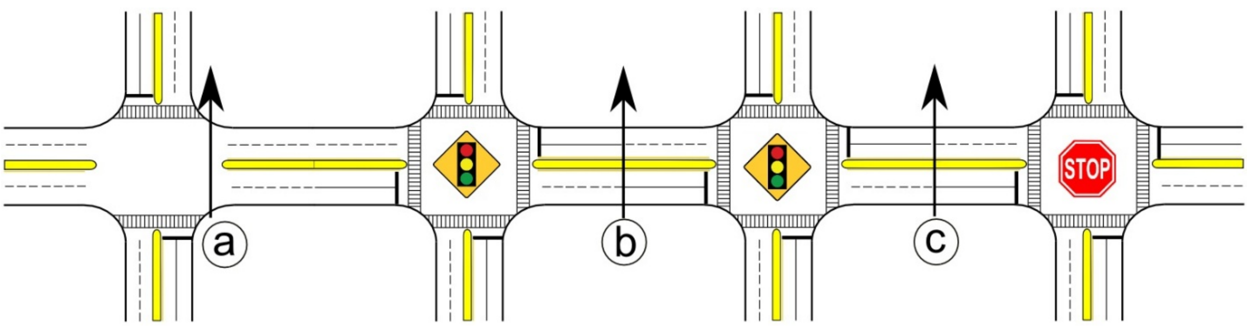

Figure 28. Depiction of intersections and crossing locations for the fourth point-of-law item in the computer survey.

To determine whether the proportion of correct responses (Figure 29) for these questions differed according to age, Pearson's product-moment correlation coefficients were obtained. For the walking without sidewalks item, correct responses were significantly associated with greater age (r = .26, N = 101, p = .009). No other significant correlations were found. The question regarding legal crossing locations (Figure 29) was the most poorly understood, with fewer than 60% of participants in either age group responding correctly. It is entirely possible that the only reason participants scored above chance for this question is a bias towards choosing the middle of the three options shown on the map.

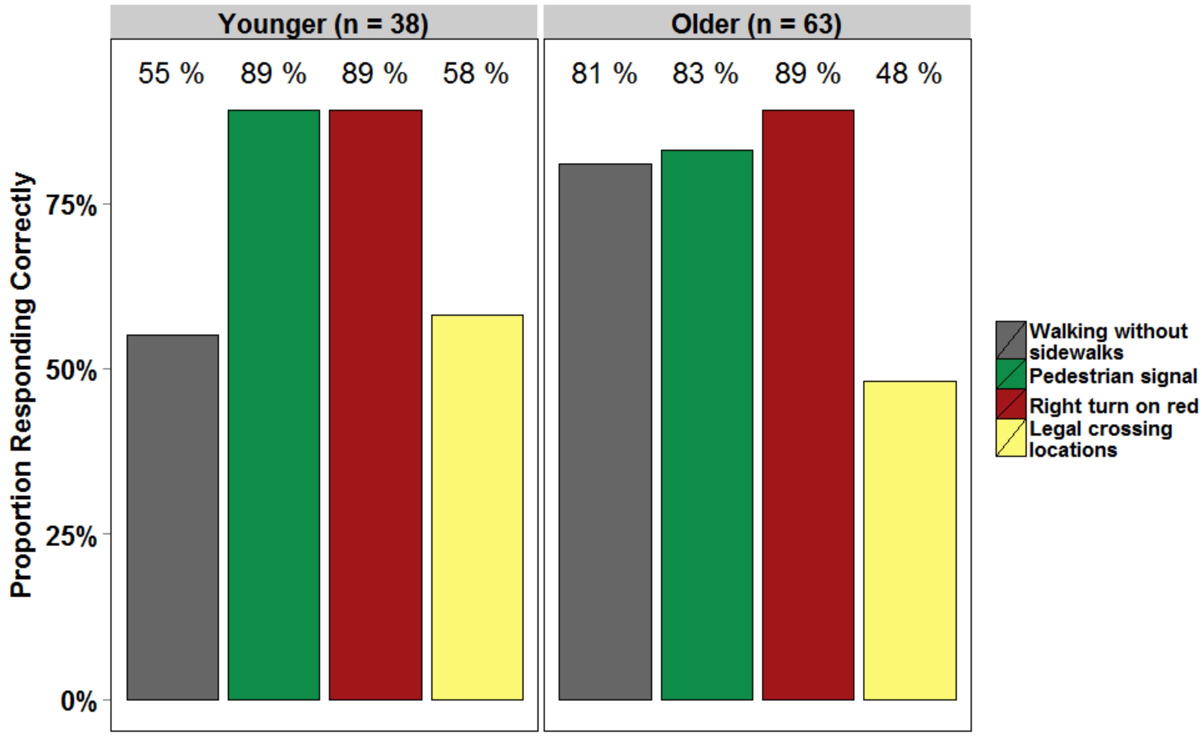

Figure 29. Proportion of correct responses by age group for the four survey items assessing knowledge of points of law.

The remaining survey questions had no direct bearing on crosswalks but were included to add to existing data for the Florida Department of Transportation. Pearson's product-moment correlations for age group and each of those four questions (Appendix B) were obtained, and no statistically significant relationships were found.

Conclusions

In general, there was no strong support for influence of crosswalk marking type on crossing behavior in the observational study. A lower proportion of pedestrians were observed using the crosswalks at the Carolina intersection compared to before the special emphasis crosswalks were installed there, and post-conversion no difference was observed between the proportions of pedestrians using a crosswalk at the special emphasis compared to the standard location. However, determining if installation of the new crosswalks influenced pedestrian behavior at the Carolina intersection is somewhat problematic in light of the fact that pedestrian crossing behavior substantially changed at the Georgia intersection even though its crosswalks remained the same during the entire observation period. However, if special emphasis crosswalk markings did induce a large change in pedestrian behavior, we are fairly confident that such a change would have been detected despite changes in patterns of pedestrian traffic. There was some suggestion that post-conversion to special emphasis, there was a reduction (50%) at the Monroe and Carolina of motorists blocking the crosswalk. However, this must be considered tentatively in that this difference did not reach conventional levels of significance.

In regards to pedestrians' reported confidence, when asked about the specific crosswalk they had just used, that motorists will yield to pedestrians in the crosswalk, we found that as age increased, confidence declined at special emphasis crosswalks while increasing with age at standard crosswalks. These were small and unexpected effects. In the same survey, feelings of safety while crossing did not vary by crosswalk type, but did with age.

However, in the computer survey investigating participants' ratings of their typical levels of confidence and safety when using each type of crosswalk, both age groups reported higher feelings of safety in special emphasis crosswalks than in standard ones. This is potentially problematic, given that older adults are at elevated risk for pedestrian-vehicle crashes (Harruff, Avery, & Alter-Pandya, 1998; Hoxie & Rubenstein, 1994; Lee & Abdel-Aty, 2005; Loo &Tsui, 2009; Sklar, Demarest, & McFeeley, 1989; Zegeer et al., 2005).

Neither age nor type of crosswalk had any effect on confidence that drivers would yield. In contrast, participants indicated a greater degree of surety that turning drivers would yield to them if they were in a special emphasis crosswalk than in one with standard markings.

As it seems more likely that decision-making processes when preparing to cross a roadway are influenced by general evaluation of safety factors, such as vehicular traffic, visibility, width of the roadway, presence of a median, etc., than by memory of those factors during one specific crossing that was just completed, the results of the general survey are probably the most germane to understanding pedestrian behaviors. As such, it would be useful to repeat this survey with only one type of crosswalk marking presented to each participant, to determine whether experimental demands significantly influenced survey results. It is possible that participants being shown two types of crosswalk markings inferred that they should have a preference, however slight, for one over the other, and responded accordingly. If the results stand, they could be used in conjunction with further research on whether elevated confidence at crosswalks is a risk factor for crashes, as Herms (1972) suggested, to determine whether installing crosswalks which make pedestrians feel better while crossing is a priority, or whether it would be better to install crosswalks associated with lower confidence and safety in an attempt to elicit greater levels of caution among at-risk pedestrians. If future research suggests that increased feelings of confidence and safety are desirable, special emphasis crosswalks are indicated, but if not, standard crosswalks would be better. In either case, educating pedestrians about the risks and how those risks can be minimized may be the best approach.

Regarding understanding of pedestrian law, older adults evinced a greater understanding than did younger ones of the correct side of the street to walk on when no sidewalk is present. The remainder of the survey questions, comprising questions on both pedestrian law and opinions of aspects of Florida's roadways, showed no significant association with age.

Task 1.3. Understanding the Impact of Standard and Special Emphasis Crosswalks on Driver Behavior and Attentional Allocation

This simulator study examined whether crosswalk type has an impact on driving behavior as participants navigate simulated roadways. Participants drove down a simulated roadway with pedestrians navigating the sidewalk on either side. Participants encountered both standard and special emphasis crosswalks at different points during the drive. Eye movements were recorded during the task so that we could investigate whether or not participants attended to pedestrians differentially as a function of crosswalk type. We also examined braking reaction time to unexpected pedestrian events. These data were analyzed to determine whether the presence of crosswalks influenced drivers to be more cautious and whether any crosswalk type was associated with greater success in avoiding vehicle-pedestrian crashes. At a subset of crosswalks, pedestrians initiated crossing as the participant's vehicle approached. The onset of yielding behavior was recorded and examined as a function of crosswalk type.

Figure 30. An overhead view of the intersection simulator scenarios were based on. The simulator tiles were able to display standard, special emphasis, or unmarked crosswalks at each intersection.

Method

Participants

Overall, 21 younger-aged, 22 middle-aged, and 25 older-aged adults were recruited for the study. However, 4 younger-aged, 1 middle-aged, and 1 older-aged participant were excluded from the analysis due to simulator sickness, failure to follow instructions, or experimenter error. This left 17 younger-aged (6 females), 21 middle-aged (11 females), and 24 older-aged participants (10 females) whose data were valid for analysis.

Stimuli and Apparatus

A NADS MiniSim high-fidelity driving simulator developed by The National Advanced Driving Simulator at the University of Iowa (Iowa City, IA), was used for the study. The NADS MiniSim incorporates a dashboard with a virtual instrument cluster, steering wheel; accelerator and brake pedals; and three 42" plasma displays that gives the driver a 180° horizontal and 50° vertical field of view of the simulated environment. Each display has a resolution of 1360 x 768 pixels and a refresh rate of 60 Hz.
The simulator tile is based on the intersections of the observation study which took place concurrently on Monroe Street (see Figures 30 and 31), and follows FDOT design specifications (http://www.dot.state.fl.us/rddesign/DS/13/STDs.shtm).

Participants were asked to drive in a single simulator scenario that featured a straight roadway with light traffic in the opposing lanes and 19 signalized intersections, with each intersection featuring either a special emphasis crosswalk, a standard crosswalk, or an unmarked crosswalk. Participants were asked to follow a 45 mph speed limit. For the first 18 intersections of the scenario, each crosswalk type was presented a total of 6 times, with each crosswalk type being presented 3 times in a row for the first 9 intersections, and 3 times in a row for the last 9 intersections. For each half of the first 18 intersections, order of presentation of crosswalk type was counterbalanced between subjects using a Latin square design. At each intersection, a pedestrian was placed on the right side of the roadway at the entrance of the first crosswalk participants drove over.

For some of the intersections, the pedestrian stood still and waited for the signal to cross (first 9 trials of the scenario and 6 of the last 10 trials). For the other 4 intersections, the pedestrian started to cross once the participant was 2.75 seconds away from driving over the crosswalk (this time was chosen as a result of pilot testing with older and younger participants) This made it so that the participant either had to drive around the crossing pedestrian or stop and wait for them to cross. At 13 of the intersections, a parked vehicle was placed on the right shoulder of the roadway a few feet away from the pedestrian and 20.55 feet away from the outer edge of the crosswalk, making it so that the participant could not see the pedestrian until they started driving past the parked vehicle (see Figure 32). This vehicle was present at all 4 of the intersections where the pedestrian was made to cross and 9 of the intersections where the pedestrian was made to stand and wait.

The 19th and last intersection, named Holt Drive in the simulator, differed from the others in two ways. First, the participant had been asked to drive straight until reaching Holt Drive, at which point they were to turn right. This served to make the conditions of the drive more realistic. Upon reaching this street they were forced via placement of a number of construction cones to make a right-hand turn at this intersection, so that if they forgot where they had been instructed to turn, they would still execute the task correctly (see Figure 33, Figure 34). Second, the pedestrian entered the crosswalk, which traversed the cross street instead of the main street, creating the potential for a pedestrian-vehicle conflict when the driver made the right-hand turn. Rather than being an unexpected event, this is a case in which the pedestrian had legally entered the crosswalk and the driver would be expected to yield. As in the other intersections with crossing pedestrians, the participant either had to stop for the pedestrian or (illegally) go around them.

Figure 31. Driving simulator tile with standard crosswalk.

Figure 32. Driving simulator tile with special emphasis crosswalk. The vehicle was located approximately 20 feet from the nearest crosswalk line.

Figure 33. View of the approach to the final intersection, where the participant executed a right turn. Note that although the truck appears to be very close to the crosswalk, it is approximately 20 feet away. Because the aspect ratio of these screen captures differs from the aspect ratio of images shown in the simulator, these screen captures may not a perfect representation of what participants saw in the scenario.

Figure 34. View of turn at final intersection in crosswalk task.

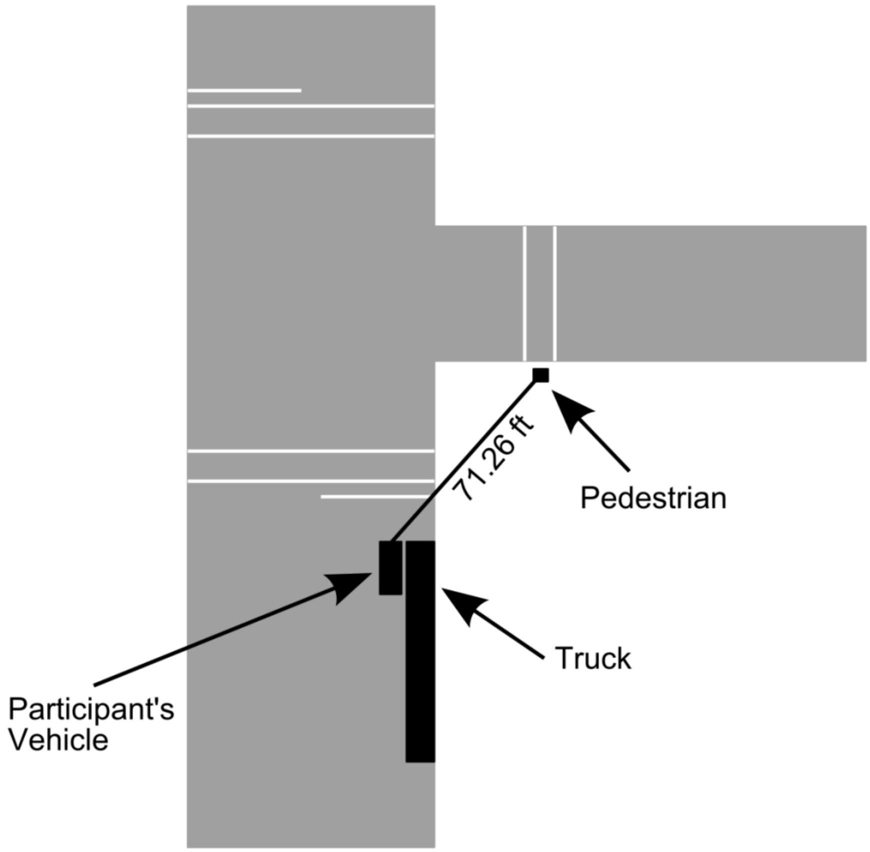

Figure 35. Depiction of the distance between the participant's vehicle and the pedestrian on the last trial of the scenario. Note that all of the pavement markings in the scenario are not shown and that the widths of the markings shown are not to scale relative to the distance shown.

Procedure

Participants were first asked to read and sign an informed consent form. They were then calibrated on the mobile eye tracker and asked to drive in a practice simulator scenario for the purpose of acquainting them with the driving simulator. Next, they completed the primary scenario described above. Finally, participants completed a questionnaire that assessed any simulator sickness and then were debriefed and compensated. Because we were interested in vehicle-pedestrian crashes, which have a very low base rate, the scenario was designed to be extremely difficult, and care was taken to be sure participants understood this during debriefing to alleviate any distress as a result of hitting pedestrians during the simulation.

Results

Brake Reaction Time

In our experiment, brake reaction time refers to the difference in time between the moment a pedestrian started crossing the road and the moment the participant pressed on his or her brakes at a level that was greater than or equal to 5% of the total force that can be applied to the brake pedal in our simulator. As the distribution of the brake reaction time data was found to be positively skewed, a log-transformed version of the variable was used in the analyses below.

In order to assess the extent to which order of presentation of the crosswalks affected brake reaction time, a mixed effects ANOVA was employed using crosswalk type, presentation order, and their interaction as fixed factors, and participant as a random intercept. Overall, all factors were observed to be statistically significant at the .05 level (all Fs > 5), providing evidence that presentation order did affect the speed at which participants made a brake response to crossing pedestrians. Since participant reaction to crossing pedestrians in the simulator was significantly different once they had already been exposed to such an event, only the first reaction time event for each participant was used in subsequent analyses. Figure 36 and 37 are boxplots of the uncorrected brake reaction time data for the first pedestrian crossing event as a function of crosswalk type and age group, respectively.

To assess the extent to which age group and crosswalk type affected brake reaction time, brake reaction time was submitted to an ANCOVA that used crosswalk type and age group as factors, and the speed at which a participant was traveling at the start of the reaction time event as a covariate (start speed; *Mdn* = 46.75, *IQR* = 4.42). As the distribution of the start speed data was negatively skewed, a square root version of the variable was used in the analysis. Overall, neither crosswalk type, age group, nor their interaction, predicted brake reaction time (all ps > .66).

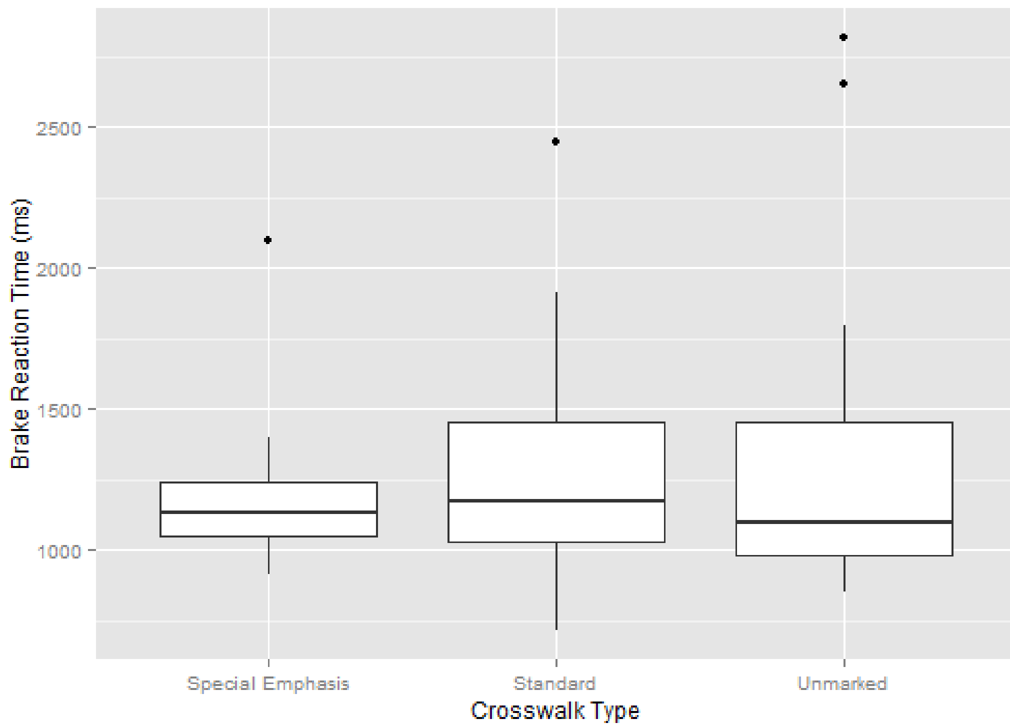

Figure 36. Brake reaction time from the first crossing event as a function of crosswalk type.

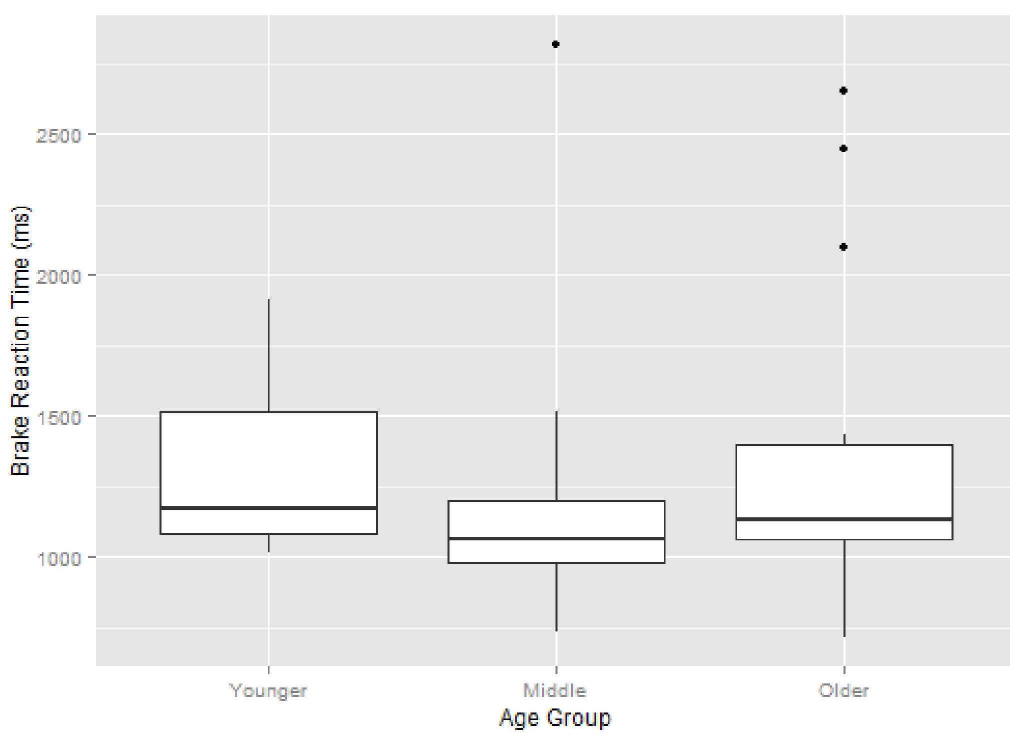

Figure 37. Brake reaction time from the first crossing event as a function of age group

Crashes

Overall, a total of 8 crashes occurred with pedestrians at the first crossing event, with 3 of them being made by middle-aged participants and 5 of them being made by older-aged participants. Across crosswalk types, the crashes were spread out, with 3 of them being made at a special emphasis crosswalk, 2 of them being made at a standard crosswalk, and 3 of them being made at an unmarked crosswalk. Overall, neither age group nor crosswalk type was informative when it came to predicting the probability of a crash (all ps > .29).

The last trial was a situation where pedestrian-vehicle conflict would be likely: Although pedestrians had the right-of-way, drivers may not be aware that they should yield or may not see the pedestrian in time to yield. During the last trial a total of 11 crashes occurred, with 4 of them being made by middle-aged participants, 4 of them being made by older-aged participants, and 3 of them being made by younger-aged participants. Across crosswalk type, 6 of the crashes were made at a standard crosswalk, 3 of them were made at a special emphasis crosswalk, and 2 were made at an unmarked crosswalk. Once again, neither age group nor crosswalk type was informative when it came to predicting the probability of a crash (all ps > .29).

Probability of Yielding to a Pedestrian with Right-of-Way

Overall, 43 out of 60 participants stopped during the last trial. Broken down by age group, 16 out of 24 older-aged (67%), 15 out of 19 middle-aged (79%), and 12 out of 17 younger-aged adults (71%) yielded to the pedestrian. Across crosswalk type, 15 out of 22 participants stopped when a standard crosswalk was present (68%), 14 out of 18 stopped when a special emphasis crosswalk was present (78%), and 14 out of 20 (70%) stopped when an unmarked crosswalk was present. Overall, neither age nor crosswalk type were informative when it came to predicting the probability of a stop (all ps > .49).

Figure 38 shows participants' distance from the crosswalk at their minimum speed for the trial. Data points for participants who stopped during the event are green and red for those who did not stop during the final trial. For those participants who did not stop during the last trial, their placement on the y-axis shows their minimum speed during the trial.

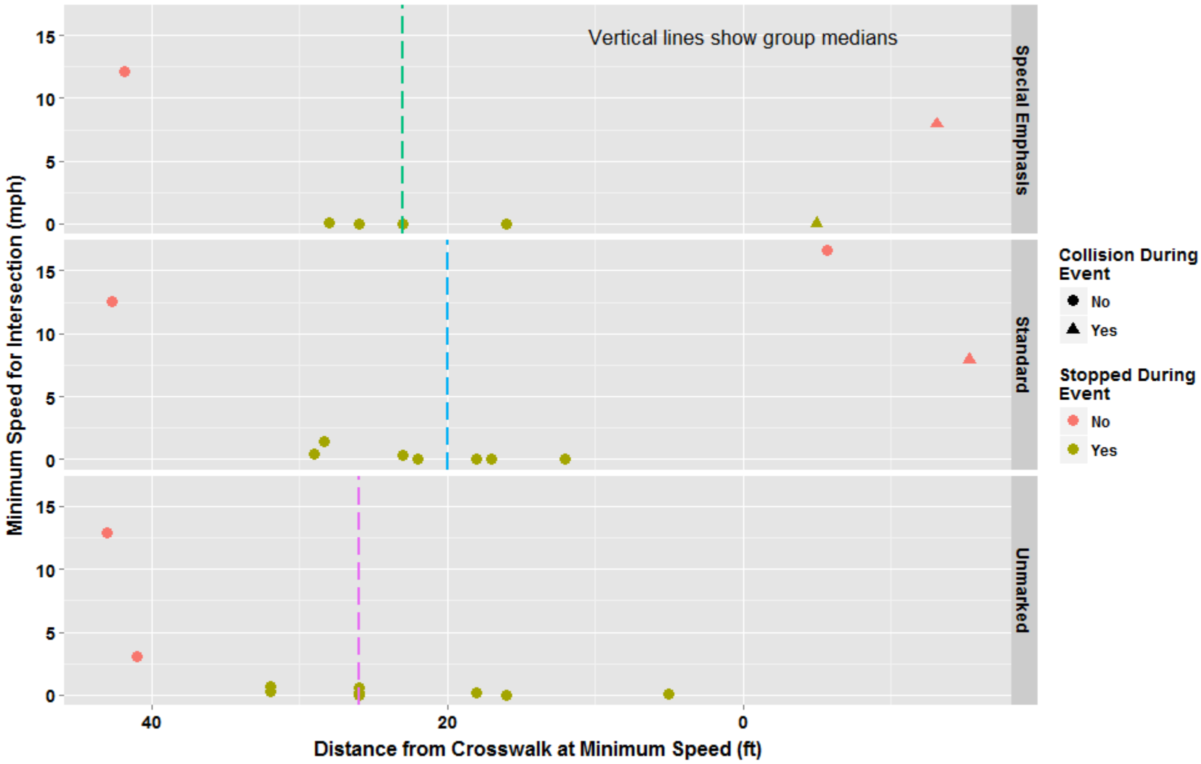

Figure 38. Distance from crosswalk at minimum speed on last trial. Vertical line shows the median distance for each crosswalk type. A negative distance means the participant had passed the crosswalk before yielding.

Eye Movement Analysis

Participants' eye movements were recorded during the driving task so that their allocation of visual attention could be compared between crosswalk types. Due to the typical problems associated with using a head-mounted eye tracker (e.g. headband slippage), complete eye movement data was only available for a subset of the participants who completed Task 1.3 This consisted of a total of 27 participants (10 younger, 4 middle-aged, and 13 older adults). Please note that not all participants are included in all analyses because some participants had usable data for some parts of the task but not others.

Of primary interest was whether either the likelihood of fixating or time taken to fixate a pedestrian would vary as a function of crosswalk marking. Due to the order effects observed in the driving simulator data, comparisons between crosswalk types were based only on the first type of crosswalk a participant encountered. For each intersection, for trials where the pedestrian was fixated at least once, a Kruskal-Wallis test compared the median index of the first fixation on the pedestrian between crosswalk types. There was no evidence that the median fixation index differed between crosswalk types, $X^2(1, N = 19) = 2.97$, $p = .23$ (see Table 13). Due to the small number of observations available for analysis, the failure to find a crosswalk effect may be due to a lack of statistical power.

Table 13. Median number of fixations before the first fixation on the pedestrian by crosswalk type.

Crosswalk Type	Median Fixations
Unmarked (*n* = 10)	10.5
Standard (*n* = 10)	12
Special Emphasis (*n* = 7)	7

A separate analysis was conducted on the eye movement data from the final intersection, where a right turn was executed. In this analysis, the time to fixate the walking pedestrian, counting from the time when he was first visible, was compared between crosswalk types. There was no evidence that the time to notice, as defined as the participant having fixated the pedestrian, varied between crosswalk types, $X^2(2, N = 27) = 2.97$, $p = .23$ (see Figure 39).

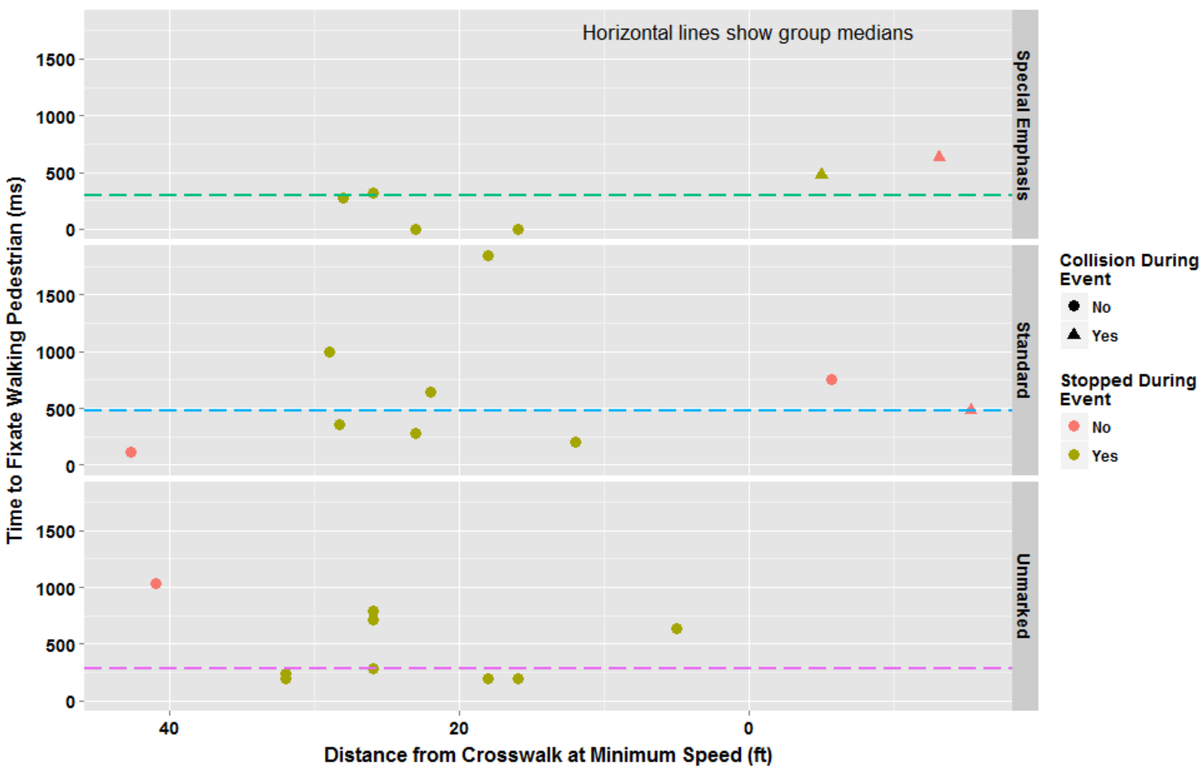

Figure 39. Time to fixate pedestrian by crosswalk type and yield distance. Horizontal lines show the median fixation time for each crosswalk type. A negative distance means the participant had passed the crosswalk before yielding.

Conclusions

Overall, crosswalk type and age group did not substantially predict brake reaction time or the probability of a crash with a pedestrian. In general, these findings provide evidence for the notion that the type of crosswalk featured at an intersection does not greatly influence drivers' noticing of crossing pedestrians. So while there was a perceptual advantage: special emphasis marked crosswalks are much easier to detect, and can be detected more accurately at further distances, an effect on pedestrian and driver behavior was not observed. Recommendations based on these findings are discussed at the end of this report.

Chapter 3. Task 2 - Evaluating the Time Necessary to Respond to Signal Changes as a Function of Age

Task 2.1. Modeling Experiment: A Goals, Operators, Methods, Selection Rules (GOMS) Analysis of Perception-Response Time to a Yellow Signal.

This study was aimed at determining (through cognitive modeling) whether yellow signal durations, which are based on predictions about how long it takes the average driver to perceive and react, are sufficiently long for older drivers. Bonneson and Zimmerman (2004) report that 80% of red signal running related crashes are due to unintentional violations that occur within the first 1.5 seconds of a cycle change. These unintentional violations occur when a driver is caught in a “dilemma zone”, where they can neither safely stop nor clear the intersection before the signal changes to red. This is more likely to happen to drivers who approach the intersection at speeds faster than the posted speed limit and those with very slow reaction times. One solution to this problem has been to lengthen yellow signal clearance intervals. Previous work has found that red signal running can be reduced by as much as 50% by increasing the duration of the yellow signal phase by 0.5 to 1.5 seconds, but not to a duration longer than 5.5 seconds (Van der Horst & Wilmink, 1986; Bonneson & Zimmerman, 2004; Retting et al., 2008).

Currently, the perception-reaction time (PRT) used in formulas to calculate yellow signal phase durations is 1 second, meaning that 1 second is assumed to be sufficient for a driver to perceive the signal change and react to it appropriately. Given that older adults are known to have slower response speeds than younger adults, it may be that 1 second is not a sufficient estimate for older drivers and that increasing yellow signal duration may especially benefit older drivers. Consistent with this, past work has found that older drivers’ dilemma zone tends to be closer to the intersection than younger drivers’. Older drivers’ dilemma zone was found to extend from a distance 3.2 seconds from the intersection to 1.5 seconds from the intersection, while younger drivers’ zone was. 3.9 to 1.85 seconds from the intersection. (Rakha, El-Shawarby, & Setti, 2007).

GOMS modeling provides a technique to estimate completion times for routine tasks. Tasks are separated into individual operations (e.g. eye saccade, eye fixation, cognitive processing, psychomotor action) each with their own cycle time estimations. The original operator time estimates for the GOMS model were given by Card, Moran, & Newell (1983), but only estimates for younger adults were provided. As a follow-up, Jastrzembski & Charness (2007) meta-analytically calculated cycle times for older adults to allow for age differences in task completion estimates. Derived from the existing literature, these estimates account for older adults’ slower processing and movement times, slower learning rates, and age-related declines in memory capacity. These were the parameter estimates used in our model to estimate decision times of younger and older adults in a yellow-signal task.

Method

For each individual modeled task, task components are correlated to individual operators (see Appendix E for full models, parameter estimates given in Table 14). The operators are ordered serially and their cycle times are summed to estimate overall task completion time. Due to differences in operation cycle time estimates, models for older and younger adults will result in different task completion time estimates. For the current yellow-signal decision scenario, three models were completed: Cautious Go, Cautious Stop, Semi-Cautious Go. Driver caution was modeled by including operators accounting for drivers scanning the field of view for potentially dangerous stimuli (i.e. other vehicles in proximity to the driver) after the dilemma state (yellow signal) is reached. All models assume that the driver is intending to go straight through the intersection (i.e., not turning). The Semi-Cautious Go model includes the driver looking at the opposing left turn lane to check for other drivers making late left turns across the modeled driver's lane and looking at the perpendicular right turn lane for possible incursions into the modeled driver's lane. The Cautious Go model simply adds to the Semi-Cautious Go model by allowing for another fixation to check the perpendicular traffic to the left to check for drivers that may run their red signal. The Cautious Stop Model allows for one fixation to the rear-view mirror to check for close-following traffic before action is taken to brake.

Table 14. Younger and older adult estimates for Model Human Processor Parameters.

Parameter of Interest	Younger Adult Estimate (Card, Moran, & Newell, 1983)	Older Adult Estimate (Jastrzembski & Charness, 2007)
Duration of eye fixations (F)	230 ms	267 ms
Cycle time of the perceptual processor (P)	100 ms	178 ms
Cycle time of cognitive processor (C)	70 ms	118 ms
Cycle time of the motor processor (M)	70 ms	146 ms
Power Law of practice constant	0.40	0.49
Fitts' Law slope constant (Fitts)	100 ms/bit	175 ms/bit
Effective capacity of working memory	7 items	5.4 items
Pure capacity of working memory	2.5 items	2.3 items

Results

The Cautious Go model predicts that it will take 1740 ms and 2339 ms after the onset of the yellow signal to make the decision to go through the intersection for younger and older drivers, respectively. The Cautious Stop model predicts the brake response time of an extremely cautious driver who has chosen to not go through the intersection. This model predicts that it will take 1344 ms and 2111 ms to make the decision to stop and to press on the brake pedal for younger and older drivers, respectively. Finally, the Semi-Cautious Go model predicts the decision time of a semi-cautious driver who has chosen to go through the intersection. This model predicts that it will take 1440 ms and 1954 ms to make the decision to go through the intersection for younger and older drivers, respectively. A detailed outline of each model is included in Appendix E**.**

Conclusions

The substantially longer decision and action times of older adults suggest that older adults would benefit from greater yellow signal durations. However, before making recommendations we validated the time estimates produce by GOMS modeling against the driving simulator data of younger and older adults in Task 2.2.

Task 2.2. Simulator Experiment: Perception-Response Speed for Yellow Signals.

The purpose of Task 2.2 was to validate the time estimates produced by GOMS modeling against the driving simulator data from younger and older adults. Specifically, we were interested in validating the Cautious Stop model. This provides an obvious reaction time (brake time) to measure in the simulator and compare to the model. Other models provide the time to make a decision that may not require an overt response, which cannot be easily assessed in simulator driving measures.

Method

Participants

The final sample for Task 2.2 includes data from 27 younger (M = 23 yrs, SD = 1.9), 22 middle (M = 58, SD = 4.0), and 25 older (M = 72, SD = 4.5) participants. All participants were licensed drivers over the age of 21, were recruited from the Tallahassee, FL area, and received $15 compensation for their participation.

Materials

Driving Simulator. A NADS MiniSim high-fidelity driving simulator developed by The National Advanced Driving Simulator at the University of Iowa (Iowa City, IA), was used for the study. The NADS MiniSim incorporates a dashboard with a virtual instrument cluster, steering wheel; accelerator and brake pedals; and three 42” plasma displays that gives the driver a 180° horizontal and 50° vertical field of view of the simulated environment. Each display has a resolution of 1360 x 768 pixels and a refresh rate of 60 Hz.

Procedure

Participants completed Task 2.2 during a single 1 hour visit to the lab. After signing the informed consent form, participants were seated in the driving simulator and instructed on how to adjust the seat so that they were a comfortable distance from the steering wheel and pedals. Next, participants were given general instructions on how to control the vehicle during the simulated driving task (e.g. how to shift into drive, steer, etc…).

The main simulated driving task, which took about 15 minutes to complete, consisted of a straight drive where participants encountered a total of 13 intersections (3 practice, 10 for the main task) and were instructed to maintain a speed of 40 miles per hour. Yellow signal duration was systematically manipulated between subjects, with half of the participants in each age group randomly assigned to either the “short” or “long” yellow signal phase duration condition; the yellow signal duration in the “short” condition was 2 seconds, and 4 seconds for the “long” condition. The participant’s distance from the intersection when the signal changes to yellow was manipulated within subjects (near, far). On the far distance trials, the signal changed to yellow 8 seconds after the participant passed an invisible trigger point on the roadway. This meant that the participant had more time to react to the yellow signal before the signal changed to red. On the near distance trials, the signal changes to yellow 10 seconds after the participant passed the trigger point on the roadway. On these trials the participant had less time to react to the signal change because they were closer to the intersection. This manipulation, as well as the shortening of yellow light durations in some conditions, was done to push participants into a dilemma situation. Of the 10 “critical” intersections, the signal remained green on 2 trials and changed to yellow when the driver approached on 8 trials. For 4 of the 8 stop trials, the signal changed to yellow approximately 16 seconds before the participant reached the intersection (corresponding to about 940 feet at 40 mph) and 20 seconds before the participants reached the intersection (corresponding to about 1173 feet at 40 mph) for the remaining 4 trials.

A subset of participants (7 younger, 16 middle, and 12) older adults also completed a practice driving scenario before beginning the main task. This was implemented because we found that older participants were failing to understand basic operation of the driving simulator, and this was affecting data quality from those participants, whose lack of ability to operate the simulator was causing them not to experience the intended dilemma zones. The original driving scenario included 3 practice trials (intersections), but this did not provide sufficient opportunity for practice for older participants. The practice scenario took about 10 minutes to complete and included explicit instruction and feedback on steering, accelerating/decelerating, and braking, as well as opportunities to practice each of these.

Results

Table 15 displays a number of descriptive statistics for the reaction time data. All analyses were conducted using R version 2.15.1.

Table 15. Descriptive statistics for the reaction time data (time between signal change to yellow and first depress of the brake pedal for intersection at which participants stopped).

Reaction Time to Yellow Signal Change				
Variable	Mean	Std Dev.	Median	Interquartile Range
Signal Duration				
Long	2222	3487	1733	1100
Short	2475	1796	1958	2192
Distance from Yellow Signal				
Near	1593	1051	1217	700
Far	2662	3286	2017	1367
Age Group				
Younger	2144	898	1992	1200
Middle	2202	1606	1717	1350
Older	2693	4686	1533	1242

Participants Included in the Analysis

Some participants were excluded from the analysis due to either equipment problems, participant noncompliance with instructions, or experimenter error. The analyses reported here are based on data from, 21 younger-aged (11 females, M_{age} = 22.76, SD_{age} = 2.12), 22 middle-aged (12 females, M_{age} = 57.91, SD_{age} = 4.13), and 21 older-aged (9 females, M_{age} = 71.76, SD_{age} = 4.59) participants. Out of these, 36 participants were assigned to the long yellow signal duration scenario (18 females, M_{age} = 51.28, SD_{age} = 21.38) and 28 participants were assigned to the short yellow signal phase duration scenario (14 females, M_{age} = 50.46, SD_{age} = 20.82).

Variable Definitions

Distance from Yellow Signal (Near vs. Far). The delay in time between when the yellow signal trigger is activated by the participant and the time the signal phase actually changes to yellow. This results in either participants being near or far from the intersection when the signal changes to yellow. This is a within-subjects variable.

Age Group (Younger, Middle, Older). The age group that the participant belongs to. This is a between-subjects variable.

Yellow Signal Duration (Long vs. Short). The length of time the signal remains yellow. The long delay is 4 seconds and the short delay is 2 seconds. This is a between subjects-variable.

Speed at Reaction. This is the speed of the participant's vehicle when they first reacted to the yellow signal. This is a within-subjects variable.

Reaction time. This is the difference in time between when the signal phase changes to yellow and the time when the participant first depresses the brake pedal by 5%. This is a within-subjects variable.

Comparison of GOMS Cautious Stop Predictions to Observed Reaction Times

To appropriately validate the GOMS model, we used mean reaction times that have been adjusted by speed at reaction measurement as the older participants (M = 33.97, SD = 5.61) tended to drive more slowly than their younger counterparts (M = 36.87, SD = 2.93). These adjusted means were calculated by submitting age group and mean-centered speeds at reaction to a mixed-effects model with a random intercept for each participant. Log reaction times for each intersection were used in the analyses, as the distribution of the reaction time data was found to be extremely skewed in the positive direction. A table comparing the GOMS-predicted reaction times to the speed-adjusted, observed reaction times is presented in Table 16. (Note that these reaction times have been converted back to their original scale.) Overall, the GOMS model appears to have underestimated the reaction times for both age groups; however, it appears that it did do well in predicting the difference between age groups.

Table 16. Predicted and observed reaction times for the GOMS Cautious Stop model.

Age Group	Predicted	Observed	Difference
Younger	1344	2297	953
Older	2111	3099	988
Difference	767	803	36

As for the results of the mixed-effects model, the difference in log reaction time between older and younger participants was significant at the .05 level, $t(40) = -3.16$, $p = .003$, $\beta = -0.30$. As expected, older adults reacted more slowly. In addition, speed at reaction measurement was found to negatively correlate with log transformed reaction time, $t(142) = -11.53$, $p < .001$, $\beta = -0.09$, indicating that higher speeds were associated with faster reaction times, which is as expected given that the younger adults in the sample drove faster than the older adults.

Effect of Signal Distance, Yellow Signal Duration, and Age Group on Reaction Times for Intersections Where Participants Stopped for the Signal

A model comparison approach was used to assess the impact that signal distance, yellow signal phase duration, and age group had on reaction times to the yellow signal changes on trials where the participant stopped for the signal. First, an initial linear regression model was calculated using the above variables in addition to the mean centered speeds at reaction. As expected the residuals within each participant were found to correlate (*ICC* = .45). To correct for this, the model was modified in such a way that each participant was allowed to have their own random intercept, thus transforming the model into a mixed-effects model. Overall, this substantially improved model fit ($X^2(1) = 73.69$, $p < .001$). In terms of fixed effects, age group, $F(2, 60) = 3.83$, $p = .03$, signal distance, $F(1, 224) = 188.45$, $p < .001$, and speed at reaction measurement, $F(1, 244) = 325.64$, $p < .001$, were found to predict log reaction time. Yellow signal phase duration did not affect reaction time at a level that was significant at .05, $F(1, 60) = 0.52$, $p = .473$, $\beta = .052$. For age group, both middle, $t(60) = -2.17$, $p = .034$, $\beta = -.190$, and older-aged participants, $t(60) = -2.58$, $p = .012$, $\beta = -.233$, were found to have lower log reaction times than younger participants. In addition, trials on which the signal changed when participants were further from the intersection tended to result in longer reaction times than trials with on which the signal changed and the participant was closer to the intersection ($\beta = .550$). Finally, speed at reaction measurement was once again found to negatively correlate with reaction time ($\beta = -.086$).

Conclusions

Although the GOMS Cautious Stop model underestimated the reaction times for both younger- and older-aged participants, it did do well in predicting the difference in mean reaction time between both groups. In addition, for intersections where participants stopped for the signal, only age group, signal delay, and speed at reaction measurement predicted reaction time. Overall, these results suggest that older adults may take substantially longer to perceive and react to the onset of yellow signals compared to younger adults, and both modeling and simulator data suggest that it will typically take well over 2 seconds for older adults to perceive and respond to a yellow signal event.

Chapter 4. Task 3 - Flashing Yellow Arrow Perception and Factors that Influence Comprehension

Driving maneuvers requiring gap-acceptance judgments, such as left turns in North America, are among the most difficult and perilous (Alexander, Barham, & Black, 2002; Yan, Radwan, & Guo, 2007), and appear to be especially difficult for older drivers (Alexander et al., 2002). One concern is that drivers in a left turn-only lane may generalize the right-of-way that is ordinarily signaled to drivers in through lanes by a circular green (CG) to protected/permissive Left-Turn (PPLT) displays where the CG signal indicates only that turns are permissible when there is a safe gap in oncoming traffic (Knodler, Noyce, Kacir, & Brehmer, 2005). It has been suggested that a flashing yellow arrow (FYA) is more likely to be interpreted by drivers as an indicator that turning is not permissible until a safe gap has been identified. Following a comprehensive investigation, Brehmer, Kacir, Noyce, and Manser (2003) concluded that FYA permissive indication was a viable alternative to CG.

At present, it remains unclear whether older drivers comprehend FYA signals as well as younger drivers. Comprehension tests suggest that while older drivers may be more susceptible than younger drivers to mistaking CG signals for protected signals, and thus failing to yield to oncoming traffic during left turns, the use of flashing signals raises the accuracy of older drivers such that their performance is comparable to that of younger drivers (Noyce and Kacir, 2001). Recently, a report by the Missouri Department of Transportation found differences between age groups, with older adults misinterpreting the meaning of the FYA almost 75% of the time in some situations. Across all age groups about 19% of participants misinterpreted a FYA as giving right of way in a scenario in which there was oncoming traffic (MoDOT, 2008). In addition to more data on the comprehensibility of FYA signals to older drives, further research is also needed to establish the potential benefit of supplemental signs, and the effectiveness of current FDOT tip cards in conveying knowledge of FYAs.

In the current contract we have conducted a review of the literature relevant to driver comprehension of FYA PPLT displays (Task 3.1), assessed FYA comprehension in the laboratory (Task 3.2), and have examined drivers' reactions to FYA in simulator scenarios in which misunderstanding of the meaning of the FYA would result in a crash. Together, the results of these studies will help to support the FYA signal as an effective countermeasure as part of the implementation of FDOT's Aging Road User Strategic Safety Plan.

Task 3.1. Flashing Yellow Arrow Literature Review

Crashes in which left-turning vehicles are struck by oncoming traffic at signalized intersections (left-turn crashes) are both common and severe (Wang & Aty, 2008). Generally, older adult drivers are at greater risk for intersection crashes (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998), and left-turn crashes are particularly dangerous for older adult drivers relative to younger drivers (ADOT, 1996). This increased risk is related to perceptual and cognitive declines that accompany the aging process, which in turn impair the ability of older drivers to correctly judge the speed and distance of oncoming vehicles and the gaps between vehicles (Scialfa et al., 1991; Stamatiadis et al., 1991).

One solution to reduce the likelihood of left-turn crashes has focused on offsetting left-turn lanes at signalized intersections to allow left-turning drivers a less obstructed view of oncoming traffic. Additionally, Florida, along with a number of other states, has recently begun to implement new traffic signals featuring a flashing yellow left-turn arrow to improve both safety and traffic flow at busy intersections. In terms of safety, the new signal configuration aims to prevent the misconception that a circular green within a Protected/Permissive Left-Turn (PPLT) display guarantees right-of-way for left turning drivers. Within the context of this configuration a solid green arrow guarantees right-of-way (opposing traffic has red) for left turning drivers, a solid yellow arrow warns of an impending transition to red (stop), and a flashing yellow arrow indicates that left turns are permissible, but only when there is a safe gap in oncoming traffic.

The flashing yellow arrow (FYA) option for PPLT signals received interim approval in 2006 after an initial evaluation, and standards for implementing the FYA were included in the 2009 edition of the Manual on Uniform Traffic Control Devices (MUTCD). Published in 2003, the National Cooperative Highway Research Program (NCHRP) Report 493 that served as the basis for this approval details the results of a series of laboratory and field-based studies conducted over a 7-year period that evaluated the safety and effectiveness of different PPLT signal displays and phasing. Since the start of the work reported here, a number of other studies have been conducted to further understand the complex set of factors related to the effectiveness and safety of PPLT signal displays. In this review, we provide an overview of critical factors related to driver knowledge and comprehension of the left-turn permissive phase of FYA PPLT displays, highlighting those factors that are particularly relevant to understanding the safety and effectiveness of the signal for older drivers.

Signal Head Configuration

Different types of signal heads are used in PPLT displays across the United States. Reporting results from a survey of traffic engineers across all 50 states, NCHRP Report 493 identified the three most commonly used configurations for PPLT displays: the five-section cluster (doghouse; 63% of displays), five-section vertical (19% of displays), and five-section horizontal (9% of displays; see Figure 40). While some states did report using three and four-section signals in PPLT displays, these were uncommon and accounted for less than 10% of all reported PPLT signal displays in use at the time of the report.

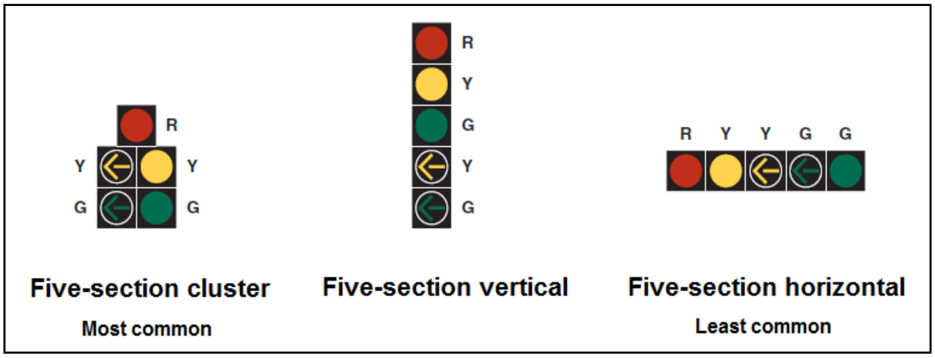

Figure 40. Signal head configurations used in PPLT displays.

Several studies we reviewed included signal head configuration as a possible factor in driver comprehension of PPLT signals. In laboratory-based studies conducted as part of NCHRP Report 493, the five-section horizontal PPLT signal arrangement was associated with poorer driver comprehension than either cluster or vertical arrangements, particularly when the through signal was red, though these results were not replicated in a subsequent driving simulator study (see also Noyce & Kacir, 2001). However, consistent with the laboratory study findings, some field studies have reported higher crash rates at intersections using the horizontal signal arrangement compared to the cluster (doghouse) arrangement (Yu, Qi, Yu, Guo, & Chen, 2008). In the field study presented in NCHRP Report 493, the five-section horizontal signals were also associated with more driver hesitation at the beginning of the protected turn phase, which was attributed to greater mental workload imposed by the simultaneous illumination of the green arrow and red signals on combined signal heads. However, the authors also noted that this was related to PPLT signal phasing and not to the PPLT display arrangement, nor did this vary systematically across study locations.

Type of Permissive Indication

The laboratory study conducted as part of NCHRP Report 493 also compared driver comprehension of different types of permissive left-turn indications (see also Noyce & Kacir, 2001 for additional discussion of the results from this study). In addition to the FYA, they also looked at driver comprehension of the circular green, flashing circular yellow, flashing circular red, and flashing red arrow permissive indicators. The lowest response accuracy for the permitted phase was observed for the flashing red circular and arrow indicators (63.8% and 55.6%, respectively), and the best overall response accuracy was observed for the flashing circular yellow (85.8%). The FYA permissive indication outperformed both flashing red indicators, with a comprehension rate of 75.2%, as well as the circular green (70.5%).

Knodler et al. (2005) conducted both driving simulator and static laboratory-based tasks that compared comprehension accuracy of the FYA and flashing red arrow (FRA) signals when used in separated left-turn lanes. Overall, the FYA was well-understood by drivers. The FYA signal had a higher rate of “yield” responses (70%) than did the FRA (< 40%). However, the FRA elicited a higher percentage of “stop first” and “stop and wait” responses than did the FYA. Consistent with this, the FYA signal was also associated with more “fail critical” (“go” responses) than did the FRA signal. The authors’ recommendation based on these results as that while the FYA is well-understood by drivers, supplemental signage or driver training may be necessary when a FYA signal is used at wide median intersections.

In a study conducted for MoDOT in 2008, Henery and Geyer report poorer comprehension for the FYA signal compared to the more common CG permissive indication. In this study drivers were shown pictures of six different left-turn scenarios at signal controlled intersections on a laptop computer screen and asked “If you want to turn left and you see the signals show, you would...” Answer choices were “GO (you have right of way)”, “YIELD (wait for gap)”, and “STOP”. Participants were also asked whether they had ever seen the FYA signal before. Questions consisted of 2 FYA questions, 2 “left turn yield on green” questions with the R10-12 sign (Figure 21), and two control questions (what were these?). Drivers’ comprehension of the FYA signal was poorer overall than for the other signals evaluated in the study. In particular, the rate of “critical fail” responses was high compared to the circular green (CG) indication (18.7 go w/ FYA and red through; 9.7 w/ FYA and green through). Experience modified this somewhat but even among drivers who indicated they had seen the FYA signal before, performance for the FYA questions was poorer than for the CG permissive LT signal. It is important to note that the R10-12 supplemental sign was used with the CG permissive indication in this study.

Other laboratory and simulator studies comparing driver comprehension of the FYA and CG indicator under more typical conditions have failed to find any significant differences (e.g. Smith & Noyce, 2000; Knodler et al., 2002; Noyce, 2003; Knodler, Noyce, Kacir, and Brehmer, 2005; Schattler, Rietgraf, Burdett, & Lorton, 2013).

Consistency of Application

The speed and accuracy of driver comprehension of traffic signals can be influenced by the consistency of signal application. Noyce (1999) reviews human factors literature related to traffic signal comprehension and points out that having variability in signal application and configuration increases information processing demands for drivers. For example, if multiple signal head arrangements are used within the same area, drivers’ visual search may be slower because they would not immediately know where to search for the relevant signal information. Driver information processing complexity is reduced by having a single PPLT indicator and signal configuration. Consistent with this, Qi et al. (2012), based on results from a field study, recommend that when the FYA PPLT is implemented at a location they be installed at intersections throughout the surrounding area. This is based on earlier recommendations from Yu et al. (2008), based on a field study in which they found lower crash rates in areas where PPLT display configuration was consistent across intersections in the area compared to those where PPLT display configurations varied.

Prior Experience with Signal

In general, studies find that the FYA signal is well understood by drivers with no prior experience with the signal. However, studies do find that experience with the signal further improves driver comprehension of the signal (e.g. NCHRP, 2003; MoDOT, 2008).

Because the MUTCD allows the use of both the FYA and CG permissive indicators, it is of interest whether exposure to the FYA signal negatively affects driver comprehension of the currently more common CG indication. This question was addressed in a series of laboratory and simulator studies conducted by Knodler, Noyce, and Fisher (2007). Participants in the driving simulator study were first given training on the meaning of the FYA signal, then completed a driving scenario where they encountered both types of signals. Following the simulator task, the same participants also completed a follow-up lab evaluation. In addition, an independent laboratory experiment was also conducted. Participants in the driving simulator study were more likely to give correct "yield" responses to the CG indication after being exposed to the FYA. However, in the independent laboratory study there was no difference in comprehension accuracy before and after exposure to the FYA signal. Taken together, these results suggest that the implementation of the FYA is unlikely to have negative effects on driver comprehension of the CG permissive indication.

Supplemental Signs

Informational campaigns, such as public service announcements and tip cards, may not reach all drivers. Another way of informing drivers of the meaning of the FYA signal is to include supplemental signage at intersections where the sign is installed. Although most studies find that the FYA signal is well understood by drivers without the use of supplemental signs, and the 2009 MUTCD does not recommend or require supplemental signs to be used with the FYA signal, there may be instances in which such signs are beneficial. For example, Knodler et al. (2005) suggest that use of a supplemental sign may be beneficial when the FYA is used on wide median roadways or when there is a separated left-turn lane.

NCHRP Report 493 assessed the effectiveness of supplemental signs and found that they do improve comprehension, increasing the number of "yield" responses and decreasing the number of "fail-critical" go responses. Similarly, Schattler, Rietgraf, Burdett, and Lorton (2013), also found that supplemental signs further improved driver comprehension of the FYA signal, with fewer fail-critical errors for FYA with sign than for FYA without the supplemental sign.

In a survey of motorists conducted by Qi et al. (2012), the majority of motorists surveyed indicated that they preferred supplemental signs with a combination of text and a symbol (as in Figure 41).

Figure 41. Supplemental signs used with PPLT signals.
R10-12 (left), modified R10-12 (center), and R10-X12 (right).

Signal Phasing

While the FYA has been shown to be well understood by drivers, there are some conditions under which it has been found to be problematic. In particular, studies have found higher crash rates associated with the implementation of the FYA at high traffic intersections with high left-turn volumes that use lead-lag phasing (Yu et al., 2008; Deskins, 2009).

Qi et al. (2012) and Deskins (2009) both recommend against the use of lead-lead and lead-lag phasing at heavy traffic intersections with high approach speeds. When drivers are under heavy attentional load, they may not notice when the steady yellow phase begins and not take appropriate action, increasing the frequency of red signal running at that intersection. To avoid this "steady yellow confusion", Qi et al. (2012) recommend the use of lag-lag phasing.

Another potential issue noted in some studies is that driver confusion is more likely when the left turn sequence precedes the through phase. When the left turn signal is in conflict with the through signal (i.e. left-turn signal is green and through signal is red), drivers have been shown to make more errors in lab studies (e.g. NCHRP, 2003) and to hesitate at the start of the left turn phase in field studies (e.g. NCHRP, 2003; Yu et al., 2008). A recommended solution to this problem is to use independent signal heads for the left-turn lane when possible and install louvers when combined signal heads are used (e.g. Deskins, 2009; Yi et al., 2012).

Driver Age

Overall, older adults have been underrepresented in studies investigating drivers' knowledge and understanding of the FYA signal. However, when older adults have been included in studies, they have performed more poorly on tasks, indicating that they do not understand what action to take when they encounter the FYA signal. Older adults are less likely to cope well with novel situations, particularly under time constraints or stress, so it is especially important that older drivers be educated about new signals. NCHRP Report 493 and Henery and Geyer (2008) found lower accuracy with increasing age. Older drivers took much longer to respond (2-4 sec longer). For older drivers, flashing circular red and flashing yellow permissive indicators were best understood (70% correct for 65+ on flashing CR indicator). Noyce (1999) also points out that consistency of left-turn signal treatments may also especially benefit older drivers, as this would reduce information processing demands.

Of note, the small number of studies evaluating the efficacy of public information campaigns, supplemental signs, or training interventions have either not included or included only a small number of older adult participants. For example, Qi et al. (2012) included only one participant over the age of 65, while the MoDOT (2008) study conducted by Henery and Geyer included only 4 adults over age 65.

Conclusions

Overall, the FYA signal is well understood by drivers and, at best, is associated with fewer “fail critical” incorrect responses/actions. However, there are some important caveats. First, the signal arrangement has a significant effect on signal comprehension, with 5-section heads showing the lowest comprehension rates (e.g. NCHRP, 2003). Second, driver experience with the signal also influences driver understanding. For drivers unfamiliar with the FYA, accuracy was poorer than for drivers who had seen the signal before. However, even when drivers had not seen the FYA signal before, the “incorrect” responses drivers gave tended to be of the sort that would not put the driver in harm’s way (stop and wait vs. go). When a supplemental sign was used with the FYA, driver comprehension was improved (Schattler, Rietgraf, Burdett, & Lorton, 2013). In field studies where crash rates were compared before and after installation of a FYA signal, the signal did not tend to be associated with increased crash rates. However, use of the FYA is not recommended at busy intersections with high through and left turn volume. When driver attention is divided / taxed, as is the case at busy intersections, the FYA may make drivers less likely to notice the yellow signal indicating the end of the permissive left turn phase. In these cases, the FYA was associated with increased crash rates (Yu et al., 2008). Signal phasing is also a factor, with greater change of confusion / missing the change to solid yellow arrow occurring with lead – lag or lead - lead phasing (Deskins, 2009; Qi et al., 2012).

Task 3.2. Perception and Comprehension of Protected-Permissive Left Turn (PPLT) Displays

As a first step to understanding FYA comprehension, we conducted a computer-based laboratory task in which younger, middle-aged, and older drivers were shown images (sometimes animated to depict the flashing of the FYA) of different phases of a FYA PPLT signal. At first they were required to provide the meaning of the FYA (and other signals) in a free-response task. Then participants were shown driving scenes, some featuring the FYA, and were asked to choose from three options the appropriate course of action. Scenarios were from the point of view of a driver attempting to turn left, and oncoming traffic either provided a sufficient or insufficient gap to turn safely. Finally, speeded comprehension was assessed. We assessed speed and accuracy of comprehension, as well as whether or not mistakes would have led to a critical error (e.g., indicating turning now would have been appropriate with a FYA signal present and oncoming traffic too close to avoid a crash).

In this, and the driving simulator experiment to be described later, some participants received educational materials to understand the effectiveness of these materials at conveying the meaning of the FYA to drivers. However, in this experiment, these materials were only provided to participants after the comprehension task to get a baseline of participants' understanding in the absence of any additional information.

Method

Participants

A total of 88 participants, recruited from the Tallahassee, Florida area, completed the flashing yellow arrow lab task. The current sample included data from 28 younger (*M* = 22.36, *SD* = 1.5, range = 21 to 27 years), 29 middle-aged (*M* = 58.03, *SD* = 3.9, range = 51 to 64 years), and 31 older adults (*M* = 71.39, *SD* = 5.4, range = 65 to 84 years). Participants completed the task in a single session and were compensated at a rate of $10 per hour.

Materials

Stimuli for Task 3.2 consisted of 96 images generated from a 3D model of a signal-controlled intersection created in SketchUp 8 Pro. The model depicted a commercial/residential setting and was created in accordance with guidelines found in the Manual on Uniform Traffic Control Devices (MUTCD) and FDOT Design Standards. The intersection had two through lanes and a dedicated left turn lane in each direction. Images were generated from virtual cameras using the Phantom HD Gold settings, placed at an eye height of 4 ft, with the lens positioned in the center of the left turn lane and 2 ft behind the stop bar. Images were exported at a resolution of 1600 x 1200 and displayed on a 19 inch CRT monitor with participants seated at a distance between 50 and 70 cm from the monitor.

Procedure

Task 3.2 consisted of two parts, a comprehension task designed to assess participants' understanding of the meaning of different traffic signals and a reaction time designed to assess the speed at which participants can determine the correct action based on both the signal and traffic conditions. Participants completed both parts of the FYA lab task during a single experimental session and received $10 compensation.

The comprehension task consisted of two sections, a free response section where participants were presented with images of traffic signals (see Figure 42) and asked to describe in their own words the meaning of that signal for the driver in the left-turn lane, and a multiple choice section where participants indicated which of three possible actions (“Wait, remain stopped”, “Wait, go when safe”, and “Go now”) was correct based on both the left-turn signal and traffic conditions (see Figure 43). In both sections of the comprehension task the participant was instructed to respond as if they are a driver in the left turn lane who has not yet entered the intersection and is at a complete stop. They were also informed that the speed limit on all roads shown was 45 mph. To minimize variability of participants’ experience, they listened to pre-recorded instructions (instruction text was presented on the screen while participants listened to instructions). For the free response task, participants were given the option of having the experimenter type in responses for them if they wished. Otherwise, participants typed their own responses.

Another purpose of the current study was to assess the effectiveness of FDOT’s FYA tip card in teaching drivers the correct meaning of the FYA left turn signal. Following the comprehension task, which was intended to assess participants’ baseline knowledge about PPLT signals prior to exposure to any educational materials, half of the participants in each age group viewed a computer-based version of the FYA tip card (tip card condition) and the remaining participants in each age group did not receive any additional information about the FYA signal (no tip card condition). A sample FYA tip card and additional details about the computer-based version of the tip card are given in Appendix G.

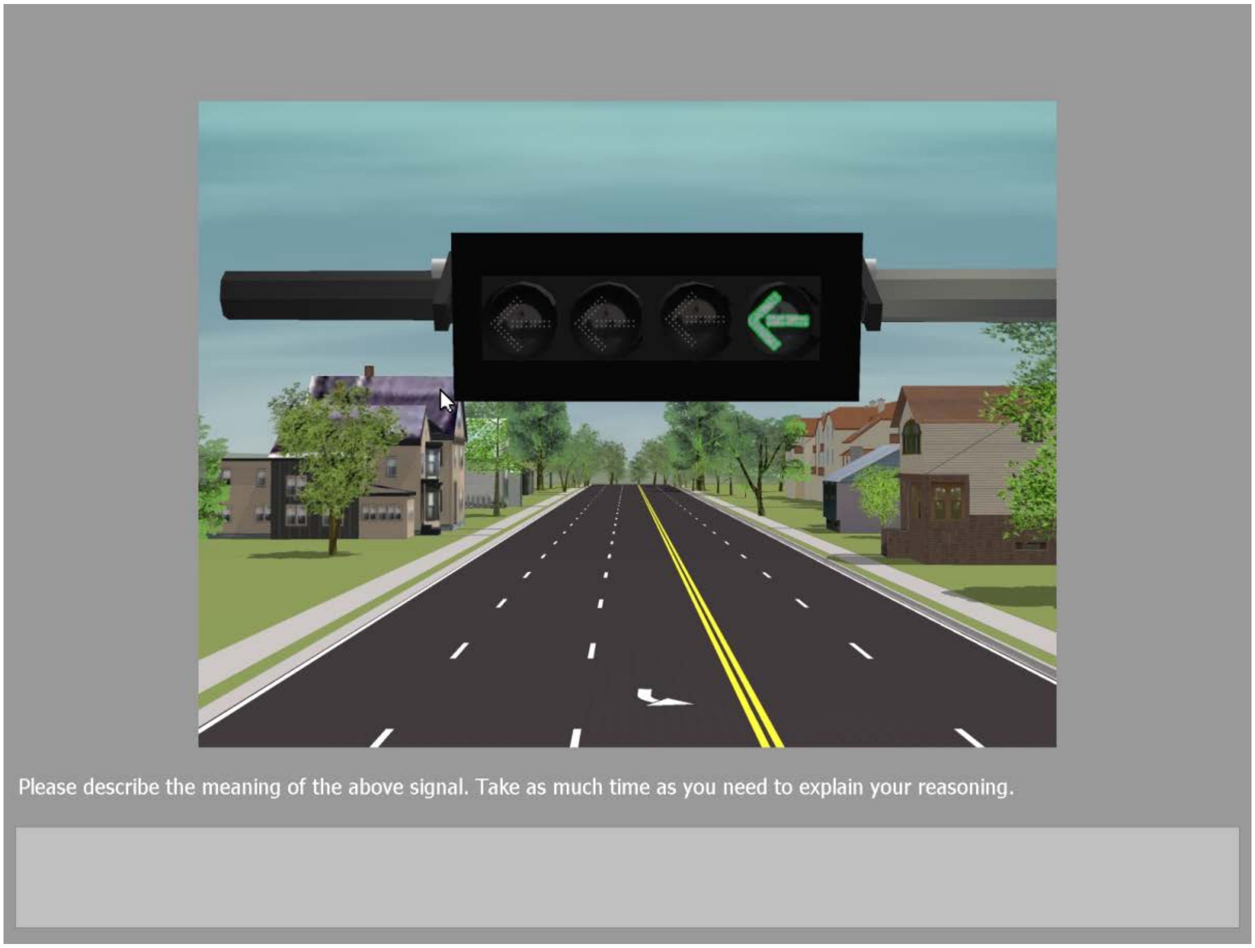

Figure 42. Sample image from the free response section of the FYA lab task. The participant typed their answer, and the text was displayed in the gray box below the prompt.

Figure 43. Sample image from the multiple choice section of the FYA lab task. The participant clicked a response option to select it and pressed the enter key to confirm their response. Participants were free to change their answer up until they pressed the enter key.

Response speed was emphasized in the reaction time task. In this task, participants were shown intersections, again from the perspective of a driver in the left turn lane, and were asked to decide as quickly as possible, based on the left turn signal and traffic conditions, whether they should stop or go. The stimuli in the reaction time task differed on several dimensions: signal phase (green arrow, steady yellow arrow, or flashing yellow arrow), the distance of oncoming traffic (small gap of 120 ft, large gap of 500 ft), and whether a supplemental sign was present or absence. Example stimuli from the reaction time task are shown in Figure 44. To prevent participants from being able to fixate on one portion of the screen to watch for changes instead of making the more complex judgments required by the instructions, stimuli were also varied superficially by changing the positions of the visible vehicles and the scenery, none of which should affect participants' decisions.

Figure 44. Sample images from the reaction time FYA lab task. The top panel shows a large gap in traffic, and the bottom panel shows a small gap in traffic.

Results

Data from 4 participants were excluded from analyses. Two middle-aged adults were excluded, one because they had misunderstood task instructions and another because they had completed the task twice (data from first experiment appointment is included in analyses). Data from two younger adults was excluded due to experimenter error. The analyses that follow are based on data from the remaining 84 participants, with the final sample consisting of 26 younger (M = 22.38, SD = 1.5), 27 middle-aged (M = 58.19, SD = 3.9, and 31 older adults (M = 71.39, SD = 5.4).

Comprehension Task

Free Response. Accuracy on the free response section of the task was scored by two independent raters using the criteria outlined in Appendix F. Cohen's kappa was computed as a measure of inter-rater agreement between the two coders. A kappa value of .86 indicated excellent inter-rater agreement. A third coder scored the items on which coders 1 and 2 disagreed.

Participants' knowledge of the correct meaning of left-turn signal phases differed significantly between the green arrow(GA), steady yellow arrow (SY), red arrow (RA), and flashing yellow arrow (FYA) signals, $F(3,252) = 37.39$, $p < .001$, $\eta_p^2 = .31$. When compared between signal phases, there was no difference in participants' response accuracy between the GA and RA phases, $F(1,84) = 3.08$, $p = .08$, $\eta_p^2 = .04$, or between the FYA and SY phases, $F(1,84) = .66$, $p = .42$, $\eta_p^2 = .01$ (see Figure 45).

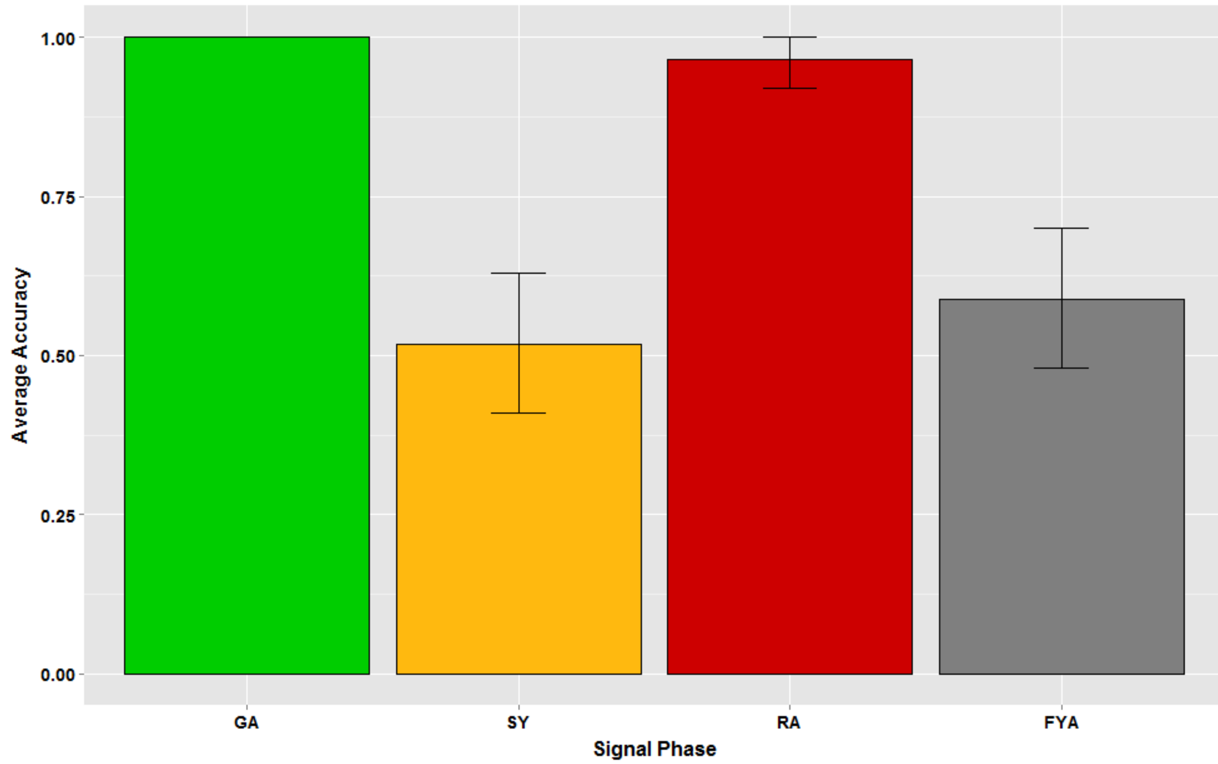

Figure 45. Average accuracy by signal phase for the free response task. Error bars show the 95% confidence interval.

Overall, across all signal phases, accuracy differed across age groups (see Figure 46). Follow-up tests revealed that older adults' free response accuracy was poorer than younger adults' (p = .03). However, accuracy was similar between younger and middle-aged adults (p = .12), as well as between middle-aged and older adults (p = .83). Age group did not interact with signal phase: The differences in free response accuracy between signal phases were similar between age groups, F(6,246) = 1.15, p = .33, η_p^2 = .03 (see Figure 47).

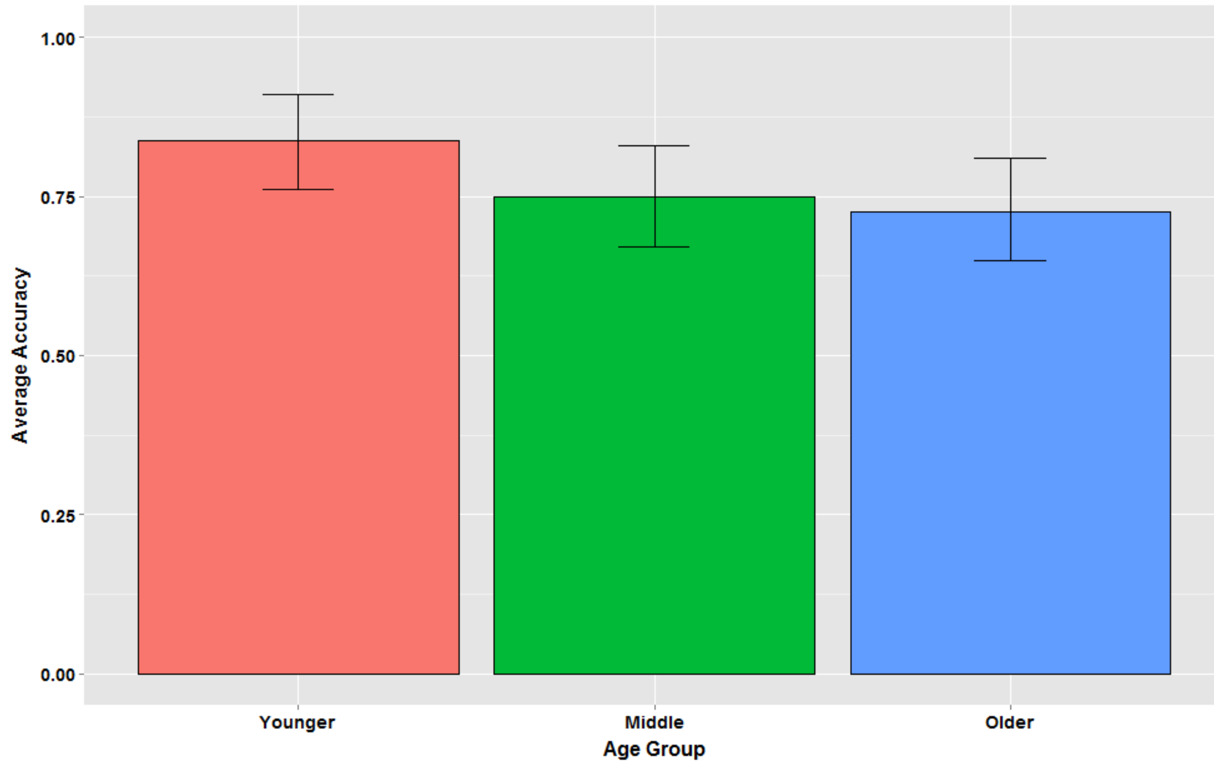

Figure 46. *Free response accuracy by age group. Error bars show the 95% confidence interval.*

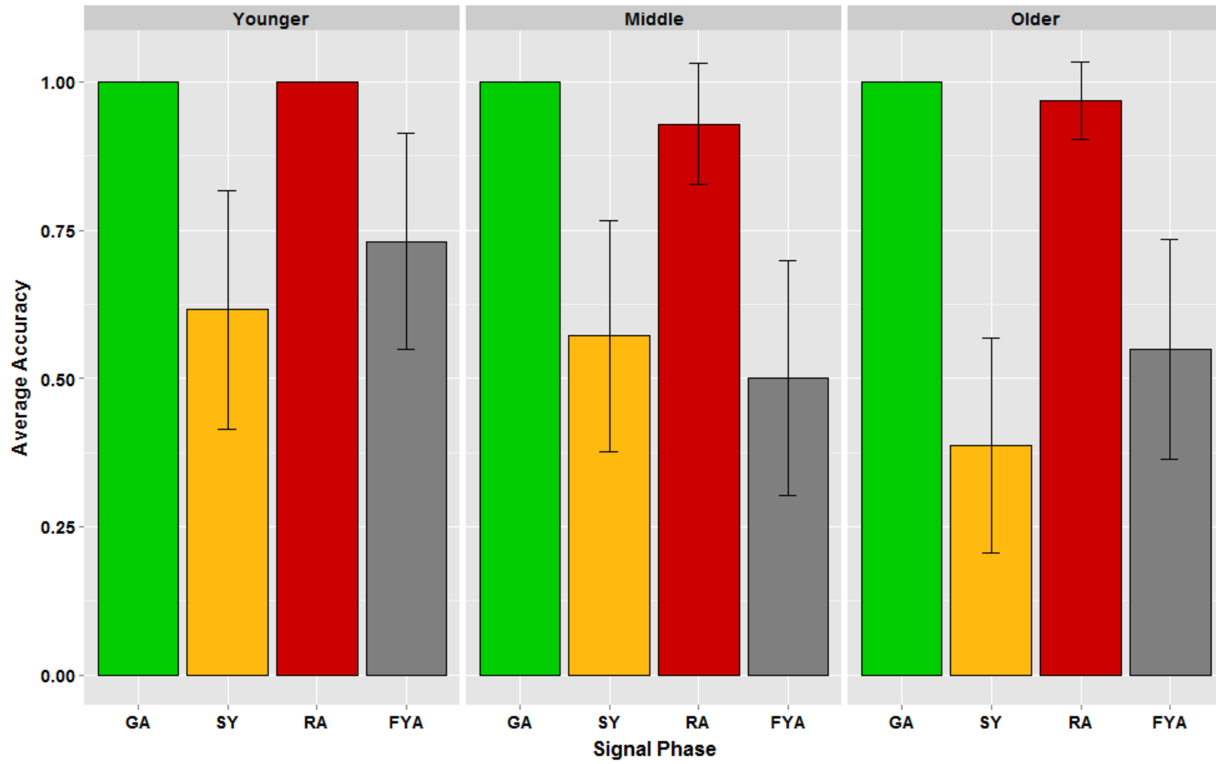

Figure 47. Average accuracy by signal phase and age group for the free response task. Error bars show the 95% confidence interval.

Across all age groups, average free response accuracy for the FYA signal was around 60%. While an error rate of 40% is far from ideal, not all misconceptions about the signals' meaning would put drivers' in immediate danger. Specifically, the most problematic misconception of the FYA signal's meaning would be that it signals that the left-turning driver has right-of-way, as that could lead drivers' to turn in front of oncoming traffic. On the other hand, if drivers who don't understand the FYA signal's meaning simply wait for the signal phase to change and do not turn, while this can lead to traffic delays, it would not put the driver in any immediate danger. To assess the frequency of dangerous compared to less dangerous misconceptions of the FYA signal's meaning, we classified participants' incorrect free responses to the FYA signal as critical (dangerous) or non-critical (less dangerous). If a participant did not provide enough information in their response to determine an error category, that response was not classified. As with accuracy scoring, error classification for FYA signal trials was done by two raters initially, and a third rater who scored items on which the first two coders disagreed. Again, inter-rater agreement between the first two coders was good (kappa = .73). The error type scoring criteria are provided in Appendix F.

Out of a total of 85 responses to the FYA item on the free response task, there were 35 incorrect responses (59% accurate). Of those 35 incorrect responses, 23 included sufficient information to classify those responses as critical or non-critical. As can be seen in Figure 48, non-critical errors were more common than critical errors, $X^2(1, N$

=23) = 3.52, *p* = .06, though this difference did not reach conventional significance (*p* < .05). Although there was not a sufficient number of observations to conduct analyses, an age breakdown of the number of critical and non-critical errors is given in Table 17.

Table 17. Critical and non-critical free response errors to FYA trials by age group.

	Critical	Non Critical
Younger	3	2
Middle	4	7
Older	0	7

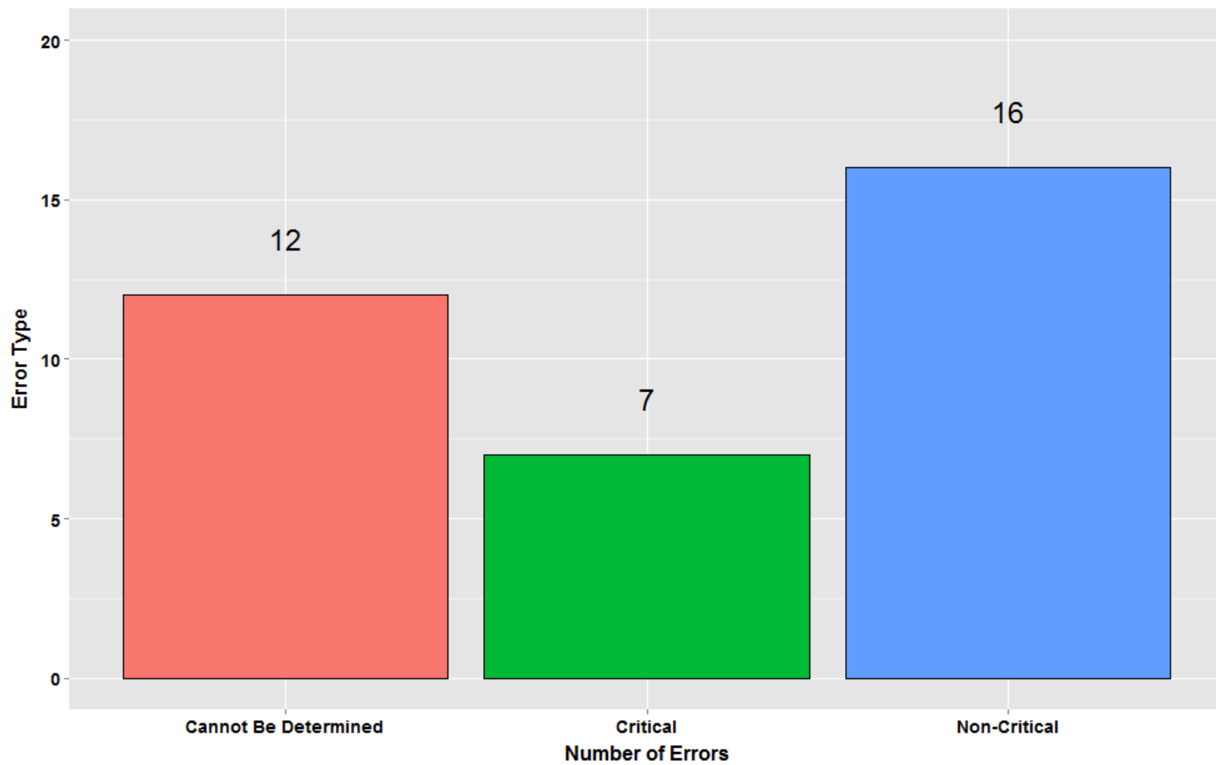

Figure 48. Frequency of error types for incorrect responses to FYA free response items.

To better understand the source of participants' misconceptions about the FYA signal, the content of the incorrect free responses to the FYA signal were further examined. Responses were sorted into 5 categories. Table 18 shows the number of responses for each of these categories. The most common misconception, by a large margin, was that the FYA signal meant the same thing as the SY signal. Many of the critical errors to FYA items were due to participants' belief that it meant the same thing as a SY signal. Specifically, participants believed they should "hurry up and turn" before the left-turn phase ended, a misconception that could lead drivers to make unsafe turns.

Table 18. Content of incorrect participant responses to FYA trials on the free response section of the comprehension task.

	Number of Responses
Signal is about to change to red	24
Left-turning driver has right-of-way	2
Uncertain – Would wait for signal to change or base response on other drivers' behavior	2
Use caution only – no other details provided	3
Cannot be determined from information given	4
Total	**35**

Multiple Choice. In the multiple choice section of the comprehension task, participants viewed scenes from the perspective of a driver in the left-turn lane, which included oncoming traffic, and chose from three different response options (go now; wait, go when safe; wait, remain stopped). The apparent distance of oncoming traffic from the driver was varied so that on some trials the car would appear very close (small gap; approximately 120 feet away) and on other trials it would be far enough away for the driver to safely execute a left turn (large gap; approximately 600 feet away).

Table 19 gives the number of participant responses for each category, separated by traffic conditions (large gap, small gap) and signal phase (flashing yellow arrow, green arrow, steady yellow arrow, or red arrow).

Table 19. Percentage of participants giving each response for the multiple choice section of the comprehension task. FYA = Flashing yellow arrow, GA = green arrow, SY = steady yellow arrow, RA = red arrow

	Large Gap in Traffic				Small Gap in Traffic			
	GA	SY	RA	FYA	GA	SY	RA	FYA
Go now	98%	27%	11%	38%	78%	5%	2%	1%
Wait, go when safe	2%	35%	4%	51%	22%	35%	8%	64%
Wait, remain stopped	0	38%	86%	11%	0%	60%	89%	35%

Response accuracy in the multiple choice task differed significantly between signal phases (GA, SY, RA, FYA), $F(3,246) = 36.39$, $p < .001$, $\eta_p^2 = .31$ and gap size (small, large), $F(1,82) = 10.20$, $p = .002$, $\eta_p^2 = .11$. However, the difference in accuracy between gap size conditions varied significantly between signal phases, $F(3,246) = 14.70$, $p < .001$, $\eta_p^2 = .15$, such that accuracy was significantly better for the large gap condition for the GA signal, $F(3,246) = 14.70$, $p < .001$, $\eta_p^2 = .15$, but significantly worse for the large gap condition for the SY, $F(3,246) = 14.70$, $p < .001$, $\eta_p^2 = .15$, and FYA, $F(3,246) = 14.70$, $p < .001$, $\eta_p^2 = .15$, signal phases (see Figure 49).

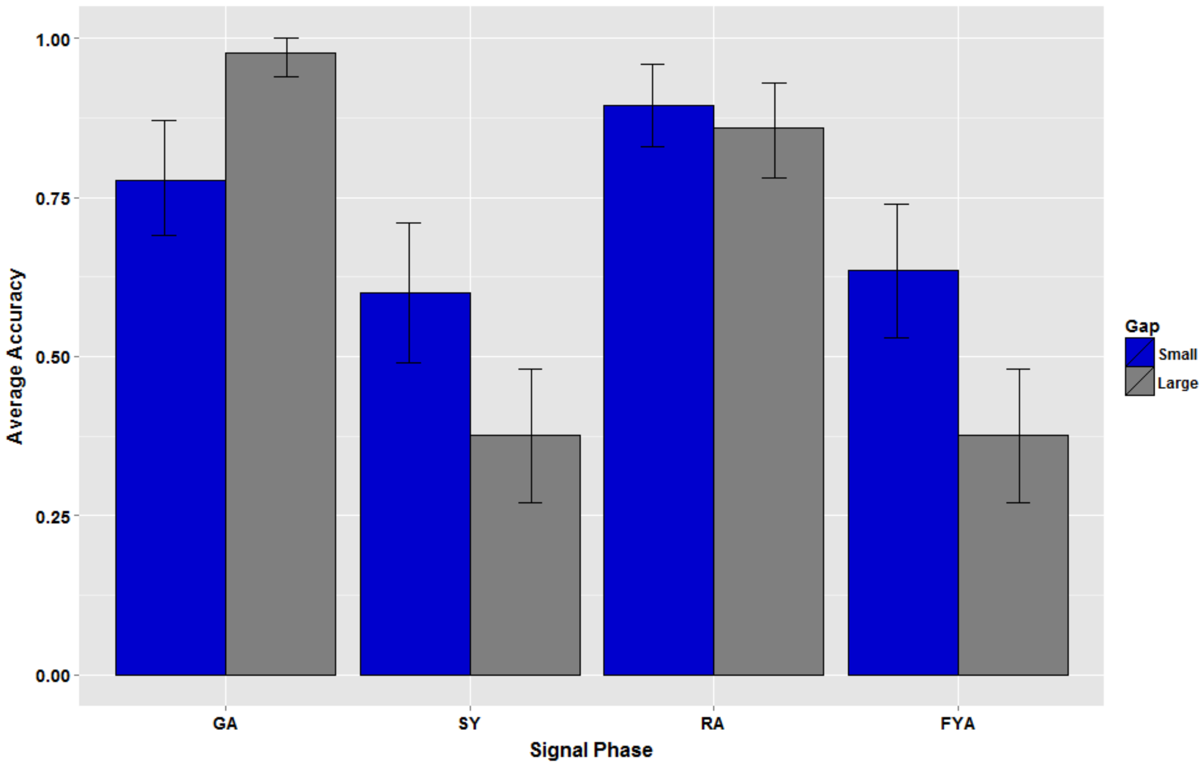

Figure 49. Multiple choice accuracy by signal phase and gap.

There was a main effect of age group on multiple choice accuracy, $F(1,82) = 6.55$, $p = .002$, $\eta_p^2 = .14$ (see Figure 50). Follow up tests revealed that older adults' accuracy on the multiple choice task was significantly poorer than younger adults' ($p = .001$), but average accuracy did not differ between older and middle-aged adults ($p = .21$) or between younger and middle-aged adults ($p = .15$).

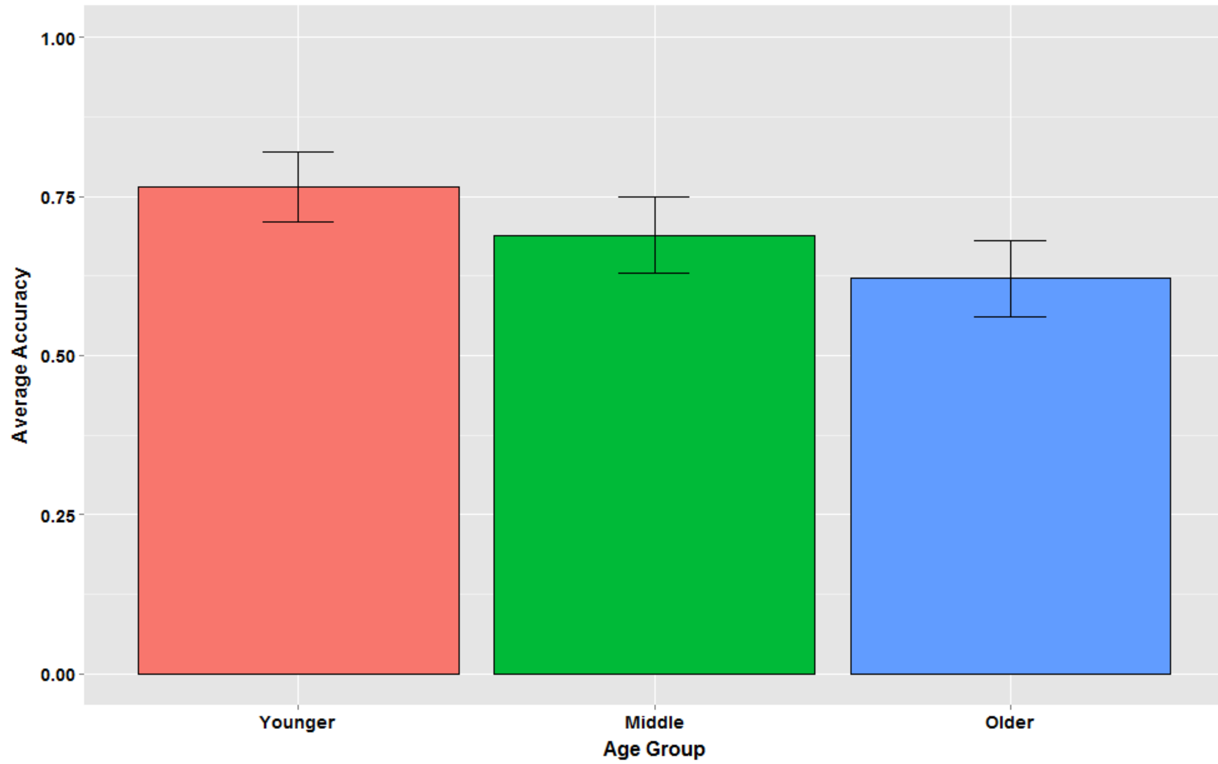

Figure 50. Multiple choice accuracy by age group.

We also examined the frequency of critical errors on FYA trials for the multiple choice task. In this task, we considered “go now” responses to FYA items showing an approaching vehicle close to the intersection (small gap condition) to be a critical error. For FYA trials showing an approaching vehicle at a far distance (large gap condition), we classified a “go now” response as a non-critical error. Incorrect responses for FYA trials are highlighted in Table 19. Only one critical error response was given in the multiple choice task. Instead, participants uncertain of the signal’s meaning tended to favor more conservative decisions (i.e. not turning when uncertain). In the large gap condition, where the oncoming vehicle was pictured at a simulated distance of 500 to 600 feet away, a distance at which most people would be able to safely execute a left-turn, 43 out of the 84 participants (51%) chose the option “Wait, go when safe” rather than “Go now.”

Reaction Time Task

The reaction time task was designed to assess the speed and accuracy at which participants made left-turn decisions based on both the signal phase (GA, SY, or FYA) and traffic (small gap, large gap). While participants were told to take as much time as they needed to respond to items on the comprehension task, in the reaction time task participants were instructed to respond, based on the left turn signal and traffic, as quickly and accurately as possible whether they should stop (wait to turn) or go (make a left turn).

Response accuracy. A mixed-ANOVA on response accuracy was conducted with sign block (supplementary sign, no sign), signal phase (GA, SY, FYA), type of signal head (3-section horizontal, 4-section horizontal), and gap size (small gap, large gap) as within-subjects factors and age group (younger, middle, older) and tip card condition (tip card, no tip card) as between-subjects factors.

This analysis revealed main effects of signal phase, $F(2,156) = 39.74$, $p < .001$, and gap size, $F(1,78) = 84.38$, $p < .001$, which were qualified by a significant signal phase by gap size interaction, $F(2,156) = 62.76$, $p < .001$ (see Figure 51). For trials where there was a small gap in traffic, participants were less accurate on GA trials than on either SY or FYA trials. In small gap trials, oncoming traffic was close enough to the intersection that most participants should have been hesitant to execute a left turn unless certain they have right of way (see Figure 44 for examples of stimuli). The lower accuracy for GA trials, where the correct response was "go", may reflect participants' tendency to exercise caution, even in cases where they can assume they have right of way. For trials where there was a large gap in traffic, performance was near ceiling for GA trials, as most participants correctly responded that the correct action for those trials was "go." On the other hand, the poor performance for SY trials reflects many participants' tendency to hurry through yellow signals if no traffic is approaching. A "go" response on any SY trial, regardless of gap size, was scored as incorrect in the current task. For FYA trials, participants' response accuracy was poorer for large gap than for small gap trials. For the current task, the correct response for FYA trials differed between the small and large gap size trials. For small gap trials, the correct response for the FYA signal was "stop," as participants should stop and wait for a larger gap in traffic. For large gap trials, the correct response for the FYA signal was "go," as it would be both safe and legal to proceed with a left turn in that situation.

The poorer accuracy for the FYA signal on large gap trials again likely reflects participants' tendency to choose to stop and wait when they are unsure of the meaning of a traffic signal. Because the purpose of the FYA tip card is to teach drivers the correct meaning of the FYA signal, a clear measure of its effectiveness would be a significant improvement in response accuracy for large gap trials when participants reviewed the FYA tip card before completing the response time task. To address this question, response accuracy on large gap, FYA trials was compared between the tip card and no tip card conditions.

Average accuracy for large gap, FYA signal trials was near ceiling; the distribution of average accuracy for FYA, large gap trials showed substantial negative skew. That is, most participants performed extremely well, with 50% of participants achieving average accuracy of 94% or better for those 16 items. Because ANOVA can yield biased test results under these conditions, a Mann-Whitney *U* test was used to compare accuracy between the tip card and no tip card conditions. This test revealed a small but not statistically significant accuracy advantage for the tip card condition ($U = 676.5$, $p = .06$), which would be considered a small effect, $r = .21$. It is likely that the lack of a significant effect of tip card condition is due to the generally high performance of participants in both groups; most participants inferred the signal's correct meaning without any prior experience with the FYA signal.

Also of interest in the current study is whether the tip card made participants more likely to make dangerous errors. It is possible that introducing a flashing yellow-arrow signal that allows drivers to proceed with caution when there is also a steady yellow arrow that means drivers should stop could lead some drivers to mistakenly assume right of way. In the response time task, such errors would be evident in performance for FYA trials in which there is a small gap in traffic. A Mann-Whitney *U* test was used to compare accuracy for FYA small gap trials between the tip card and no tip card conditions; there was no evidence that the tip card led to any increase in potentially dangerous errors ($U = 820$, $p = .52$, $r = .07$, also see Figure 52).

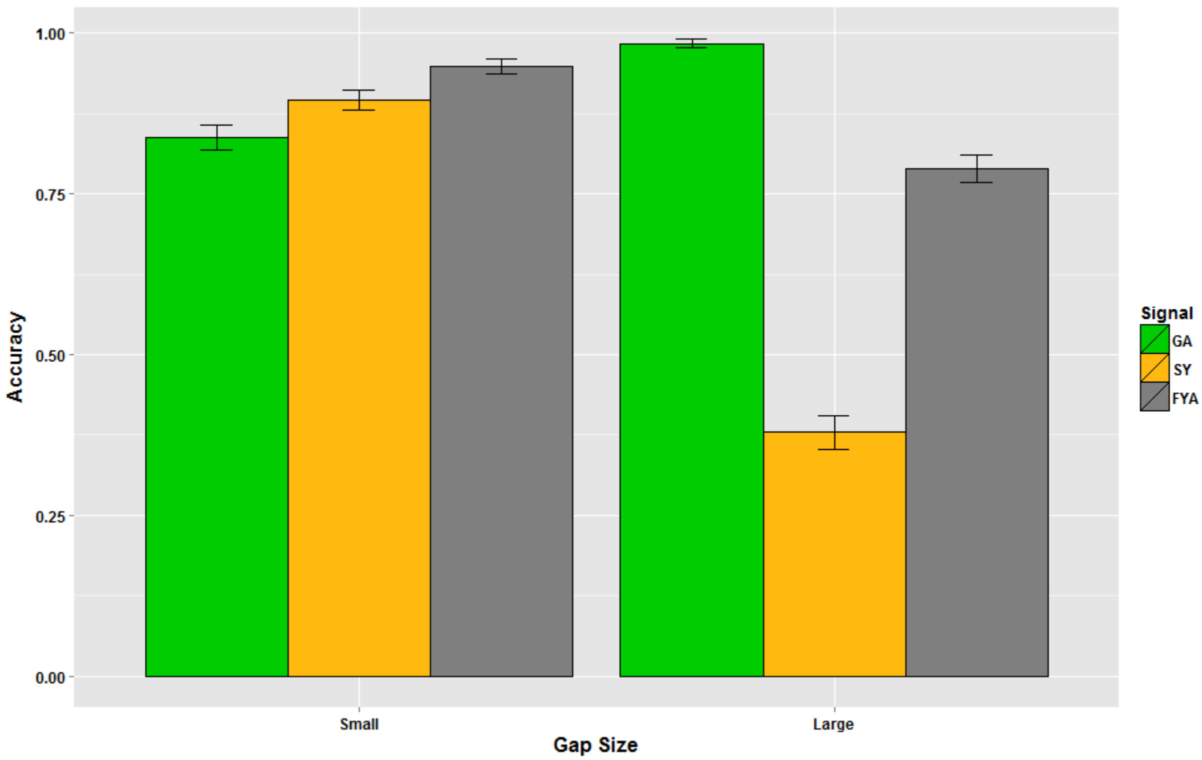

Figure 51. Accuracy on the response time task by signal phase and gap size.

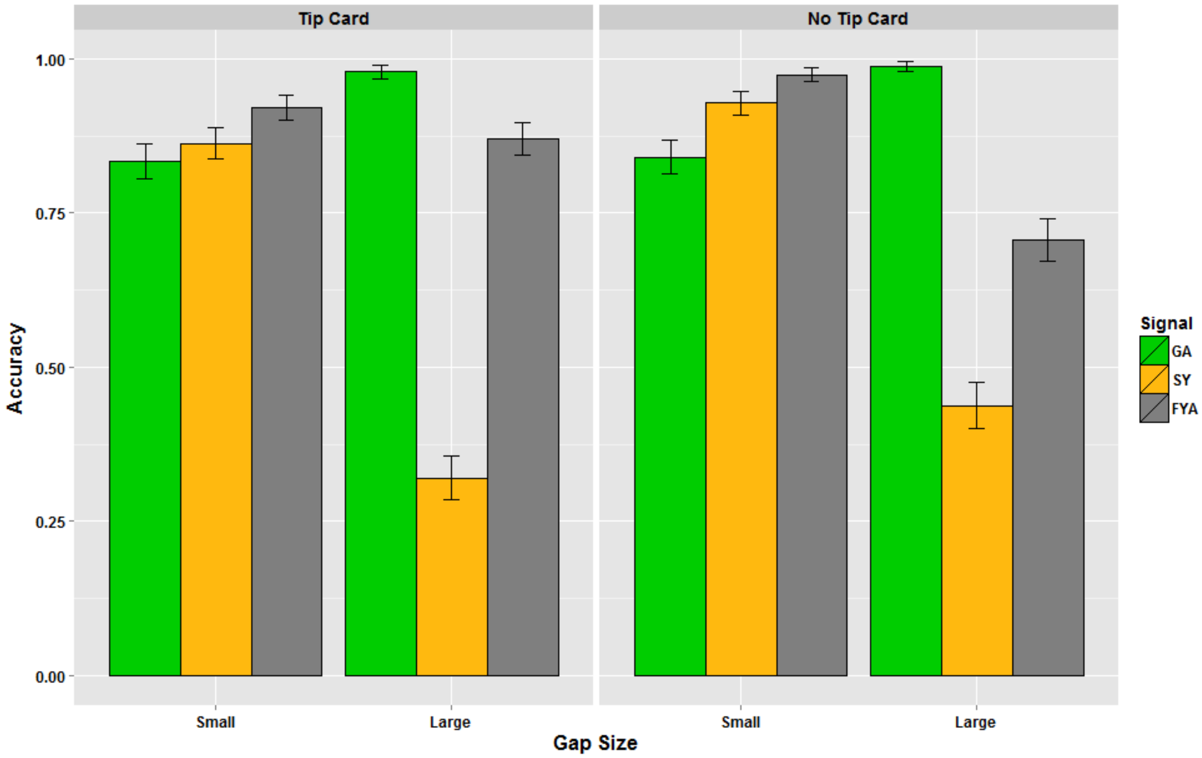

Figure 52. Participant response accuracy on the reaction time task gap condition, signal phase, and tip card condition.

Signal phase also interacted with age group, *F*(4,156) = 3.94, *p* = .004, such that older and middle aged adults performed better on SY trials than did younger adults. While all participants were more likely to say they would stop at the SY signal when there was a small gap in traffic than when there was a large gap, middle-aged and older adults were overall more likely to say that they would stop at the SY signal, regardless of gap condition (see Figure 53).

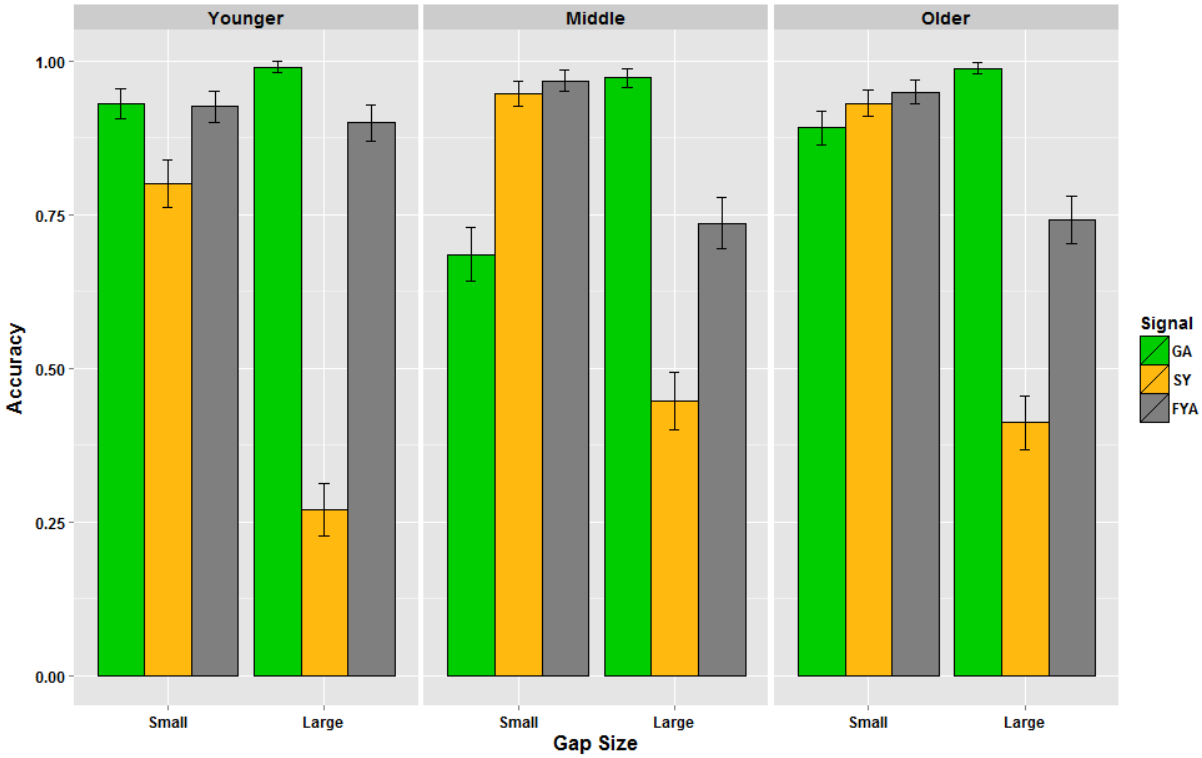

Figure 53. Response accuracy for RT task by age group, signal phase, and gap condition

In the current study we also evaluated whether the presence of a supplementary sign at an intersection would improve response accuracy on FYA trials. To assess this, a Wilcoxon matched-pairs signed ranks test compared accuracy on FYA trials for the first 48 trials of the task, where no supplemental sign was present, and the last 48 trials, where a supplemental sign appeared on the mast arm. Overall, there was no benefit in accuracy for the trials where a supplementary sign was present, $W = 630.5$, $p = .95$. This pattern was similar when accuracy between the no sign and sign blocks was examined separately for the tip card ($W = 92$, $p = .28$) and no tip card conditions ($W = 244$, $p = .53$).

<u>Critical errors in the reaction time task</u>. We also compared the incidence of critical errors on the reaction time task, as what participants say they will do under ideal (e.g. unlimited decision time) conditions may differ from the type of errors made when one must respond quickly. On FYA trials, a “go” response on a trial where there is a small gap in traffic would be considered a critical error. In total, there were 2688 responses made on FYA trials, of these, 70 were classified as critical errors. Of these 70 critical errors, significantly more critical errors ($n = 53$) were made by participants in the tip card condition than by those in the no tip card condition ($n = 17$), $X^2(1, N = 70) = 18.51$, $p = .004$. However, a follow up analysis that included age group found no evidence that the degree of increase differed substantially across age groups, $X^2(2, N = 70) = 1.41$, $p = .50$ (see Table 20 and Figure 54).

Table 20. Critical error count for the reaction time task by age group and tip card condition.

	Tip Card	No Tip Card	Total
Younger	25	6	31
Middle	9	5	14
Older	19	6	25
Total	53	17	70

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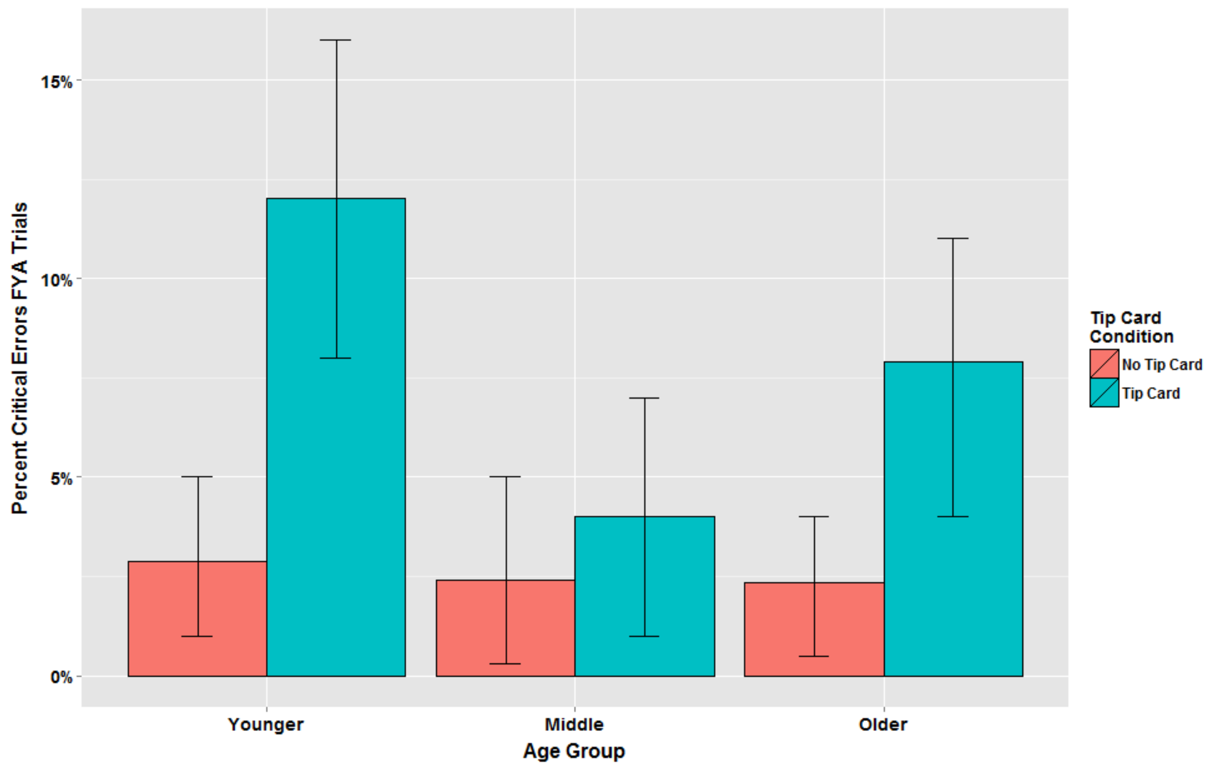

Figure 54*. Percent critical errors by age group and tip card condition for FYA trials. Graph includes only FYA, small gap trials. Error bars show the 95% confidence interval.*

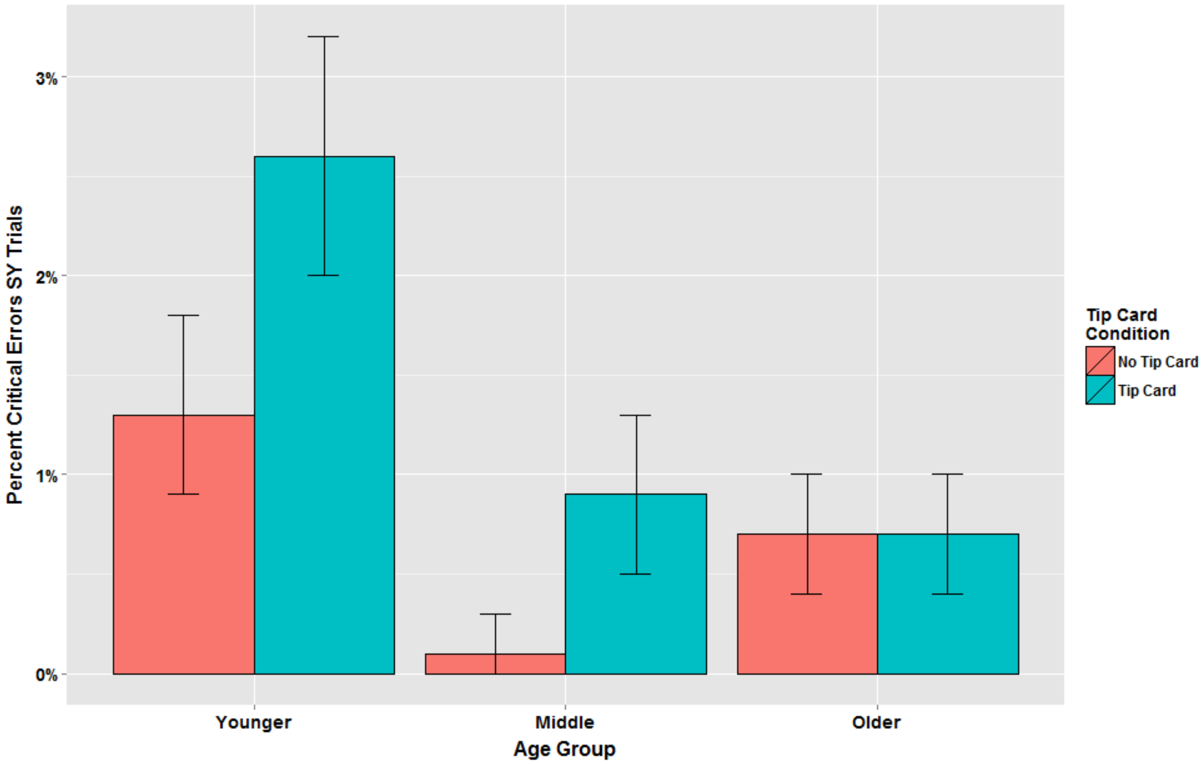

Figure 55. Percent critical errors by age group and tip card condition for SY trials. Graph includes only SY, small gap trials. Error bars show the 95% confidence interval.

Response Time for Accurate Trials. Next, we examine response time for accurate trials on FYA trials. Data from six participants with average accuracy of zero on FYA trials were dropped from the analysis, leaving a total of 78 participants with complete data (see Table 21). An ANOVA on log-transformed reaction time for FYA trials with gap size as a within-subjects factor and age group and tip card condition as between subjects factors revealed main effects of age group, $F(2,72) = 18.37$, $p < .001$, and gap condition, $F(1,72) = 11.50$, $p = .001$. However, these main effects were qualified by several significant interactions; gap size interacted with both age group, $F(2,72) = 3.20$, $p = .05$, and tip card condition, $F(1,72) = 7.07$, $p = .01$.

Table 21. Participants included in response time analysis for Task 3.2.

	Tip Card	**No Tip Card**
Younger	13	13
Middle	13	11
Older	14	14
Total	40	38

As can be seen in Figure 56, participants tended to take longer to respond on FYA trials where there was a large gap in traffic. This is likely because on large gap trials participants required processing time to judge whether oncoming traffic was far enough away for them to safely execute a turn, whereas on short gap trials they were able to immediately discern that oncoming traffic was too close to safely execute a left turn.

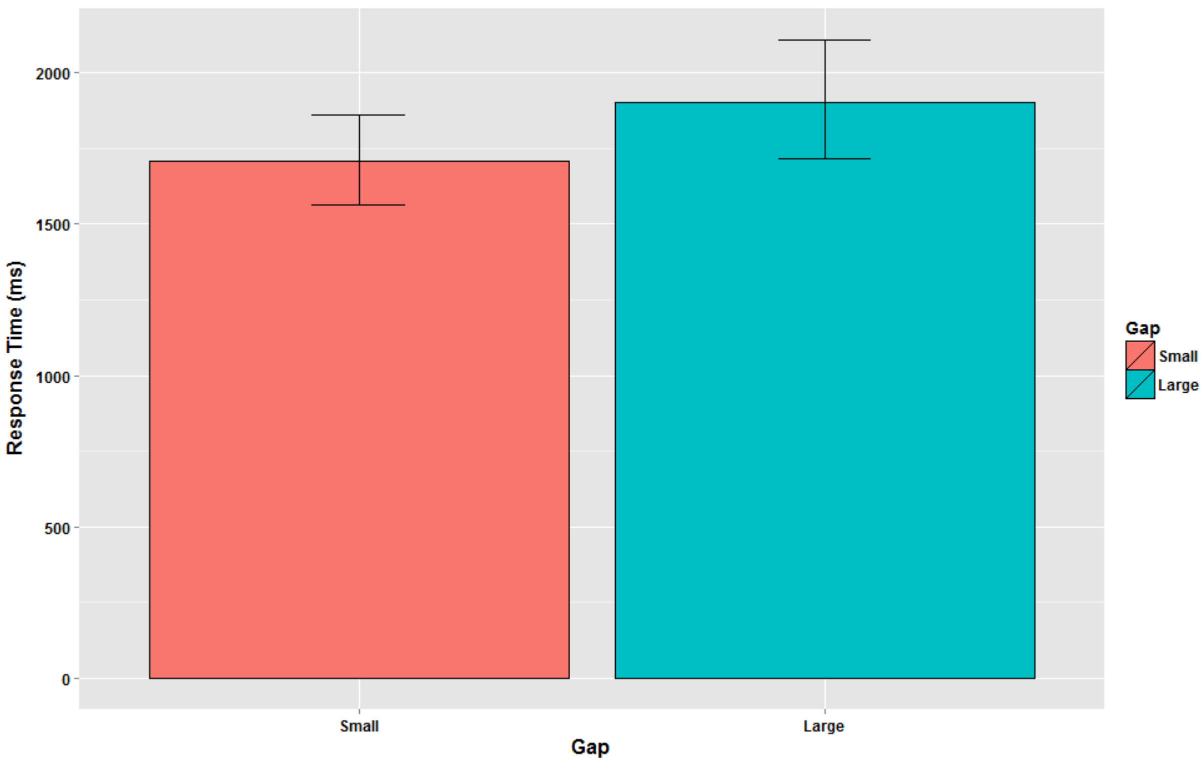

Figure 56. Response times for accurate FYA trials by gap size. Error bars show the 95% confidence interval.

However, the degree to which response times for FYA trials differed between gap size conditions varied between age groups; while older and middle aged adults took more time to make decisions on large gap trials than on short gap trials, younger adults' response times did not differ between short and large gap trials (see Figure 57).

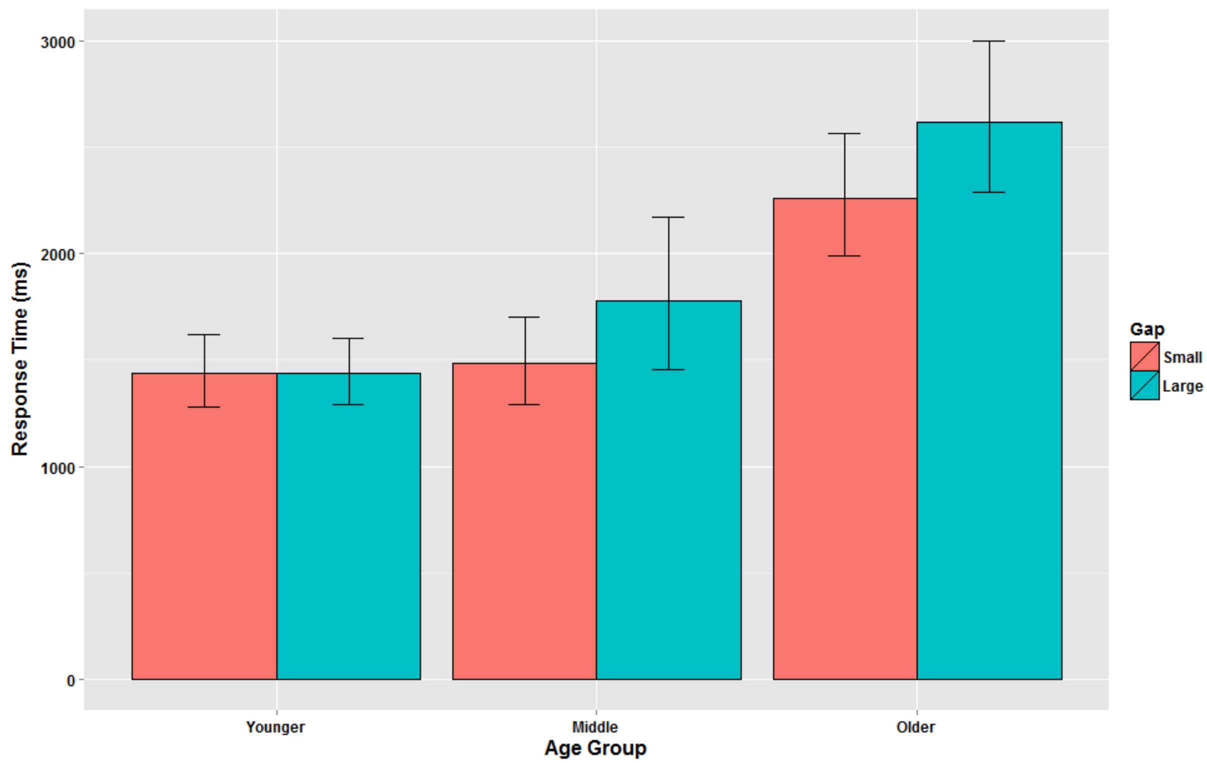

Figure 57. Response times for accurate FYA trials by age group and gap condition. Error bars show the 95% confidence interval.

Response time between small and large gap trials also differed between the tip card and no tip card conditions (see Figure 58). For participants who reviewed the tip card prior to completing the reaction time task, there was no significant difference in response time for small and large gap FYA trials. However, for participants who did not review the tip card, response times were significantly longer for large gap trials than for short gap FYA trials (Figure 58). The participants included in this analysis all correctly inferred the correct meaning of the FYA signal for the conditions shown in the task, but the participants who did not review the FYA tip card were reluctant to make a “go” response on an FYA trial, even when traffic conditions would have been safe to make a turn. This finding suggests that drivers’ unfamiliarity with the FYA signal could lead to increased, rather than decreased, wait times at intersections.

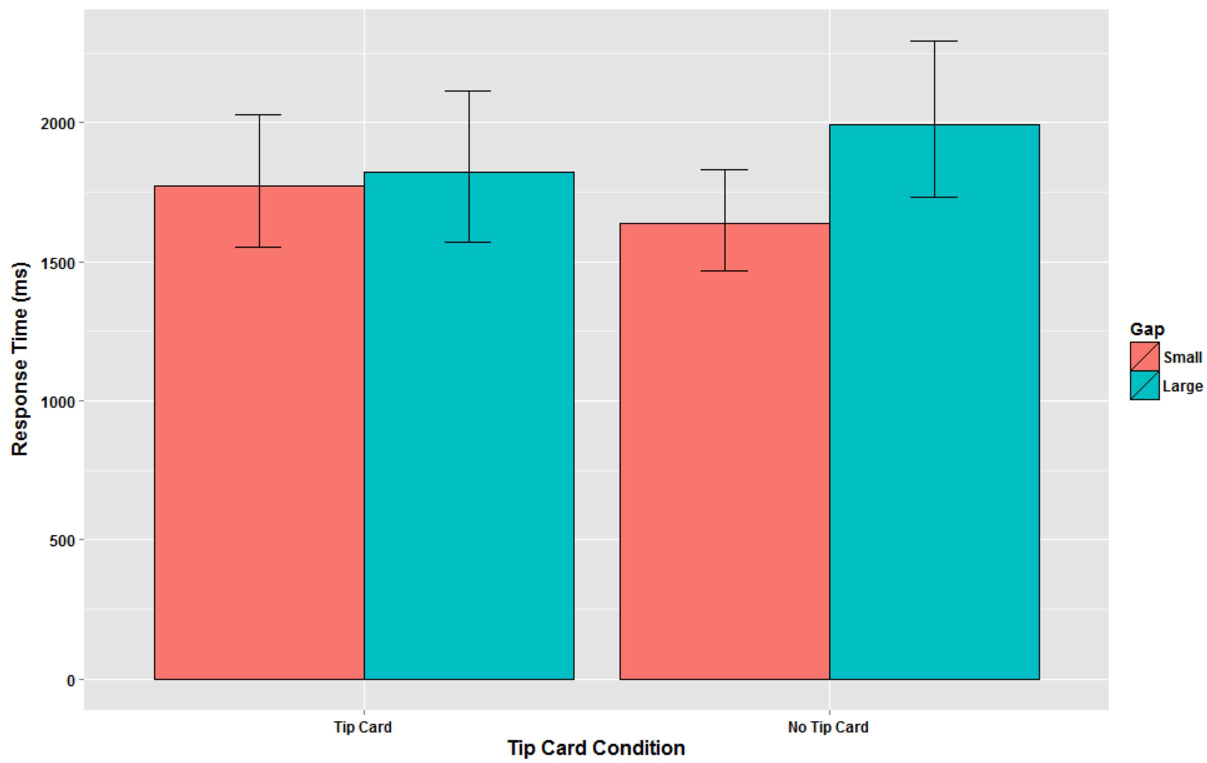

Figure 58. Participant response times for accurate FYA trials by gap condition and tip card condition.

Debriefing Task

Following the reaction time task, we asked participants about their prior experience with the FYA signal. Participants answered three questions:

1. Have you ever encountered the flashing yellow arrow traffic signal while driving? Response options were “yes” or “no.”

2. If you have encountered the flashing yellow arrow signal while driving, did you feel that you understood its meaning the first time you saw it? Response options were “yes”, “no”, or “Have not seen.”

3. If you have encountered the flashing yellow signal before, what did you think it meant the first time you saw it? This was a free response item.

Overall, 68% of participants who completed Task 3.3 (*n* = 57) reported that they had not seen the FYA signal while driving, while the remaining 32% (*n* = 27) reported that they had encountered the FYA signal while driving. The proportion of participants who reported prior real-world experience with the FYA signal was equally distributed across the tip card and no tip card conditions (see Table 22).

Table 22. Participants reporting prior experience with the FYA signal by tip card condition.

Prior experience with FYA	Tip Card Condition	No Tip Card Condition
Yes	13	14
No	29	28

Of the 27 participants who reported having encountered the FYA signal while driving, prior to their participation in Task 3.3, 89% (*n* = 24) reported that they felt they understood the signal's meaning at that time.

Item three in the debriefing task asked participants who reported having encountered the FYA prior to their participation in the current task to explain what they thought the FYA signal meant at that time. As was done for the free response section of the comprehension task, we scored the content of participants' responses to Item 3. A total of 19 out of 27 participants (70%) provided the correct meaning of the FYA signal. Table 23 gives the breakdown of critical and non-critical errors for responses to Item 3 of the debriefing task, and Table 24 summarizes the content of those incorrect responses.

Table 23. Error type for free response item in the debriefing task.

	Tip Card Condition	**No Tip Card Condition**
Critical	0	1
Non-Critical	0	5
Cannot be Determined	2	0

Table 24. Content of incorrect participant responses to on the free response section of the debriefing task

	Number of Responses
Signal is about to change to red	2
Signal is broken / malfunctioning	2
Hurry and execute left turn	1
Use caution only – no other details provided	1
Could not be determined / Other	2
Total	**8**

Conclusions

In general, the FYA signal was infrequently mistaken as indicating right-of-way. When participants misunderstood or were uncertain regarding the meaning of the signal they were conservative in their response. This was in the absence of being presented any information about the signal (i.e., the FYA tip card). During the "free response" task, no older adult made a critical error (interpreting that the FYA indicated right-of-way). During the multiple choice task, in scenes in which there was a small gap in traffic (making a left turn unsafe), only 1% of participants responded that the FYA would allow them to turn right away. After this portion of the task, some participants were presented with FDOT's FYA tip card. For the following response time task, although performance was near ceiling, there was a trend for participants exposed to the tip card to perform slightly more accurately, and the pattern of response times was consistent with those not receiving the tip card being more uncertain in conditions in which the FYA was present and there was a gap in which a turn was possible. Overall, supplemental signage and FYA configuration (3 vs. 4 signal head configuration) made little difference. However, before concluding that the FYA is easily understood and the FYA tip card improves understanding of the signal (especially since there was some indication that although overall errors went down after reading the tip card, safety critical errors increased), it is important to confirm these findings in a more realistic driving situation. The one analysis showing an increase in errors after tip card exposure may not accurately reflect the decision drivers must make during a dynamic driving task. To preview these results, in a more realistic driving scenario tip card exposure has a clearly beneficial effect while not increasing critical errors.

Task 3.3. Simulator Assessment of Driver Behavior in Reaction to FYA PPLT Displays as a Function of Age and Training

Next, we examined the effect of comprehension of FYA signals in the context of simulated driving. Younger and older drivers made left-turns at intersections, with a subset of these intersections displaying a FYA. These scenarios were designed in such a way that mistaking the FYA for conveying right-of-way would have resulted in a crash. A trigger caused an oncoming vehicle to appear in the opposing lane, and would have come dangerously close to the participant's vehicle if he or she decided to turn rather than yield to the oncoming vehicle. We recorded yielding behavior, crashes, and other indications (e.g., time spent at the intersection) that participants did not understand the meaning of the FYA. As in the previous experiment, participants were either exposed to or not exposed to FDOT's FYA Tip Card.

Method

Participants

A sample of 77 participants were recruited for Task 3.3, which included 32 younger adults (*M* = 23.31, *SD* = 3.1 years), 1 middle aged adult (Age 61), and 44 older adults (*M* = 73.25, *SD* = 5.8). Because the current task included turns, 11 older adult participants were unable to complete the task due to simulator sickness. Of the remaining 66 participants, an additional nine participants were excluded from analyses. Two participants were excluded because they were not within the age ranges included in the current study, and the remaining 7 participants were excluded due to equipment problems, experimenter error, or failure to comply with task instructions. The analyses that follow are based on the remaining 57 participants, consisting of 26 younger adults (*M* = 22.96, *SD* = 2.0) and 31 older adults (*M* = 73.26, *SD* = 5.8).

Procedure

In Task 3.3 participants completed a driving task where they navigated a virtual environment following voice commands designed to simulate a GPS. Prior to driving the main scenario, participants completed a guided training scenario to familiarize them with the driving simulator and the GPS-style instructions. An experimenter remained in the room with the participant during the training scenario to give instructions and feedback. Aspects of controlling the simulator (monitoring changes in speed without inertia, handling the sensitive steering wheel, braking smoothly when there is no sense of slowing, etc.) were addressed one at a time and participants were coached on each aspect as they drove. This proved valuable in identifying and correcting areas where participants simply did not understand simulator controls before the main task began. Such situations included participants being unable to identify the rear and side mirrors within the monitor displays and monitoring the tachometer instead of the speedometer due to differences between the simulator display and the participants' own cars. Also, participants with wider feet often unknowingly depressed both the brake and the accelerator simultaneously due to the pedals' close spacing, and needed to be coached on how to compensate for that because they would be attempting to brake according to instructions but unable to stop, which would compromise results in the main scenario. If a participant felt ill during the practice scenario, the experiment was discontinued and that participant did not complete the main task.

After the practice scenario, participants who had been randomly assigned to the tip card condition were told the following and given a copy of FDOT's FYA tip card:

> *Before we continue, we would like you to learn about a new kind of traffic signal that is starting to be used in Florida and is already being used in other states. Please read this tip card thoroughly. Take as much time as you like to learn about this new signal, and let me know when you are ready to proceed.*

Participants in the no tip card condition continued with the main driving task immediately after the training scenario. However, after the main driving task all participants, regardless of condition assignment, were told the purpose of the experiment and given a copy of the tip card to take with them.

During the main driving task participants encountered seven signal-controlled intersections at which they were instructed by a recorded message played approximately 500 feet prior to each intersection to either continue driving straight, turn right, or turn left at that intersection (e.g. "Turn left on Fox Street"). If a participant made a wrong turn, the drive was terminated and that participant's data was excluded from analyses. A total of five participants, one younger adult and four older adults, were excluded for this reason.

Two of the four intersections where participants were instructed to turn left (Intersections 4 and 7) included a flashing yellow arrow left turn signal (see Appendix H for a scenario map). At these intersections, the signal phasing was manipulated so that the signal phase would change from the green left-turn arrow to red as the participant approached the signal. Approximately two seconds later, the FYA signal phase would begin. By this time, a fast approaching oncoming vehicle would be visible in the opposing through lane and would be between 200 and 300 feet from the intersection, traveling at 50 miles per hour. In our previous studies of left-turn decisions, most participants would not have executed a turn in front of the oncoming vehicle unless they believed they had right-of-way (see Figure 59).

Figure 59. Sample image of an intersection with a FYA left-turn signal. At this point in the trial, the FYA signal would be displayed. In the image above, the signal is in the off phase of the flash. The oncoming vehicle is approximately 125 ft away and approaching at a speed of 50 mph.

Results

Data from 57 participants were included in analyses, 28 of which were assigned to the no tip card condition and 29 to the tip card condition (see Table 25 for age breakdown).

Table 25. Condition assignment by age group for Task 3.3.

	No Tip Card	**Tip Card**
Younger	13	13
Older	15	16
Total	28	29

Intersection Wait Times

One benefit of the FYA signal is that it could reduce wait times at intersections by allowing signals that would typically only have a protected left-turn phase to also include a permissive phase. However, if drivers do not know the meaning of the signal, rather than assuming they have right of way, they may instead choose not to turn until the next protected turn phase, increasing rather than decreasing average wait times at intersections. In the current study, we utilized a very long FYA phase (50 seconds), followed by a protected left-turn phase. An oncoming vehicle approached and passed at the beginning of the FYA phase, but no traffic was present for the remainder of the FYA signal phase. We calculated intersection wait times as the time between when a participant stopped at the intersection (or reached their minimum speed for the intersection) and the onset of the left turn, which was defined as when a participant's acceleration was above a set threshold.

To examine the effect of the FYA tip card on intersection wait times, a 2x2x2 mixed-model ANOVA with intersection number (1, 2) as the within-subject factor and age group (younger, older) and tip card condition (tip card, no tip card) as between-subjects factors was conducted on log-transformed wait times. There were main effects of intersection and tip card condition, and no other main effects or interactions were statistically significant at the < .05 level.

Overall, participants tended to spend less time waiting at the second FYA intersection (*Median* = 3.2 s) than on the first (*Median* = 1.87), $F(1,53) = 11.76$, $p = .001$, though wait times varied considerably between participants, with some participants waiting for less than a second and others waiting for as much as 49 seconds.

Participants in the tip card condition spent less time waiting (*Median* = 1.8 s) to turn than did participants who did not review the tip card prior to completing the driving scenario (*Median* = 3.92 s), $F(1,53) = 13.87$, $p < .001$ (see Figure 60), and the effect of tip card condition was similar across age groups, $F < 1$, and did not vary between FYA intersection 1 and 2, $F < 1$ (see Figure 61).

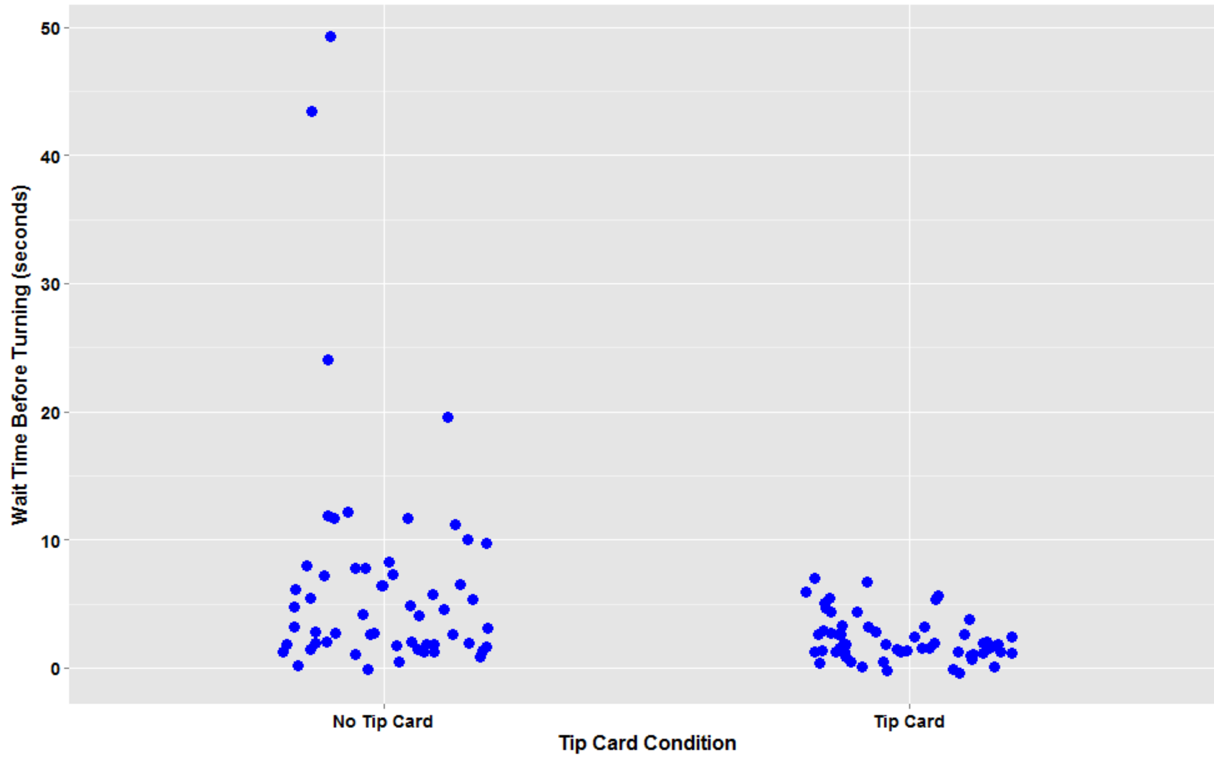

Figure 60. Wait times at FYA intersections by tip card condition for Task 3.3.

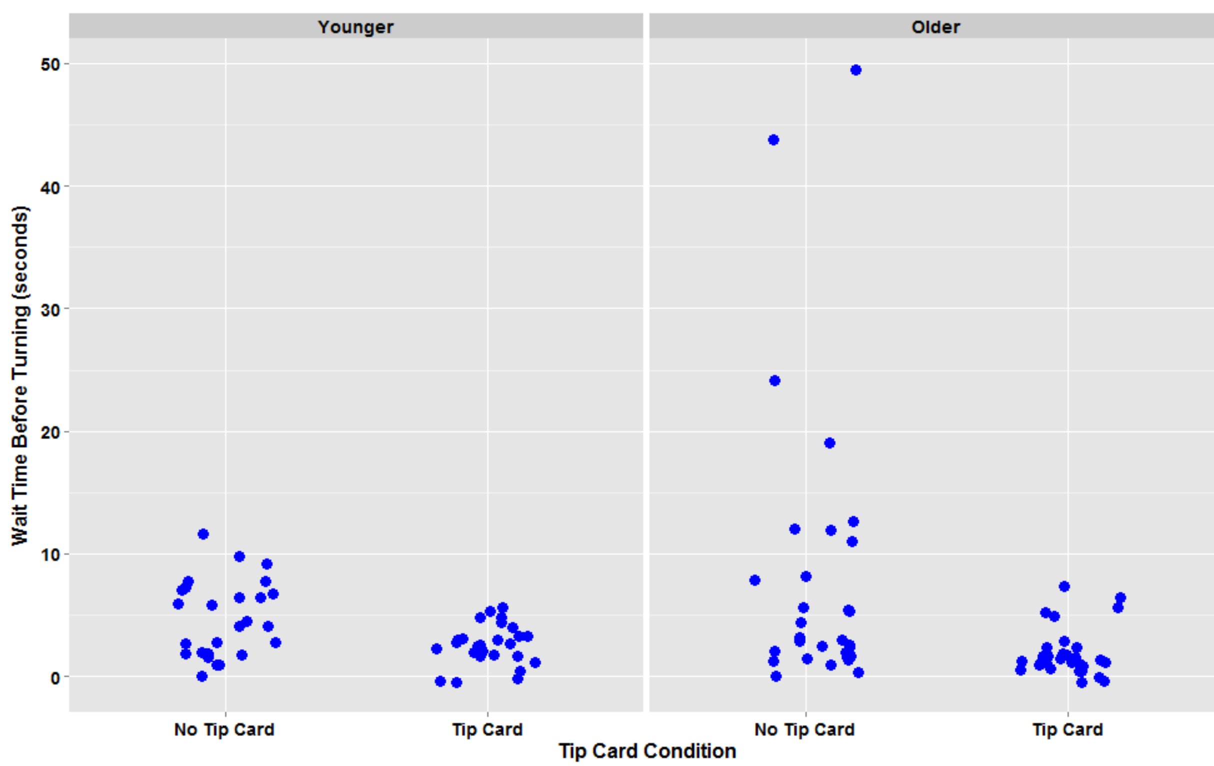

Figure 61. Wait times at FYA intersections by tip card condition and age group for Task 3.3.

Rolling Stops

The shorter waiting times for participants in the tip card condition were, at least in part, due to participants in the tip card condition being more likely to make rolling stops, which are legal at an FYA signal. Across both FYA intersections, participants in the tip card condition made significantly more rolling stops compared to participants in the no tip card condition, $X^2(1, N = 48) = 18.75, p < .001$ (see Table 26).

Table 26. Rolling and full stops by tip card condition for Task 3.3.

	Rolling Stop	**Full Stop**
No Tip Card	9	47
Tip Card	39	19
Total	48	66

There was no evidence of age group differences in the tendency to make a rolling stop at a FYA intersection, $X^2(1, N = 48) = .75, p = .39$ (see Table 27). The frequency of rolling stops increased between the no tip card and tip card conditions to a similar degree for both younger, $X^2(1, N = 27) = 8.33, p = .004$ and older adults, $X^2(1, N = 21) = 10.71, p = .001$ (see Table 28).

Table 27. Rolling and full stops by age group.

	Rolling Stop	**Full Stop**
Younger	27	25
Older	21	41
Total	46	68

Table 28. Rolling and full stops by tip card condition and age group for Task 3.3.

	No Tip Card		**Tip Card**	
	Rolling Stop	Full Stop	Rolling Stop	Full Stop
Younger	6	20	21	5
Older	3	27	18	14

Safety

There were no crashes during any of the left turns in the current study. As described in the method section, the oncoming vehicle at the FYA intersections was timed so that it would be close enough and approaching at sufficient speed that most participants would not turn in front of it unless they believed they had right-of-way. Of the 114 left turns made at FYA intersections (2 per participant), participants waited for the oncoming vehicle to pass in 109 of those turns, and there were only five instances of a participant turning in front of the oncoming vehicle. Of these five instances, four occurred during the FYA signal phase. For each of these turns, the distance between the participant's vehicle and the oncoming vehicle was calculated at the point in the turn where the participant’s vehicle was crossing the path of the oncoming vehicle (see Figure 62). These distances ranged from 97.31 ft to 317.18 ft, none of which would have put the participant in danger at a real intersection.

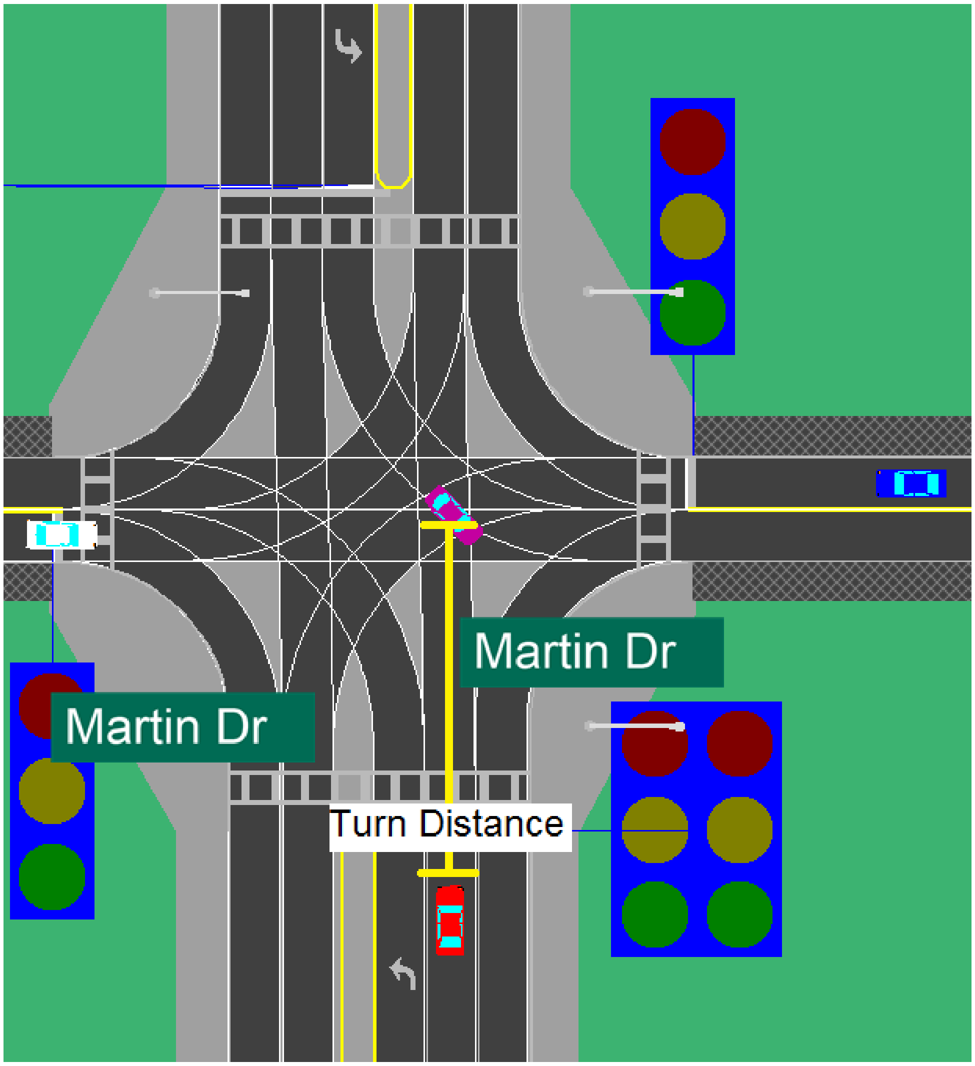

Figure 62. Calculation of distance to oncoming vehicle in Task 3.3.

Conclusions

The current study found evidence that the FYA signal was generally well understood by drivers, even when they did not review the FYA tip card prior to completing the driving scenario. In the current study, no drivers made dangerous turns in front of oncoming traffic during the FYA signal phase and no crashes were observed. The FYA tip card was found to be effective in teaching drivers about the meaning of the FYA signal. Compared to participants who reviewed the tip card, those who did not review the tip card spent more than twice as long waiting to make a left turn, even though there was no oncoming traffic present. The tip card was equally effective in reducing wait times for older and younger adults. Although the decreased wait times for the tip card condition were associated with a significant increase in the number of legal, rolling stops, there was no evidence that drivers were more likely to make unsafe turns after reviewing the FYA tip card.

Chapter 5. Summary of the Studies

Benefit of the Project

This project has provided relevant data to aid the formulation of policy and recommendations. Some of the findings with relevant policy implications are:

Task 1 (1.1 – 1.3).

At least at signalized intersections, we observed little advantage of special emphasis crosswalks over standard markings. Cost savings might be achieved by only placing special emphasis crosswalks at locations associated with greater pedestrian risk. Special emphasis crosswalks appear to have greater potential to warn motorists of the presence of pedestrians compared to standard markings (in our laboratory task, they could be detected more easily and at a greater distance). This additional warning may be especially beneficial for older pedestrians. Due to slower walking speeds, older pedestrians tend to be more exposed to crash risk and if a crash does occur, they are more likely to experience more severe injuries compared to younger pedestrians. However, this greater potential observed in Task 1.1 needs to be considered in light of the fact that our studies did not find a large difference in terms of driver behavior. A driver detecting a crosswalk is only one step in the process of avoiding a crash with a pedestrian. Educational campaigns might assist drivers in how to adjust their behavior once a crosswalk is detected.

Task 2 (2.1 – 2.2).

GOMS modeling underestimated simulator-based response times in a yellow signal braking situation, but accurately estimated the age difference in responding. Hence GOMS modeling can be a useful tool for predicting age-differences in speed of responding in yellow signal decision-making situations. The assumed parameter of 1 s for perception-reaction time (Bonneson & Zimmerman, 2004) to the onset of a yellow signal appears to be an underestimate based on driver responses in simulator scenarios, and a serious underestimate for older drivers, for whom the average perception-reaction time appears to be well over 2 s as indicated by modeling and simulator data.

Task 3 (3.1 – 3.3).

FYA signals appear to be appropriate for Florida drivers of all ages. Few safety-critical errors were made in response to FYA signals, confirming previous studies. However, we have more confidence that these signals are appropriate for the large and growing aging road-user population of Florida. Furthermore, we have behavioral evidence that FYA Tip Cards can increase comprehension of FYA signals in a way that would improve traffic flow. As FYA signals are deployed to a greater extent and become more familiar to drivers, we would expect comprehension to improve even more.

Specific Recommendations Based on Study Findings

1) Tasks 1.1 to 1.3 found that special emphasis crosswalk markings more effectively warn drivers (especially older drivers) that they are approaching a marked crosswalk in the roadway. However, special emphasis crosswalks did not help participants locate pedestrians in the roadway, nor did special emphasis crosswalks change pedestrian behavior (Task 1.2) or driver behavior (Task 1.3). At signalized intersections, there appeared to be little difference, either in pedestrian or driver behavior, between the two types of marked crosswalks. However, the advanced warning that pedestrians might be present provided by special emphasis crosswalks might still be beneficial to older pedestrian and drivers at locations judged to be high risk for pedestrian crashes. Special emphasis crosswalks provide a more salient cue that pedestrians may be crossing. However, unless drivers know the meaning of that cue and how to adjust their behavior, the salience of the cue may make little difference. At high risk locations a combination of educational efforts and increased salience may be needed to reduce pedestrian crashes involving drivers and pedestrians of all ages.

It should further be emphasized that these findings apply to signalized intersections, and standard and special emphasis crosswalk markings may have different effects at midblock locations. In our survey data, we found that participants often misunderstood where it would be legal to cross. We recommend that Florida continue its campaign to educate pedestrians regarding crosswalk use and legal midblock crossing locations.

2) Based on the findings of Task 2, we recommend that low estimates of perception-response time (PRT) be avoided in calculations of yellow signal duration. Locations with large older adult populations might consider lengthening yellow signal durations to improve the safety and comfort of aging road users. At a minimum, we recommend additional study of yellow signal duration to confirm that typical RPT estimates of between 1 and 1.5 seconds are sufficient. All GOMS models and the simulator study conducted suggest that this may be an underestimate even for younger adults.

3) Based on a review of the literature, a lab comprehension task, and a driving simulator study (Task 3.1 to 3.3), we recommend the implementation of FYA signals at appropriate locations in Florida, installed consistently throughout the area surrounding those locations. When failures of comprehension did occur, drivers rarely interpreted the FYA as suggesting right-of-way for the left turning driver, and no crashes or dangerous left turns were observed in the simulator study. Compared to other protected/permissive Left-Turn (PPLT) displays that feature a circular green, FYA signals appear to be safer, and traffic flow is improved compared to fully protective left-turn signals.

4) We recommend the continued/increased dissemination of FYA Tip Cards and other educational materials to help drivers understand the meaning of FYA signals. It was rare that participants mistook the FYA as indicating that he or she had right-of-way, but some participants did report this meaning in Task 3.2. Even if this is a rare misunderstanding, it is an important one to address. However, we found that there is potential for the FYA Tip Card to improve traffic flow. Participants who did not view the

tip card waited at the intersection longer, presumably while they assessed the meaning of this relatively novel signal. Once FYAs become more commonplace, these dissemination activities might be decreased.

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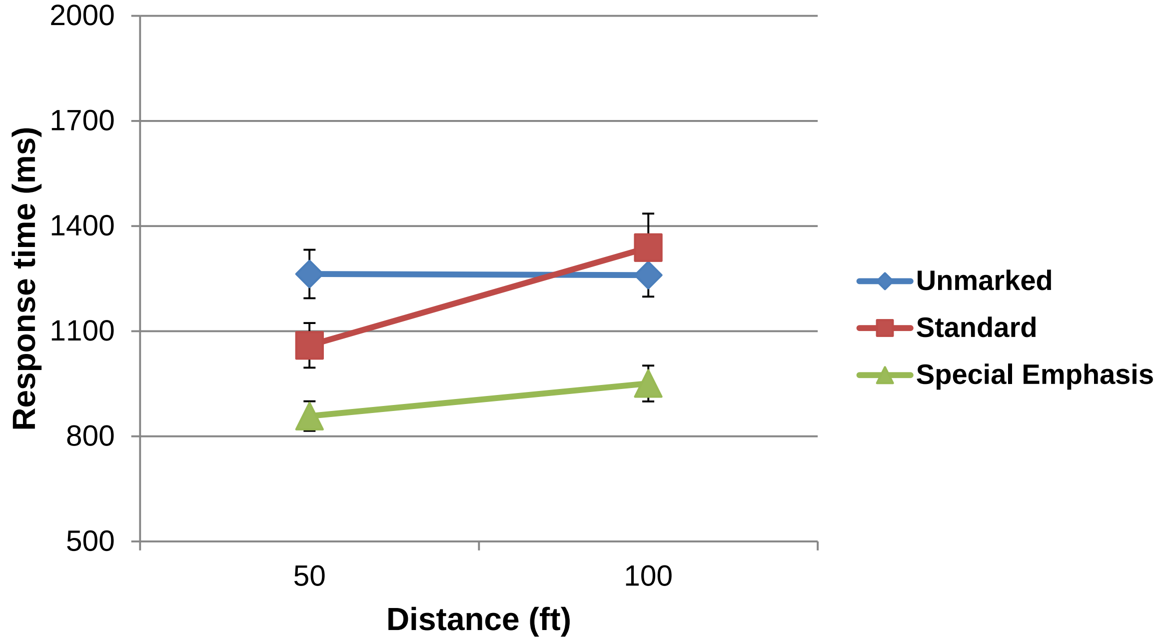
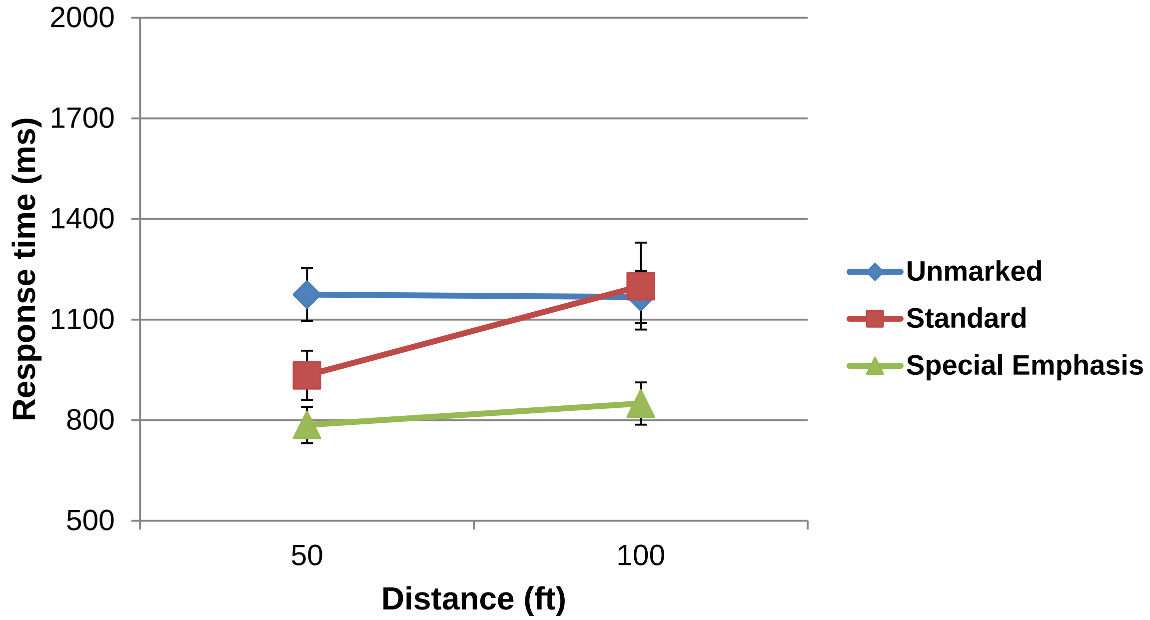
Appendix A. Task 1.1 Response Time and Accuracy by Age Graphs

<u>Crosswalk Identification Task</u>: Response Time

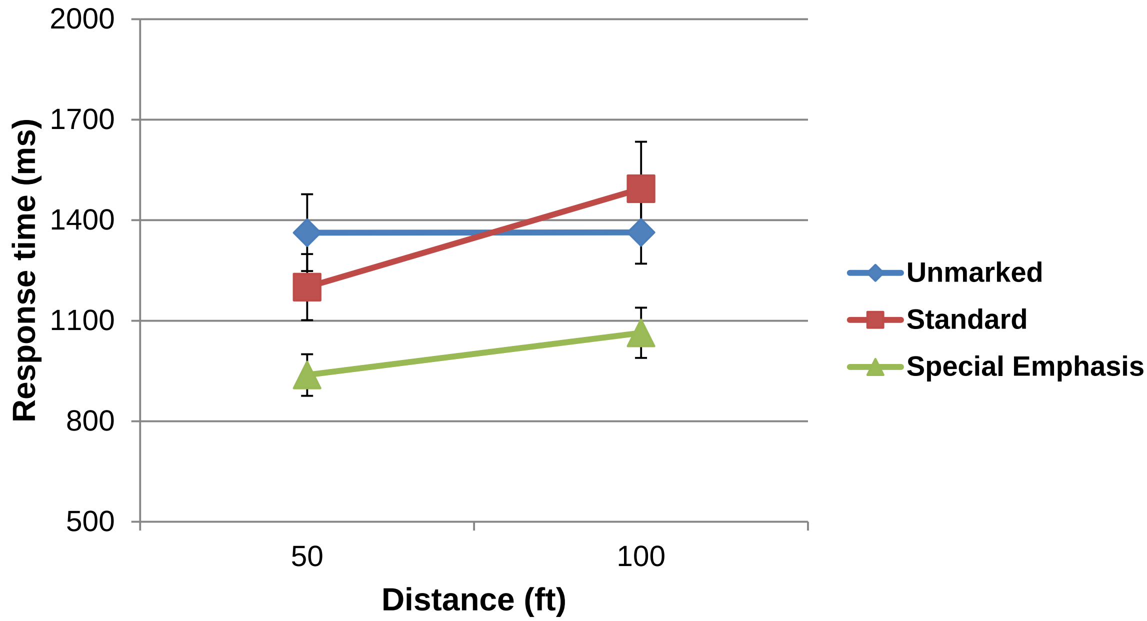
YOUNGER:



MIDDLE AGE:



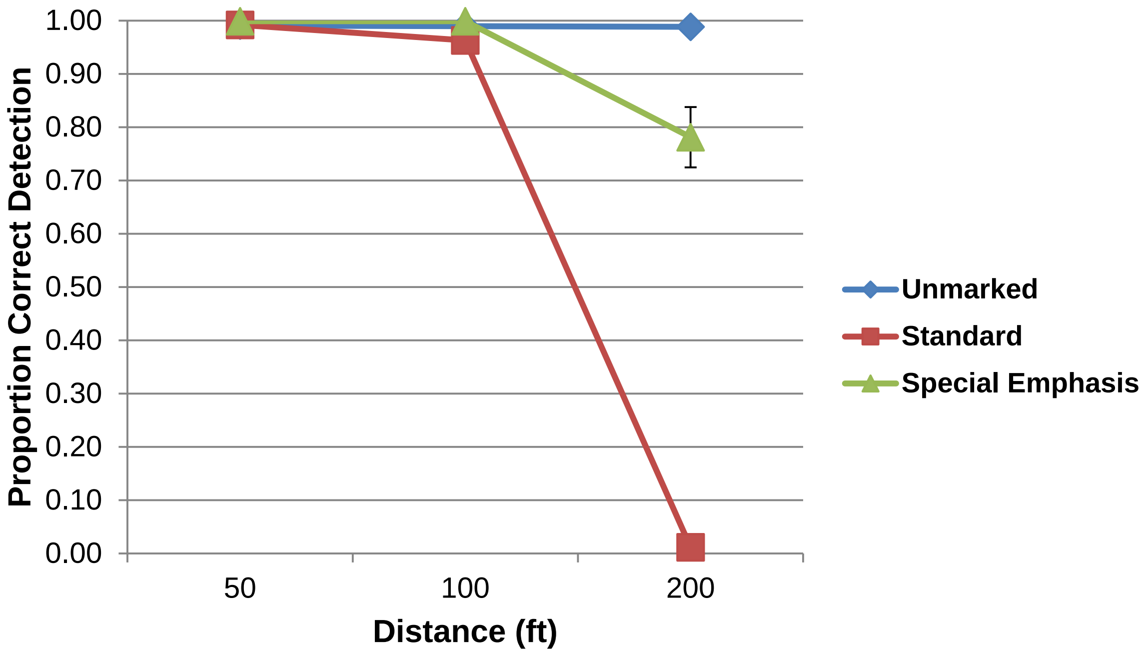
OLDER:



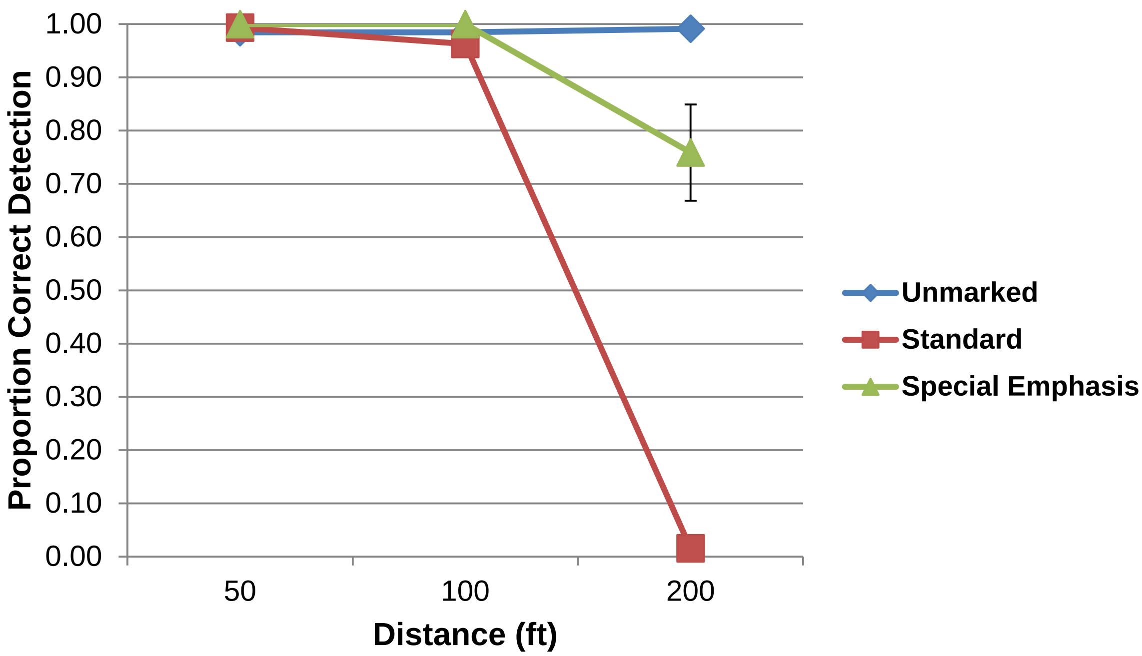
2000
1700
1400
1100
800
500
Response time (ms)
50
100
Distance (ft)
Unmarked
Standard
Special Emphasis

Crosswalk Identification Task: Accuracy

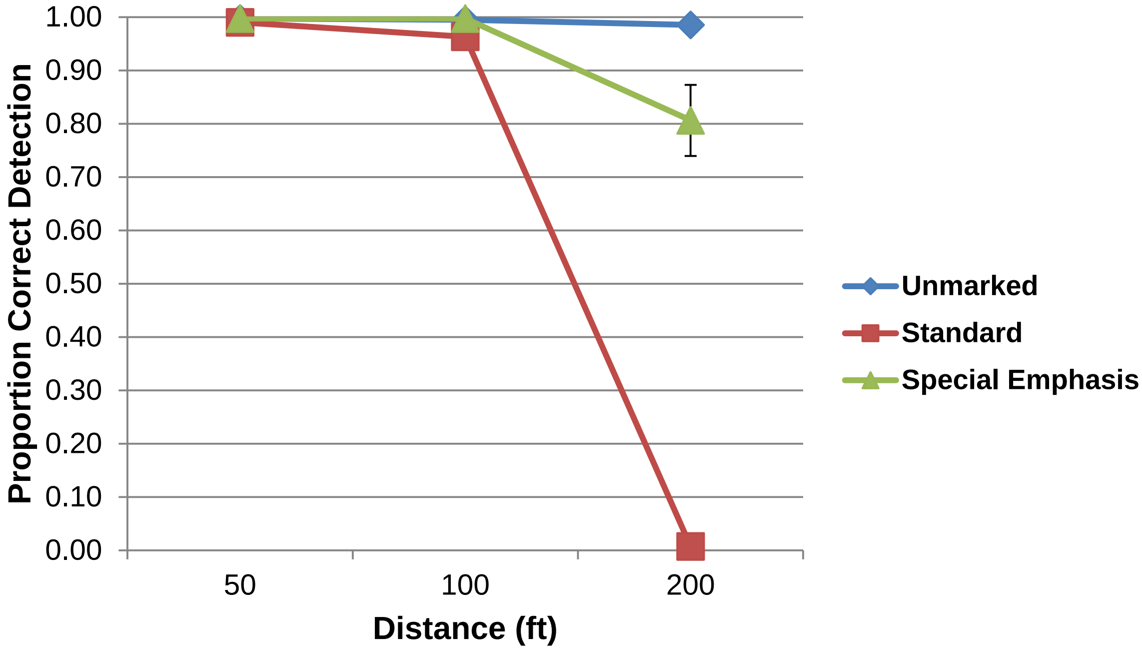
YOUNGER:



MIDDLE AGE:

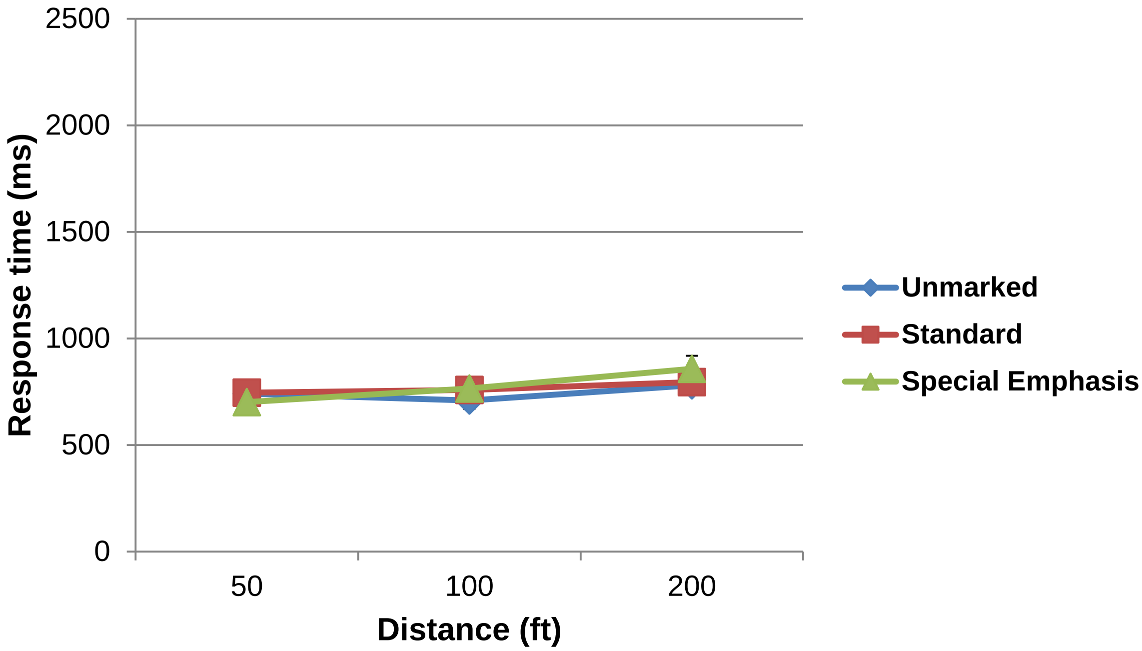


OLDER:

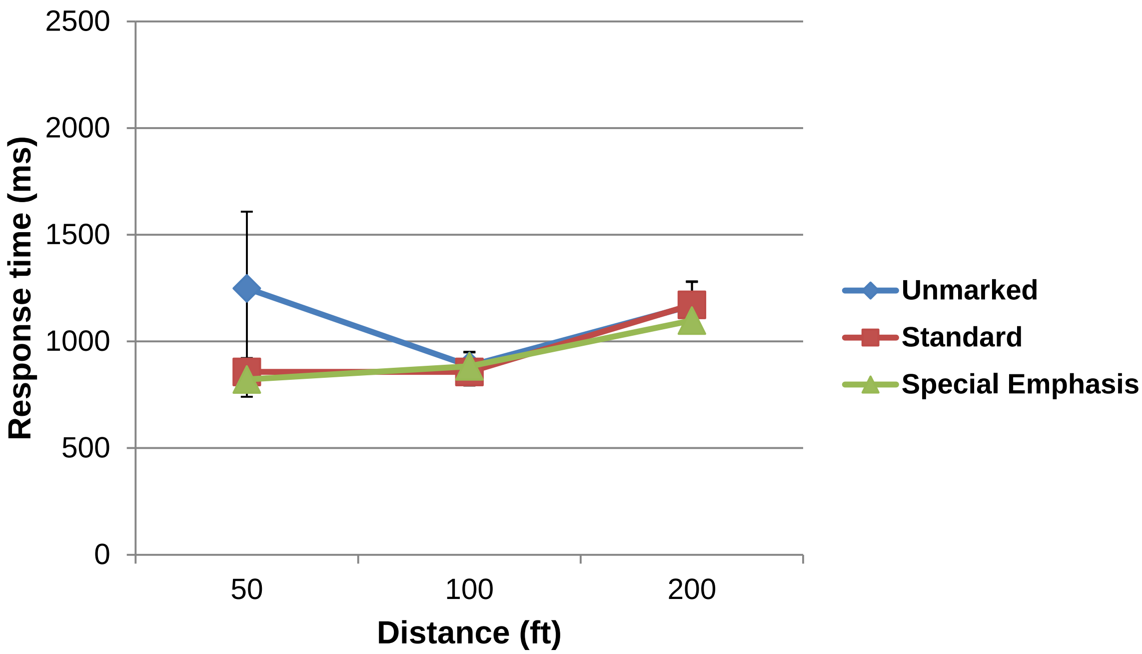

Proportion Correct Detection
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
50
100
200
Distance (ft)
Unmarked
Standard
Special Emphasis

<u>Pedestrian Detection Task</u>: Response Time

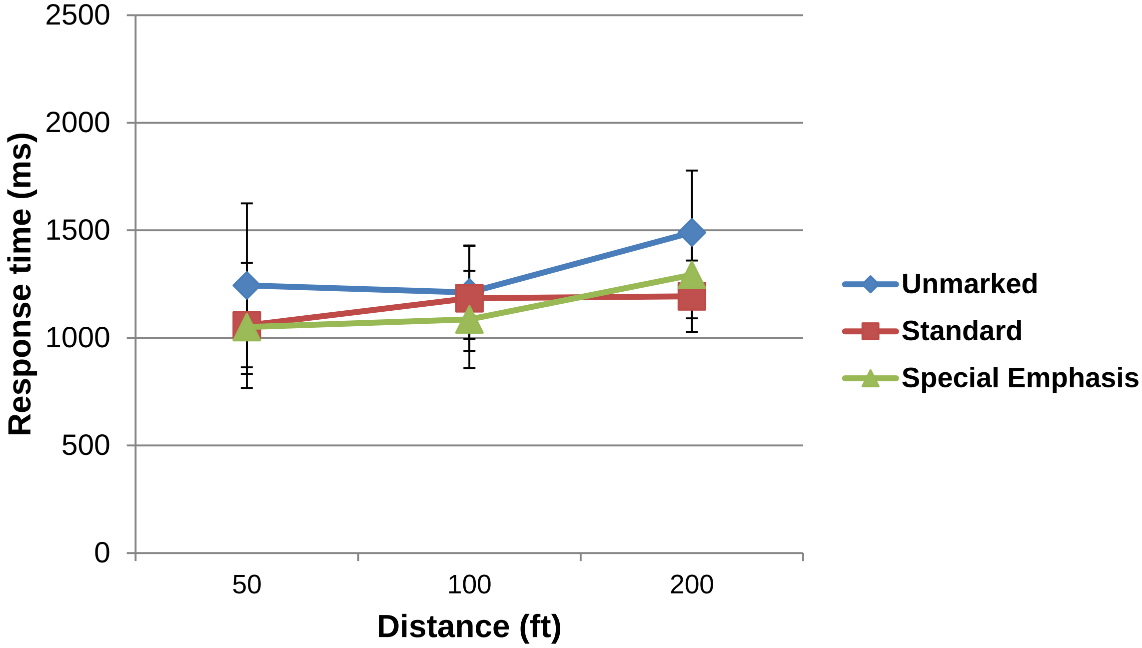
YOUNGER: Low Probability of Pedestrian



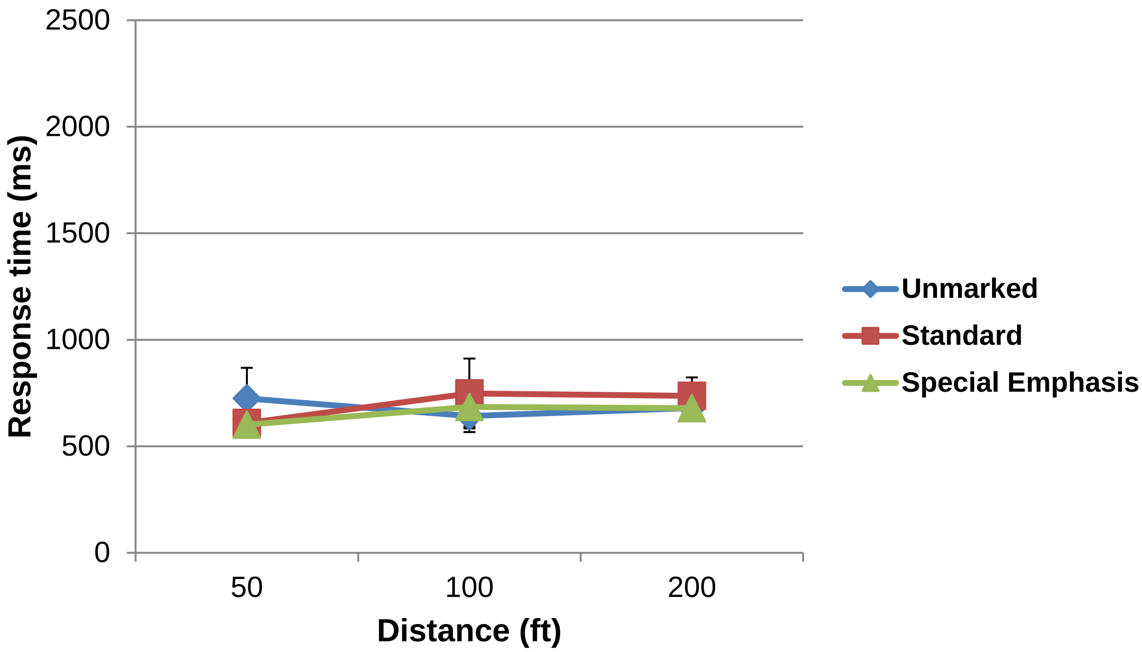
MIDDLE AGE: Low Probability of Pedestrian



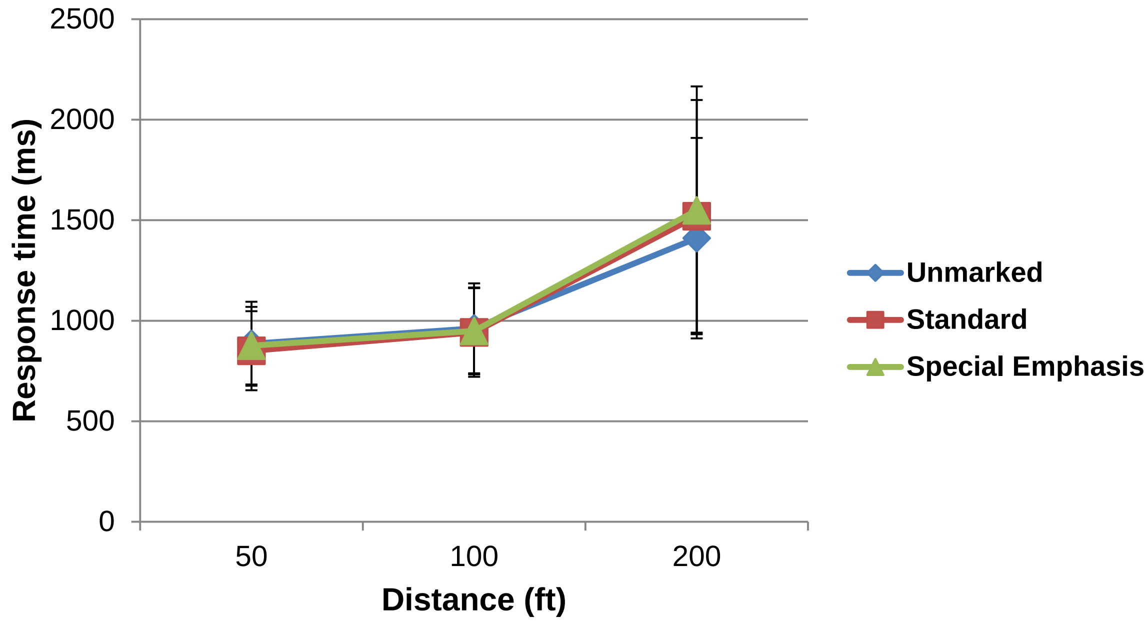
OLDER: Low Probability of Pedestrian



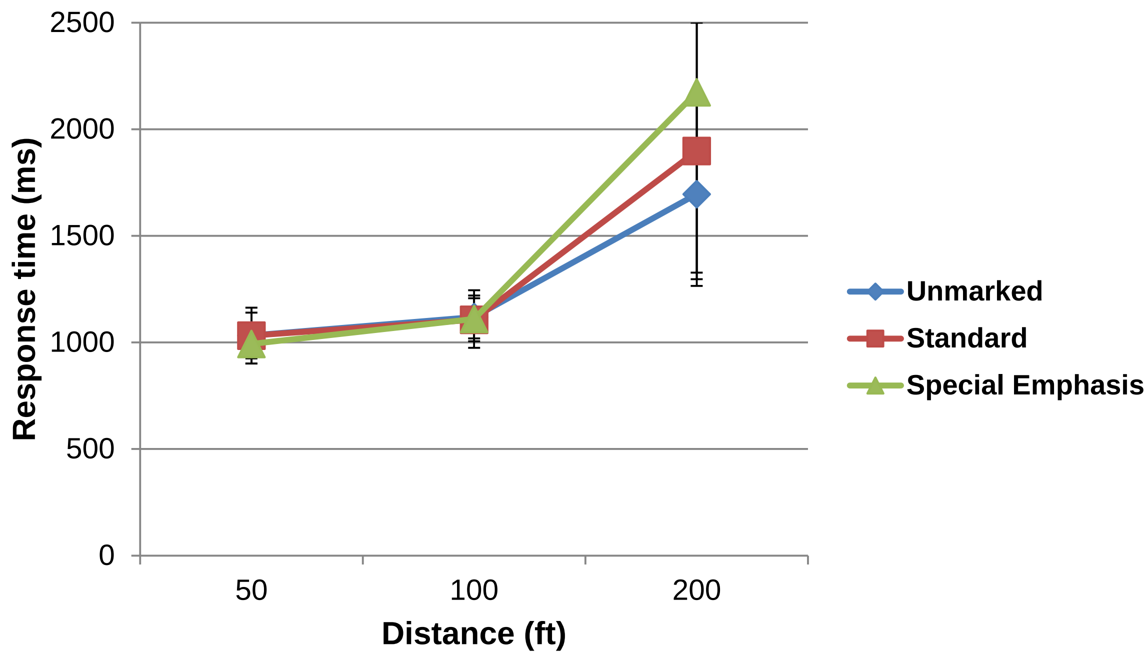
YOUNGER: High Probability Pedestrian



MIDDLE AGE: High Probability Pedestrian

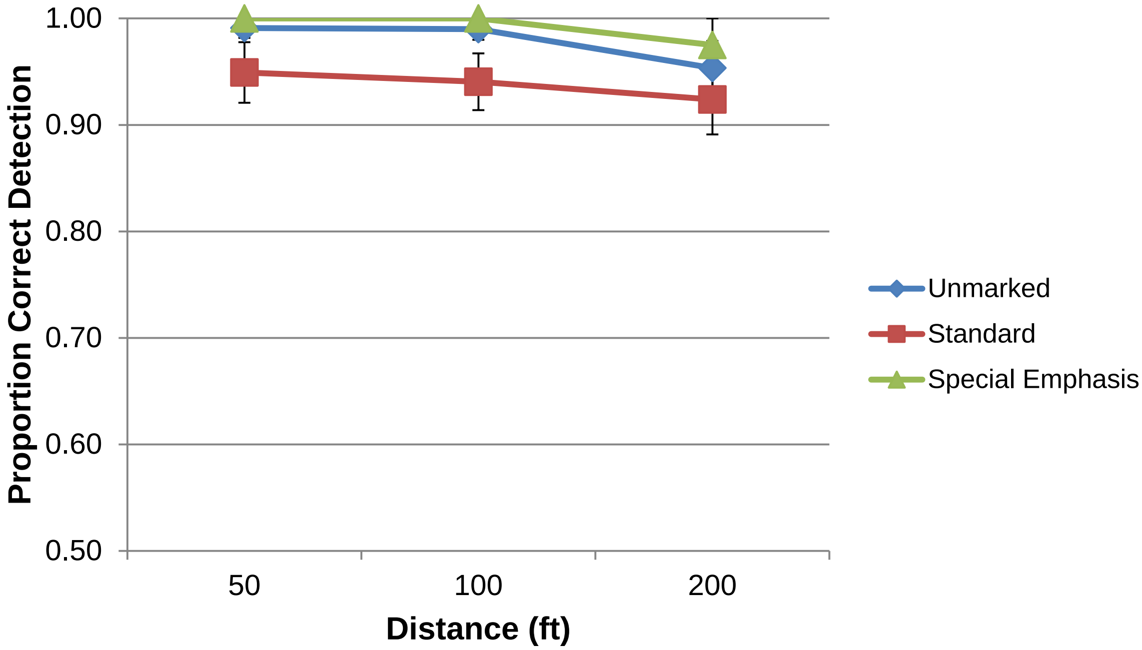


OLDER: High Probability Pedestrian

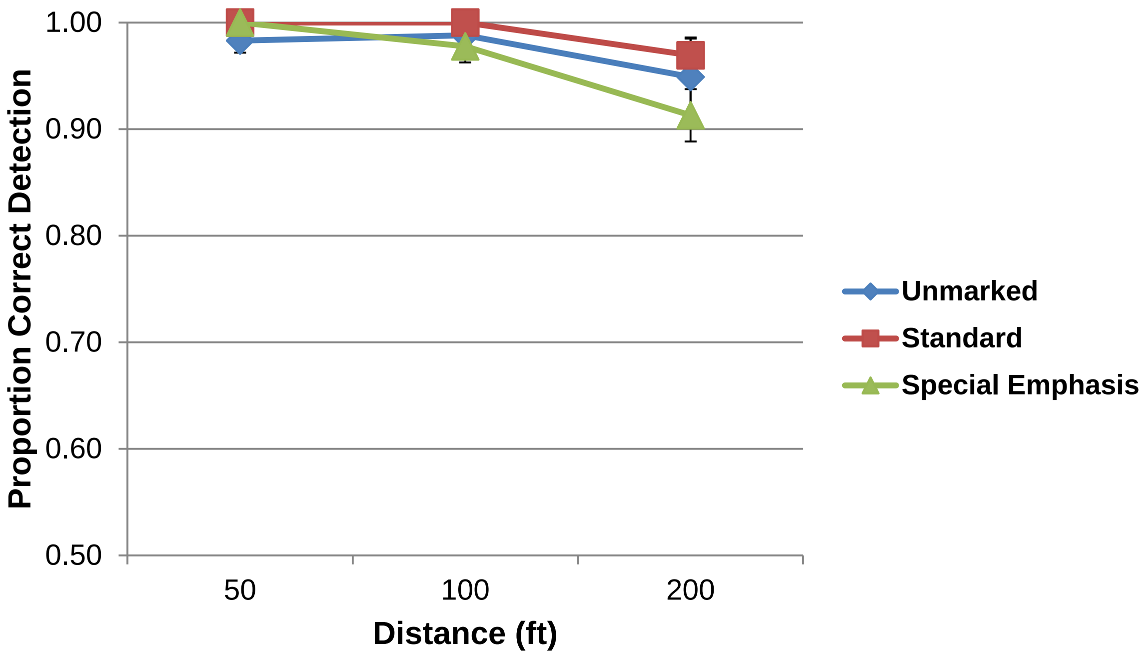


<u>Pedestrian Detection Task</u>: Accuracy

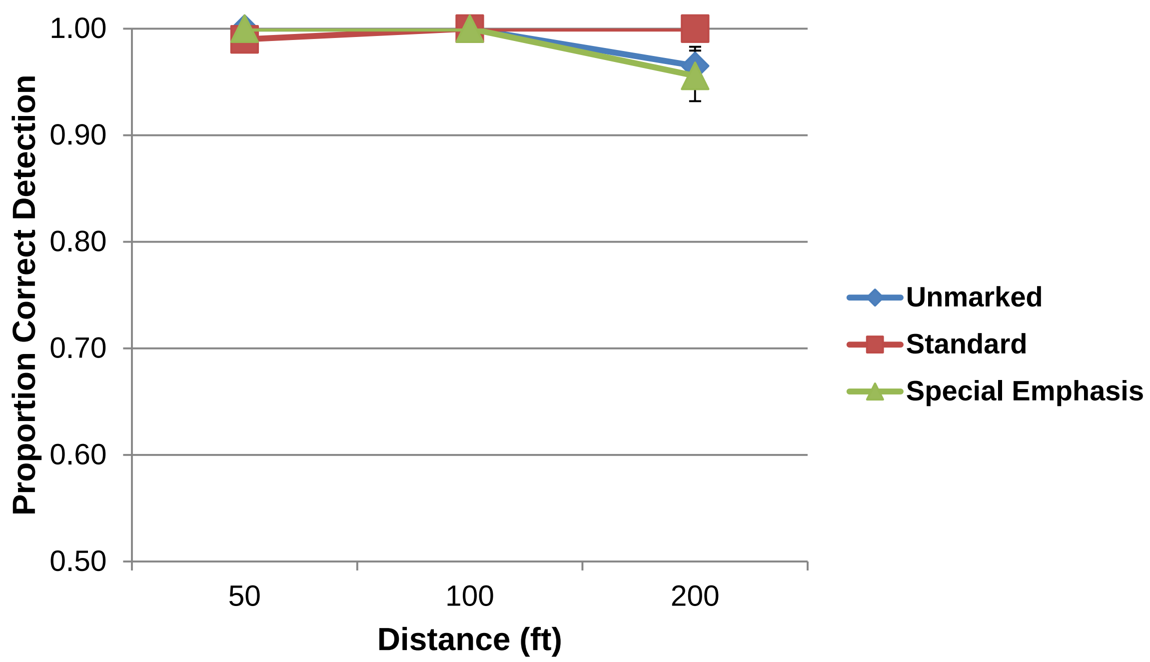
YOUNGER: Low Probability of Pedestrian



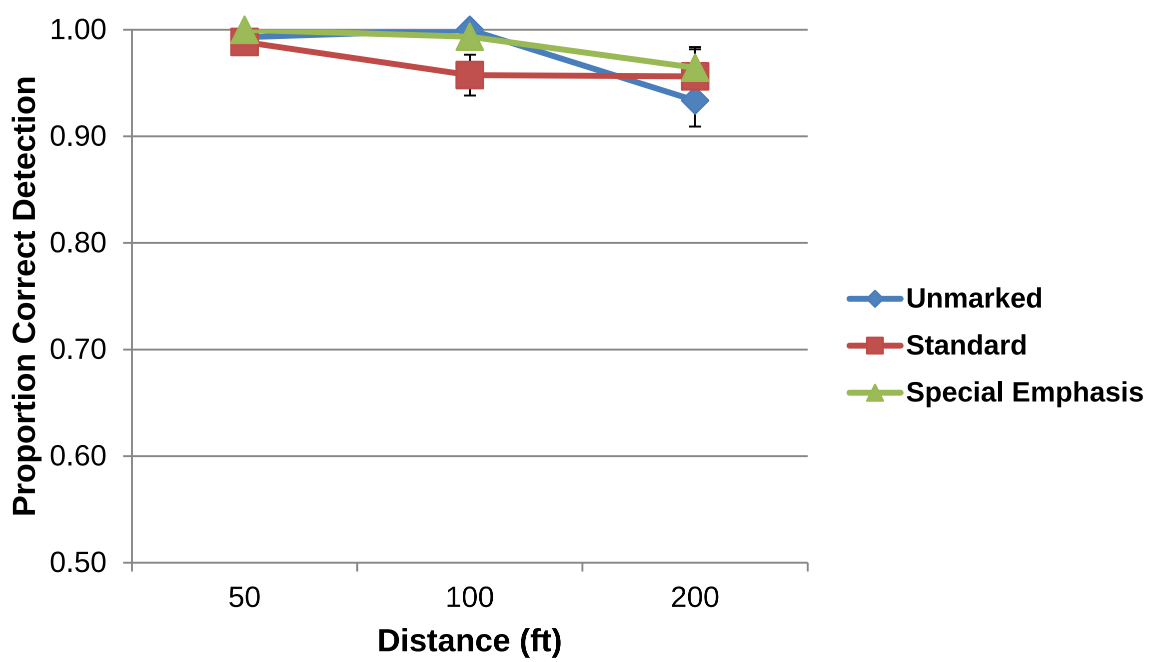
MIDDLE AGE: Low Probability of Pedestrian



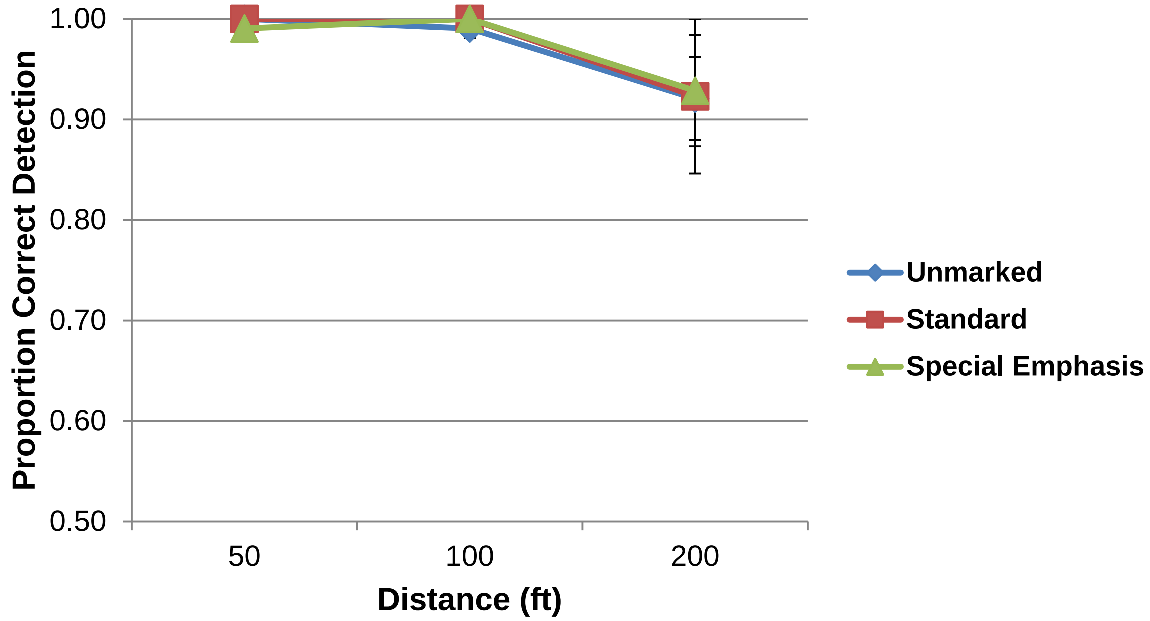
OLDER: Low Probability of Pedestrian



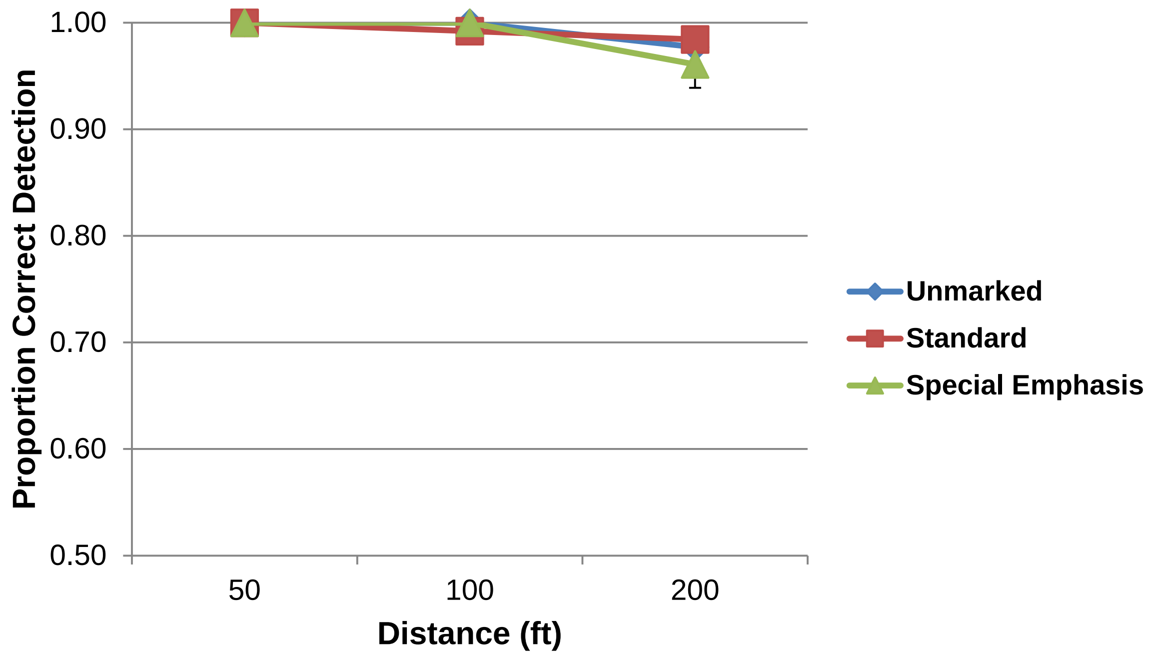
YOUNGER: High Probability Pedestrian



MIDDLE AGE: High Probability Pedestrian



OLDER: High Probability Pedestrian



Appendix B. Pedestrian Surveys

Survey Administered in Field Task

Date ___________Time __________ ID _______

Hi, would you be willing to help us out with a brief survey for $10? It'll take less than five minutes.

Great, thanks! I'm ____________ with the FSU Department of Psychology, doing research on behalf of the Florida Department of Transportation. I'll be asking you some questions about the crosswalk you just used. Anything you say is confidential, and your answers cannot be linked to you in any way.

1. Have you completed a survey about crosswalks with us before?

1) Yes **(If yes, "Okay, we can't continue today then, but thank you for being so willing to help us!")**
2) No **(if no, use the time and pedestrian number from the coding sheet as the ID, e.g. 2:13 and Ped 3 would be 213_3)**

2. What is your birth year? _____ **(If 1995 or later, ask if they're 18. If not, they cannot continue.)**

3. (Circle participant's gender.) 1) Male 2) Female

4. Using this scale **(point to bottom scale)**, please rate how ***confident*** you are that motorists will stop and wait for you when you're in this crosswalk.
   1) Not at all 2)Not very 3) Somewhat 4)Very 5)Completely

5. Using this scale **(point to bottom scale)**, please rate how ***safe*** you feel while using this crosswalk.
   1)Not at all 2)Not very 3) Somewhat 4)Very 5)Completely

6. Using this scale **(point to bottom scale)**, please rate how ***slippery*** you felt the crosswalk was.
   1)Not at all 2)Not very 3) Somewhat 4)Very 5)Completely

7. Please answer "yes," "no," or "I don't know" for each of the following questions.

Y / N / IDK Do you feel vehicles typically yield to pedestrians in crosswalks at this intersection?
Y / N / IDK Do you feel turning vehicles typically yield to pedestrians during the walk signal at this intersection?
Y / N / IDK Do you feel pedestrians typically cross at crosswalks at this intersection?
Y / N / IDK Do you feel it is safer to cross in the middle of the block than at the crosswalks at this intersection?

8. Where do you typically cross Monroe Street at this location?
   1) At the crosswalks
   2) Near the crosswalks, but you don't actually use them
   3) At the middle of the block, away from the crosswalks
   4) At any convenient location, you don't really have a preference

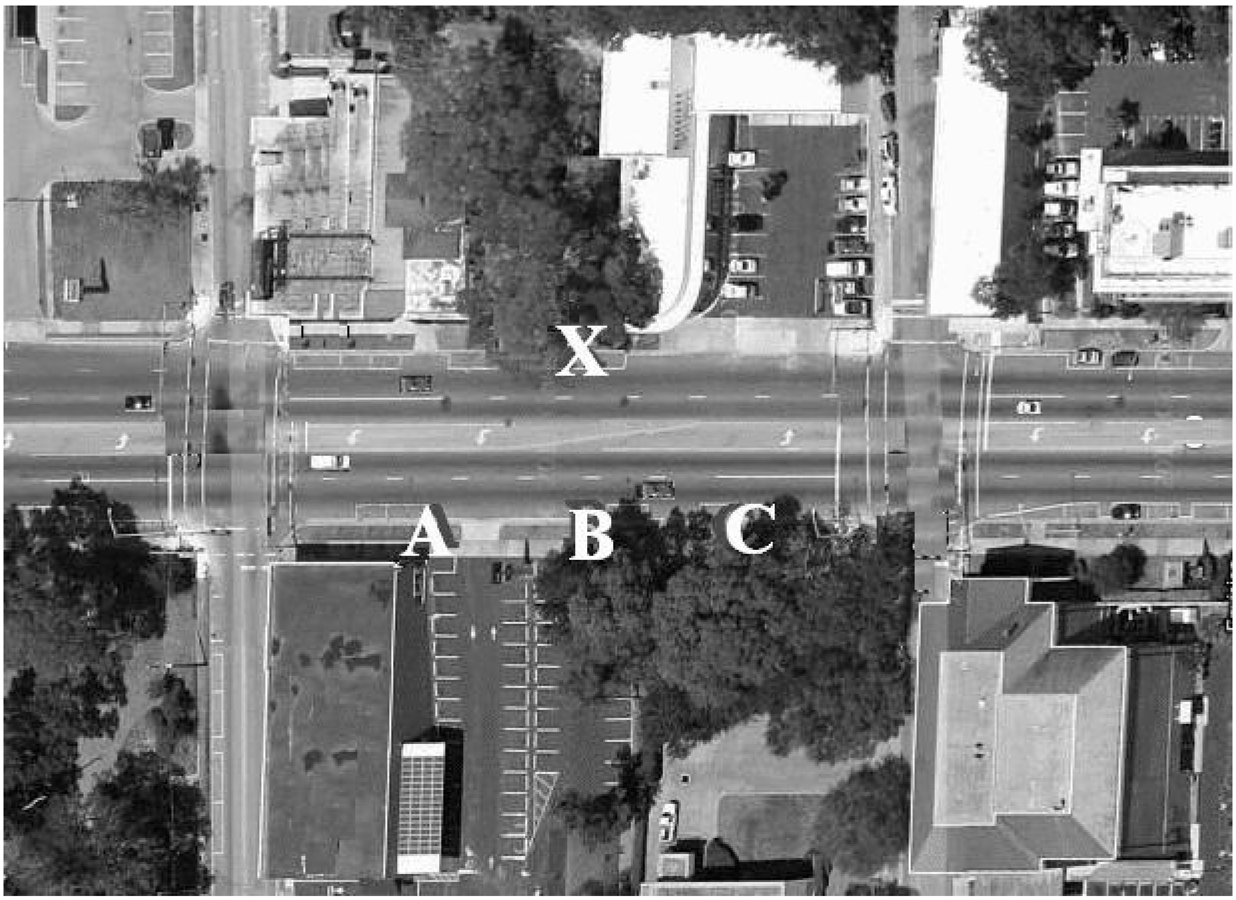
9. Under which condition do you most typically cross Monroe Street at this location?
   1) Only when pedestrian signal indicates walk
   2) Only when traffic clears completely

3) Anytime you feel a gap in traffic is big enough for you to cross safely

10. How often do you cross Monroe Street at this location? **(point to top scale)**

1) This is the first time 2) less than 1 time/mo. 3) 1 to 3 times/mo. 4) 1 to 4 times/wk 5) 5+ times/wk

11. Here is a picture of this location – we're standing right here **(point)**. Take a moment to look from here to that crosswalk over there **(point to the other crosswalk in the study)** to get a feel for the distances. Now if your destination is the building marked by the big X, please mark the route you would walk to get there from the starting point marked by the big A. Please do the same for starting points B and C. Your destination is still the X.



Note: Question 11 was removed from the surveys when given at locations other than the two depicted in the above image.

1. Ok, we're done with the picture and back to talking about what you're doing today. Where are you walking from? ____

2. And where are you walking to? ____

3. We are observing about half the people who cross this street today, to see how people use crosswalks at this location. You may or may not have been observed. As you were crossing the street, did you feel or think you were being observed?
    1) Yes 2) No

4. What is your highest level of education?
    1) Some high school
    2) High school diploma or GED
    3) Some college
    4) 2-year degree
    5) 4-year degree
    6) Some post-graduate education
    7) Graduate or professional degree

Perfect. Now I just need you to sign a receipt so we can pay you, and I have a sheet to give you that explains what the study's about.

(After they sign the receipt, give them an envelope.) Your $10 and the explanation of the study are in here. Thank you so much for helping us!

Survey Administered in Laboratory

This survey was computer-administered using MediaLab (Jarvis, 2008). One question was presented per page, along with its response options. For questions regarding specific crosswalk type, the overhead view of the crosswalk was presented on the instruction screen and also on every question screen.

When you are walking along a road without sidewalks, you should:

a) Walk on the right, in the direction of traffic
b) Walk on the left, facing traffic

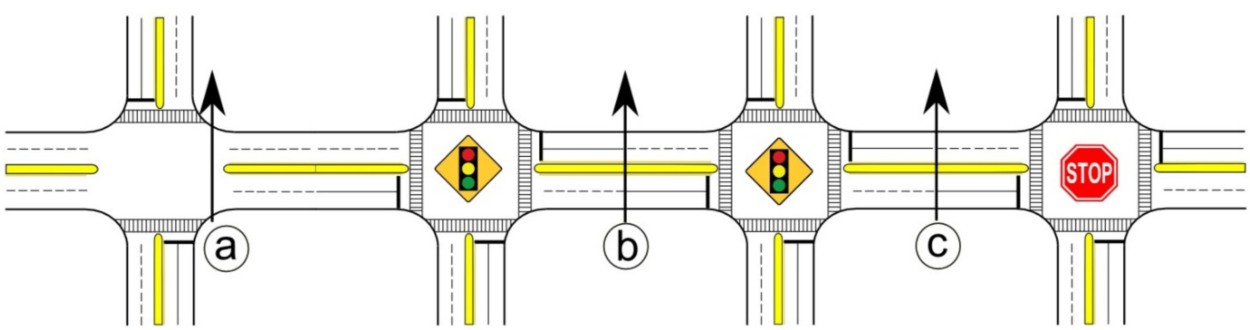
At an intersection with a pedestrian signal, the pedestrian can START crossing with which of the following signals:

a) Flashing hand
b) Steady walking man
c) Flashing hand with countdown
d) Steady hand

Vehicles making a permitted right turn on a red signal shall:

a) Stop before entering the crosswalk, then proceed if clear
b) Stop before entering the crosswalk when a pedestrian is immediately visible
c) Turn right without stopping

Which of the arrows in this diagram shows a crossing that is NOT legal for pedestrians in FL?



(Buttons for A, B, and C were displayed directly above the letters in the diagram.)

In your opinion, how safe are the roads in Florida for pedestrians and bicyclists?

a) Very safe
b) Somewhat safe
c) Neither safe nor unsafe
d) Somewhat unsafe
e) Very unsafe

What is the top reason you think Florida may be unsafe for pedestrians and bicyclists?

a) Road or sidewalk conditions
b) Signals not working or not properly timed
c) Aggressive driving
d) People not following laws and signals
e) Not enough enforcement of laws, signals and rules
f) Inadequate bus stop facilities or placement
g) Weather conditions

You would walk or ride a bicycle more for either daily needs or recreation if safety issues in your community were addressed:

a) Strongly agree
b) Agree
c) Neutral
d) Disagree
e) Strongly disagree

When an intersection's traffic signal has a push button for pedestrians, do you use it?

a) Yes
b) No

Please use this overhead view of a crosswalk to answer the next set of questions. Click the Continue button at the bottom right when you're ready to begin.

Using the scale below, please rate how CONFIDENT you are that motorists will stop and wait for you when you're in a crosswalk that looks like this.

a) Not at all
b) Not very
c) Somewhat
d) Very
e) Completely

Using the scale below, please rate how SAFE you feel while using a crosswalk that looks like this.

a) Not at all
b) Not very
c) Somewhat
d) Very
e) Completely

In general, do you feel vehicles typically yield to pedestrians in this type of crosswalk?

a) Yes
b) No
c) I don’t know

In general, do you feel turning vehicles typically yield to pedestrians during the walk signal at this type of crosswalk?

a) Yes
b) No
c) I don’t know

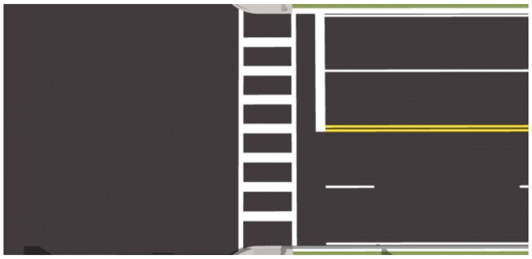
In general, do you feel pedestrians typically use this type of crosswalk if it's available?

a) Yes
b) No
c) I don’t know

In general, do you feel it is safer to cross in the middle of the block than in this type of crosswalk at an intersection?

a) Yes
b) No
c) I don’t know

Please use this overhead view of a crosswalk to answer the next set of questions. Click the Continue button at the bottom right when you're ready to begin.



Using the scale below, please rate how CONFIDENT you are that motorists will stop and wait for you when you're in a crosswalk that looks like this.

f) Not at all
g) Not very
h) Somewhat
i) Very
j) Completely

Using the scale below, please rate how SAFE you feel while using a crosswalk that looks like this.

f) Not at all
g) Not very
h) Somewhat
i) Very
j) Completely

In general, do you feel vehicles typically yield to pedestrians in this type of crosswalk?

d) Yes
e) No
f) I don’t know

In general, do you feel turning vehicles typically yield to pedestrians during the walk signal at this type of crosswalk?

d) Yes
e) No
f) I don’t know

In general, do you feel pedestrians typically use this type of crosswalk if it's available?

d) Yes
e) No
f) I don’t know

In general, do you feel it is safer to cross in the middle of the block than in this type of crosswalk at an intersection?

d) Yes
e) No
f) I don't know

What is your gender?

What is your age?

What is your ethnicity?

What is your race?

What is your 4-digit birth year?

Appendix C. Observational Study Coding Sheet and Definitions.

Sheet ID __________ Exp ID: __________

Situational Variables Time: [ ]

# of Cars Stopped	0-2	3-5	6-10	> 10

Cars Turning: __________ Illegal Left Turns: __________

	Don't Walk	Walk	Count
Peds Arriving			

Front Cars' Positions:
Left lane: Stop / Past / Intruded / Blocked
Right lane: Stop / Past / Intruded / Blocked

Behavioral Variables

Ped X	Age Group	Arrived	Direction Crossing	Mobility Aid?	Crossed With Signal?	Attended to Traffic First?	Finished In Time?	Crosswalk: Complete?	Midblock: Traffic?	Walk Sp.	Survey?
Ped 1	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 2	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 3	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 4	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 5	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 6	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA

# of Other Peds: __________

Other Factors:

Emergency Vehicle / Accident / Road Rage / Car Running a Light

Notes: ____

If ped did not cross w/signal, was there any oncoming traffic within a block in either direction? Y / N

If yes, was the traffic on the same side of the roadway as ped, the other side, or both? S / O / B

Situational Variables Time: [ ]

# of Cars Stopped	0-2	3-5	6-10	> 10

Cars Turning: __________ Illegal Left Turns: __________

	Don't Walk	Walk	Count
Peds Arriving			

Front Cars' Positions:
Left lane: Stop / Past / Intruded / Blocked
Right lane: Stop / Past / Intruded / Blocked

Behavioral Variables

Ped X	Age Group	Arrived	Direction Crossing	Mobility Aid?	Crossed With Signal?	Attended to Traffic First?	Finished In Time?	Crosswalk: Complete?	Midblock: Traffic?	Walk Sp.	Survey?
Ped 1	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 2	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 3	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 4	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 5	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA
Ped 6	Y / M / O	D / W / C	To / Away	Y / N	E / O / L / No	Y / N	Y / N	Y / N / NA	N / S / M	W / R / Acc	Y / N / NA

# of Other Peds: __________

Other Factors:

Emergency Vehicle / Accident / Road Rage / Car Running a Light

Notes: ____

If ped did not cross w/signal, was there any oncoming traffic within a block in either direction? Y / N

If yes, was the traffic on the same side of the roadway as ped, the other side, or both? S / O / B

Observational Coding Definition Sheet

Experimenter – fill in your designated experimenter number (this will be assigned to you)

INTERSECTION INFORMATION

Type of Crosswalk – indicate whether the crosswalk being observed is standard (looks like a lane) or special-emphasis (looks like a ladder)

Experimenter Location – circle the corner where you are taking observations

Obs. Start Time – indicate what time you arrived at the intersection

Obs. End Time – indicate what time you left the intersection

Weather – circle whether it was sunny or overcast while observing; also note the approximate temperature during the observation period

SITUATIONAL VARIABLES

Time – record the time the first pedestrian arrived at the light during this light cycle (light cycle begins when the steady red hand is displayed)   (this item will not be used on the training coding sheet)

# of Cars Stopped – circle the number of cars stopped when the pedestrian walk stage of the light cycle began

Cars Turning – tally the number of cars turning at the intersection across the crosswalk(s) in use while pedestrians are crossing

Illegal Left Turns – tally the number of cars making illegal left turns at the intersection across the crosswalks(s) in use while pedestrians are crossing

Front Cars Position – indicate whether the front cars were stopped behind the stop bar, past the stop bar, intruding into the crosswalk, or blocking the crosswalk altogether

Peds Arriving – tally the number of pedestrians arriving during the Don't Walk, Walk, orphase of the pedestrian signal page down or stop listening

BEHAVIORAL VARIABLES

Ped X – circle the next available pedestrian number when a pedestrian arrives at the crosswalk (This item does not appear on the training coding sheet)

Age Group – circle the appropriate age group for the pedestrian
- Y – Younger (18 – 35)
- M – Middle (36 – 64)
- O – Older (65+)

Arrived – circle the part of the pedestrian signal cycle at which the pedestrian arrived
- D – Don't Walk
- W – Walk
- C – Count

Direction Crossing – circle the direction in which the pedestrian was walking
To – toward the corner at which you are observing
Away – away from the corner at which you are observing

Mobility Aid – circle Y or N to indicate whether or not the pedestrian was using a mobility aid while crossing (cane, walker, wheelchair, etc.)

Crossed With Signal – circle the appropriate time at which the pedestrian crossed the intersection
E – Early; the pedestrian entered the roadway before the pedestrian walk signal, knowing it was about to change as indicated by behavior (looking at both the signal and the traffic)
O – On Time; the pedestrian crossed as the walk signal appeared
L – Late; the pedestrian crossed after the walk signal/during the count
No – the pedestrian did not pay attention to the signal; only looked for the presence of vehicles

Attended to Traffic First? – Indicate whether the pedestrian looked at traffic immediately before stepping into the roadway
Y – yes
N – no

Finished In Time – circle Y or N to indicated whether or not the pedestrian finished crossing before the end of the countdown

Crosswalk: Complete – Bright green duct tape on curbs and, in some cases, the street marks the crosswalk zone, which includes several feet to either side of the crosswalk markings. IF the pedestrian spent at least part of the crossing time within the crosswalk zone, circle the appropriate response as to whether or not the pedestrian completed crossing while remaining within the crosswalk zone the whole time.
Y – yes
N – no
NA – pedestrian did not complete (stopped and turned around, etc.)

Midblock: Traffic – IF the pedestrian crossed at midblock (outside of the crosswalk zone), circle one of the following:
N – no traffic approaching the intersection within a block in either direction
S – traffic, but all of it stopped at a light
M – traffic, moving

Walk Speed – circle the appropriate answer for the pedestrian's walking speed
W – walk
R – run
Acc – the pedestrian accelerated their pace partway through the crossing

Survey – circle Y or N to indicate whether or not the pedestrian participated in the survey if approached, or NA if not approached

# of Other Peds – tally the number of additional pedestrians present if more than 6 are present

Other Factors – circle which factors were present (if any)

Notes – write any extraordinary events/behaviors that are not otherwise covered in the coding sheet

Appendix D. Pedestrian origination and destination points for each survey location.

When a specific business or location name is not given:

Categories	
Work	The pedestrian reported that they were going to or from work but did not give a specific location.
Car	The pedestrian said they were going to or from their car, a parking lot, or a parking garage.
Bus Stop	The pedestrian said they were going to or from the bus stop, bus station, or that they were "taking the bus".
Residence	The pedestrian said they were going home, to a friend or relative's house, or named a nearby apartment complex or neighborhood.
Other	The stated destination is unclear, nonspecific, or cannot be categorized

Monroe / Carolina (n = 31)			
Location	Number Origin	Number Destination	Total
Residence	7	7	14
Hotel Duval	4	3	7
Firestone	3	1	4
Car	3	3	6
Lake Ella / Other park	2	1	3
Library	2	1	3
Work	2	0	2
ProBank / bank	0	6	6
Bus Stop	1	4	5
Other	7	5	11

Monroe / Georgia (n = 7)			
Location	Number Origin	Number Destination	Total
ProBank / bank	2	1	3
Car	1	2	3
Bus Stop	0	1	1
Residence	1	0	1
Other business	2	2	4
Work	0	1	1
Other	1	0	1

Monroe / Gaines (n = 30)			
Location	Number Origin	Number Destination	Total
Caldwell Building / DEO	10	4	14
Other government building	1	1	2
Car	8	17	25
Bus Stop	0	1	1
Work	8	5	13
Cafeteria	2	0	2
Other	1	2	3

Monroe / Sharer (n = 7)			
Location	Number Origin	Number Destination	Total
Econolodge	2	0	2
Library	0	2	2
China Super Buffet	0	1	1
Affordable Dentures	1	0	1
Circle K	0	1	1
Bus Stop	0	3	3
Residence	1	0	1
Other	3	0	3

Pensacola / Ausley (n = 12)			
Location	Number Origin	Number Destination	Total
Residence	7	7	14
Hotel Duval	4	3	7
Firestone	3	1	4
Car	3	3	6
Lake Ella / Other park	2	1	3
Library	2	1	3
Work	2	0	2
ProBank / bank	0	6	6
Bus Stop	1	4	5
Other	7	5	11

There was only one survey collected at Tennessee and Macomb (standard crosswalk). That individual was traveling from The Shelter to Mike’s (either pawn or liquor).

Appendix E. GOMS Models

Cautious Go Model

	Operator	Young (ms)	Old (ms)
INITIAL STATE			
Signal change in periphery	Perceptual	100	178
Fixate signal / Saccade	Eye Fixation	230	267
Decode signal meaning	Cognitive	70	118
Fixate stop line	Eye Fixation	230	267
Gauge time to arrival at intersection	Cognitive	70	118
Determine action	Cognitive	70	118
DILEMMA STATE: CAUTIOUS DRIVER GOING THROUGH YELLOW			
Fixate opposing left-turn lane	Eye Fixation	230	267
Determine traffic situation	Cognitive	70	118
Fixate traffic left	Eye Fixation	230	267
Determine traffic situation	Cognitive	70	118
Fixate traffic right	Eye Fixation	230	267
Determine traffic situation	Cognitive	70	118
Decide to proceed through intersection	Cognitive	70	118
	Predicted Time:	**1740**	**2339**

Cautious Stop Model

	Operator	Young (ms)	Old (ms)
INITIAL STATE			
Signal change in periphery	Perceptual	100	178
Fixate signal / Saccade	Eye Fixation	230	267
Decode signal meaning	Cognitive	70	118
Fixate stop line	Eye Fixation	230	267
Gauge time to arrival at intersection	Cognitive	70	118
Determine action	Cognitive	70	118
DILEMMA STATE: CAUTIOUS DRIVER STOPPING AT YELLOW			
Saccade to rearview mirror	Eye Fixation	100	178
Determine traffic situation	Cognitive	70	118
Decision made to stop	Cognitive	70	118
Move foot to brake pedal	Motor + Fitts	264	485
Press brake pedal	Motor	70	146
	Predicted Time:	**1344**	**2111**

Semi-Cautious Go Model

	Operator	Young (ms)	Old (ms)
INITIAL STATE			
Signal change in periphery	Perceptual	100	178
Fixate signal / Saccade	Eye Fixation	230	267
Decode signal meaning	Cognitive	70	118
Fixate stop line	Eye Fixation	230	267
Gauge time to arrival at intersection	Cognitive	70	118
Determine action	Cognitive	70	118
DILEMMA STATE: CAUTIOUS DRIVER GOING THROUGH YELLOW			
Fixate opposing left-turn lane	Eye Fixation	230	267
Determine traffic situation	Cognitive	70	118
Fixate perpendicular right turn lane	Eye Fixation	230	267
Determine traffic situation	Cognitive	70	118
Decide to proceed through intersection	Cognitive	70	118
	Predicted Time:	**1440**	**1954**

Appendix F. Free Response Scoring Criteria from Task 3.2.

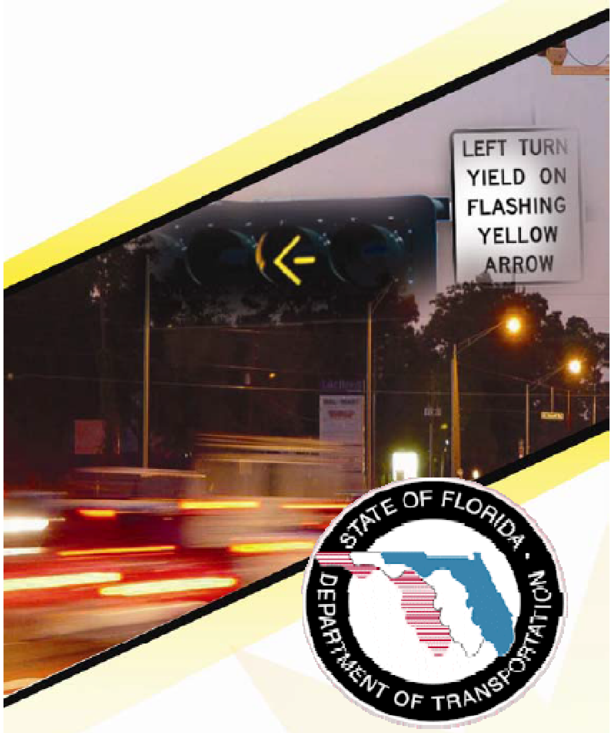
Arrow	Correct Response Must Include	Examples of Correct Responses	Examples of Incorrect Responses
Green	Indicates that left turning driver has the right of way and may proceed with the turn. Responses that say that the left turning driver may go but do not explicitly say that the left turning driver has right of way will still be considered correct.	"Left hand turn allowed. Go." "It means you can proceed left only." "Left turn go."	No incorrect responses given
Steady Yellow	Indicates that the left turning driver should prepare to stop or clear the intersection / complete their turn if they have already entered the intersection when the signal changes. May also say that the signal is about to turn red but need not do this for the response to be considered correct.	"left turn caution prepare to stop" "you need to slow down and prepare to stop" "This signal indicates that I should not enter the intersection and begin to brake."	"That is a green light to turn left if no one's in your way." "Yellow turn arrow. Stop first and may turn left if no other traffic is coming toward you." "I must slow down but I can proceed."
Flashing Yellow	May either explicitly say that the left turning driver does not have right of way or indicate that left turning drivers may proceed when traffic allows, which indicates that they understand that the left turning driver does not have right of way. A response that indicates that the driver must stop first would be considered correct only if the answer also indicated that the left turning driver could proceed with caution / proceed when safe to do so.	"Caution when making left turn." "make a left with caution" "left turn allowed with caution" "left turn proceed with caution prepare to stop"	"slow down and prepare to stop, you can't make the left turn" "To me, it would mean the same as the steady yellow. It might be changing quickly.." "prepare to stop on left turn" "means something is about to occur" "This signal indicates that I should slow down and be ready to stop as I approach the intersection."
Red	Indicates that the left turning driver must stop. May also indicate that the left turning driver does not have right of way, but need not do this for the response to be counted as correct.	"Stop and do not turn while red." "you have to stop, no turning" "do not turn left"	"left"

Response categories for incorrect responses on FYA free response items.

Error Category	Definition	Example Responses
Critical	Any misconception about the FYA signal's meaning that would lead the driver to assuming they have the right of way when they do not. If the participant mistakes the FYA for a SY signal, their response would only be considered a critical error if they indicated that they would hurry to complete their turn before the red signal phase.	"hurry up" "This means the driver has the right of way but to be cautious of other opposing traffic." "I can turn on flashing left" "Red light approaching. Can turn left, if driver has time."
Non-critical	Response suggests that the driver does not understand the meaning of the signal, but the misconception would not lead them to assume they have right of way when they do not. If the participant mistakes the FYA for a SY signal, their response would only be considered a non-critical error if they indicated that they would slow down and prepare to stop.	"left turning vehicles should prepare to stop" "I wait" "slow down and prepare to stop, you can't make the left turn" "the flashing arrow is somewhat distressing. i have never seen a yellow flashing turn light. i would probably slow done to see what is goin on in taffic"
Cannot be Determined	The participant's response does not include enough information to determine what action they would take in response to the FYA signal. If a participant mistakes the FYA for a SY signal but their response does not indicate whether they would slow down and prepare to stop or continue through the intersection, it is not possible to determine whether that response is a critical or non-critical error.	"means something is about to occur" "about to turn red" "caution"

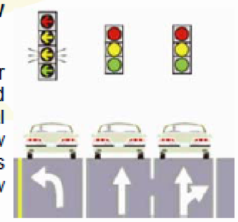
Appendix G. FYA Tip Card

Flashing Yellow ARROW



What you need to know!

What is a flashing yellow arrow?



It is a new type of signal placed over a left turn lane at a signalized intersection where one of the signal indications is a flashing yellow arrow. Other signal indications shown are the green arrow, yellow arrow, and red arrow.

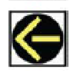
Why is it a better left-turn signal?

Flashing yellow arrows are the result of a national study conducted by the Federal Highway Administration, which demonstrated that the new signal indication:

- Is a low-cost safety measure to help prevent crashes.
- Moves more traffic through an intersection.
- Provides additional traffic management flexibility.
- Provides a clear distinction between when motorists who are turning left are protected from oncoming traffic and when they must yield.

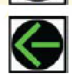
How do they work?

Red arrow means STOP and remain stopped. No left turns allowed.



Yellow arrow means prepare to stop or complete your left turn if you are in an intersection.

Flashing yellow arrow means left turns allowed. Yield to oncoming traffic and pedestrians. The oncoming traffic has green light.



Green arrow means GO. It is safe to turn left, oncoming traffic must stop.

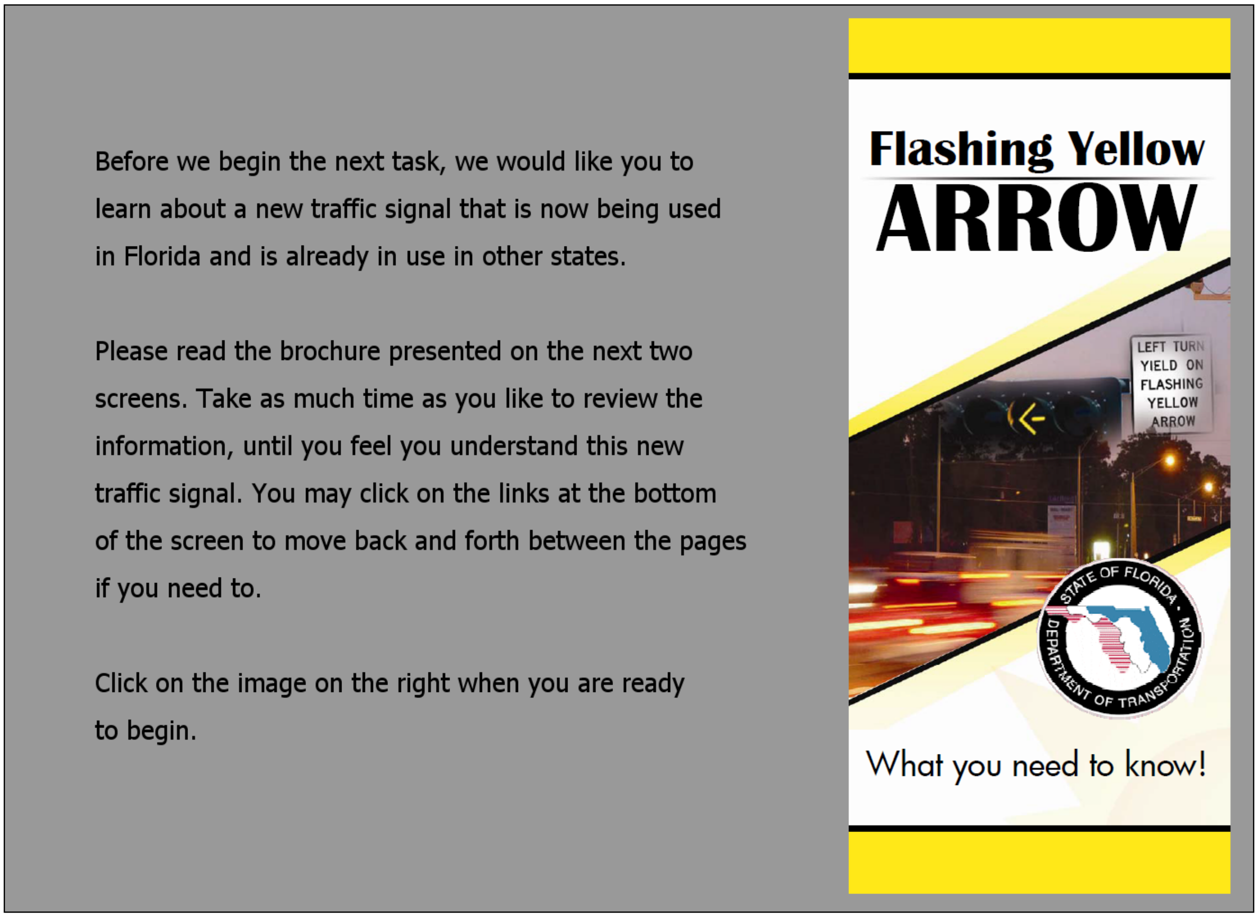
Where will these signals be installed?

FDOT will be installing flashing yellow arrow signals at various locations throughout the state on a case by case basis. We will complete full evaluations prior to statewide implementation.

For more information, visit our Web Site at: www.dot.state.fl.us/trafficoperations/

Computer-Based FYA Tip Card Task

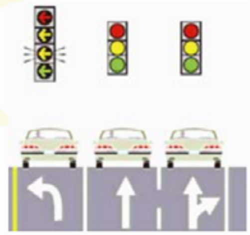
Following the multiple-choice section of the comprehension task, participants who were assigned to the tip card condition saw the following introduction and instruction screen. Participants were able to switch between pages in the tip card by clicking on links at the bottom of each page (see screen captures from task). After participants finished reviewing the tip card, they were given one final chance to review the information before moving on to the response time task. This was done in case a participant clicked the “finished reading” link by mistake. Reading time for each screen was recorded, as well as the number of times a participant went back to review the previous page. Screen captures from the computer-based tip card are presented below.



Introduction screen for the computer-based tip card.

What is a flashing yellow arrow?

It is a new type of signal placed over a left turn lane at a signalized intersection where one of the signal indications is a flashing yellow arrow. Other signal indications shown are the green arrow, yellow arrow, and red arrow.



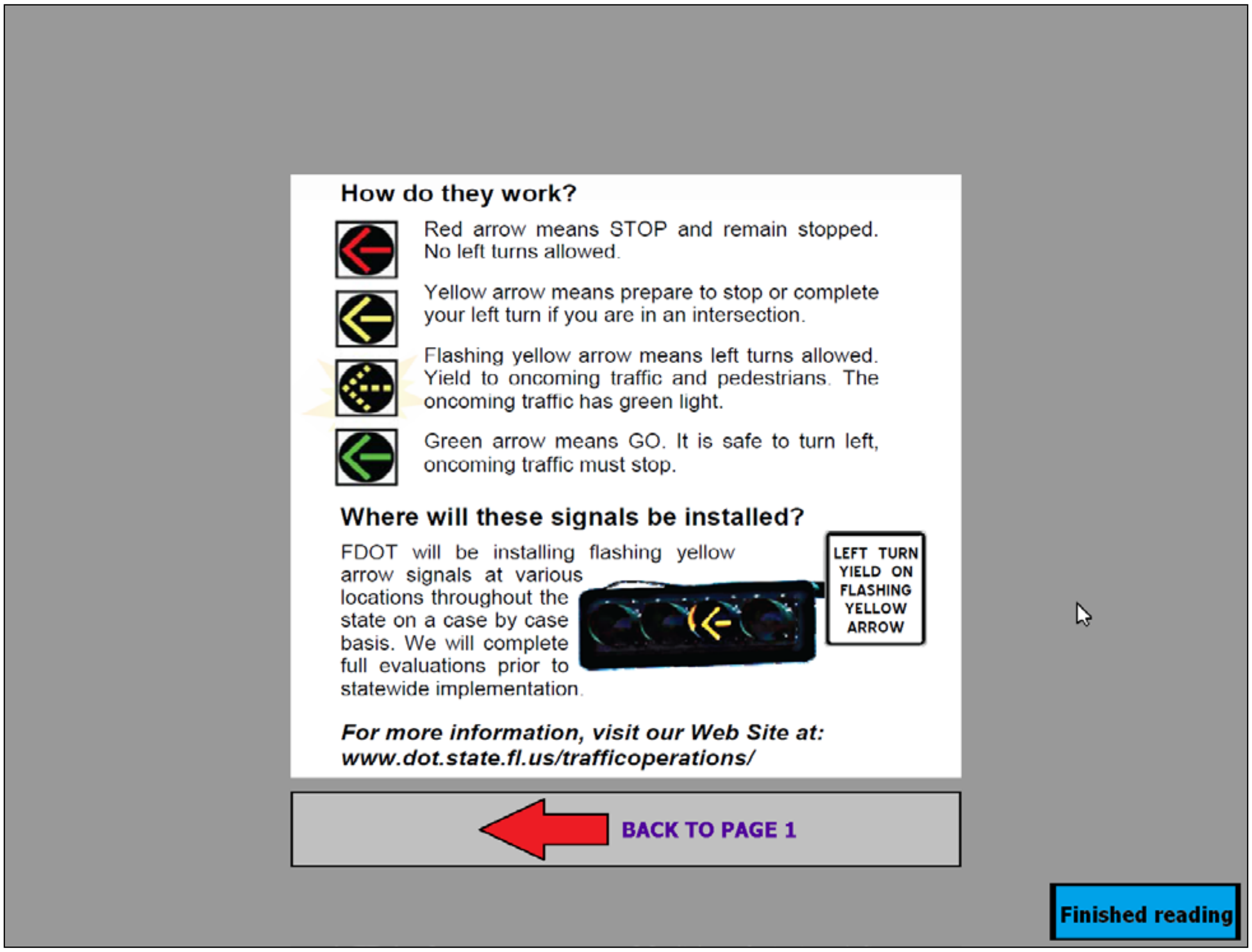
Why is it a better left-turn signal?

Flashing yellow arrows are the result of a national study conducted by the Federal Highway Administration, which demonstrated that the new signal indication:

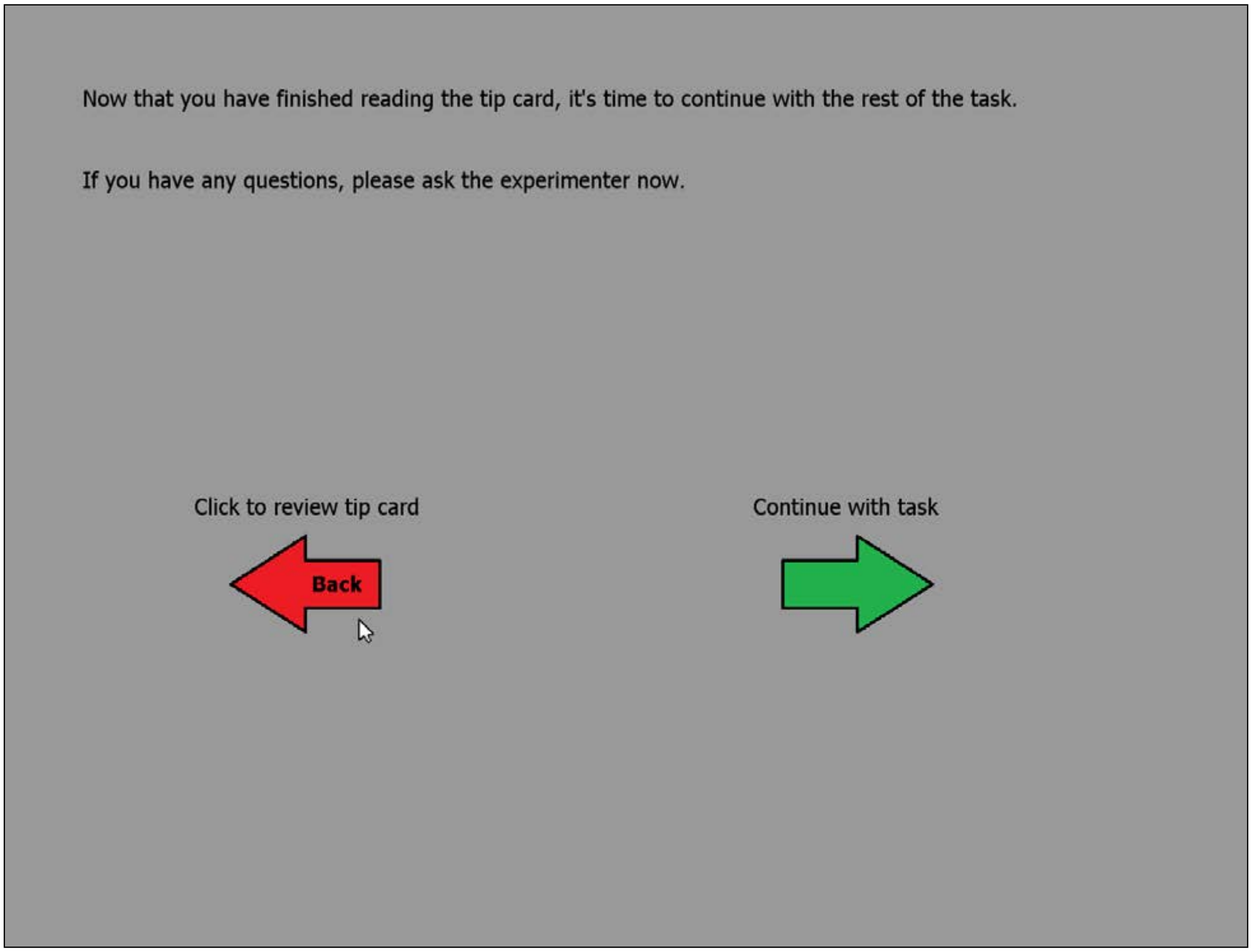
- Is a low-cost safety measure to help prevent crashes.
- Moves more traffic through an intersection.
- Provides additional traffic management flexibility.
- Provides a clear distinction between when motorists who are turning left are protected from oncoming traffic and when they must yield.

CLICK TO GO TO PAGE 2

Page 1 of the computer-based tip card.



Page 2 of the computer-based tip card.



Final screen of the computer-based tip card task.

Present summary statistics about card viewing?

Appendix H. Task 3.3 Scenario Map