Final Report: Aging Driver And Pedestrian Safety: Human Factors Studies BDK83 977-09

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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 Florida Department of Transportation or the U. S. Department of Transportation.

Prepared in cooperation with the 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)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. Source: http://www.fhwa.dot.gov/aaa/metricp.htm (Revised March 2003)

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16. Abstract

We conducted six tasks with younger (ages 21-35), middle-aged (ages 50-64), and older (ages 65 and up) drivers and pedestrians. Task 1 evaluated effective word order for message signs, showing that decision making efficiency for standard orders for Dynamic Message Signs (DMS) and Portable Changeable Message Signs (PCMS) did not differ significantly from experimental orders, though some trends favored experimental orders. Task 2 assessed the role of headlight beam setting on sign perception, showing that fluorescent sheeting was only superior to standard sheeting under low beam conditions. Task 3 assessed the efficacy of supplemental pedestal traffic signals, showing no advantage in driver stopping behavior for pedestal-active conditions. Task 4 evaluated the effectiveness of internally illuminated overhead street signs using standard sheeting compared to highly reflective sheeting. Legibility distance was improved for standard sheeting (vs. reflective) only in middle-aged drivers and marginally for older drivers. Task 5 evaluated the effectiveness of pedestrian crossing buttons using different forms of feedback. An observational study showed a trend (not statistically significant) for an advantage in compliance with traffic signals when enhanced feedback buttons were used at Tallahassee intersections compared to no-feedback buttons. An experimental field study showed better confidence that a button was pressed with enhanced feedback only in middle-aged and older pedestrians. Compliance was related to intersection characteristics - higher for high traffic and longer intersections - and was greatest for middle-aged pedestrians. Task 6 assessed the efficacy of character size for two dynamic message signs, one with 16.8” and one with 18” characters, finding that legibility was greater for the 16.8” character display, though it had 3 times brighter pixels.

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Pedestrian, driver, older driver, signal, age, sign perception, fluorescent, DMS, PCMS, lab study, field study, legibility	No restrictions

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Executive Summary

According to Census Figures for 2009[1] Florida has one of the oldest state populations in the U. S. The estimates show that 3,195,841 of its 18,557,969 citizens are age 65 or older, and 515,070 are age 85 or older. Given the greater vulnerability of these citizens to crashes, both as drivers and as pedestrians, the state tries to provide road environments that can reduce driver and pedestrian error and thereby maximize safety, in accord with the goals of the Florida Department of Transportation's aging road user program, 'Safe Mobility for Life.' We made use of human factors techniques, including lab and field studies, to assess the efficacy of sign and signal characteristics on driver and pedestrian behavior.

The perspective we have taken, particularly for road signs and traffic signals, is that an effective sign will be one that can attract attention, be legible, and be comprehensible soon enough that the observer can safely take appropriate action. We conducted six tasks to assess such features of signs and signals. Task 1 evaluated effective word order for message signs. Task 2 assessed the role of headlight beam setting on sign perception. Task 3 assessed the efficacy of pedestal traffic signals. Task 4 evaluated the effectiveness of internally illuminated overhead street sign names using standard, non-reflective sheeting compared to highly reflective sheeting. Task 5 evaluated the effectiveness of pedestrian confirmation buttons using different forms of feedback. Task 6 assessed the efficacy of character size for two dynamic message signs.

Task 1 revealed that 1) accuracy was reasonably high for a question about the just-displayed information about the license (78%), make/model (91%), year (70%), and color of an alerted vehicle (80%) and did not vary by age of the driver; 2) the standard ordering of phase 2 information and the experimental ordering were roughly equivalent, with slightly better recognition for license tag and make/model in the standard order but slightly superior recognition for model year in the experimental order; 3) Speed of response to the queries was fastest in younger drivers, with middle-aged and older drivers taking roughly 1.5 times longer to respond; 4) response times were slightly shorter for the experimental order; 5) drivers responded more slowly to the license tag query than the year, and responded most quickly to make/model and color queries; age effects were more pronounced in the more difficult judgments. In conclusion, altering message order does not provide an advantage over the standard order for fast-paced judgment tasks about component parts of the message when people attend fully to the Dynamic Message Sign (DMS) display. In a pilot study we examined message order for two phase warning messages displayed on Portable Changeable Message Sign (PCMS). . We obtained a trend for an experimental ordering that showed the action in in an initial phase and distance and cause in a second phase, minimizing fixation time (total eye fixation duration on the display) relative to the MUTCD recommended order where cause and distance are presented first and action is presented second (or to Cause, then Action and Distance). There was also a trend for faster processing when the PCMS was positioned in a compatible location to the action to be taken (e.g., on the left side of the road for a merge left action) for older drivers. Further research should focus on determining the efficacy of such message orders and PCMS placements in simulated driving conditions.

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[1] Table 1. Estimates of the Resident Population by Selected Age Groups for the United States, States, and Puerto Rico: July 1, 2009 (SC-EST2009-01). Source: U.S. Census Bureau, Population Division. Release Date: June 2010.

Task 2 revealed that headlamp intensity (low versus high beams) produced different sign legibility results for a naming task for signs with fluorescent sheeting and standard sheeting. Generally, accuracy was very high for older drivers (94%); however, they had a slight but significant disadvantage compared to younger and middle-aged drivers (99%). For low beams, the fluorescent yellow sheeting was superior to the standard sheeting (greater viewing distance of an additional 40 feet). For high beams, the two sheetings were equivalent in terms of viewing distance (and equivalent to that of fluorescent sheeting at low beam intensity). The expected age differences were found with younger drivers able to identify the sign information at a greater distance than the middle-aged and older drivers, who did not differ. We conclude that that warning signs with fluorescent sheeting are to be preferred to warning signs with standard sheeting for better visibility at night, assuming that drivers are likely to be using low beams as their preferred night driving mode. Low beams seem more likely to be used in city (lit) environments at night and high beams in rural settings, hence it may be best to deploy fluorescent sheeting signs in urban environments.

Task 3's lab study that presented photos for left turn stop/go decisions provided no evidence that adding a pedestal signal aided either accuracy or decision speed for drivers. A field task that required drivers to make left and right turns through an intersection with and without active supplementary pedestal signals showed no evidence that presence of the supplemental pedestal signal affected either the approach speed, time to begin deceleration, deceleration rate, or stopping point for the vehicle on red light trials. Participants' responses to post-experimental questions revealed that most were unlikely to notice when the supplemental signal was activated. . The current lab and field studies yielded no evidence that supplemental pedestal signals aided or distracted drivers under conditions where the main signal was clearly visible.

Task 4's field study, which was run at night, examined the efficacy of standard and reflective sheeting of overhead illuminated street signs in terms of legibility. Average legibility distances did not differ between the two sheeting types for younger drivers. However, for middle-aged and older participants, average legibility distances were larger for the standard than for the reflective signs. There were no differences in sign reading accuracy between participant age groups or between standard and reflective signs. Standard sheeting is to be preferred to reflective sheeting under normal illuminated conditions for overhead illuminated signs.

Task 5 involved both an observational and a field study conducted with pedestrians to assess the efficacy of pedestrian crossing buttons that provided different kinds of feedback (standard no feedback, auditory, auditory plus vibration). In the observational study conducted on Tallahassee streets, crossing buttons at intersections that gave auditory feedback showed a slight tendency toward more use by pedestrians than buttons at intersections without auditory feedback. More button pressing was observed at larger intersections (with more vehicle traffic) than smaller intersections. Compliance with crossing signals (observed in the observational study and self-reported in the field study) varied by age group, with middle-aged pedestrians most compliant and younger pedestrians least compliant. Due to the objective and unobtrusive nature of an observational study, researchers could not approach the pedestrians to inquire their age. Therefore, age group was determined through an estimation based on the pedestrian's physical appearance. Compliance did not differ based on the type of feedback provided by the signal button. In the field study, self-reported compliance was most strongly influenced by amount of traffic at the intersection and size of the intersection. In the field study, participants were more confident that their button press was registered when the signal button provided feedback, either auditory or tactile. In the field study button-pressing condition, confidence that the button was pressed was generally higher for the auditory only and tactile plus auditory signal buttons compared to the non-feedback button, though this was only significant for the middle-aged and older pedestrian groups. It was also the case that confidence that the button was pressed was significantly associated with reported willingness to comply with the traffic signal. Based on this set of findings, although augmented feedback buttons do convey better feedback to middle-aged and older pedestrians, we cannot recommend universal deployment of the more expensive augmented feedback buttons, given the discrepancy between what pedestrians indicate they would do and what they actually do in real settings. A caveat is that real settings contain numerous uncontrolled variables that may have obscured small differences in compliance favoring feedback buttons. For example, more expensive feedback buttons may already have been deployed at intersections where there is generally less compliance. Hence, the presence of the augmented feedback button would not have a major effect on pedestrian compliance.

In Task 6, the legibility for 16.8” characters on a Daktronics Vanguard VF-3000 was compared to that for a standard Precision Solar Controls SMC-1000-ST featuring 18” characters to attempt to see if smaller characters would “bloom” to be equivalent to larger ones permitting observers to read the sign equally well. However, the Daktronics pixels were 3 times as bright as the Precision Solar Control pixels. Thus we could not make an unbiased comparison to assess blooming effects independent of luminance effects. The Daktronics sign showed a significant advantage in accuracy and confidence that increased with sign distance. Accuracy declined with distance and with age of observer. We conclude that the Daktronics sign is associated with better legibility than the larger character size Precision Solar Controls sign. Further study is needed to assess how much of the advantage is due to the brightness difference for pixels relative to any blooming effect for the smaller characters.

Table of Contents

List of Tables

List of Figures

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Chapter 1. Rationale for and Description of the Studies

Introduction

The population in the United States continues to age. In 2000, 12 percent of the US population was over the age of 65 and 1.5% were 85+. As of 2009 (year of the latest available estimates), those who were 65 years of age or older made up about 13% of the population, while those who were 85 years of age or older made up about 2%. In Florida, 17% of the population in 2009 comprised adults aged 65 or older and 3% of the population was comprised of adults 85 years of age or older. (United States Census Bureau, 2009). To accommodate normative age-related changes in perceptual, cognitive, and psychomotor processing (e.g., Fisk et al., 2009) in order to provide safe mobility for life (e.g. Florida Department of Transportation, 2010) it is necessary to design a safer roadway system (Transportation Research Board, 2004). Older adults face a greater risk on the road because of age-related declines in both physical (e.g., bone density) and physiological functioning. Thus, their chances of being seriously injured or killed in a crash are much higher (e.g., Evans, 2004). Similarly, older pedestrians are more at risk of death in a crash than their younger counterparts (Dunbar et al., 2004; Evans, 2004; Oxley, Fildes, & Dewar, 2004).

In an attempt to reduce the number and severity of roadway crashes, researchers have adopted a human factors approach (Wickens, Lee, Liu, & Becker, 2004). The discipline of human factors uses a set of rigorous methodologies to understand the interaction between humans and other elements of a system (e.g., roadways; Karwowski, 2006) in order to optimize human well-being and system performance. A useful model is to consider factors such as sign/signal salience, attention, and age.

In terms of roadway design, the roadway, including its signs, medians, barriers, and other roadway objects, and the drivers and pedestrians who use it are the system of interest. Approaches to improving this system could include improved driver screening, training, and better design of roadway environments. With respect to screening, Ball and colleagues (2006) found that in a large sample of older adults, those who performed worse on a useful field of view (UFOV) task were more likely to be involved in an automobile crash within years of the UFOV measurement. Others (Owsley et el., 1991; Sims et al., 2000) have reported similar findings. However, in a study measuring the predictive value of this assessment tool, Bédard and colleagues (2008) found that, although statistically significant in relation to driving performance, the UFOV was of limited predictive value in determining older adults' fitness to drive (Bédard, Weaver, Darzins & Porter, 2008). This study also found limited predictive ability with other assessment tools such as the Trails A Test and the Mini-Mental State Examination, as well as individuals' past crash records.

Driving simulators, on the other hand, may provide a viable option for assessment and training. In a study looking at the correlation between driving performance in a simulated environment and actual performance five years after assessment, Hoffman and McDowd (2010) found that, in a sample of older adults, those who displayed impaired performance in the simulator were more likely to have an at-fault accident within 5 years of assessment. This suggests that driving simulators may be of use in assessing driving ability. Unfortunately, users of driving simulators on occasion experience what is termed simulator sickness—a form of motion sickness, whose symptoms include oculomotor disturbance and disorientation (Kennedy et al., 2010). The impact that simulator sickness has on attrition could be either mild or extreme depending on the nature of the virtual environment (Reason & Brand, 1975). In one case, Edwards and colleagues (2002) experienced 40% attrition due to sickness. Fortunately, researchers are finding that users can be habituated to simulators by exposing them to the devices on multiple occasions (Howarth & Hodder, 2008; Smither et al., 2008).

Improving the road itself is, of course, one of the more effective ways of improving driver and pedestrian safety. Roadways could always be improved in various ways, such as by using wider lanes, reflective lane markings, brighter and larger signs, etc. However, because state agencies are limited by their budgets, improvements need to be made where they are the most effective. Human factors research is a valuable tool for measuring the efficiency of potential improvements and can guide state agencies wishing to allocate funds effectively.

Humans tend to have limited information processing capabilities and allocate their attention serially to different features in the environment according to their salience. In general, salient features are more conspicuous than non-salient features. With roadway signs, for example, a high contrast ratio between the text/symbol of a sign and its background will make the sign easier to read. This is a pretty simple concept, however, when it comes to more complex signs or placing complex or non-complex signs in visually complex locations, the legibility of a sign will become more difficult to predict. In their theory of Feature Integration, Treisman and Gelade (1980) argued that some features such as color, size, and some aspects of shape, act as preattentive features that “pop-out” to a viewer. For example, with a simple 2-color sign, if the color of the text or symbol of the sign is different from the background, then the text or symbol should be very easy to discern for the viewer. However, if a sign has multiple colors or if multiple items on a sign have the same color, then discerning the main message of the sign may be more difficult. A similar rule holds for luminance (Wickens et al., 2004). The ability to discern a sign’s message becomes increasingly difficult as the luminance ratio of the sign’s foreground to background decreases. Indeed, a sign’s luminance may be one of its more important features. Mace, Garvey, and Heckard (1994) found that smaller signs can compensate for their size by being more luminous. For example, they found that a small 24-inch reflective sign can produce the same legibility distances as a larger 36-inch standard sign.

Feature Integration Theory also has implications for sign placement. That is, if a sign contains the same features as the objects which it is partially occluding, then that sign would be more difficult to detect than a sign that contained different features. For example, a sign with a green background would be relatively difficult to detect if it was partially occluding a green building, but less difficult to detect if it was partially occluding a white building. Mace, Perchonok, and Pollack (1982) argued that it’s possible to compensate for such visual complexity by increasing the brightness of the sign.

Also, driver expectations may be critical to the process of attending to roadway signs and signals. Wickens and colleague’s (2003) SEEV model of selective attention best describes attention on the roadway. This model takes into account the saliency, effort, expectation, and value placed on an object. For example, for a driver to notice a traffic signal, it is ideal if that signal allows for the driver to use as little effort as possible to attend to it, that it’s salient enough for the driver to notice it, that the driver expects it, and that the driver places an appropriate amount of value on noticing and reacting to it. Value refers to the amount of importance placed on noticing an object. For example, a driver would usually place more value on noticing a stop sign or traffic light than on noticing the sign for a retail store. Expectancy refers to the probability of an event taking place. In the roadway example, a driver would more likely expect a lighted signal to change from green to yellow than for a pedestrian to run out in front of their vehicle.

Usually, important signals on the roadway require minimal effort from drivers to attend to them; however, a situation could arise where a driver has to use more effort to attend to a signal. For example, in stop-and-go traffic, a driver, who is paying needed attention to a lead vehicle, would have to expend more effort than normal in reading a road-side sign.

As mentioned earlier, driver age is an important consideration in roadway design. Aging typically degrades perceptual, cognitive and psychomotor functioning (Fisk et al., 2009), and this can be seen in laboratory studies of perception of traffic signs showing older driver legibility distances to be about 80% of those for younger ones (Dewar, Kline, Scheiber & Swanson, 1997). Thus, special care is needed to ensure that roadway design works well for older drivers and pedestrians.

To investigate age as a factor, we adopted the strategy of sampling younger, middle-aged, and older adults. Further, we make use of lab, field, and observational studies to assess sign and signal perception and comprehension and their role in decision making. Each methodology has strengths and weaknesses. Laboratory studies have high internal validity, given the ability to have tight control over experimental variables, but have questionable external validity (ability to generalize to real world settings). Field studies have high external validity but may lack internal validity because of the difficulty of controlling for all factors present in the field. Observational studies are not capable of determining cause and effect relationships but can show associations among variables that can point to risk factors. Together these methodologies can help uncover relevant data for informed design decisions.

Objectives and Supporting Tasks

Both pedestrians and drivers require guidance from signs and signals in order to navigate road systems safely. The purpose of this project is to improve our knowledge about the factors affecting sign and signal legibility and usability in order to develop appropriate guidelines for the Florida Department of Transportation (FDOT) and for local governments that depend on their recommendations. By addressing the needs of an aging population through sampling drivers and pedestrians across the life-span, we are better able to fulfill the goals and objectives of the Safe Mobility for Life Coalition's Aging Road User Strategic Safety Plan:
http://www.safeandmobileseniors.org/FloridaCoalition.htm#Strategic_Plan).

We employed a combination of lab-based and field-based tasks and observational studies using a range of younger (ages 21-35), middle-aged (ages 50-64), and older (ages 65 and up) driver and pedestrian populations. Projects were carried out at the Traffic Engineering and Research Lab (TERL), 2612 Springhill Road, Tallahassee, Florida, supplemented by lab-based tasks at Florida State University, and at Broadmoor Estates, an appropriated housing neighborhood[2], that was needed to be able to provide adequate distance to warning signs for one study.

[2] We thank Blueprint 2000 http://www.blueprint2000.org/about.html for permission to use Broadmoor Estates.

Chapter 2. Message order for DMS and PCMS signs

Changeable message signs, both dynamic message signs (DMS) and portable changeable message signs (PCMS), are used to signal abnormal traffic situations and to provide alerts to drivers. However, such signs have limited space available for portraying text messages. A driver approaching a sign may attend to, perceive, and comprehend the message at varying distances from the sign, and depending on speed of approach, may not have the time to see the full cycle of text displays. Further, in the case of missing person Silver (cognitively-impaired older adult) and Amber (abducted child) Alerts (see http://www.floridasilveralert.com/ and http://www.fdle.state.fl.us/MCICSearch/Amber.asp), the driver (or passenger) must remember information long enough to write it down or make a phone call when they detect the target vehicle. Hence, guidelines have been developed for displaying multiple text lines over time across the message face.

In Florida, following suggestions in the MUTCD, the suggested order for alerting motorists to traffic situations (emergencies, construction, and maintenance closures) is to present information in the order of problem, location of problem, and action that the driver should take (Florida Department of Transportation, 2008).

For public information announcements such as Silver and Amber Alerts, information is typically provided in two phases, with the first phase indicating the type of alert (e.g., child abduction for an Amber Alert), and the second phase identifying information for the target vehicle in the order: color, year, make, model, license tag, and a phone number to call (Figure 1). It is reasonable to assume that the license tag may be the most critical factor in determining whether a viewer will call in a sighting, given that car color, make, model, and year do not uniquely identify a target. We assessed for Silver and Amber Alerts whether the standard order or one placing the tag number and phone number in the top line leads to better recall of that critical information by viewers of the sign. As well, given the slower rate of processing of text information by older adults, putting the license tag higher in the message frame (assuming a left-to-right, and top-to-bottom reading strategy), may provide the time needed to read and remember the tag information if older adults choose to allocate most of their effort to remembering that critical identifier.

Task 1: Efficacy of DMS Message Order, Lab Task

The task 1 laboratory study was designed to evaluate the memorability of information displayed on Dynamic Message Signs (DMS) using either the standard order or an experimental order that placed license tag information in the top row of the second phase of the message.

Method.

Participant Screening

For all participants, the requirements for inclusion were that they had a valid driver's license, owned a vehicle, were able to drive at night, drove at least twice a week, and did not show significant deficits in intellectual functioning. All participants completed the following screening measures by telephone to determine eligibility for inclusion: The Short Portable Mental Status Questionnaire (SPMSQ) and Logical Memory I (LM I) subtest from the Wechsler Memory Scale – Revised Edition (WMS-R). In order to be eligible to participate, those with up to 12 years of education could make no more than two errors on the SPMSQ, while those with 13 years of education or more could make no more than 1 error. On the LM subtests from the WMS-R participants were required to earn a maximum of 7 points out of 25 on Story 1 in order to be included in the study. If participants failed Story 1, Story 2 was administered. If the participant then earned a score of 7 points out of 25 points on Story 2, they were eligible to be included in the study. These tests were meant to screen out those with severe memory problems or dementia. Participants screened into the study filled out an IRB-approved informed consent document when appearing in person for the experiment or field study.

Participants

The participants were 61 community dwelling younger (n = 20, M = 22 yr), middle aged (n = 20, M = 58.3 yr), and older (n = 21, M = 71.7 yr) drivers recruited from the Tallahassee, Florida area via newspaper ads and word of mouth. Participants were paid $10/hr for taking part in the study.

Design

The study used a 3 x 4 x 2 mixed design. Age (younger, middle, older) was the between subjects factor. Question content (tag number, vehicle make/model, model year, and vehicle color) and message presentation order (standard vs. experimental) were within-subjects factors.

Stimuli

Participants were shown a set of 64 images designed to simulate the DMS message standards. Each image conformed to the current MUTCD guidelines with a close approximation of the amber color utilized, font, the ratio of letters and spaces, the length of words allowed, and acceptable abbreviations when required. License plate numbers were randomly generated based on observed randomization factors within existing license plates. Each trial would consist of two displays to simulate a flashing display. The first phase would signal whether the alert type was a Silver or Amber Alert (Figure 1).

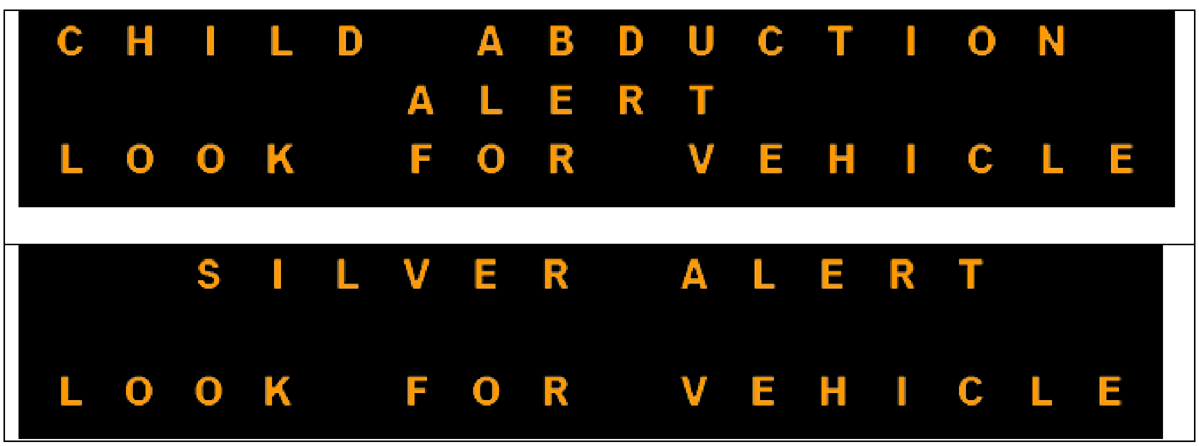

Figure 1. Amber (top) and Silver (bottom) Alert message examples

The second phase, shown in Figure 2, conformed to current MUTCD regulations (see: http://mutcd.fhwa.dot.gov/res-memorandum_amber.htm.

Figure 2. Standard example of Phase 2 of Amber or Silver Alert

The experimental manipulation in the current study placed the license plate number and number to call at the top line and moved the remaining lines down (Figure 3).

Figure 3. Experimental changed ordering example of Phase 2 of Amber or Silver Alert

Procedure

The 64 stimulus items were presented in one of three pseudorandom orders. Each sign was unique with respect to the combination of license tag (32 pseudorandomly generated tag numbers, each used twice), make, model, color, and year of vehicle. Each trial began with phase one of the sign, which signaled whether either a Silver or Amber Alert message would follow. Participants were instructed to press a key to display the second phase. The second phase of the sign contained the vehicle information and was displayed for three seconds.

After the presentation of both cycles, participants were then asked four questions about the license tag number, make/model, model year, and color of the vehicle described in the message from the previous trial, for a total of 256 questions (4 for each of the 64 stimuli). The questions were all in the following format:

"Was the license tag XXX-XXX?"

This format was intended to match up with a decision process envisioned for a real message, where a driver (passenger) would have to decide when seeing a new car after the sign whether the tag or other features matched the recently seen alert information on the DMS. If yes, the feature matched, they would make a phone call, and if not, they would keep searching characteristics of other vehicles in their field of view.

Make and model were asked as a combined pair and did not present impossible combinations (i.e. Ford Camry), while questions about car color, and model year were asked as separate questions. Model years were verified for accuracy of production to verify that they did not present impossible combinations as well.

Participants were instructed to answer "yes" or "no" as quickly and accurately as possible. The next trial began as soon as an answer was given. The number of match versus mismatch trials was balanced across each question type so that the correct answer was "yes" for half of the questions and "no" on the remaining questions.

Results

Message Content Recognition Accuracy

There was a main effect of question content on recognition accuracy, $F(3,174) = 53.92$, $p < .001$, $\eta_p^2 = .48$ Participants were more accurate in recognizing the make and model of vehicles (M = .91, SD = .07), showed similar accuracy in recognizing the license tag number (M = .78, SD = .12) and color of vehicles (M = .80, SD = .09), and were least accurate in recognizing the model year (M = .70, SD = .11) (see Figure 4).

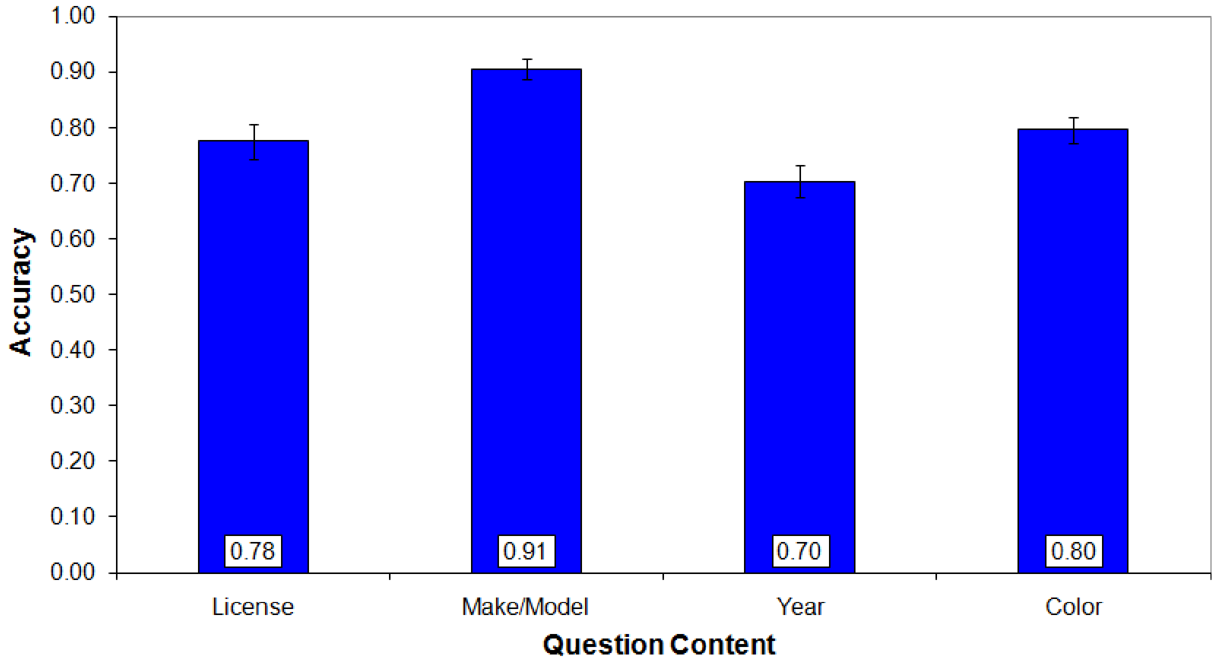

Figure 4. Recognition accuracy by question content. Error bars show the 95% confidence intervals in this and subsequent Figures.

There was also a main effect of message order such that participants were more accurate at recognizing information presented in the standard presentation order (with license tag presented in line 3) compared to the experimental order (with license tag presented in line 1), $F(1,58) = 16.12$, $p < .001$, $\eta_p^2 = .22$ (see Figure 5).

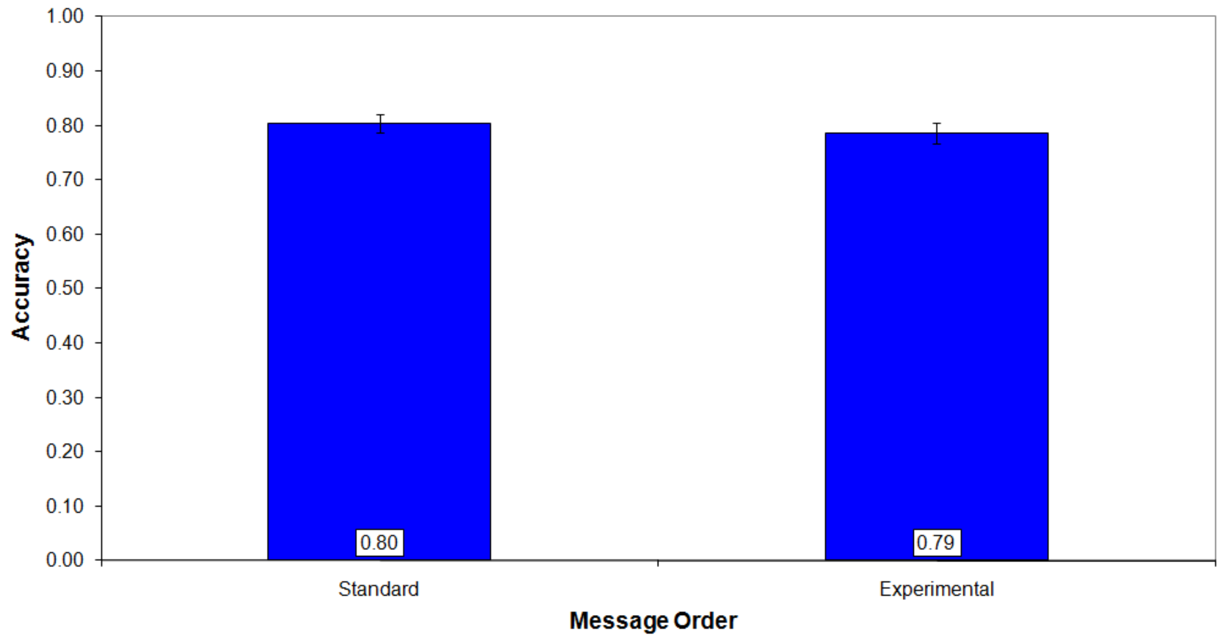

Figure 5. Recognition accuracy by message display order.

These main effects were qualified by a significant interaction between message display order and question content, $F(3,174) = 6.54$, $p < .001$, $\eta_p^2 = .10$. For questions about license tag and vehicle make/model, participants' recognition accuracy was best when messages were presented in the standard order ($\eta_p^2 = .12$ and .23, respectively). In contrast, participants' recognition accuracy for questions about model year was significantly better for messages presented in the experimental order, $F(1,60) = 5.45$, $p = .02$, , $\eta_p^2 = .08$. Performance on questions about vehicle color did not differ significantly between the two experimental orders, $F(1,60) = 3.79$, $p = .06$, $\eta_p^2 = .06$ (see Figure 6). There was no main effect of age on response accuracy, $F(2,58) = 1.23$, $p = .30$, $\eta_p^2 = .04$, nor did age interact with any other factor. Recognition memory was similar across age groups, regardless of message content or presentation order (see Figure 7).

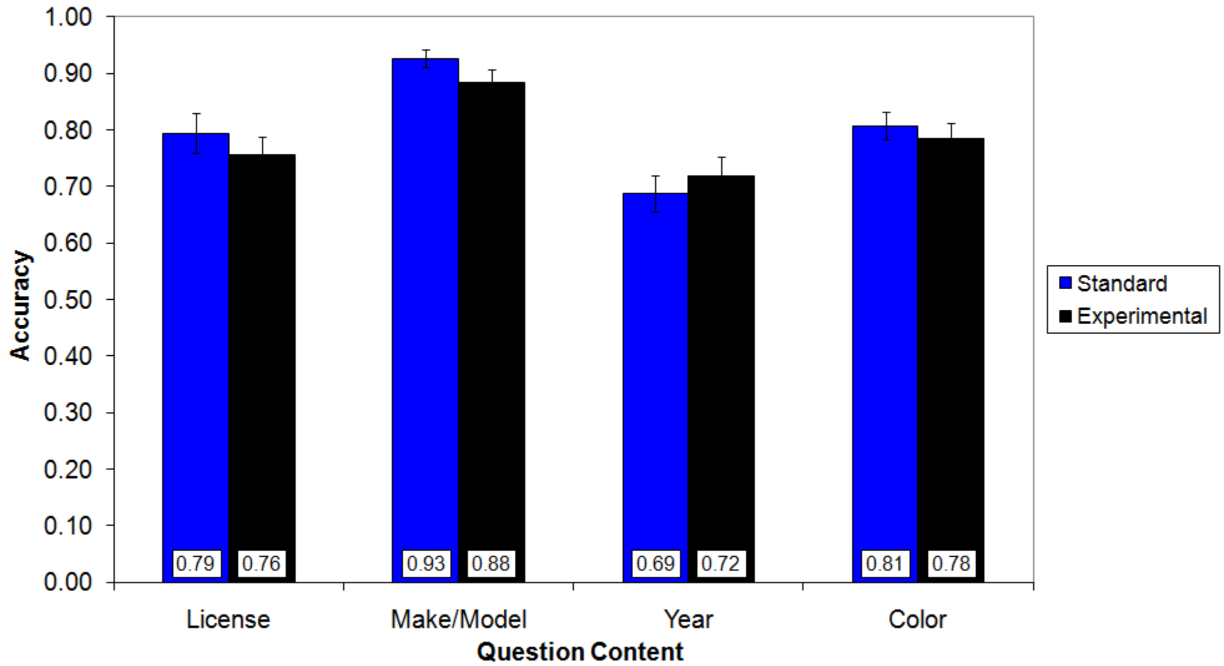

Figure 6. Response accuracy by question content and message order. Error bars show the 95% CI.

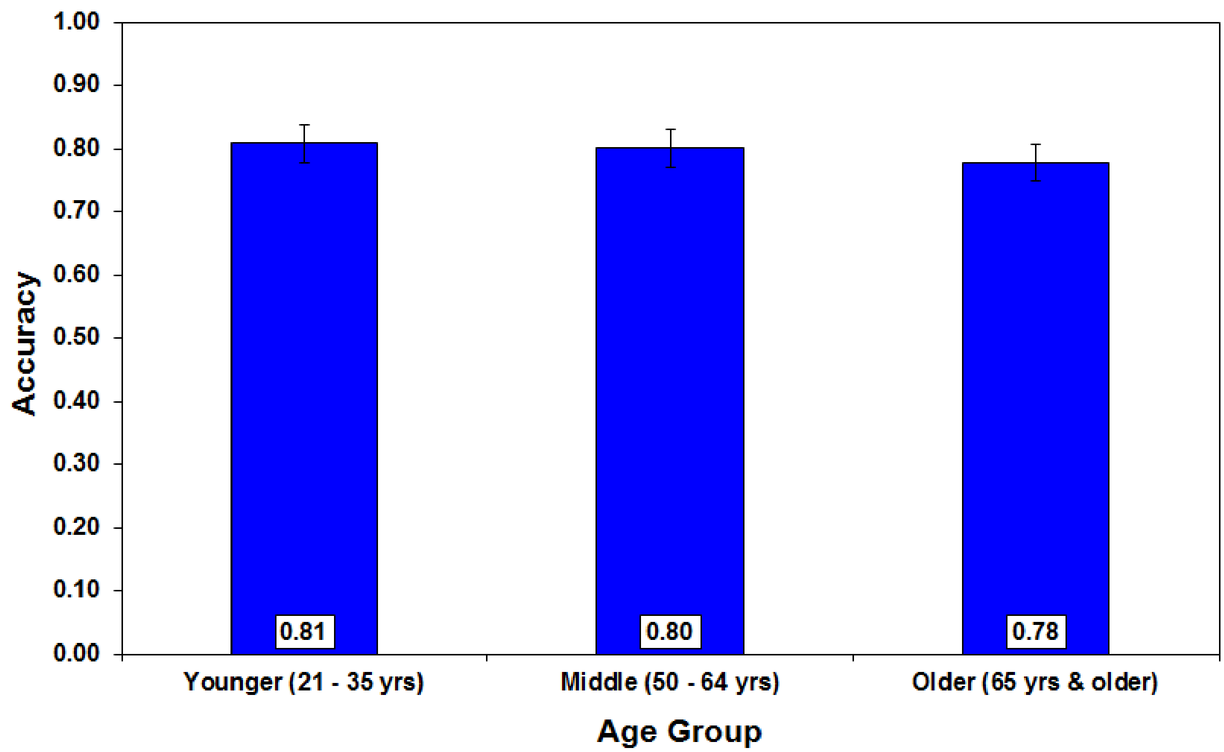

Figure 7. Response accuracy by age group. Error bars show the 95% CI.

Response Time

Paralleling the findings for message recognition accuracy, we also found main effects for question content, $F\,(3,174) = 102.73$, $p < .001$, $\eta_p^2 = .64$, and message presentation order, $F(3,58) = 12.99$, $p = .001$, $\eta_p^2 = .18$ for response time for accurate responses (see Figures 9 and 10). In contrast to the results for recognition accuracy, we also found a main effect of age on response time, $F(2,58) = 14.21$, $p < .001$, $\eta_p^2 = .33$. Younger adults' average response times were significantly faster than middle or older adults' response times, but the average response times for middle and older adults did not differ from one another (see Figure 8).

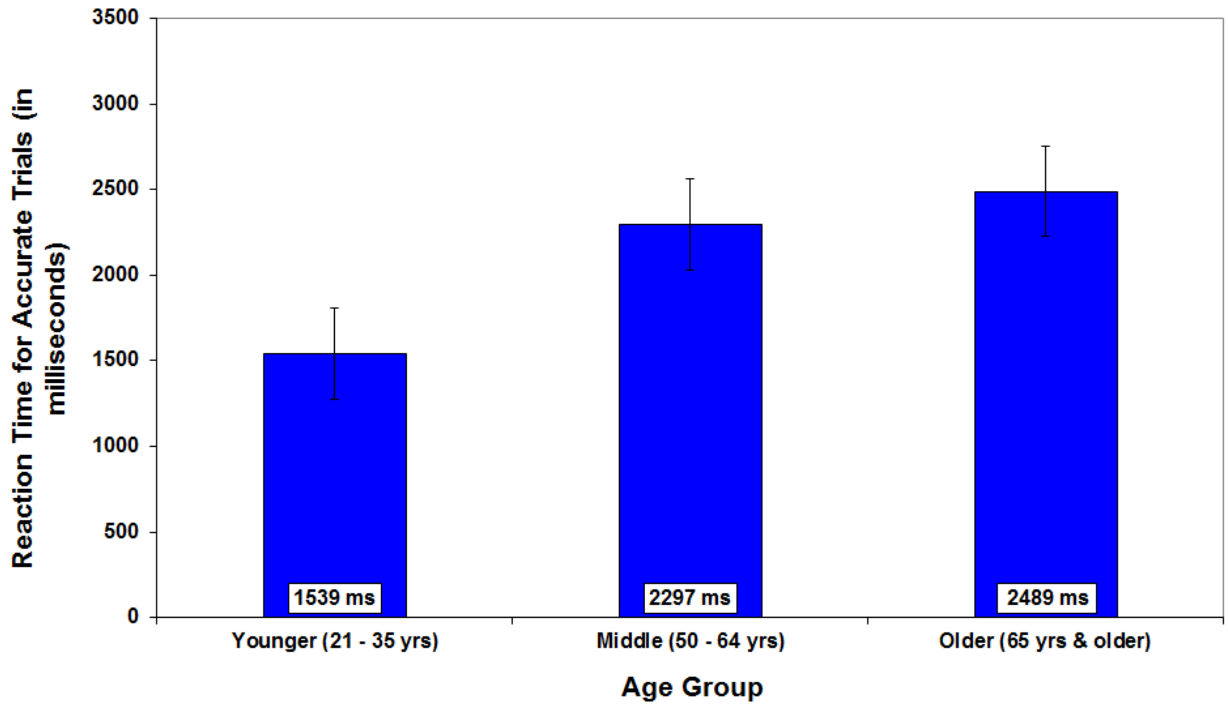

Figure 8. Response times for accurate responses by age group

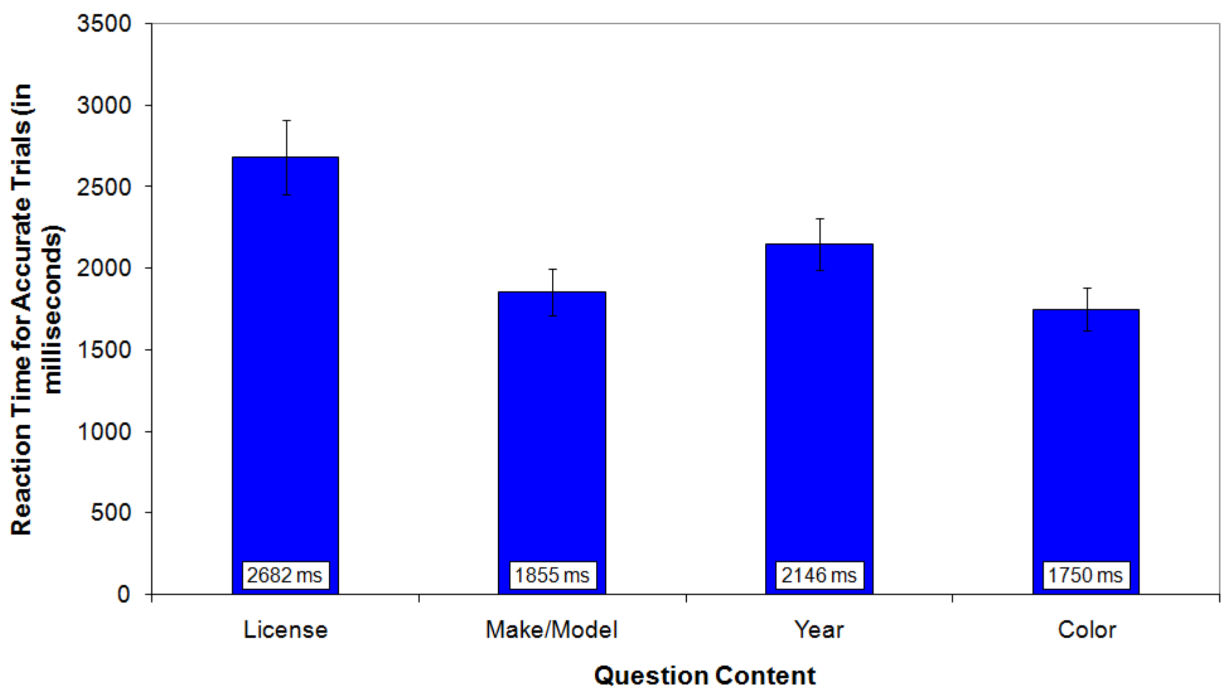

Figure 9. Response time by question content

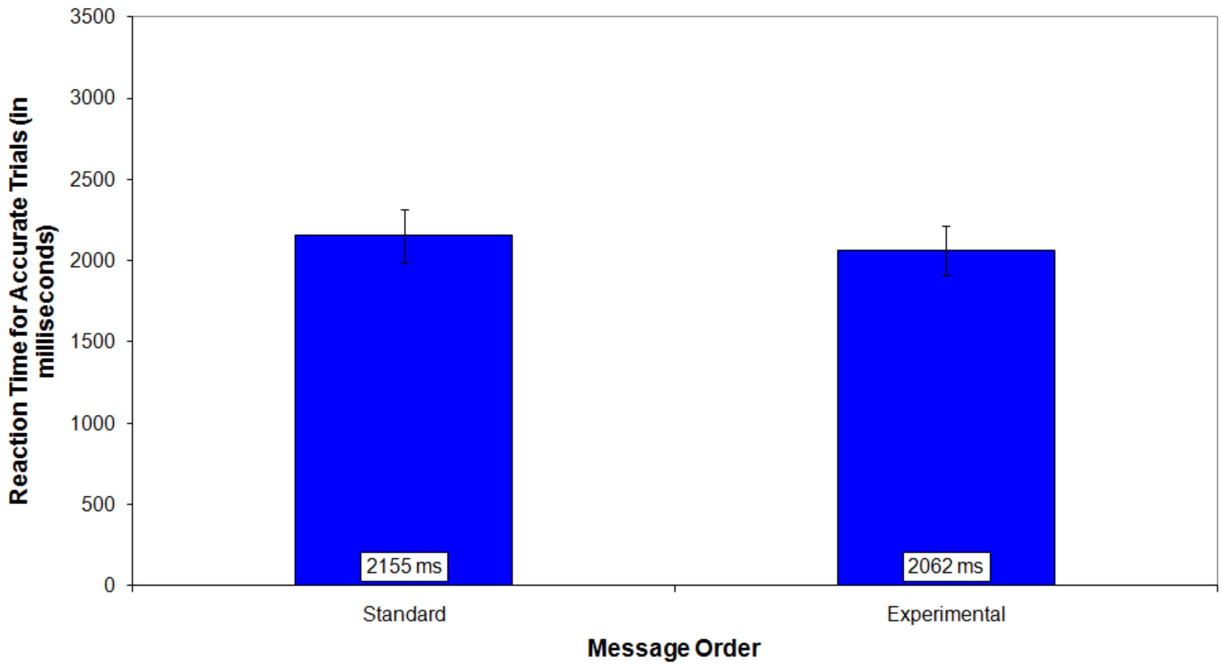

Figure 10. Response times by message order

The main effects of question content, message order, and age were qualified by significant interactions between question content and message order, $F(3,174) = 3.91$, $p = .01$, $\eta_p^2 = .06$, as well as question content and age, $F(6,174) = 3.39$, $p = .003$, $\eta_p^2 = .11$. For messages presented in the experimental order, participants were able to answer questions about model year, $F(1,60) = 10.89$, $p = .002$, $\eta_p^2 = .15$, and color, $F(1,60) = 10.35$, $p = .002$, $\eta_p^2 = .15$, significantly faster. However, for questions about license tag and vehicle make and model, response times did not differ between the experimental and standard orders, $F < 1$ and $F(1,60) = 3.29$, $p = .08$, respectively (see Figure 11).

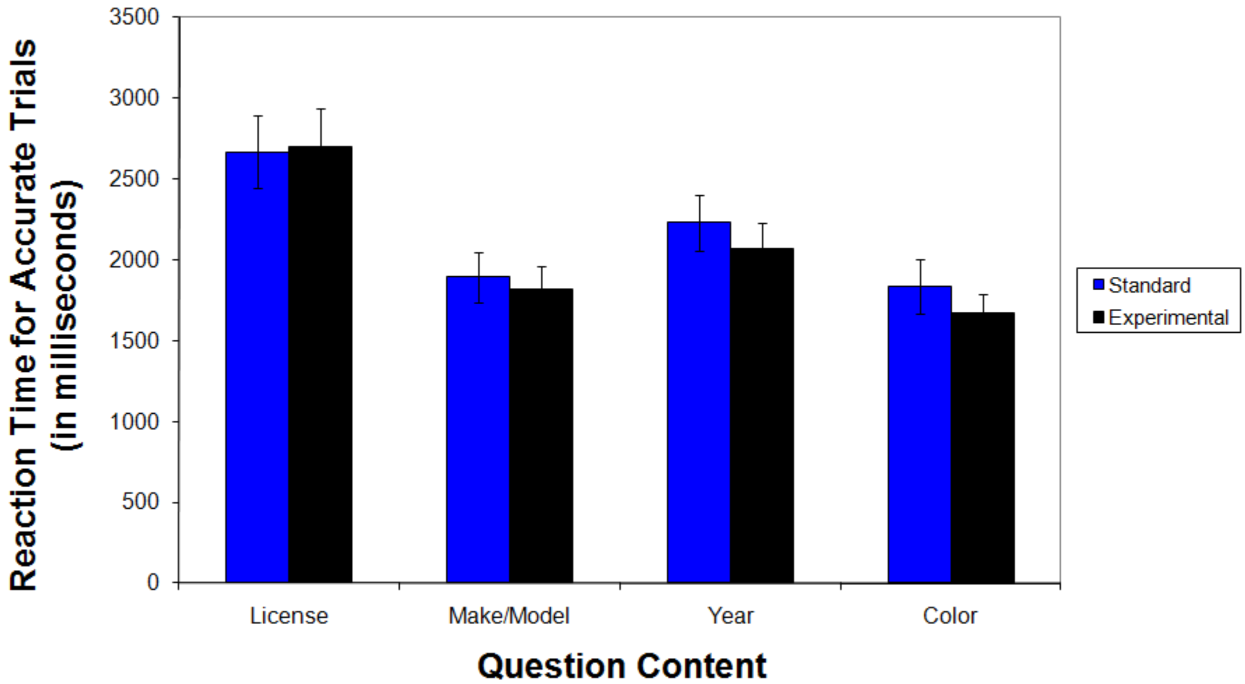

Figure 11. Response time by question content for standard and experimental message orders

Age differences in response speed differed as a function of question content, $F(6,174) = 3.39$, $p = .003$, $\eta_p^2 = .11$, such that younger adults responded significantly more quickly than older and middle adults regardless of question content, but this difference was largest for questions asking about license tag number and model year. Response speed did not differ between middle and older adults, regardless of question content (see Figure 12).

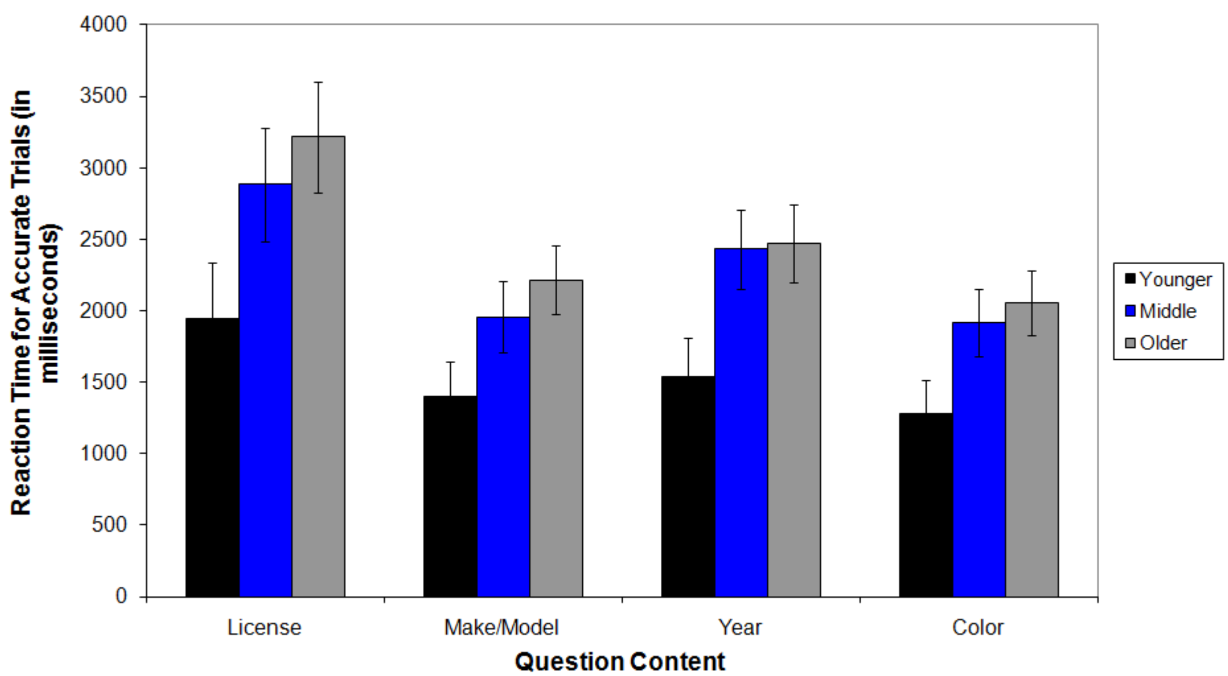

Figure 12. Response time by question content for younger, middle, and older adults

Conclusions

Overall, our results suggest that recognition memory for the information present in Silver and Amber Alert messages is best when messages are in the current standard order, with vehicle color, year, make, and model presented first and with the car's license tag presented in line three. In particular, the difference in memory performance favoring the current standard presentation order was largest for questions about the car's make and model.

Task 1 Pilot Study: Eye-Tracking – Sign Order Effects on PCMS message Comprehension

In this pilot study we made use of a high resolution eye tracker in order to examine in more detail the cognitive processes that are engaged when a driver reads a PCMS message. In particular, we examined the pattern of fixations (times when the eye was fixed on part of the message) in order to better understand the specific pattern of attention to sign elements. This was a laboratory study that used simulated messages and examined the recommended (MUTCD) orders for message elements, and experimental orders.

The MUTCD recommends an ordering for information of cause, distance, action. That is, if traffic is to be directed to merge to the left because of an obstruction in the right lane in 1000 feet, there are two options for a two phase message: 1) show cause "right lane ends" and distance "1000 feet" in the first phase, then action in the second phase "merge left", or 2) show cause only in the first phase, then action and distance in the second phase. The reason for emphasizing the cause first in both cases is to encourage the driver to comply with the action recommendation in the second phase. However, it is always going to be unclear when the driver encounters a phase, and an argument can be made that the most critical information to convey is the action if only one part of the message is heeded. Thus, we also examined how attention was allocated for two experimental orders that displayed action, distance in phase 1 and cause in phase 2, as well as action if phase 1 and cause, distance in phase 2.

Method

Design

Fifty-one photographs from a real PCMS device were used to construct sequences of 24 two-phase messages shown to drivers on a computer screen and their eye movements were recorded with eye-tracking equipment. Signs were shown half the time on the left and half on the right side of the screen. Examples of message content are shown in Figure 13.

Figure 13. Example two-phase messages presented as photographed from PCMS signs

Participants

Participants were 13 young (M = 21, SD = 0), 9 middle-aged (M = 59.8, SD = 4.8) and 11 older adults (M = 74, SD = 5.4). All participants completed the prescreening measures described in the previous section to determine eligibility to participate in the study. Participants were paid $10 per hour.

Procedure

Each trial consisted of two images displayed for 3 seconds each within a full 6 second cycle. The images looped until the participant entered a response by pressing the left or right button on a gamepad, indicating the direction to aim their car to comply with the message action.

Results

Total Viewing Time:

Eye fixations (number and time/fixation) were summed to produce a total viewing time. There was a significant effect of age, $F(2, 129) = 19.4$, $p < .01$, MSe = 1719560, with young drivers significantly faster to process the display than middle-aged and older ones (with the latter two equivalent). There was also a significant effect of message order, $F(3, 128) = 4.27$, $p < .01$, MSe = 2049453, with the experimental ordering in Condition 4 (Action/Distance & Cause) significantly faster than the MUTCD sanctioned Condition 2 (Cause/Distance & Action) and the experimental order in Condition 3 (Action & Distance/Cause). There was a trend for a significant interaction, F (6,90) =

2.344, p < .04, MSe = 709361, when assuming sphericity, but more conservative tests (Greenhouse-Geisser, Huynh-Feldt, Lower Bound) indicate that it was not statistically significant (p between.12 to .07)(see Figure 14).

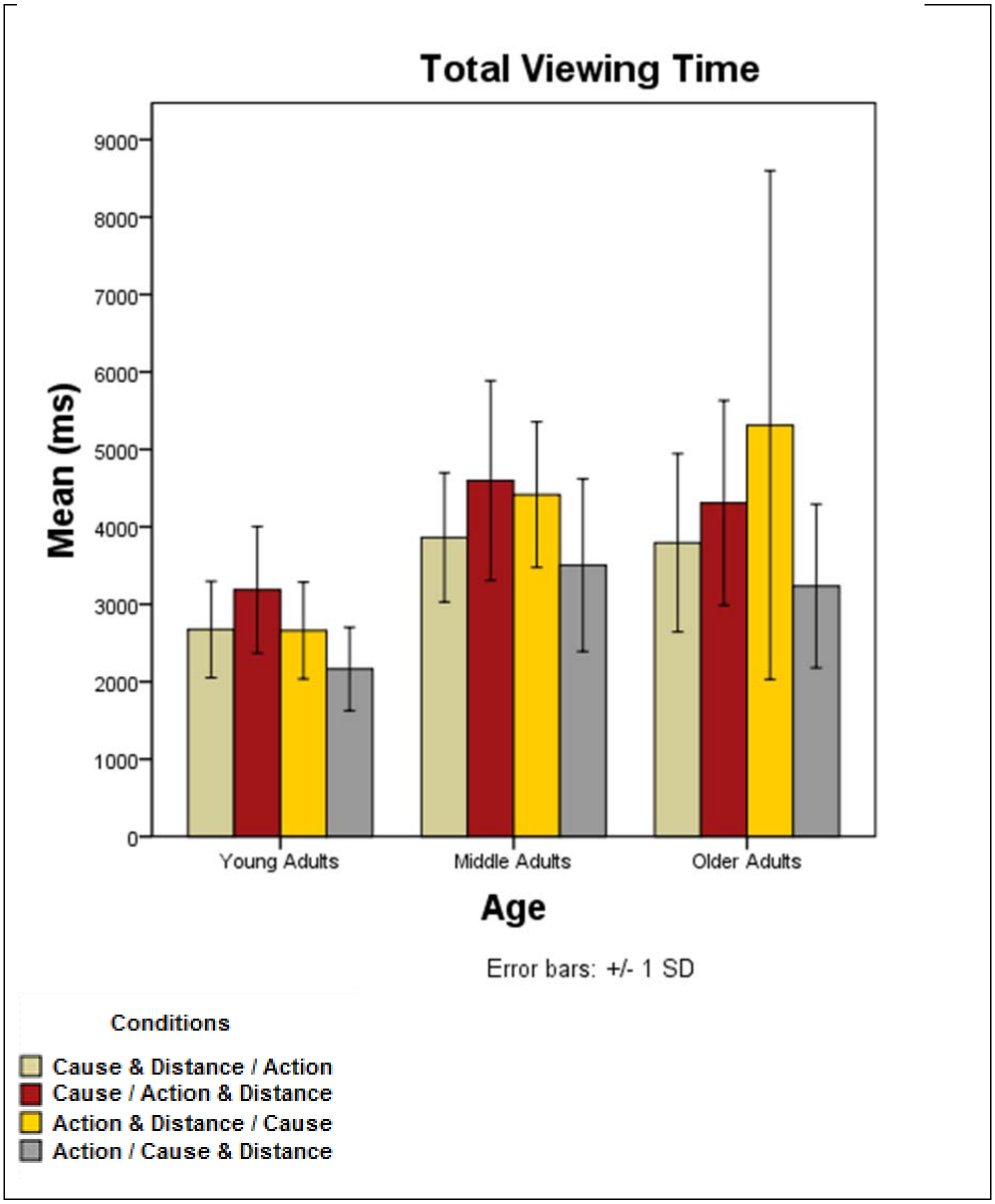

Figure 14. Viewing time as a function of age and message order

Results indicate that the quickest response from drivers was elicited by the experimental order showing the action in Phase 1 and the Distance and Cause in Phase 2 and that this was most beneficial for older drivers. However, this was only a trend.

Compatibility of action and position of the sign:

We also analyzed whether the sign placement influenced response time by collapsing across conditions to create compatible distance and action, and incompatible distance and action aggregate times. An example of a compatible distance and action would be the case where the action is "merge left" and the PCMS sign is positioned on the left. (If it were positioned on the right that would be considered incompatible.) There was a significant effect for age, F (2,30) = 8.43, p < .01, MSe =1933691, with younger drivers faster to decide than middle-aged or older adults. There was a trend for compatibility to improve performance, $F(1, 30) = 3.15$, $p < .09$, $MSe = 196607$, and a very slight trend for an interaction of age and compatibility, $p < .17$. Those effects can be seen in Figure 15.

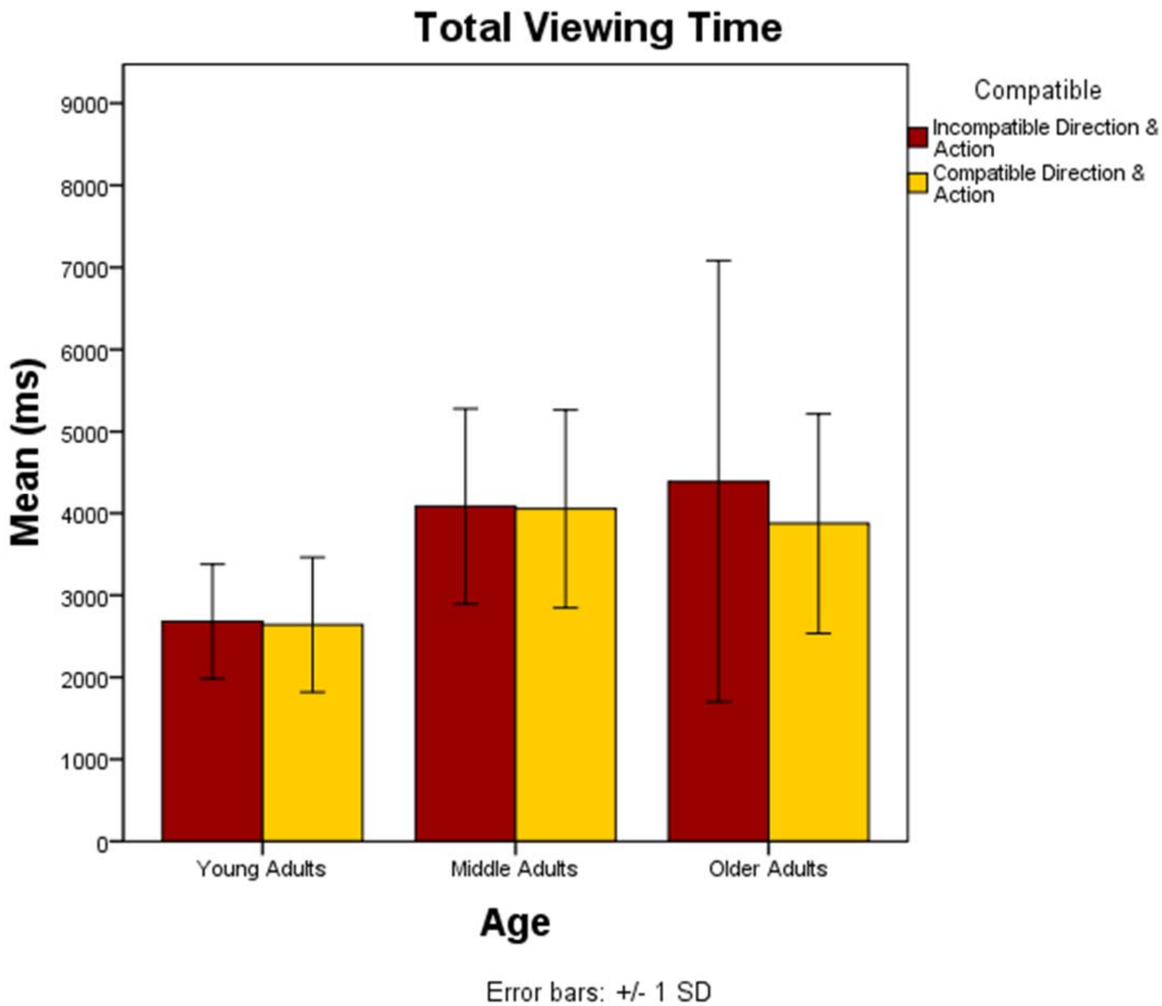

Figure 15. Total viewing time by age group and sign/action compatibility

Although younger and middle-aged drivers showed little if any compatibility effect (and young adults responded more quickly than the other two age groups), there was a slight advantage for older adults when sign action and sign position were compatible. However, this effect was not statistically significant. Because we have relatively poor power to detect effects within this pilot study due to the small sample size, replication is needed.

Conclusions

The traditional ordering of message information in PCMS devices was motivated by the assumption that a cause should be provided first to ensure compliance with a required action. However, for complex traffic situations, a 2 second response delay in indicating the action to take may make a substantial difference when a driver approaches a PCMS message. Based on preliminary results from our eye movement data, we recommend that further research be conducted on message order. It appears that there could be benefit from a change to the MUTCD regulation so that the required action is always displayed first exclusively, followed by distance and cause information. Further, it appears that signs should be placed, when possible, in a position compatible with the action required for lane change situations: on the left for left merges and on the right for right merges as this might benefit older drivers.

Chapter 3. Legibility of Warning Signs for Sheeting Type and Headlamp Beam Intensity

The purpose of this study was to replicate findings in our previous Intersection and Pedestrian Safety Research report (BD543-17), which indicated that headlamp intensity moderates the relationship between legibility distance and two sign sheeting types: standard, Type VII and fluorescent yellow, Type IX. The purpose of the previous study was to compare the viewing distances and recognition accuracy between these two signs types. However, because participants were allowed to choose freely between using low- and high-beam headlamps, the results were mixed. Further investigation revealed an interaction between sign type and viewing distance with the fluorescent sheeting sign leading to longer viewing distances when participants used their low beams, but shorter viewing distances when they used their high beams. A possible explanation for this effect is that the high beams led to glare due to the high reflectance of the fluorescent yellow sheeting and therefore made recognition more difficult for participants. Furthermore, this increased difficulty could have been caused by a reduction in the contrast between the foreground and background colors of the sign. The current study assessed the effect that headlamp intensity had on the relationship between viewing distance and sign reflectivity by systematically varying beam intensity for each driver.

Task 2: Legibility of Fluorescent vs. Standard Warning Signs Under Low and High Beam Conditions.

Method

Design

The study used a 3 x 2 x 2 mixed design. Sign type (fluorescent vs. standard sheeting) and headlight beam (low vs. high) were within-subjects factors. Age (younger, middle-aged, older) was the between subjects factor. Sign type (fluorescent, Type IX vs. standard, Type VII sheeting) and headlight beam (low vs. high) were within-subjects factors. This study was run at night.

Participants

The participants were 61 community dwelling younger (n = 22, M = 22.6 yrs, SD = 3.9 yrs), middle aged (n = 14, M = 59.9 yrs, SD = 3.0 yrs), and older (n = 25, M = 71 yrs, SD = 5.2 yrs) drivers recruited from the Tallahassee, Florida area via newspaper ads and word of mouth. All participants were prescreened to determine eligibility for participation, as described for the previous studies. Participant compensation was based on a payment schedule with students opting to receive University credit obtaining 2 hours of credit, and $10. Students were able to opt out of the additional $10 payment to receive 3 hours of credit. Students opting out of University credit, and non-student participants were paid $25 for taking part in the study.

Materials

Track

A closed track was for all testing located at Broadmoor Estates, a City of Tallahassee owned property. The track used was relatively level and straight. The starting position was marked with a line that was located ~1950 ft from the sign display.

Signs

The stimuli consisted of a set of 6 symbolic warning signs that included two versions (one fluorescent sheeting, one standard sheeting) of three unique signs: Stop ahead (W3-1), yield ahead (W3-2), and signal ahead (W3-3). All signs measured 36 inches by 36 inches and followed MUTCD guidelines with the 3 standard signs using Type VII retroreflective sheeting (3M™ Diamond Grade™ LDP), while the 3 fluorescent signs used Type IX retroreflective sheeting (3M™ Diamond Grade™ DG^3 fluorescent yellow).

Chromameter

Color space and luminance information was gathered using a Konica Minolta Chroma Meter CS-100A. Information from this device was recorded. Chromaticity readings were not taken on signs because the chromameter being used was not sensitive enough for readings in which light was less than 0.01 candela/meter^2.

Luminance meter

Luminance information not requiring color space coordinates were gathered from a Konica Minolta Luminance Meter LS-100. Analyses utilizing luminance as a factor from signs did not use the luminance information from the Chroma meter, but instead used information from the luminance meter, as this instrument was capable of reading a wider range of values.

Radar gun

Track measurements were obtained using an Applied Scientific Stalker ATS radar gun. This device was placed behind the participant's vehicle and used time and speed to determine the location of the participant during each trial. Information was reported and recorded by a Dell Latitude XT2 and processed using Stalker ATS software.

Laptop computer

Two Asus Eee PC Netbook Computers were used in this experiment, along with a Dell Latitude XT2. Both Asus computers are identical with Intel Atom Z520, 1 GB of RAM memory, and 160 GB hard drive. The Dell XT2 is equipped with Intel Core 2 Duo 1.6 GHz, 2 GB of RAM memory, and 80 GB hard drive.

Sign display

Signs were displayed on a custom-designed sign changing apparatus (see Figure 16). The device stood a total of 12 feet tall so that signs would be displayed at regulation height with the base of each sign starting at 9 ft from the ground. To facilitate the quick changing of sign heads, signs were mounted together in pairs (see Figure below). Only one sign at a time would be visible to the participant, and the head could be rotated to display a new sign for the next trial.

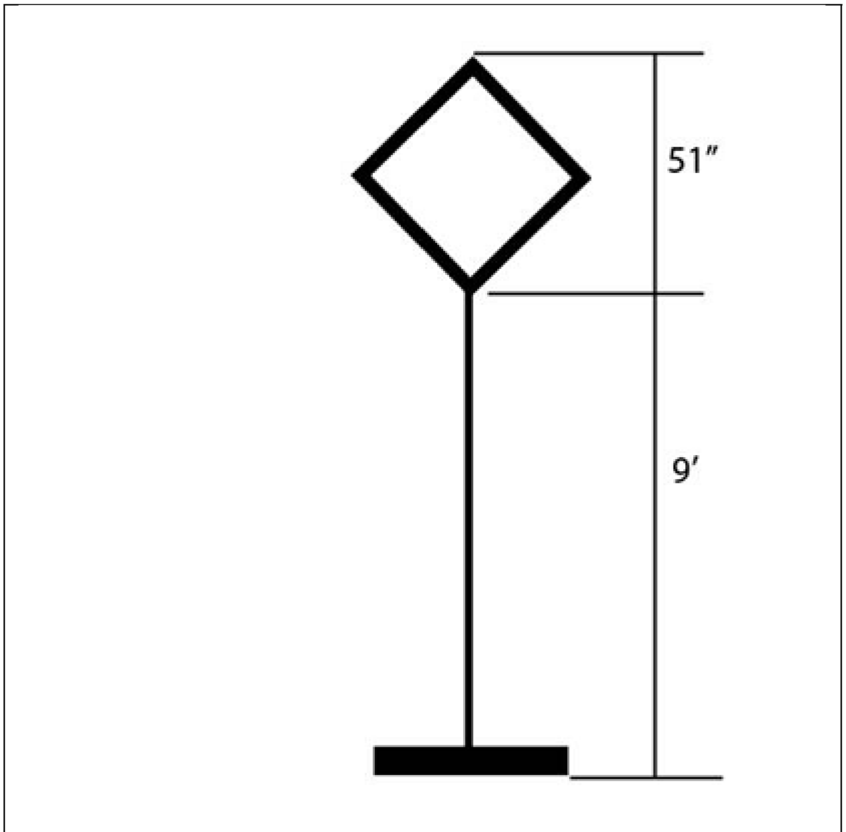

Figure 16. Diagram of Task 2 sign changing device.

Measurements

When participants arrived, measurements were obtained of both the vehicle and the participant. Measurements of the vehicle included front bumper to front wheel, front bumper to participant within car, and total length and height of the car. Additional measures were calculated from these measurements. Participant height and height to eyes were taken. For a full list of measures, see Appendix A.

Before additional headlight measurements were taken, measurements were taken using the luminance meter to ensure that ambient light was not greater than 0.1 cd/m^2. This measure was taken by aiming the luminance meter straight up without directing to a point of light (i.e., plane, star, satellite, etc.).

Headlight Measurements

Measurements of the color space and brightness of the high- and low-beam headlights were taken using a black and white board placed 3 feet and 10 feet in front of the vehicle’s driver’s side headlight. Measurements were then recorded on a laptop computer.

Procedure

Headlight beam (low vs. high) was manipulated between blocks, and was counterbalanced between subjects. The type of sign sheeting was manipulated within each block, and counterbalanced as well.

The experiment consisted of 12 trials, divided into two blocks of six trials each. At the beginning of each block of trials, participants were instructed to use either high beam or low beam headlights. The order of these blocks was counterbalanced between subjects and within groups such that half of the participants in each age group completed the low beam block first, and half completed the high beam block first.

Within each block of trials, signs were presented in one of four predetermined, pseudorandom orders, which was also counterbalanced between subjects.

Participants began each trial from a starting line located ~1950 feet from the sign display. At the beginning of each trial, the participant was instructed to drive forward until they could name or describe the displayed sign with 100% confidence and then come to a complete stop so that measurements could be recorded. On four randomly assigned trials, two in each block (1 fluorescent, 1 standard), sign luminance measures were taken from the participants' maximum viewing distance for the trial. Once all measurements had been taken, the participant was instructed to return to the start line for the next trial.

Results

Headlight Luminance

Due to problems with equipment (dead battery was the most common issue), luminance data was not taken for 9 participants. For the remaining 52 participants, as expected, participants' high beam headlights were significantly brighter than low beam headlights, $F(1,51) = 31.4$, $p < .001$, $\eta_p^2 = .38$.

Sign Viewing Distances

An analysis comparing viewing distances across age group (older, middle, younger), sign type (fluorescent vs. standard sheeting), and headlight beam intensity (high vs. low) revealed main effects of age group, $F(1,56) = 5.36$, $p = .007$, $\eta_p^2 = .16$, and sign type, $F(1,56) = 5.37$, $p = .02$, $\eta_p^2 = .09$ (see Figure below). Younger adults, on average were able to correctly identify signs at greater distances than were middle aged, $F(1,34) = 8.39$, $p = .007$, $\eta_p^2 = .20$, or older adults, $F(1,34) = 10.97$, $p = .002$, $\eta_p^2 = .20$, whose viewing distances did not differ from one another, $F < 1$ (see Figure 17).

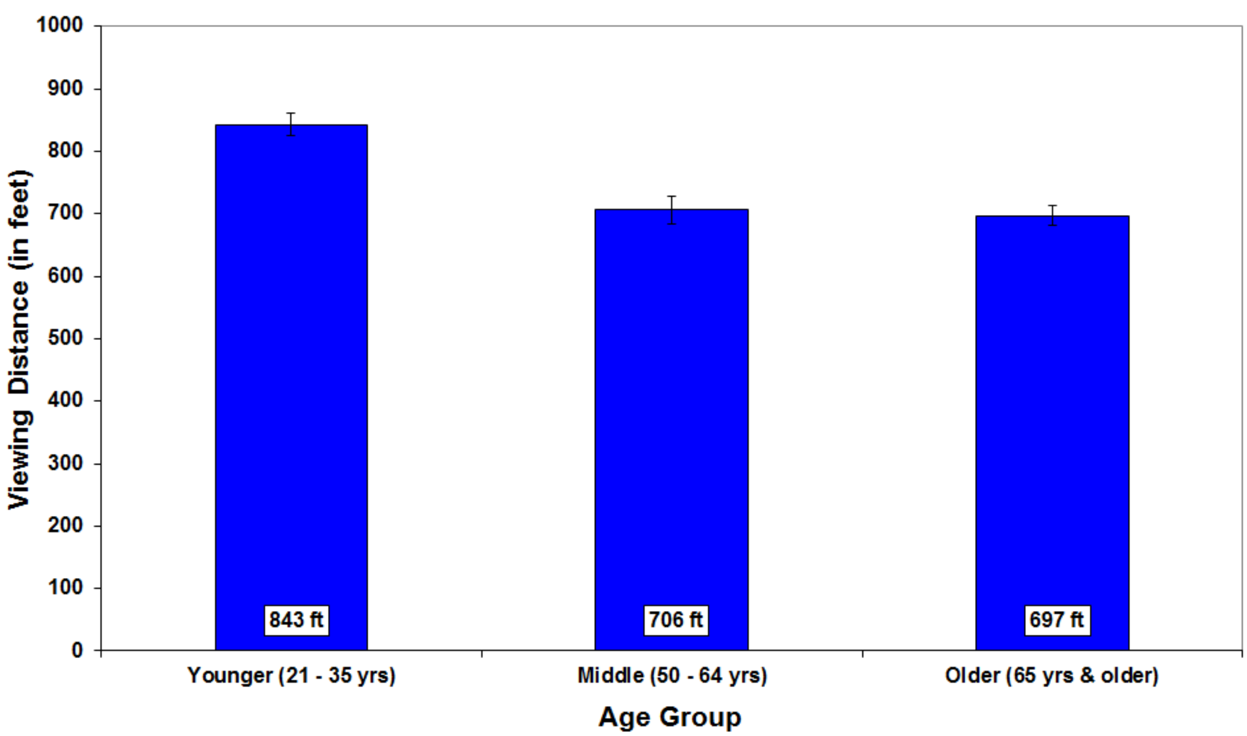

Figure 17. Viewing distances by age group

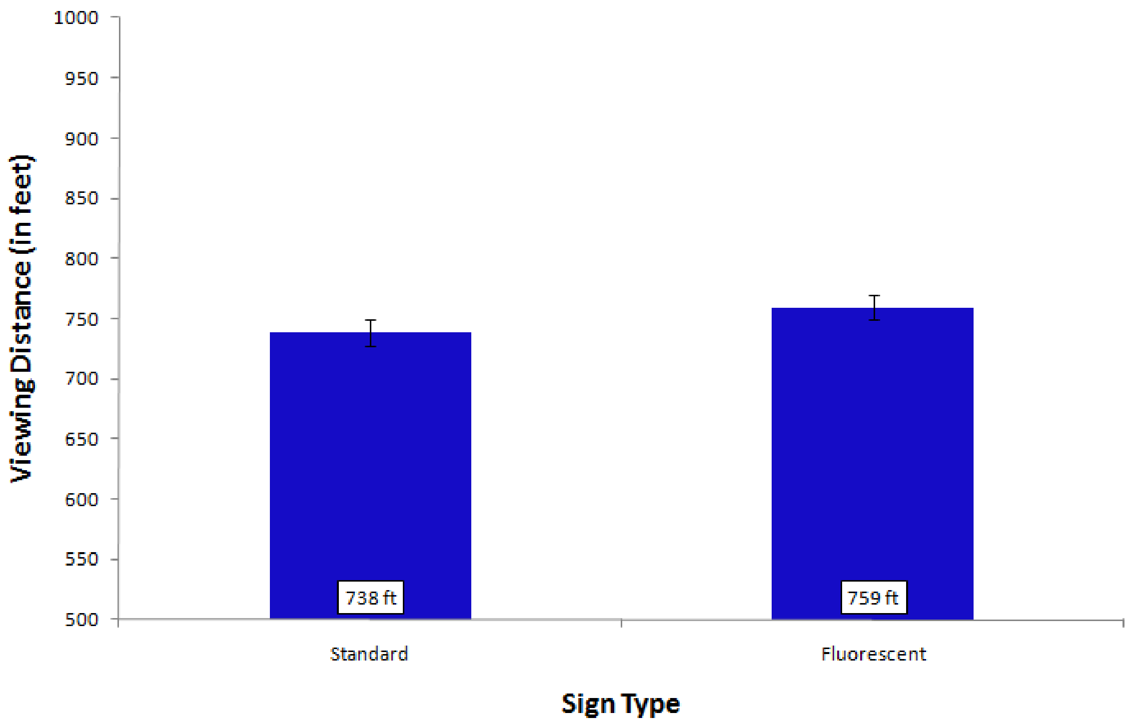

Figure 18. Average viewing distance by sign sheeting type, collapsed across high and low intensity headlights

As predicted, the main effect of sign type (Figure 18) was qualified by a significant interaction between sign type and headlight beam intensity, $F(1,56) = 5.01$, $p = .03$, $\eta_p^2 = .08$. This effect was stronger when the luminance of participants' headlights was controlled for in the analysis, $F(1,45) = 8.52$, $p = .005$, $\eta_p^2 = .16$ (see Figure 19). Under low beam conditions, the viewing distance for standard sheeting was 714 feet and 756 feet for fluorescent sheeting when headlight brightness was not taken into account. When headlight brightness was taken into account, the viewing distance for standard sheeting increased to 717 feet, while the viewing distance for fluorescent sheeting remained the same. Under high beam conditions, the average viewing distance for both standard and fluorescent sheeting was 763 feet when headlight brightness was not taken into account. When viewing distances were adjusted for headlight brightness, the average viewing distance for standard sheeting was 767 feet, while the average viewing distance for fluorescent sheeting was 764 feet.

For signs viewed with high intensity headlights, there was no difference between standard and fluorescent signs, $F(1,57) = .07$, $p = .79$, $\eta_p^2 = .001$. When low intensity beams were used, fluorescent signs were legible at significantly longer distances, $F(1,57) = 10.32$, $p = .002$, $\eta_p^2 = .15$. No other main effects or interactions reached statistical significance. Descriptive statistics for viewing distances for individual signs and conditions are given in Appendix B.

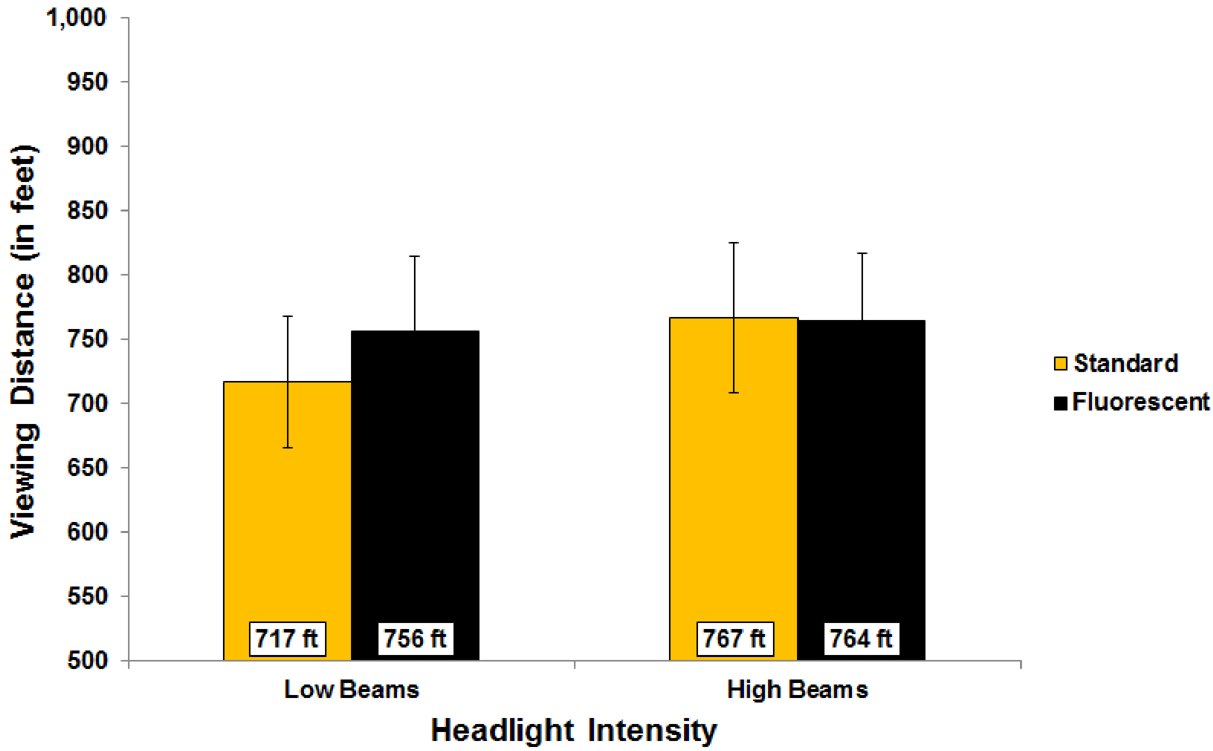

Figure 19. Headlight beam intensity by sign sheeting type interaction

Sign Identification Accuracy

Overall sign identification accuracy was at ceiling or near ceiling levels for both younger and older adults (see Figure 20). However, even at this high level of performance, $F(2,52) = 4.66$, $p = .01$, $\eta_p^2 = .15$, there were significant age differences in sign identification accuracy. Younger adults correctly identified signs more often than did older adults, $F(1,45) = 7.97$, $p = .007$, $\eta_p^2 = .15$, but younger and middle aged adults' accuracy did not differ, $F < 1$. Although middle aged adults' accuracy was comparable to younger adults', the difference in performance between middle and older adults did not reach statistical significance, $F(1,37) = 3.82$, $p = .06$, $\eta_p^2 = .09$, likely due to the smaller number of middle adults in our sample. No other main effects or interactions reached statistical significance. Descriptive statistics for viewing distances for individual signs and conditions are given in Appendix B.

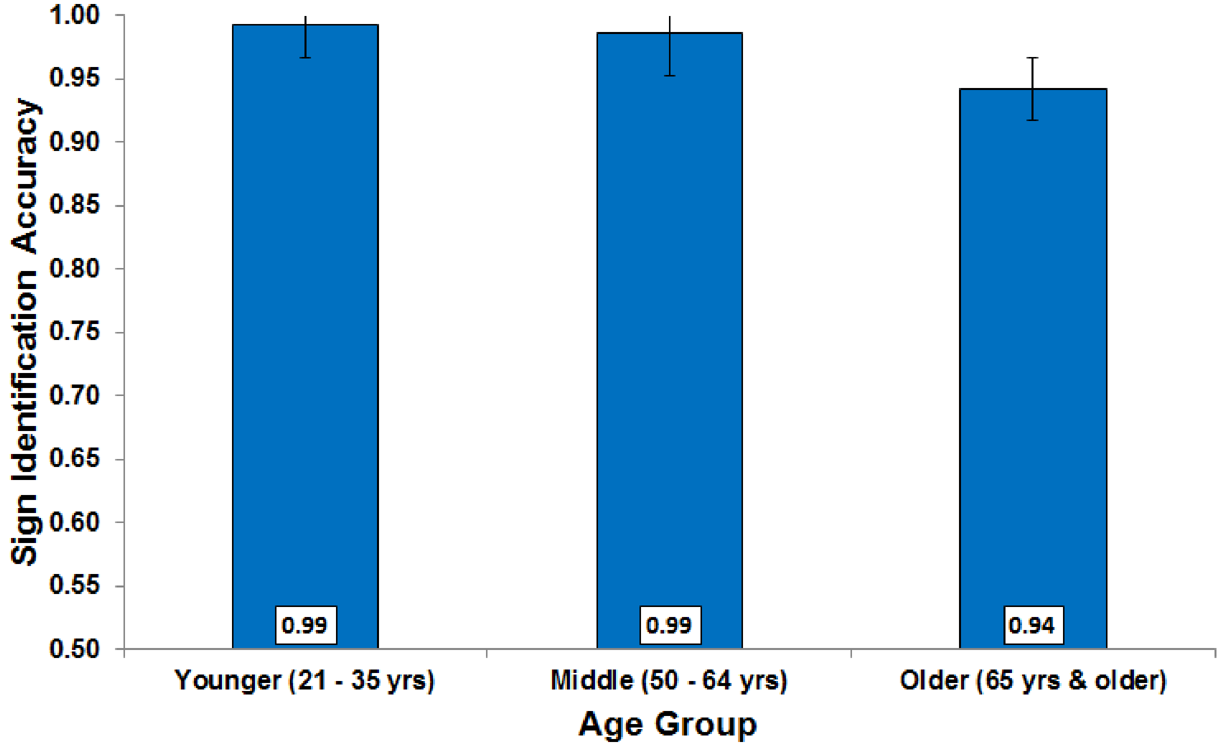

Figure 20. Sign identification accuracy by age group

Conclusions

Warning signs with fluorescent sheeting are correctly perceived at longer distances (by about 40 feet) compared to warning signs with standard sheeting only when the driver is using low beam headlights. With high beams shining on the warning sign the two sign sheetings perform equivalently. This result is consistent with the sub-analysis we conducted in a much smaller sample in our prior study (Intersection and Pedestrian Safety Research, BD543-17, http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BD543_17_rpt.pdf) that allowed drivers to choose their own headlamp intensity. We now conclude that warning signs with fluorescent sheeting are to be preferred to warning signs with standard sheeting signs for better visibility at night, assuming that drivers are likely to be using low beams as their preferred night driving mode. Low beams seem more likely to be used in city (lit) environments at night and high beams in rural settings, hence it may be best to deploy fluorescent sheeting signs in urban environments. However, further research should determine the prevalence of use of high beams in different road environments. Another possibility is to educate drivers about the advantages of using high beams to improve standard sign legibility. However, the costs to oncoming drivers in two-lane road situations must be considered, particularly the risks to older drivers who have poorer night vision and poorer dark adaptation following exposure to bright light (e.g., high beams).

Chapter 4. Lab and Field Evaluations of the Efficacy of Supplemental Pedestal Mounted Traffic Signals

Task 3: Efficacy of Supplemental Pedestal Mounted Traffic Signals

Traffic control signals must be attended to if they are to be effective in guiding driver behavior. A driver's view of a signal can be blocked or degraded by larger vehicles ahead of them, by poor weather conditions, and can be missed even under ideal conditions when the driver's attention is distracted. One way to increase the chance for driver compliance is to ensure that multiple redundant signals are present in the driver's field of view to take advantage of redundancy gain in processing visual information (Wickens et al., 2004). Mast arms containing banks of overhead lights (usually one per lane of traffic) are one way to provide signal redundancy. Another is to add a pedestal-mounted signal to a traffic signal pole. There is of course a cost to add redundant signals and the goal of this study was to assess whether adding a pedestal signal significantly changed driver behavior when approaching an intersection. We conducted two studies, one a laboratory study that permitted us to present a broad range of signal situations, and one a field study using a specific intersection.

Study 3 Laboratory Task.

The goal of this study was to determine if a supplemental pedestal signal would affect the decision process to stop or go in a left turn decision. To try to ensure that Florida drivers were not familiar with the specific intersections presented, photos were taken of intersections in the Phoenix, Arizona area.

Method

Design

The Task 3 laboratory study used a 3 x 2 x 2 x 2 mixed model design where pedestal (pedestal signal/no pedestal signal), action (green signal/red signal), distance (far/near), and match condition (left turn signal matched main signal, left turn signal did not match main signal) were within-subjects factors. Age group (younger, middle, older) was the only between subjects factor.

Participants

A total of 79 participants (36 younger, 20 middle, 23 older) completed the Task 3 laboratory study. Participants were paid at the rate of $10 per hour, and the experiment typically required 30 to 45 minutes to complete. Of this total, 14 younger adults (9 female, 5 male) completed a pilot version of the task and so are not included in the final analysis. In addition, one older adult, whose performance was not significantly better than chance (M = .57), was also excluded from the final analysis. The final analysis includes data from 22 younger adults (Mean Age = 19.7, SD = 1), 20 middle aged adults (Mean Age = 55.9, SD = 6.6), and 22 older adults (Mean Age = 71.5, SD = 6.2). All participants were prescreened to determine eligibility for participation, as described for previous studies.

Materials and Procedure

Stimuli images were created from 5 intersections using a Nikon D300 SLR with a focus point of 47mm. Each intersection contained a pedestal-mounted traffic signal on both the left and right side in addition to the mast arm signals. Images were taken from the perspective of the driver at a height of approximately 4ft and from both 50 ft and 200 ft from the stop bar. These stimuli images were then edited using Adobe Photoshop to control for three variables. First, images were sized to closely approximate a viewing experience of being 50 ft and 200 ft from the signal when represented on a computer monitor (340 mm by 273 mm) shown at a resolution of 1024 x768 pixels. Second, images were edited to remove the left turn signal pedestal-mounted traffic signal. This process was completed on every image in order for participants to see each intersection with and without a pedestal signal. Lastly, each image was then used to create one image in which the left turn signal matched the main signal of either green or red and one in which the left turn signal did not match the main signal. The left-most signal on each mast arm acted as a left turn signal as well. Images did not present impossible conditions in which the mast-arm left turn signal and the pedestal left turn signal differed. In total, 32 images were created (see Figure 21).

Stimuli were presented in a random order with each stimulus item appearing four times for a total of 128 trials. The experimental session took between 15 and 30 minutes to complete.

Figure 21. Sample stimulus including pedestal signals from Task 3 lab study

Procedure

Participants were seated approximately 24 inches from the computer monitor and were told that they would be viewing a series of pictures taken from the perspective of a driver in the left turn lane. Participants were then told to decide based on the left turn signal whether the correct action would be to stop (red signal) or go (green signal). The task instructions stressed that decisions should be made as quickly and accurately as possible, and participants were given a maximum of 3 seconds to respond. If no response was given within 3 seconds, the task automatically advanced to the beginning of the next trial. Before beginning the actual task, participants completed several practice trials to familiarize them with the task. For each item, a fixation cross was displayed and the participant could press the space bar to display the actual item. The trial ended as soon as a response was made or after the response deadline of 3 seconds had elapsed. Task instructions did not mention that a supplemental signal would be present on some trials, as drivers are not given advance warning of the presence of supplemental signals under naturalistic conditions.

Results

Item Analysis

A post hoc item analysis revealed that two items were associated with significantly lower accuracy than the other items. While the average performance for all participants, across all 32 items was near ceiling (M = .94, SD = .05), performance on two of the items were .76(.33) and .78(.32), both of which differed significantly from the average performance for the group, t (63) = -4.38, p < .001 and t (63) = -4.01, p < .001, respectively. A visual inspection suggested that the poor performance on these two items was due to the green signal being extremely dim compared to the other stimuli, so those items were excluded from the final analysis. All final analyses are based on performance on the 30 remaining stimuli, presented four times each, for a total of 120 trials. Analyses conducted with and without the problem stimuli did not change the results.

Response Accuracy

Experimenters reported that participants sometimes accidentally advanced the screen that immediately followed a trial where the 3 second response time had expired. To adjust for this, observations with response times below 300 ms (N = 181), were considered invalid and dropped from all analyses.

An analysis of variance comparing response accuracy as a function of age group, presence or absence of a pedestal signal, action (red signal, green signal), simulated viewing distance (near, far), and match condition (left turn signal matched main signal, did not match main signal), revealed main effects of age, $F(1,60) = 4.83$, $p = .01$, $\eta^2_p = .14$, action, $F(1,61) = 4.99$, $p = .03$, $\eta^2_p = .08$, and match condition, $F(1,61) = 4.60$, $p = .04$, $\eta^2_p = .07$ (see Figure 22).

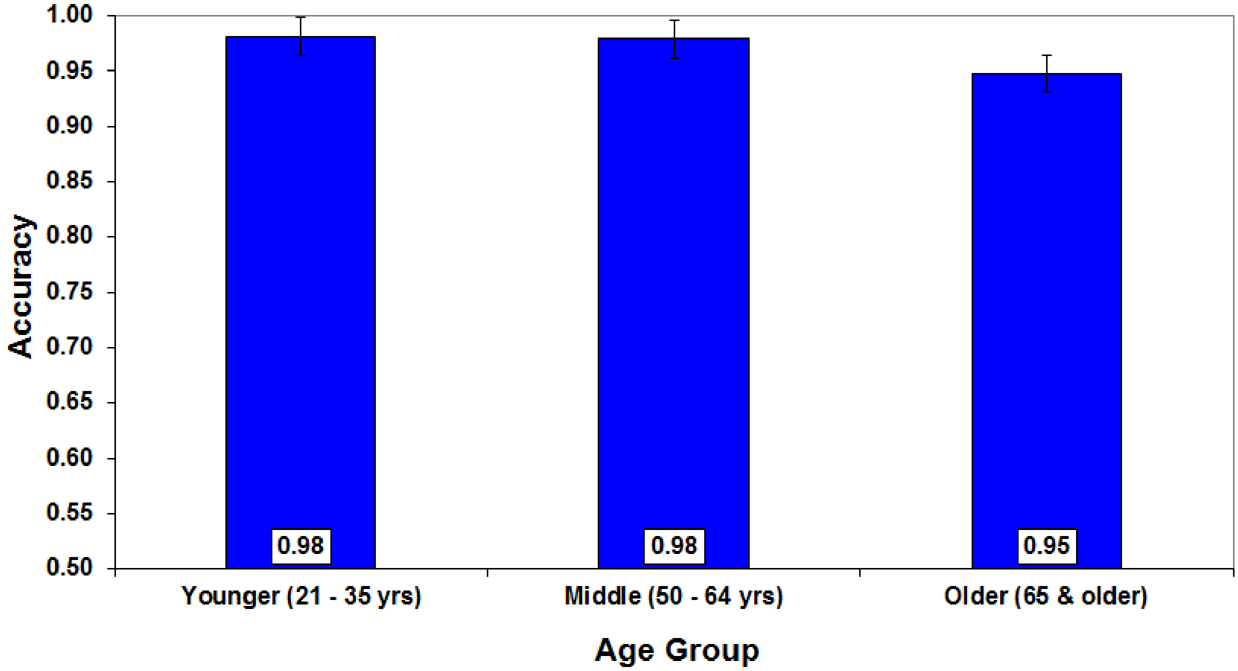

Figure 22. Response accuracy by age group. Error bars show 95% confidence intervals

As expected, accuracy for younger and middle aged adults did not differ, but older adults' accuracy, though still near ceiling, was significantly poorer than that for younger and middle adults. In addition, responses to stop trials (M = .97) were significantly more accurate than responses on go trials (M = .96). Finally, participants tended to be more accurate in responding when the left turn signal matched the main signal (M = .97) compared to when it did not match the main signal (M = .96).

Though no other factors interacted with age group, the main effects of action and signal match were qualified by two significant two-way interactions. First, action interacted with simulated viewing distance, $F(1,62) = 6.48$, $p = .01$, $\eta^2_p = .10$, such that there was no difference in response accuracy for stop and go trials at far viewing distances, $F < 1$, but response accuracy was significantly poorer for green signal trials at near distances, $F(1,63) = 6.29$, $p = .02$, $\eta^2_p = .09$ (see Figure 23).

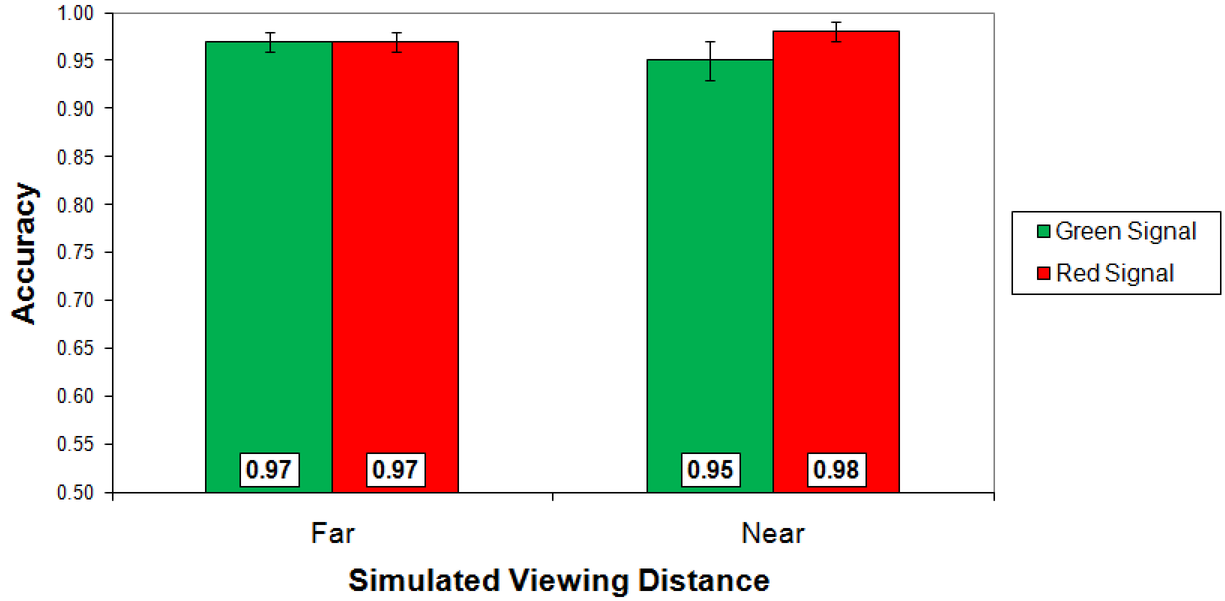

Figure 23. Response accuracy by signal for far and near viewing distances. Error bars show 95% confidence intervals

Action also interacted with match condition, $F(1,61) = 5.18$, $p = .03$, $\eta^2_p = .08$. Response accuracy was equivalent between stop and go trials when the left turn signal matched the main signal, $F < 1$, but was poorer for green signal trials when the left turn signal did not match the main signal, $F(1,63) = 7.33$, $p = .01$, $\eta^2_p = .10$ (see Figure 24). Response accuracy was identical between trials including a pedestal signal and those that did not, $F < 1$, and the presence or absence of the pedestal signal did not interact with any other key factor.

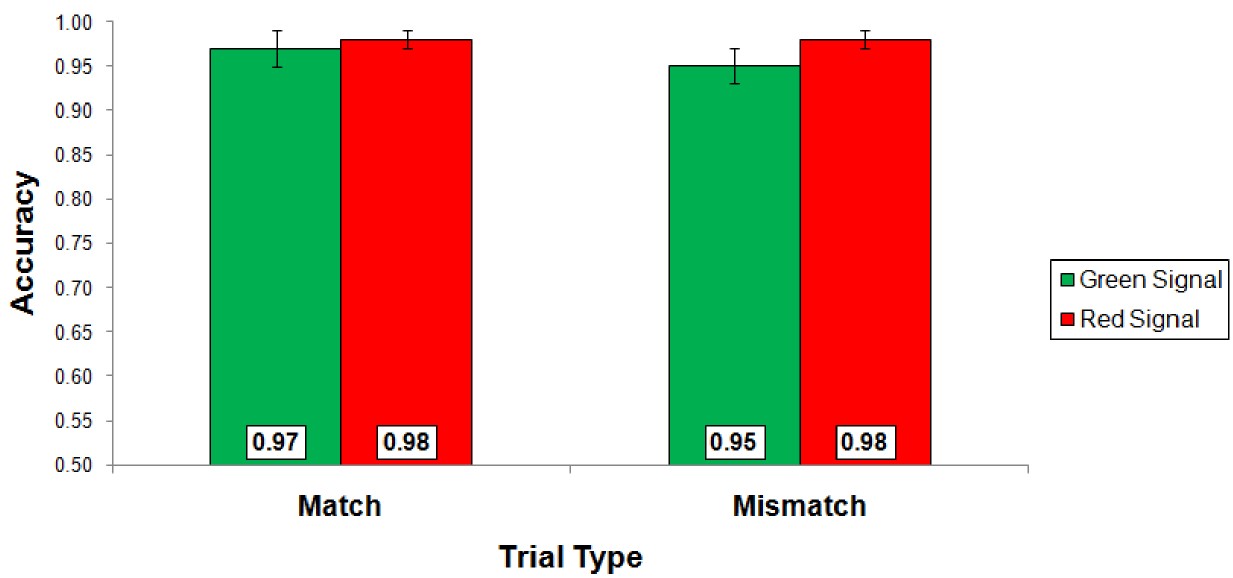

Figure 24. Response accuracy by signal for match and mismatch trials. Error bars show 95% confidence intervals

Response Time

Participants' response times for correct responses were also examined as a function of age group, presence or absence of a pedestal signal, action (red signal, green signal), simulated viewing distance (near, far), and match condition (left turn signal matches main signal, did not match main signal). There were significant main effects of age, $F(2,60) = 23.38$, $p < 0.01$, $\eta^2_p = .44$, action, $F(1,60) = 6.36$, $p = .01$, $\eta^2_p = .10$, and simulated viewing distance, $F(1,60) = 48.83$, $p < .001$, $\eta^2_p = .42$. Younger adults' response times on accurate trials were significantly faster than middle or older adults' and middle adults' response times were significantly faster than older adults' (see Figure 25).

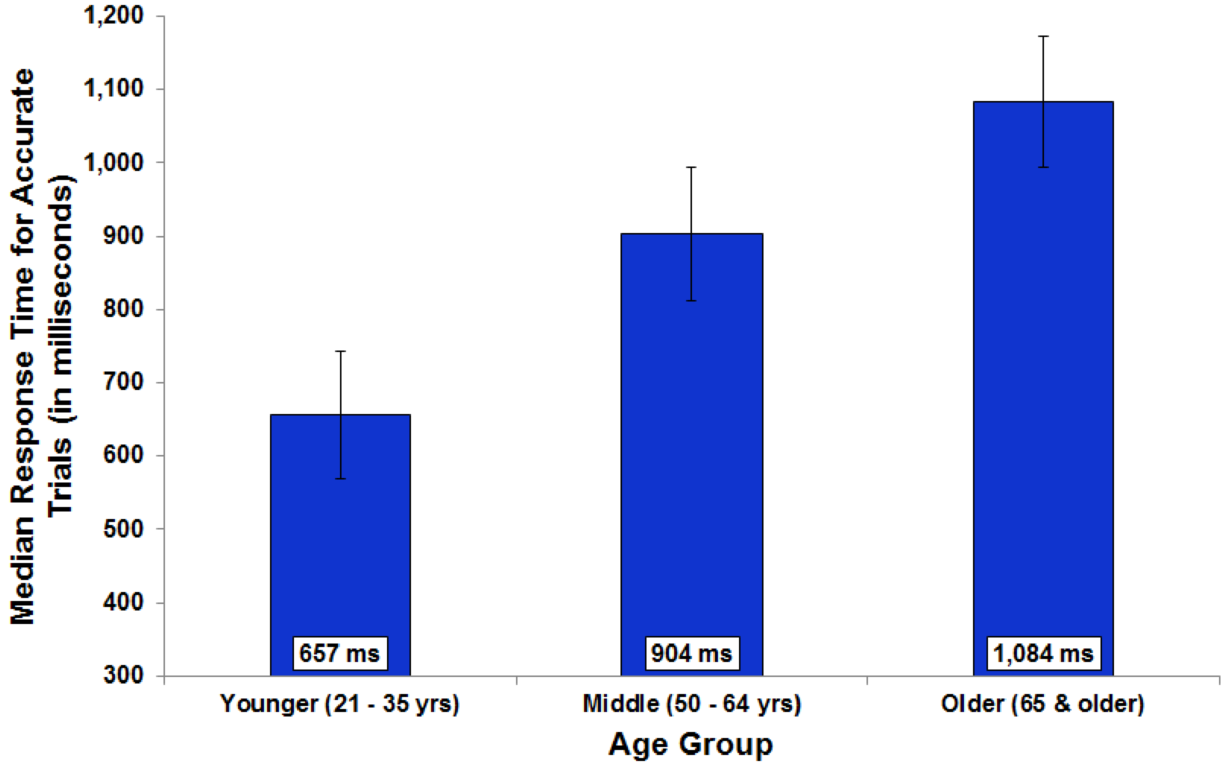

Figure 25. Response time for younger, middle, and older adults. Error bars show 95% confidence intervals

In addition, participants tended to respond more quickly on trials where the left turn signal was red than when it was green, and also responded more quickly on trials that simulated near distances than on those that simulated far viewing distances.

The main effects of signal (green, red) and simulated viewing distance were qualified by a series of significant interactions. First, action interacted with match interaction, $F(1,60) = 4.81$, $p = .03$, $\eta^2_p = .07$, such that for match trials there was no significant difference in response times for green signal and red signal trials, $F(1,63) = 2.90$, $p = .09$, $\eta^2_p = .04$, but response times were significantly faster on red light trials for mismatch trials, $F(1,63) = 11.89$, $p = .001$, $\eta^2_p = .16$ (see Figure 26).

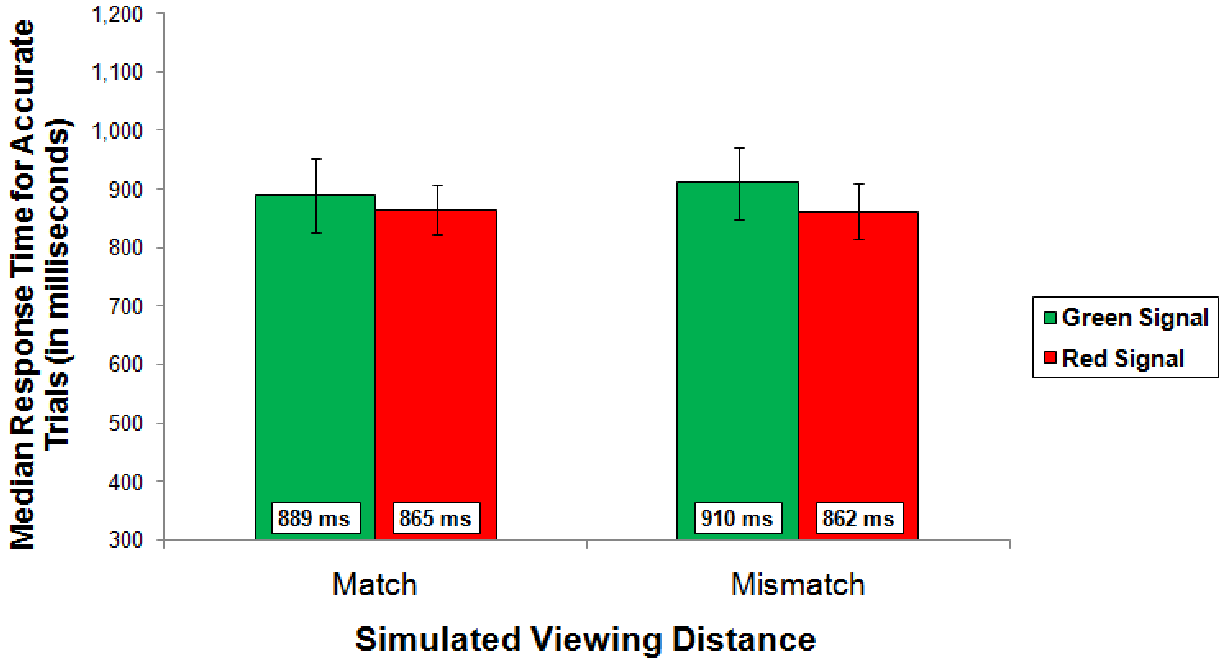

Figure 26. Response time for red and green signal trials by match condition. Error bars show 95% confidence intervals

In addition, match condition also interacted with simulated viewing distance, $F(1,60) = 12.15$, $p = .001$, $\eta^2_p = .16$. For near distances, there was no difference in response time for match and mismatch trials, $F < 1$. However, at far distances response time was faster for trials where the left turn signal and main signal matched than on trials where the left turn signal did not match the main signal, $F(1,63) = 16.07$, $p < .001$, $\eta^2_p = .20$ (see Figure 27).

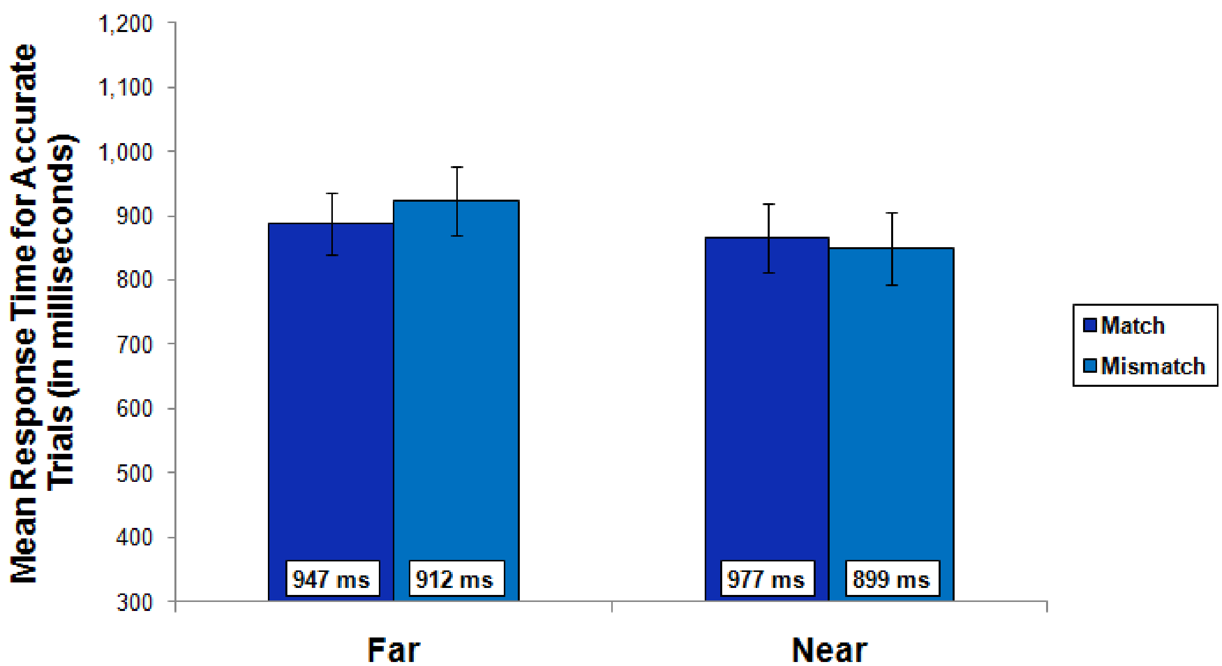

Figure 27. Response times for match and mismatch trials by simulated viewing distance. Error bars show the 95% confidence interval.

Finally, there was a three way interaction between pedestal, signal (red, green), and match condition, $F(1,60) = 9.73$, $p = .003$, $\eta^2_p = .14$. On trials where no pedestal signal was present, response time did not differ between red signal and green signal trials, regardless of whether the main signal matched, $F < 1$, or did not match, $F(1,63) = 3.68$, $p = .06$, $\eta^2_p = .06$. However, for trials where a pedestal signal was present, response time was faster for red signal trials than for green signal trials, regardless of whether the left turn signal matched, $F(1,63) = 8.31$, $p = .005$, $\eta^2_p = .12$, or did not match, $F(1,63) = 8.62$, $p = .005$, $\eta^2_p = .12$, the main signal (see Figure 28).

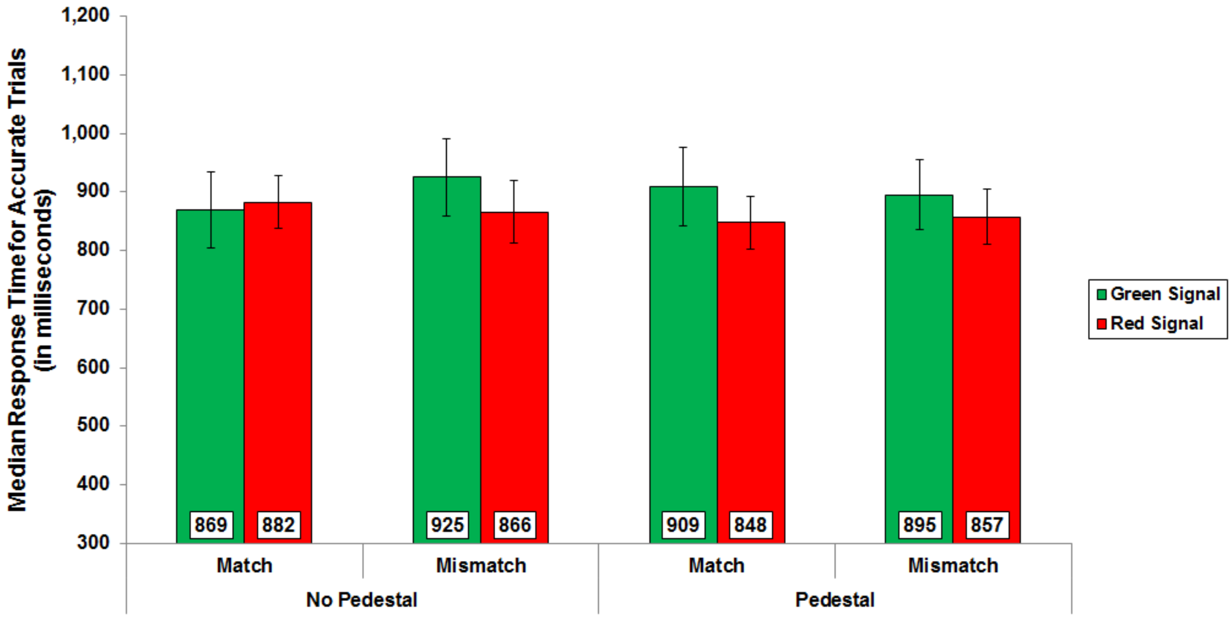

Figure 28. Response time for red and green signal trials by pedestal and match condition. Error bars show the 95% confidence interval.

Conclusions

The results of the Task 3 lab study do not suggest that the presence of pedestal signals strongly affects motorists' decision speed or accuracy. However, it is important to note that the current study used only stimuli taken with a straight, clear view of the main and left turn signals, and where there was little other traffic present. Although these stimuli are not representative of the conditions under which supplemental signals would be expected to be most beneficial, the results from the current study at least suggest that the presence of pedestal signals is not confusing to motorists, as decision speed and accuracy did not differ between trials that included a pedestal signal and those that did not. Pedestal signal effectiveness was examined further in the Task 3 field study, where more representative stimuli were included.

Study 3 Field Task.

Method

Design

The Task 3 field study used a 3 (age group) x 2 x 2 x 2 mixed model design where pedestal (pedestal signal/no pedestal signal), turn (left, right) and action (green signal, red signal) were within-subjects factors. Age group (younger, middle-aged, older) and block order (pedestal signal in Block 1 or 2) were between subjects factors. As in previous studies, participants were prescreened to determine eligibility for participation. Participants were paid $25 per session.

Participants

A total of 66 participants, which included 21 younger (Mean Age = 21.67, SD = .86), 23 middle (Mean Age = 57.83, SD = 4.93), and 22 older (Mean Age = 72.73, SD = 4.41) adults completed the Task 3 field study (see Table 1). Participants were paid $25 for the experimental session, in which participants completed the Task 3 Field study, Task 5 Field study, and a questionnaire. However, due to equipment failures and inadvertent interference during experimental trials (such as people or vehicles encroaching on the driver's path unexpectedly), there was some data loss for individual participants, so all analyses may not be based on the full number of participants that completed the study.

Table 1. Age and gender distribution of participants in Study 3 Field Task

Age Group	Male	Female	Total
Younger (21-35)	11	10	21
Middle (50-64)	6	17	23
Older (65 and up)	11	11	22
Totals	**28**	**38**	**66**

Materials

The Task 3 field study was conducted on a closed track located at the Florida Department of Transportation's Traffic Engineering Research Laboratory (TERL) (see Figure 30) during the daytime. The intersection used in the study was equipped with a standard mast arm traffic signal and two pedestal-mounted supplemental signals (see Figure 29). The track was equipped with an advanced loop located 166.42 feet from the stop line, which would activate the signal after a 1.1 second delay on red signal trials.

Figure 29. The test intersection shown with both supplemental signals enabled. The supplemental signal on the right is supported by an aluminum tripod

Procedure

Participants drove their own vehicles through the test intersection and were instructed to obey all traffic signals during the experimental session. The experiment consisted of two blocks of four trials each: One with the supplemental signals enabled, and one with the supplemental signals disconnected. The order of blocks was counterbalanced between subjects so that half the participants completed the block with the pedestal signal first and half completed the no-pedestal block first. On half of the trials within each block, the signal was green when the participant approached, and on the remaining trials the signal was red when the participant approached the intersection. The number of left and right turns was also balanced within each block. Trials were presented in a random order for each participant (see Table 2).

Table 2. Trial types used in the Task 3 field study

Trial Type	Pedestal	Action	Turn
Alpha	Yes	Red Signal	Left
Charlie	Yes	Green Signal	Left
Echo	Yes	Red Signal	Right
Golf	Yes	Green Signal	Right
Bravo	No	Red Signal	Left
Delta	No	Green Signal	Left
Foxtrot	No	Red Signal	Right
Hotel	No	Green Signal	Right

At the beginning of the experimental session, the in-car experimenter read the task instructions and guided the participant through two practice laps (one right turn and one left turn) to make sure participants were familiar with the track layout (see Figure 30). The instructions informed participants that they would be making left and right turns upon approaching the main intersection and that sometimes the signal would be red and other times it may be green. As in the lab task, the instructions did not mention the pedestal signal. Participants were given the additional instructions that they should not exceed the 20 mph speed limit, that they were not allowed to turn right on red light trials, and that they should remain stopped on red light trials until the signal changes back to green.

On each trial, the in-car experimenter informed the signal and radar operators of the trial type using a handheld radio, so the signal operator stationed at the signal cabinet could disable the advance loop on green signal trials. At the start of each trial, the participant was told whether they would be making a left or right turn at the intersection but not whether the signal would be red or green when they approached. The participant's speed as they approached the intersection was tracked using a portable radar gun. On red signal trials, the distance between the car's front tire and the stop line was measured by the cabinet operator.

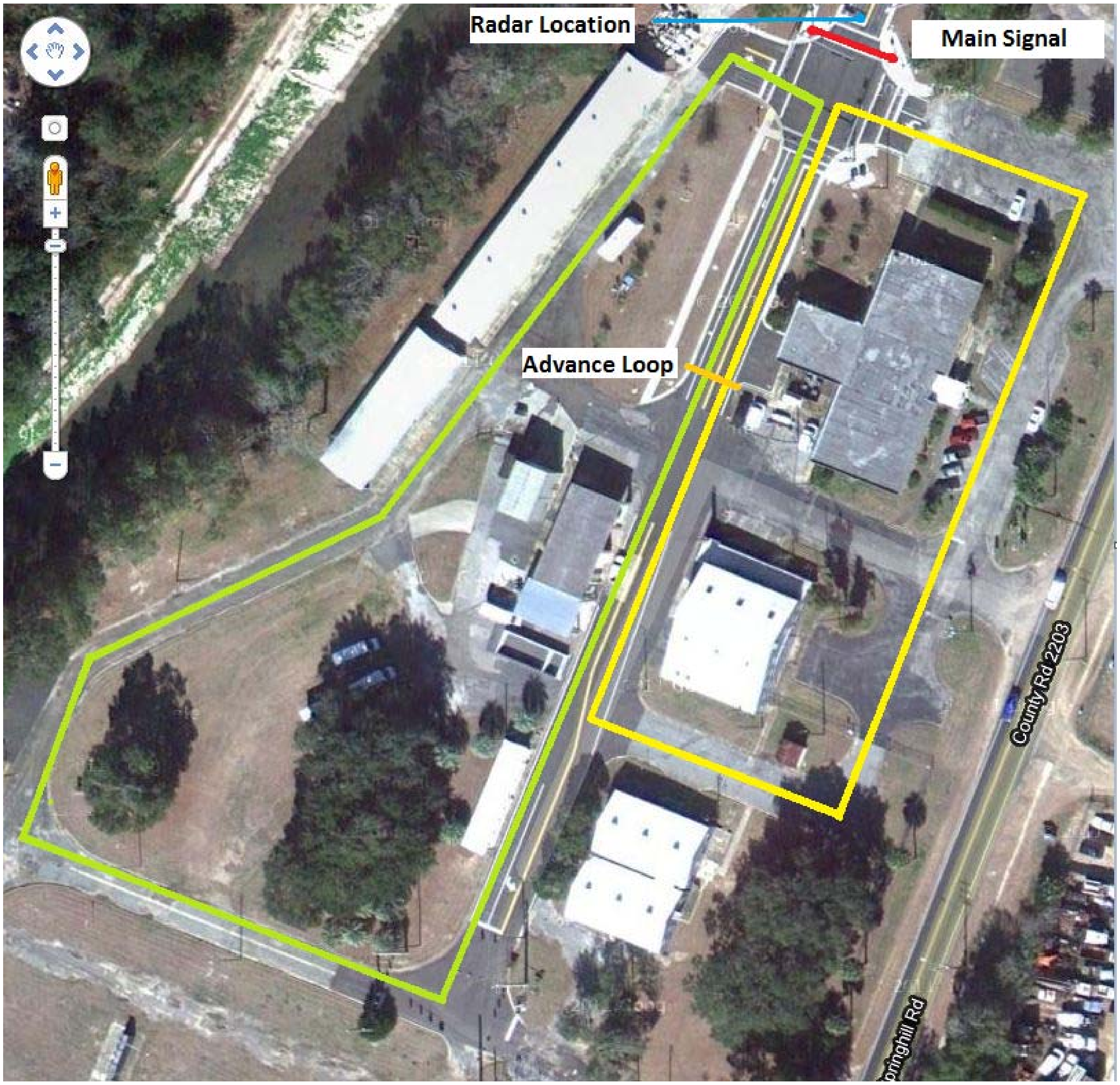

Figure 30. Track diagram for field study. Right turn path is shown in yellow, and the left turn path is shown in green

The main dependent measure was response time on red signal trials, which was determined using two different methods. First, response times were estimated using data recorded by the radar, defined by the difference in time between the onset of braking relative to the onset of the yellow signal (see Figures 31 and 32).

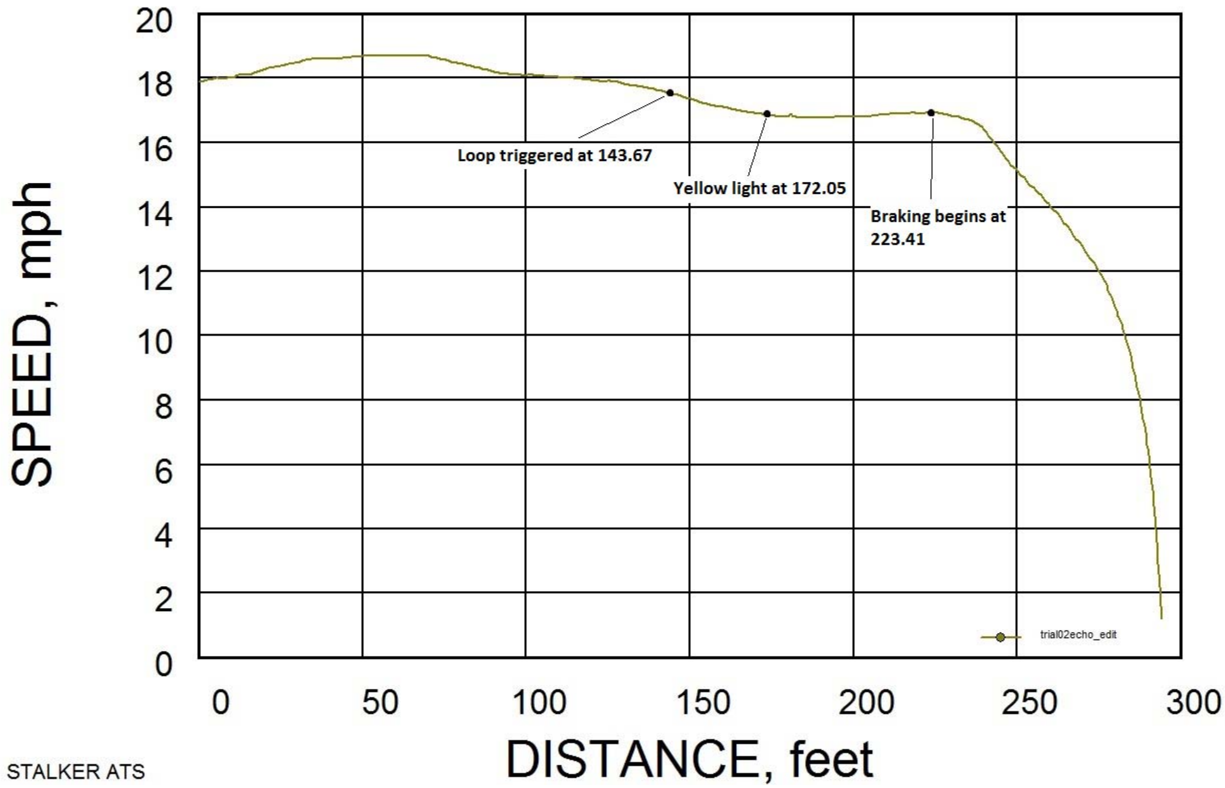

Figure 31. Sample radar data from a stop trial where a response time could be determined. Response time is calculated as the difference between the time when the yellow light is displayed and the onset of braking

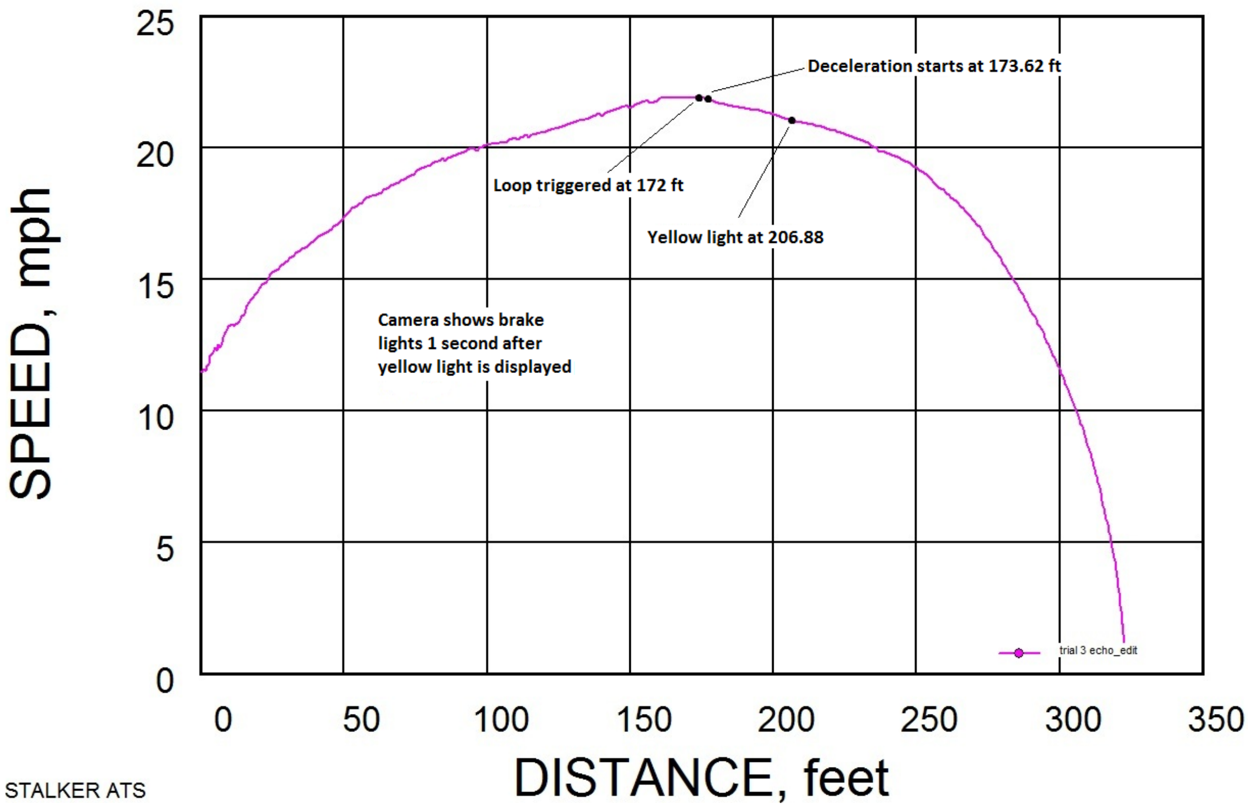

Figure 32. Sample radar data from a stop trial where an accurate response time could not be determined

A second measure of reaction time was based on video recordings taken from a stationary position behind the advance loop, defined as the difference in time between when the yellow light is visible and when the car's brake lights are activated (see Figure 33). Additional dependent measures based on data recorded by the radar include approach speed and braking distance, which was defined as the distance traveled from the onset of braking until the car reached a complete stop.

Figure 33. Camera response time example

In addition to measures of driving behavior during the experiment, we also asked participants a series of questions at the end the experimental session. The first question was a free response item where participants were asked what, if anything, was different between the first and second half of the experiment. The next question asked if the participant had noticed the supplemental signals. Finally, participants were informed that the supplemental signal was activated during half of the trials and asked to indicate whether it had been activated during the first or second block of trials.

Results

Response Accuracy

Because of the type of experimental set up used, as well as the slow travel speed (participants were instructed not to exceed 20 miles per hour), all participants complied with the signal. However, because late stops were possible and did occur on some trials, we did collect a measure of how far ahead or behind the stop line participants' cars were when they reached a complete stop (see Figure 34).

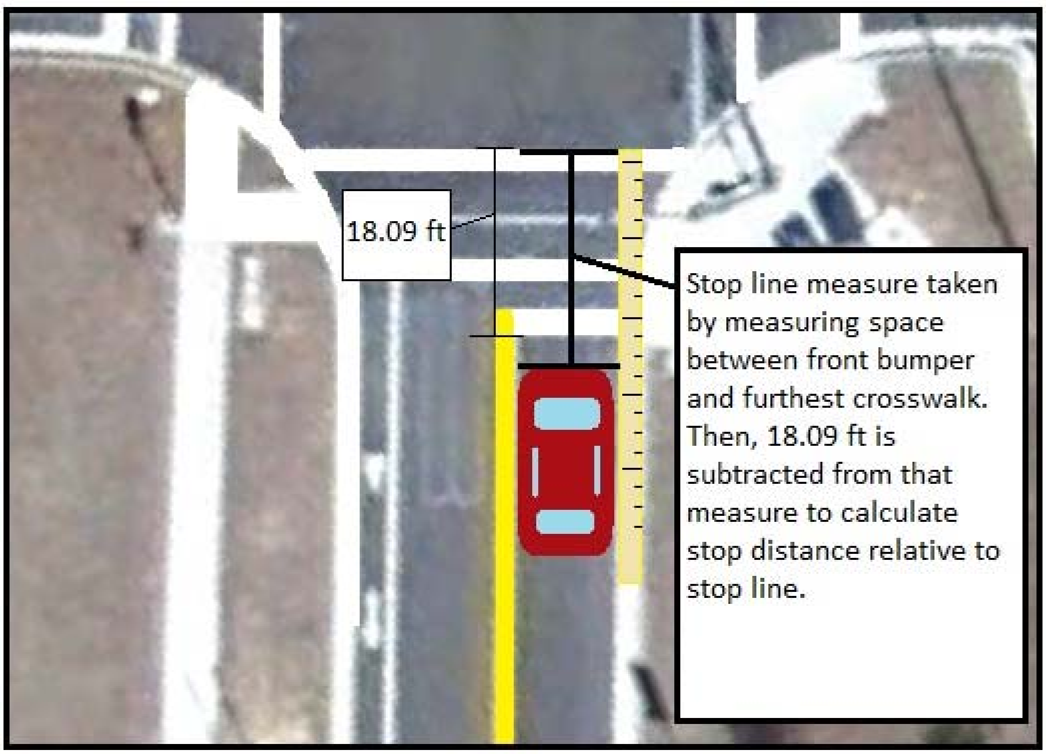

Figure 34. Diagram showing how track measures were taken

To examine potential differences in "late stops" between pedestal and no pedestal trials, as well as to determine whether this varied across age groups, a 2 x 3 mixed model ANOVA was conducted where the presence or absence of the pedestal signal was the only within-subjects factor and age group (younger, middle, older) was the between subjects factor. There was no effect of the presence of the pedestal signal on participants' tendency toward late stops, $F < 1$, nor did this tendency differ significantly across age groups, $F(2,59) = 1.45$, $p = .24$, $\eta^2_p = .05$. However, there was a significant main effect of age, $F(2,59) = 4.42$, $p = .02$, $\eta^2_p = .13$, such that younger adults tended to stop slightly ahead of the line, while older and middle adults stopped behind the line (see Figure 35).

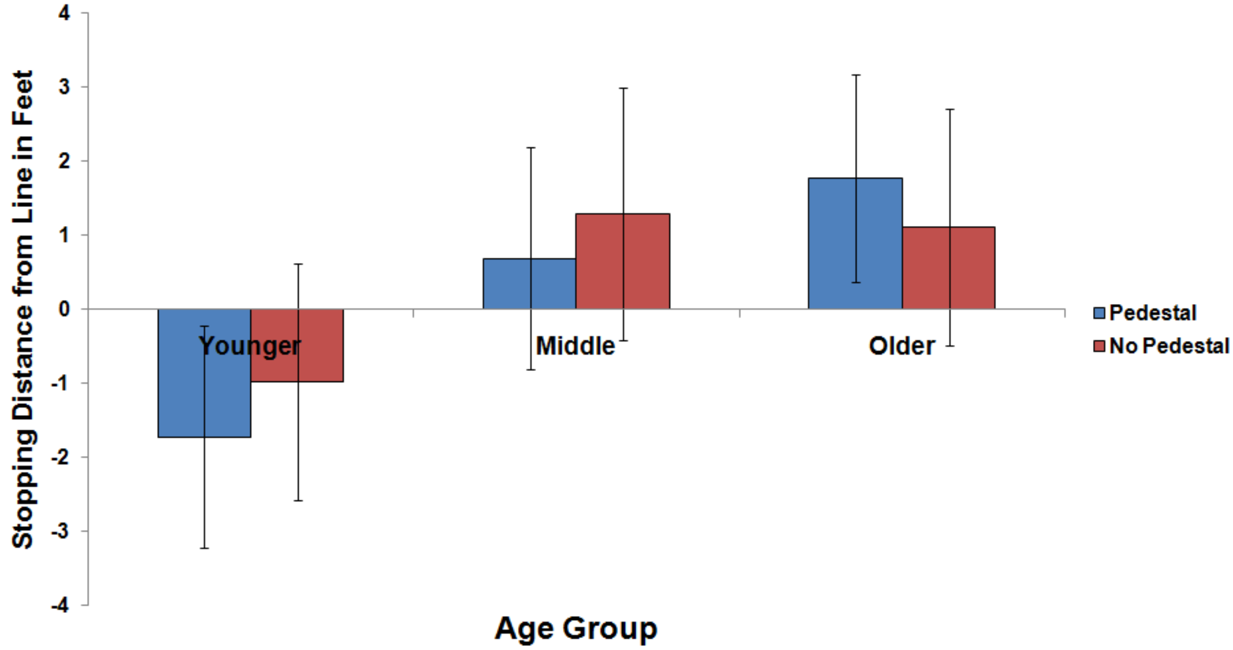

Figure 35. Average distance from stopping line in feet by age group. Error bars show 95% confidence interval.

Response Time

Two different measures of response time were collected in the current study. Although calculations based on the two measures correlated highly when compared across all observations where both measures were collected, *r* (133) = .85, *p* < .001 (see Figure 36). Because relatively few participants had complete data from both measures, analyses with will be presented separately for each response time measure (see Tables 3 and 4).

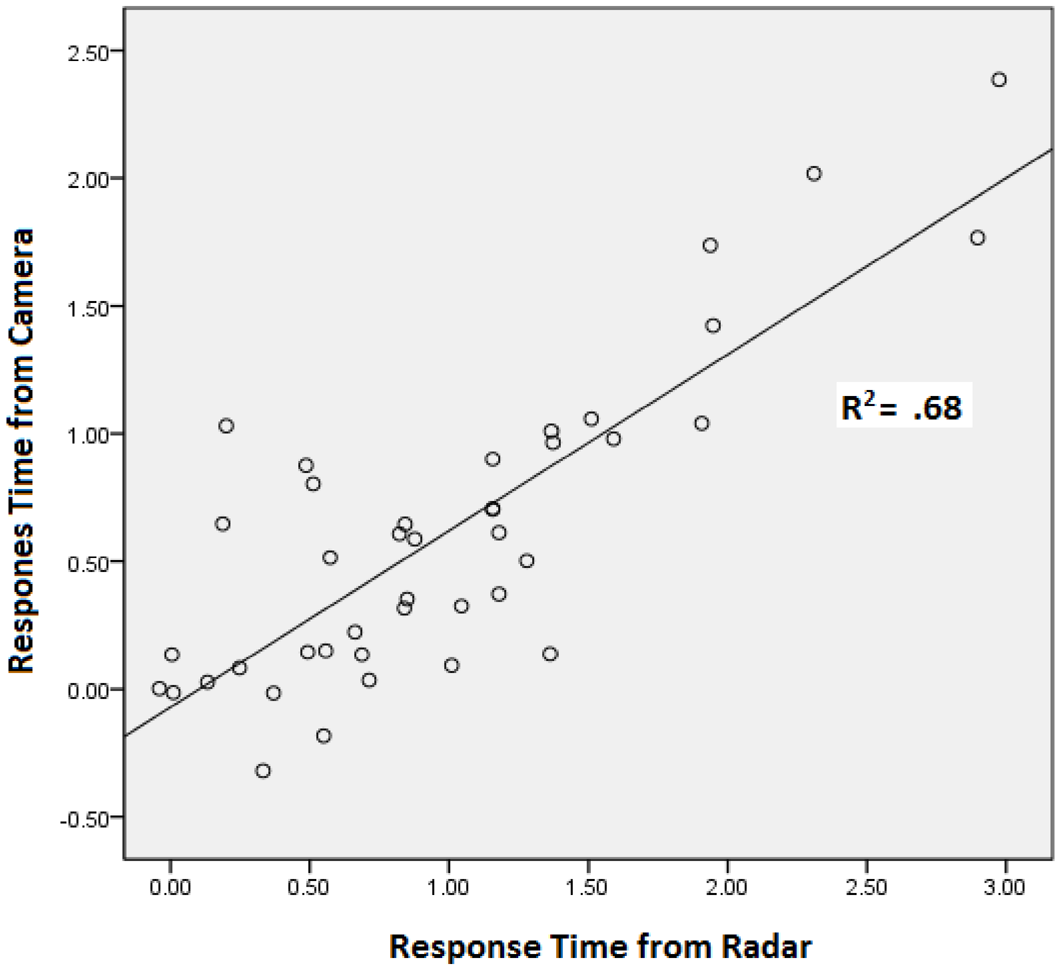

Figure 36. Scatterplot showing the relationship between response times based on radar calculations and response times based on video recordings.

Table 3. Number of stop trials where each type of response time was calculated by age group

	Radar	Camera	Both
Younger (21-35)	73	66	57
Middle (50-64)	60	42	28
Older (65 and up)	74	55	50
Total	**207**	**163**	**135**

Table 4. Participants with complete data from each type of response time measure by age group

	Radar	Camera	Both
Younger (21-35)	13	14	8
Middle (50-64)	12	8	5
Older (65 and up)	14	11	7
Total	**39**	**33**	**20**

A 2 x 3 mixed model ANOVA, where the presence or absence of the pedestal signal was the within-subjects factor and age group was the between subjects factor, was conducted to determine whether the mean response time, as calculated from the radar measure, differed between pedestal and non-pedestal trials. There was no significant difference in average response times for trials where the pedestal signal was active and those where it was not, $F < 1$, nor did this effect differ across age groups, $F < 1$. As expected, however, there was a significant main effect of age such that older adults had the slowest response times, which differed significantly from middle aged adults, $F(1,36) = 10.83$, $p = .002$, $\eta^2_p = .23$, but not from younger adults, $F(1,40) = 2.85$, $p = .10$, $\eta^2_p = .07$. Surprisingly, younger adults' response times were also significantly slower than middle adults', $F(1,36) = 5.31$, $p = .03$, $\eta^2_p = .13$ (see Figure 37).

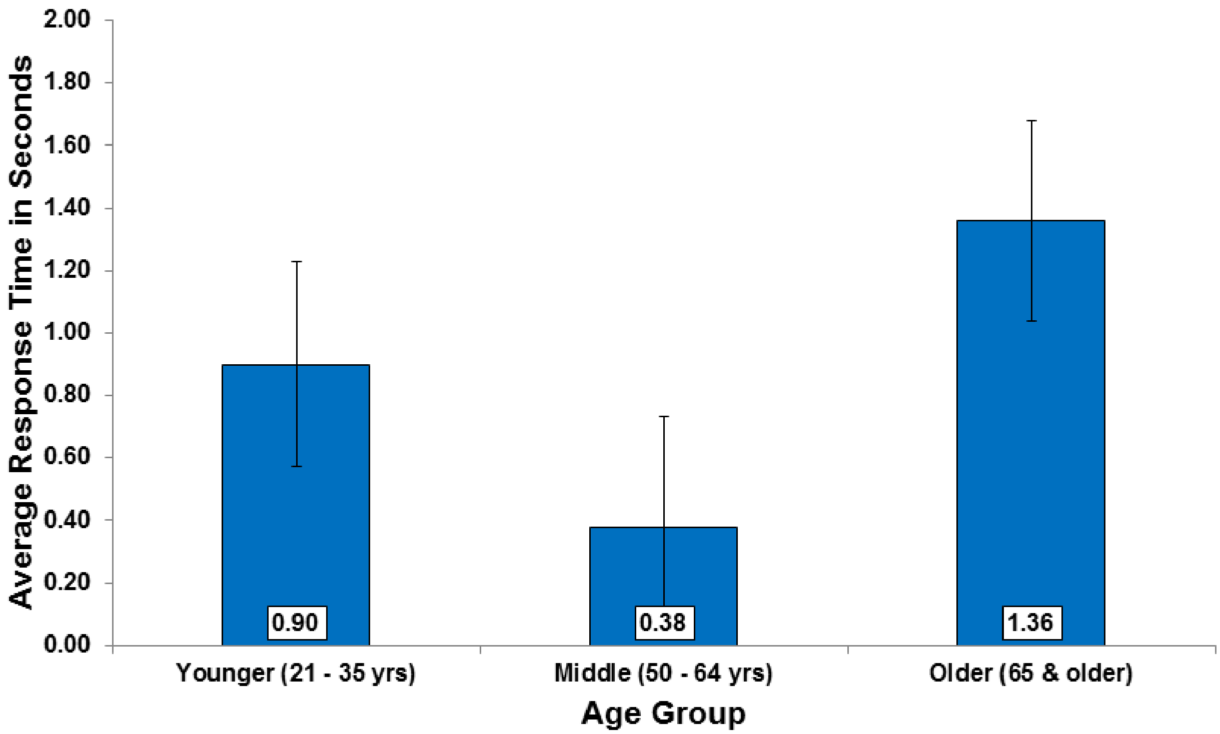

Figure 37. Average response times for radar measure by age group

Response times based on video recordings of each trial were also compared between pedestal and non-pedestal trials. Although response times based on this measure were slightly shorter on average, likely because there is a slight delay between when a car's brake lights are first activated and when the car begins to slow down, there was again no evidence of any significance difference in response times between pedestal and non- pedestal trials, $F(1,39) = 2.11$, $p = .16$, $\eta^2_p = .05$, nor did this difference vary between age groups $F < 1$. There was again a significant main effect of age, $F(2,39) = 6.00$, $p = .005$, $\eta^2_p = .24$, which followed a different pattern from what was observed for the radar-based measure of response time. Younger adults' response times were significantly faster than older adults', $F(1,31) = 6.73$, $p = .03$, $\eta^2_p = .13$. However, neither younger and middle, $F(1,28) = 1.26$, $p = ..27$, $\eta^2_p = .04$, nor middle and older, $F(1,25) = 2.48$, $p = .13$, $\eta^2_p = .09$, adults' response times differed from one another (see Figure 38).

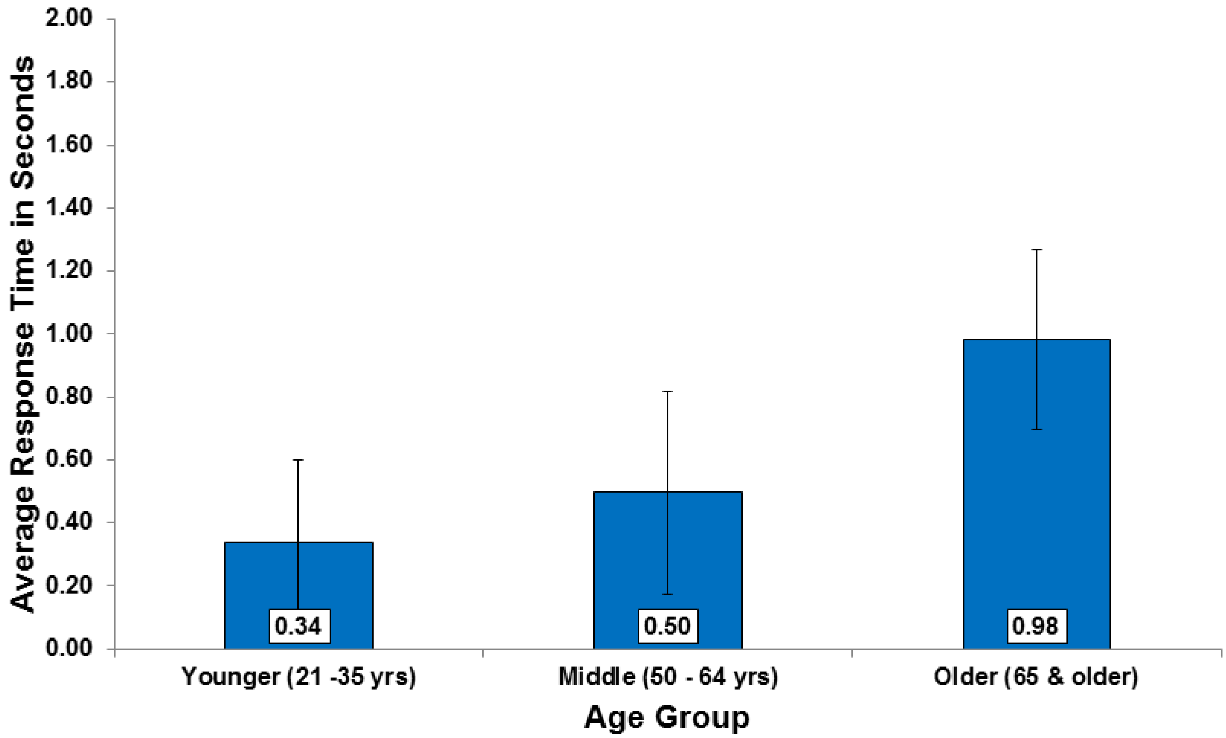

Figure 38. Average response times for video measure by age group

Approach Speed

Participants may not react immediately to a changing traffic signal. Instead, it is likely that the speed at which a driver is approaching the intersection influences the delay between when they notice that the signal has changed and when they begin braking. For this reason, we also examined first whether or not approach speed differed between pedestal and non-pedestal trials and also whether there were any differences between age groups. There was no evidence that participants varied their approach speed as a function of whether the pedestal signal was activated, $F < 1$, nor did this factor interact with age group, $F(2,52) = 2.62$, $p = .08$, $\eta^2_p = .09$. As expected, there was a significant main effect of age, $F(2,52) = 9.30$, $p < .001$, $\eta^2_p = .26$. Younger and middle aged participants approached the intersection at significantly higher speeds than did older participants, $F(1,40) = 13.62$, $p = .001$, $\eta^2_p = .25$, and, $F(1,36) = 4.57$, $p = .04$, $\eta^2_p = .11$, respectively, but younger adults' approach speed did not differ from middle aged adults', $F(1,36) = 2.87$, $p = .10$, $\eta^2_p = .07$ (see Figure 39).

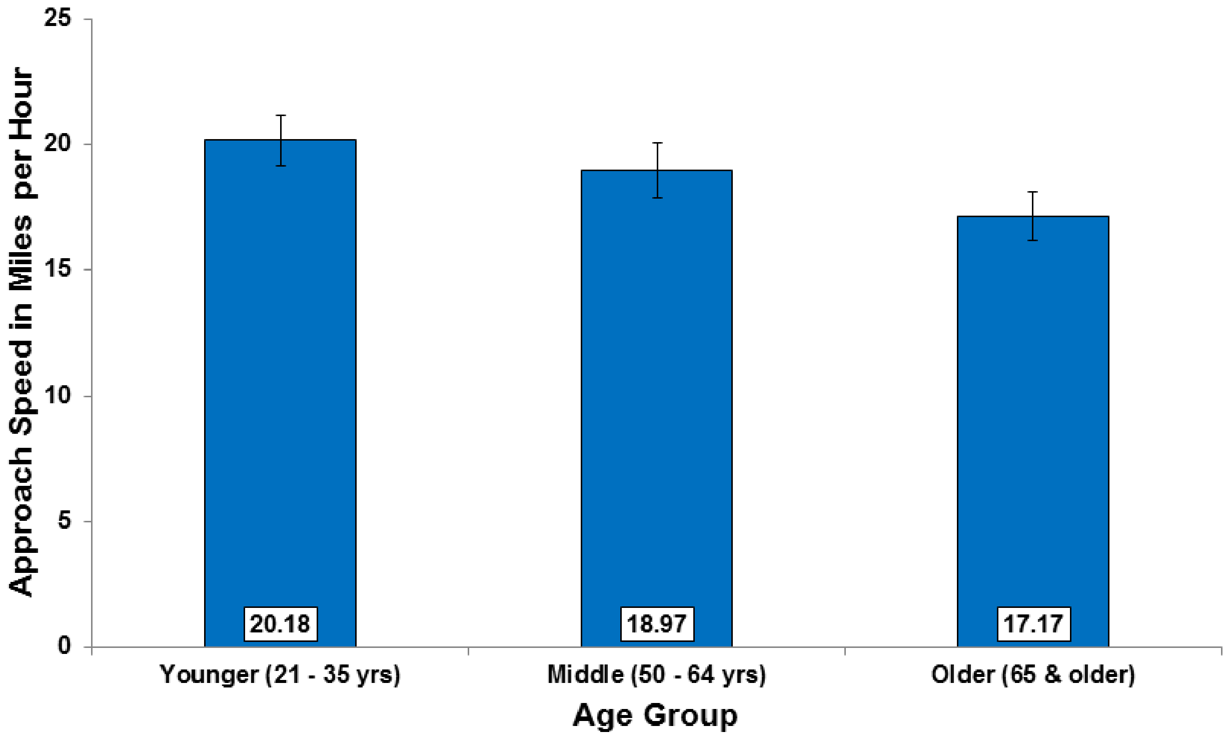

Figure 39. Average approach speed by age group. Error bars show the 95% confidence interval

Because response times based on either measure relate to approach speed, separate response time analyses were conducted while controlling for approach speed. Results were identical to those where approach speed was not entered as a covariate.

Post Experimental Questions

Participants were asked a series of questions at the end of the session to determine whether they noticed and attended to the pedestal signal during the experiment. First, participants were asked whether if they noticed anything different between the first and second block of trials. If a participant indicated that they had noticed that something differed, they were asked to tell the experimenter what it was that was different. Next, participants were asked whether or not they noticed the pedestal signal. Finally, participants were asked to indicate whether the pedestal signal was activated during the first or second half of the experiment.

There were no age differences in the frequency at which participants mentioned the supplemental signal, nor were there age differences in the frequency at which participants mentioned other aspects of the procedure that changed during the experiment (e.g. signal was green or red, asked to turn left or right) (see Table 5). However, there were age differences in the frequency at which participants mentioned either something that did not differ between trials or said that nothing differed (see Figure 40).

Table 5. Chi-square tests for age differences in the frequency at which each response was given

Did you notice differences between trials? If so, what was different?			
Response	***N***	**X^2**	***p***
Mentions supplemental signal	11	1.27	.53
Mentions other trial difference (signal, turn direction)	13	2.92	.23
Mentions something that didn't differ	10	6.20	.05
Said that nothing differed	29	6.28	.04

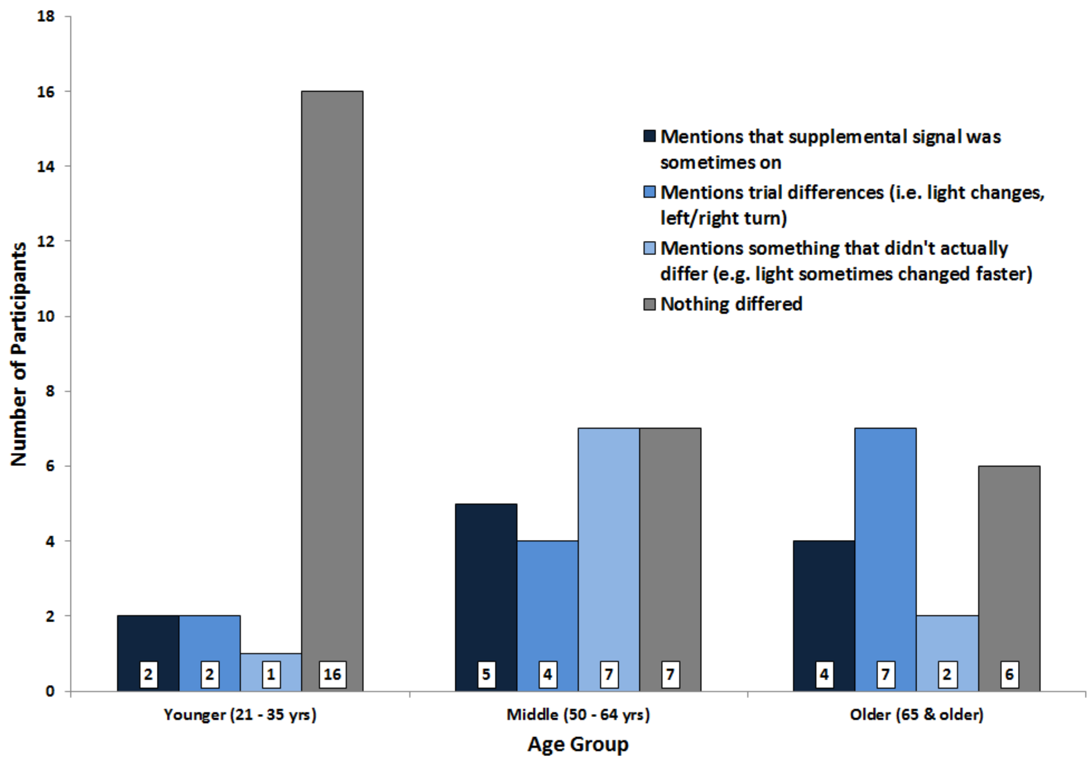

Figure 40. Number of Participants in each age group reporting each type of difference

Middle aged adults were more likely to mention an aspect of the procedure that did not actually differ between trials than were younger adults, X^2 (1, N = 8) = 4.50, *p* = .03. In addition, younger adults were more likely than older adults to say that nothing differed between trials, X^2 (1, N = 22) = 4.55, *p* = .03 (see Table 5).

When asked directly whether they had noticed the pedestal signal, participants were just as likely to say that they had seen the signal as to say that they had not, X^2 (2, N = 65) = 2.60, *p* = .11. Although more younger and middle participants responded that they had noticed the supplemental signal, this difference did not reach statistical significance for either age group, X^2 (1, N = 20) = 3.20, *p* = .07 and X^2 (1, N = 23) = 2.13, *p* = .14, respectively (see Figure 41). If a participant indicated that he or she had noticed the pedestal signal during the experiment, they were asked to say whether it had been activated during the first or second half of the experiment (see Figure 42).

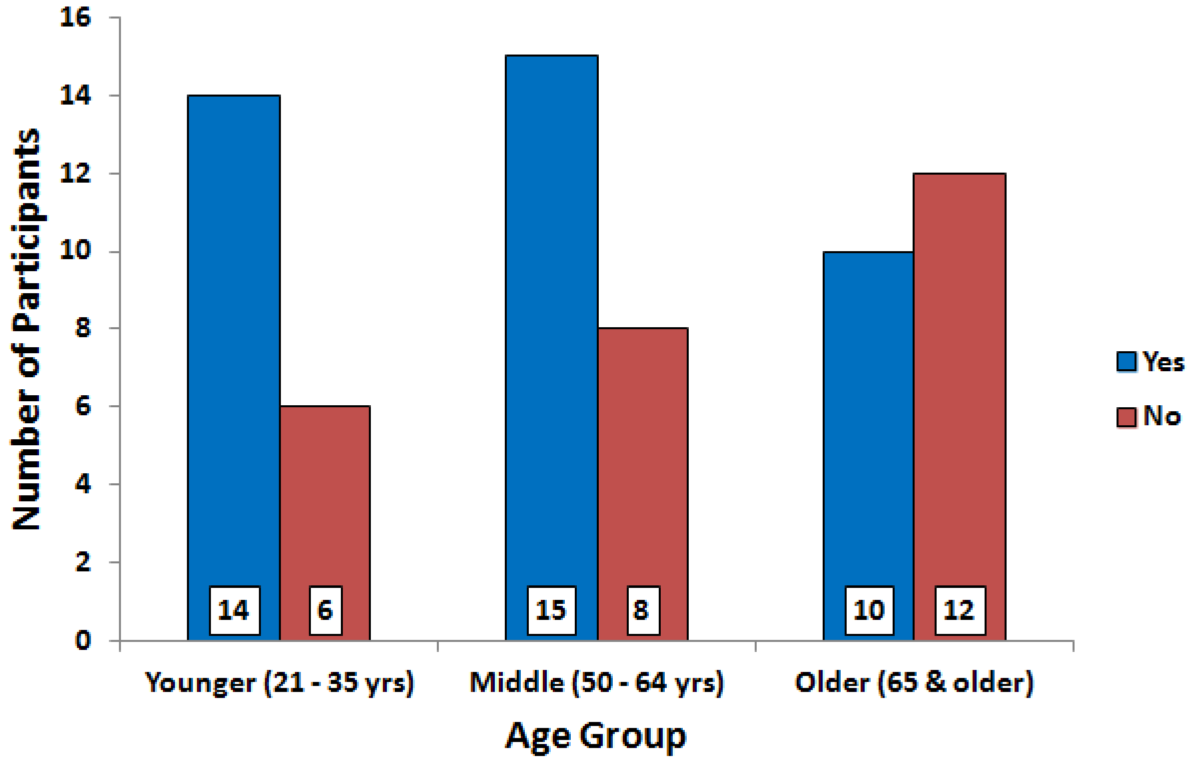

Figure 41. Number of participants in each age group that indicated that they noticed the pedestal signal

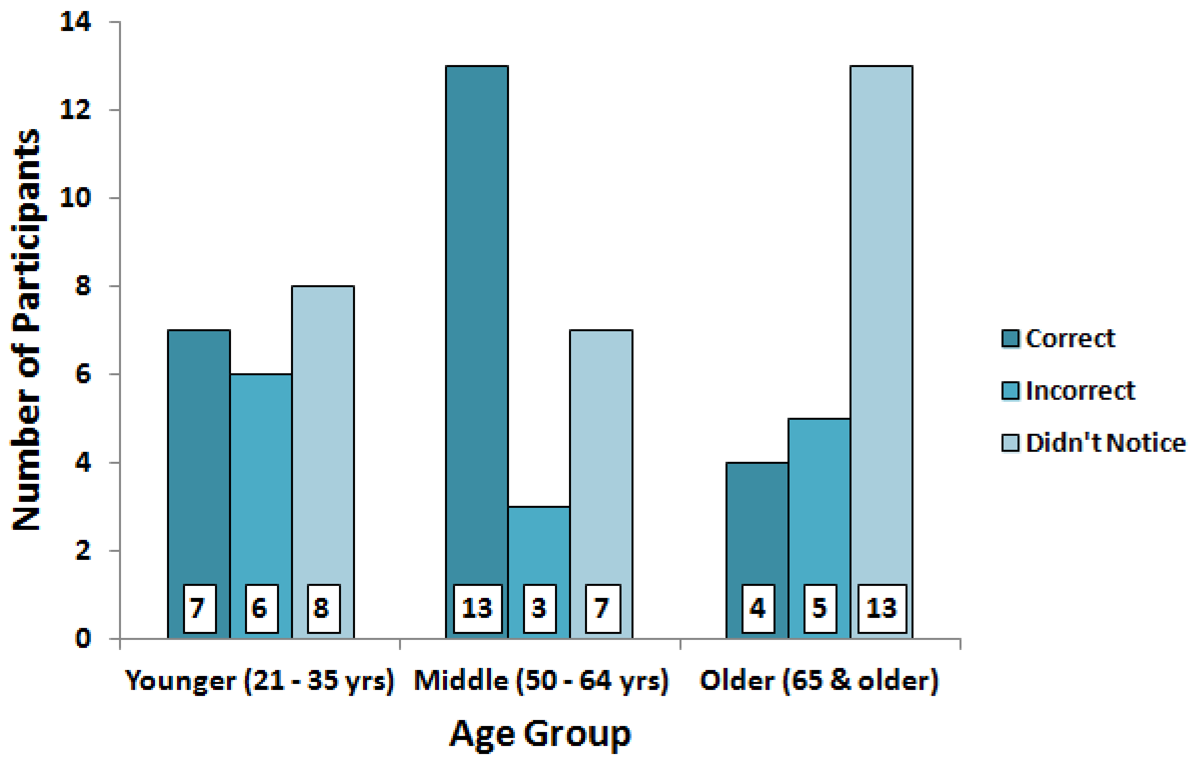

Figure 42. Number of participants in each age group correctly indicating whether the pedestal signal was activated during the first or second block of trials

Younger adults that reported noticing the pedestal signal were equally likely to be correct as incorrect in identifying whether the signal was activated during the first or second block of trials, X^2 (1, N = 13) = .07, p = .78. In contrast, middle aged adults were significantly more accurate in identifying the block of trials during which the supplemental signal was activated, X^2 (1, N = 16) = 6.25, p = .01. Older adults were no more accurate than younger adults, X^2 (1, N = 9) = .11, p = .87. Although older adults were more likely to indicate that they had not noticed the signal than were middle aged or younger participants, this difference was not statistically significant.

Conclusions

The presence of a pedestal signal did not affect driving behavior in terms of compliance with the signal (stopping behind the line on a red signal) or the time to begin decelerating when the signal changed to red, or the speed with which the driver decelerated when approaching a red signal, or for the speed of approach to the signal. Drivers when queried after the experiment infrequently reported noticing the presence of the pedestal signal when it was in operation.

The failure to find an effect of the signal cannot easily be attributed to insensitivity in our experiment as it revealed expected differences in performance on the more difficult to detect between subjects variable of age. Younger drivers stopped a few feet closer to the signal, and approached signals at a slightly higher speed (we could detect a difference of a few miles per hour). Younger drivers also responded more quickly to the red signal phase (we could detect differences of about 6/10 of a second between average young and average old response time).

We would need eye-tracking data to more fully explain the failure of a pedestal signal to affect driver performance because it would indicate what spatial locations were being fixated when drivers approached the intersection. Given that drivers more frequently encounter and hence probably attend to above intersection signal arms, it may be that there is little additional benefit to pedestal signals. The case where a driver’s view is obscured for the above intersection arm by a leading vehicle (such as a large truck) may be expected to yield an advantage for adding a pedestal signal. However, we could show no benefit in our study under the case of viewing an unobstructed intersection. Hence we do not recommend the routine installation of pedestal signals to improve driver compliance with intersection signals, particularly, the case of stopping for a red light. As with all field studies, there are caveats associated with this conclusion. We tested a pedestal signal addition with only one intersection type with an unobstructed view. We also instructed drivers to use a relatively slow driving speed (20 mph) appropriate to the particular track that we used. Also the additional signal was not a fully integrated pedestal for the right hand turn situation.

Chapter 5. A Field Study of Relative Effectiveness of Regular and Retroreflective Sheeting for Illuminated Street Signs

Given age-related changes in dark adaptation, which make it more difficult for older drivers to detect signs at night, many municipalities are using internally illuminated street signs to improve legibility for all drivers at night, but with the expectation that they will be of greatest benefit to older drivers. However, in the event of an emergency situation when power may not be available, it is also useful to ensure that such signs are still highly visible from headlight illumination. Thus, there remains a choice for the sheeting used for the signs: regular or retroreflective. In general, greater illumination of traffic signs lead to greater legibility distances (Zwahlen & Xiong, 2001). Therefore, a retroreflective sign sheeting will be easier to read than a regular sheeting to the extent to which the reflective sheeting is brighter. In support of this claim, Carlson and Hawkins (2002a) found that, due to their greater luminance, signs using retroreflective sheeting display greater legibility distances than signs using standard sheeting. On a closed track, Holick & Carlson, (2003) compared two different font types at night with car headlamps set to high and low values (13, 6 cd/m^2 luminance assessed from a blank sign at a distance of 640 feet). In general, they found that legibility distance increased with luminance. Furthermore, they found a luminance by sheeting interaction showing that, as the retroflectivity contrast ratio increased, legibility distance improved more for low luminance than high luminance conditions.

Eccles & Hummer (TRB Paper No. 01-2236) have shown a slight advantage at 4/7 sites using a before/after study where standard signs were replaced by retroreflective ones. However, such studies are difficult to evaluate given that they are observational, and changes in traffic patterns (increasing/decreasing traffic density) might account for changes in observed collision variables. One area where there may be an important advantage for retroreflective sheeting is with older drivers. A study by Anders (2000) involved younger and middle-aged to older (age 55+) drivers, in daylight and night time conditions with a number of different combinations of signs (using the phrase “test route” with a forward arrow), with one being non-reflective yellow on non-reflective purple. Motorists drove by signs on a highway in an experimental test vehicle (using low beams at night). Analyses on late braking behavior and wrong turns (taken as an index of sign perception difficulty) showed no effects of sign type but one problem with this study is that there was only a single sign tested once. However, driver preference ratings showed a strong preference for the retroreflective signs with the higher contrast ratios (character to background ratio). Older drivers did not differ much from younger ones except for rating signs, in general, easier to perceive.

Chrysler, Stackhouse, Tranchida & Arthur (2001) had older drivers (mean age 71) read experimental street signs in early evening hours in winter in St. Paul, MN at two different intersections in an instrumented car and estimated legibility distances for Type IX, Type VII (microprismatic sheeting), Type III (encapsulated lens material) and Type I (lens retroreflective) sheetings. They found greater legibility distances for the retroreflective Type VII (170 feet) and Type IX (172 feet) over Type III (142 feet) which was superior to Type I. Interactions with type of intersection and placement (right, left sides of roadways) indicated a larger advantage for the microprismatic signs.

In the following study, we assessed the efficacy of illuminated street signs for younger, middle-aged, and older drivers using both regular and reflective sign types.

Task 4: Efficacy of internally illuminated street signs

Method

Design

The design for this study is a 2 x 2 x 3 mixed model design where a fluorescent-illuminated sign panel type (retroreflective, Type III sheeting vs. standard non-reflective sheeting) and sign match (match vs. mismatch) are varied within-subjects, and age (younger, middle, and older aged adults) varied between subjects. A retroreflective version and standard non-reflective version of 8 street names were used, comprising a total of 16 signs. Each experiment contained 8 trials in addition to a practice trial, as the experiment had four versions which balance for type of panel and match/mismatch condition for each street sign stimulus. All 16 signs are used across the versions and balanced within each age group.

Materials

A Southern Manufacturing Clean Profile LED Street Name Sign (http://www.southernmfg.com/street-name-signs.html) was mounted at a height of about 6 feet relative to the ground (see Figure 43). A photo of each sign in an illuminated condition is shown in Figure 44.

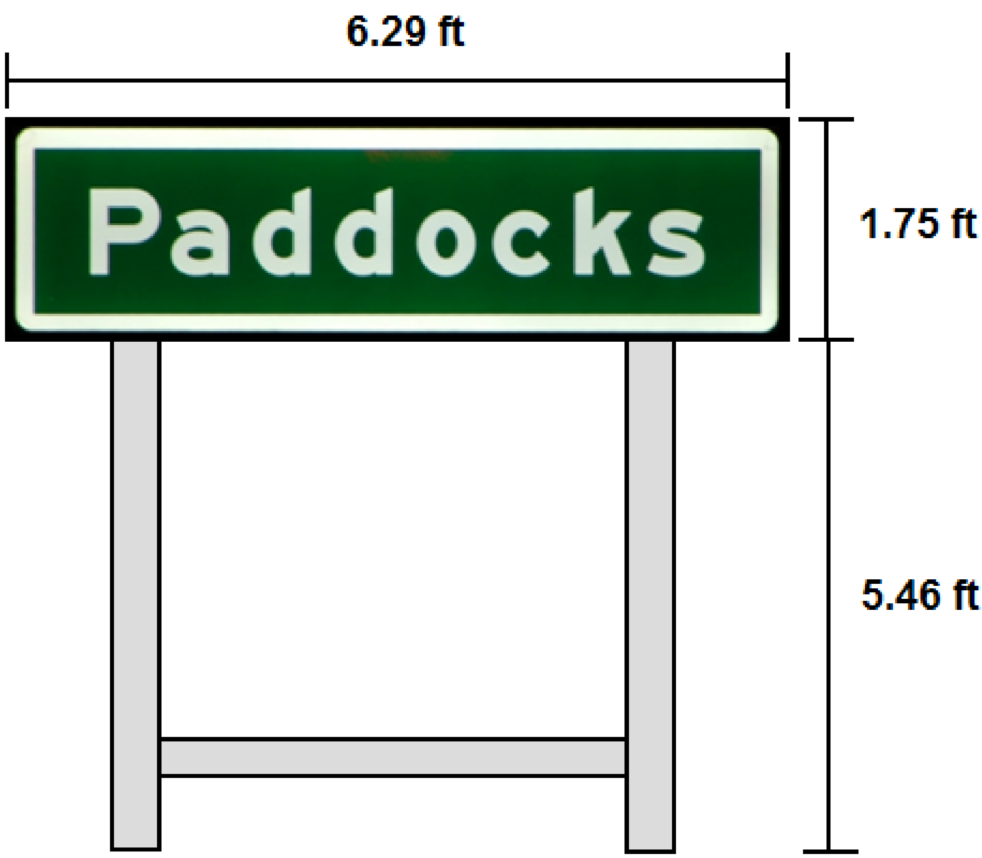

Figure 43. Diagram of sign with measurements. Ground where sign is mounted is uneven. Actual height from ground varies from 5.46 to 6 feet

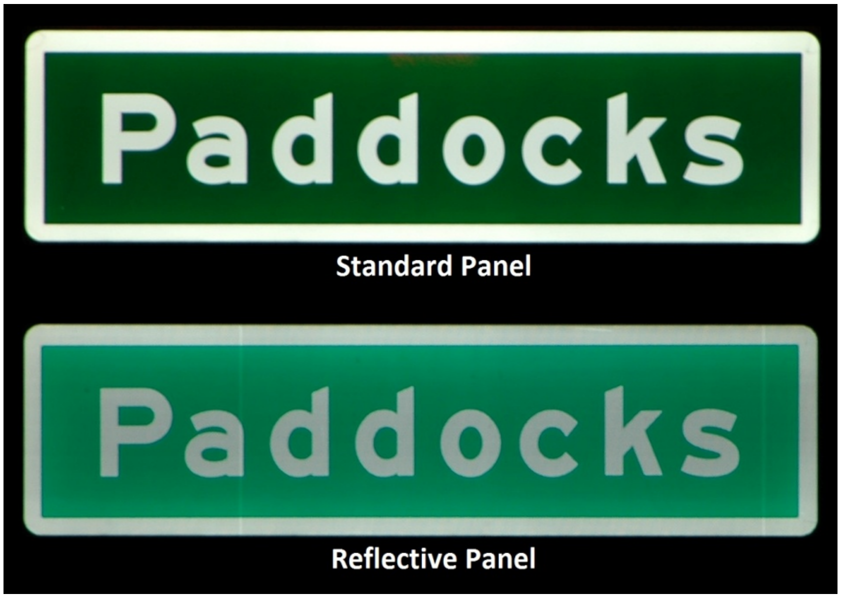

Figure 44. Photographs of a Retroreflective and a Standard Panel taken under the same ISO, F-stop, and Shutter Speed settings with a high quality Digital Camera

The experiment was conducted at night time, generally starting between 8:30 pm and 11:00 pm, with darkness defined as a luminance reading of .007 cd/m^2 or below (out of range). An in-car experimenter showed the participant a picture of one of the street names on a laptop and asked the participant to make a decision about whether the street name on the laptop matched the panel displayed at the end of the track. The participant was instructed to drive closer until they can make that decision. Half of the time, the picture matched, while half of the time, it did not match. For mismatch trials, a foil similar to the displayed word at the end of the track was used. For example, the actual sign on the track could be "Overhale", while the mismatch displayed on the laptop would be "Overnale".

Participants were instructed to use their low-beams only. When they made a complete stop and have made their match/mismatch decision, the in-car experimenter also took two luminance measures of the street sign using a Konica Minolta Chroma Meter (CS-100A; measuring candela per square meter), as a difference in legibility may be accounted for in a difference in intensities of the sign panel types (see Table 6)[3]. The start line of the track is located 765 Feet away from the sign apparatus. The radar gun, capturing distance traveled, is located behind the start line.

Table 6. Luminance measures for signs used in Task 4 (in cd/m^2)

Standard		Retroreflective	
200 feet	**500 feet**	**200 feet**	**500 feet**
31.4	11.3	9.1	20.3

[3] Note that near measurements are sometimes dimmer than far measurements. This is because the TERL track is not level. Headlights illuminate the sign less at distances under 300 ft.

Participants.

A total of 20 young (M=23 yr), Middle-aged (M=59 yr) and 20 Older drivers (M = 71) participated. All participants were prescreened to determine eligibility for participation. Participants were paid $15 each for participating in the study.

Results

Sign Viewing Distances

Only accurate trials were used in this analysis. Age group and sign type were submitted to a 2 x 3 mixed ANOVA with age group as a between-subjects factor and sign type as a within-subjects factor. The main effects of sign type and age group were qualified by their interaction, $F(2, 57) = 3.23$, $p = .047$, $\eta^2_{pl} = .10$ (see Figure 45).

Follow-up tests of the interaction revealed a significant difference between the reflective and standard sign for middle-aged drivers, $F(1, 19) = 9.90$, $p = .005$, 95% CI [-34.58, -6.96], $\eta^2_p = .34$, with a difference of 20.8 ft in favor of the standard sign. There was also a marginally significant difference of 11.9 ft in favor of the standard sign for older drivers, $F(1, 19) = 3.85$, $p = .065$, 95% CI [-24.75, .80], $\eta^2_{partial} = .17$. The sign type difference for younger drivers was found to be non-significant, $F(1, 19) = .201$, $p = .66$, $\eta^2_{partial} = .01$, $1 – \beta = .07$.

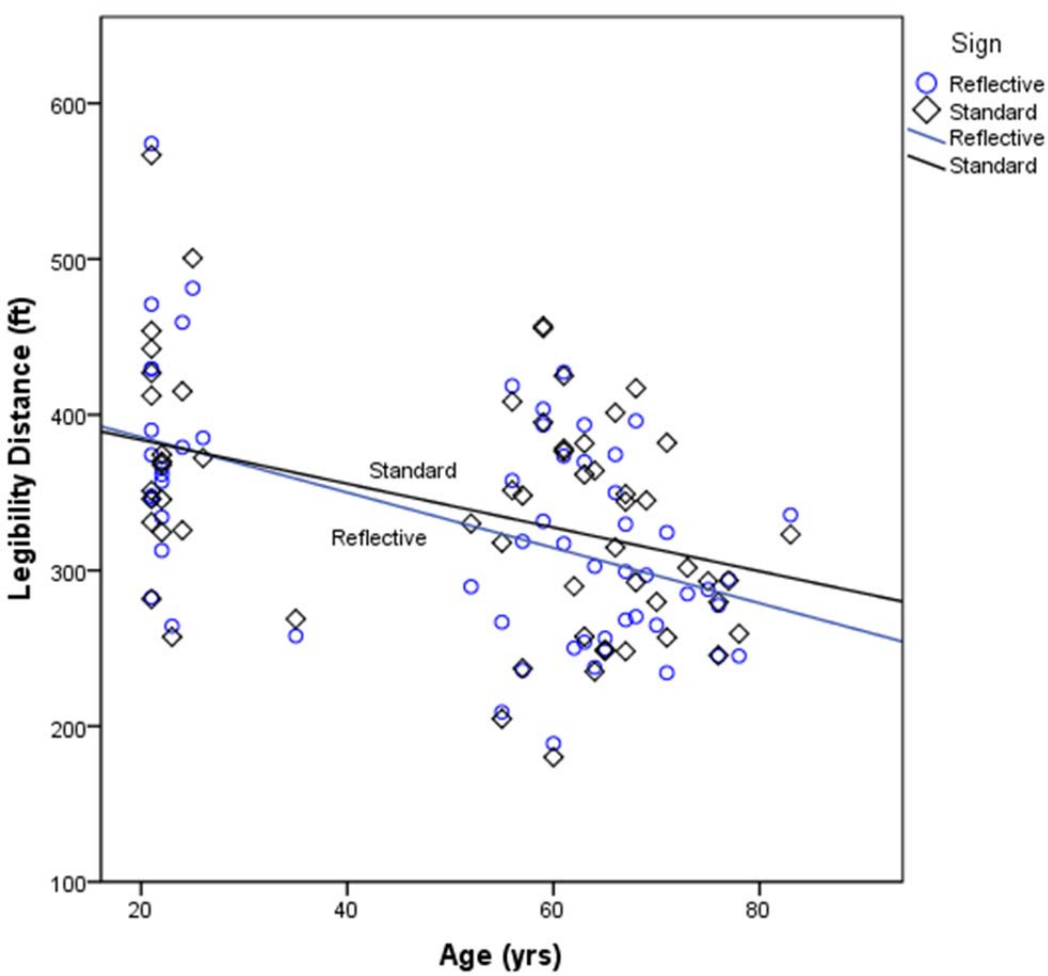

Figure 45. Legibility distance as a function of age and sign type

Sign Identification Accuracy

A 2 x 3 mixed ANOVA using sign type as a within-subjects factor and age group as a between subjects factor was conducted to examine potential differences in accuracy. The main effects for age group, $F(2, 57) = .14$, $p = .87$, $1 - \beta = .071$, $\eta^2_p = .005$, sign type, $F(1, 57) = .56$, $p = .46$, $1 - \beta = .11$, $\eta^2_p = .01$, and their interaction, $F(2, 57) = 1.26$, $p = .29$, $\eta^2_p = .042$, $1 - \beta = .26$, were found to be non-significant, suggesting that there are no population differences in accuracy across age groups and sign types, or if there are differences, the effect is very small and unlikely to be of practical significance (see Figure 46).

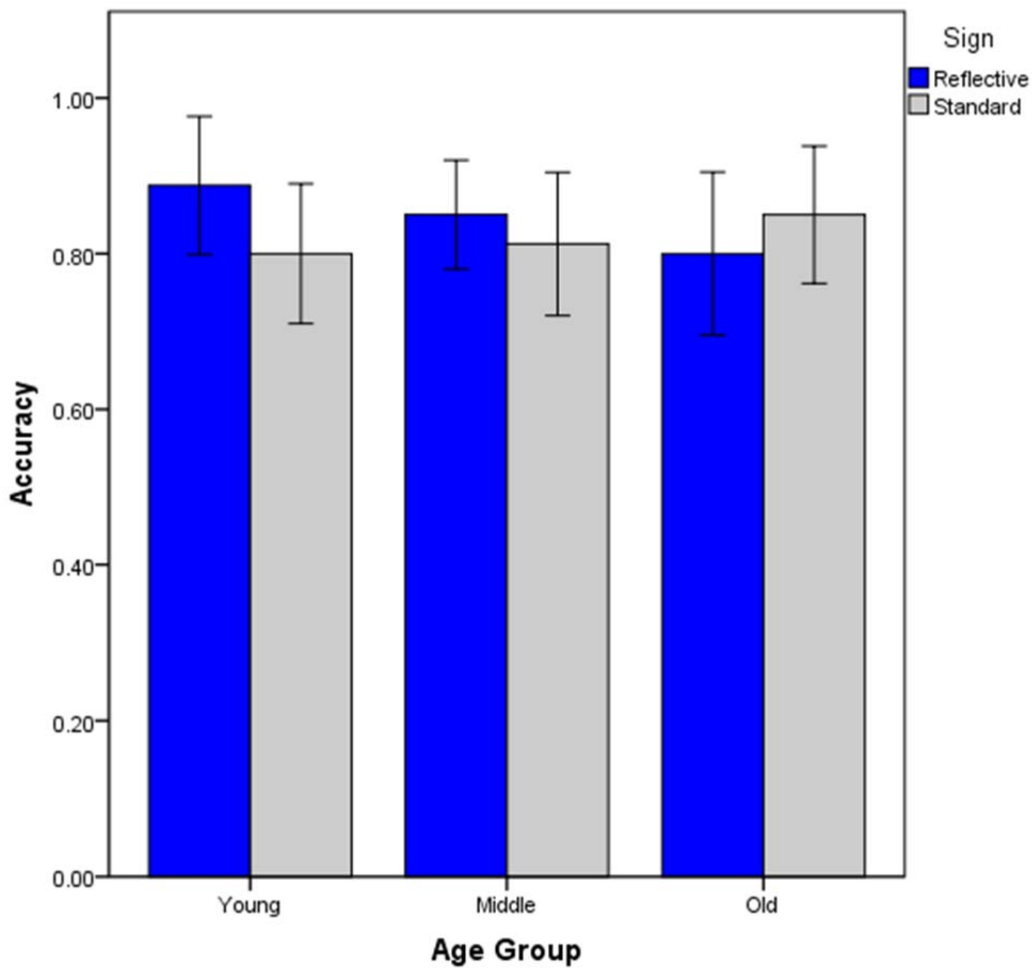

Figure 46. Accuracy as a function of age group and sign type (error bars represent 95% confidence intervals)

Sign Luminance

A mixed linear model using restricted maximum likelihood estimation was used to examine differences in luminance between the two sign types while controlling for distance. The model was implemented through SPSS MIXED, Version 18. Mixed modeling was used in this analysis because it allows for sign type, a within-subjects variable, to be used as a predictor without violating assumptions of independence. This is done by treating the intercept of the grouping factor (participant) as a random effect.

The model revealed a significant difference of 4.34 cd/m^2 (*95% CI*: 3.61 to 5.07) between the two signs when distance was held at its mean of 336.26 ft, with the standard sign being the most bright, $t(40.679) = -11.94$, $p < .001$. The model also showed that for every 1 ft increase in distance from the two signs, luminance decreased by about .06 cd/m^2 (*95% CI*: .05 to .07) (see Figure 47).

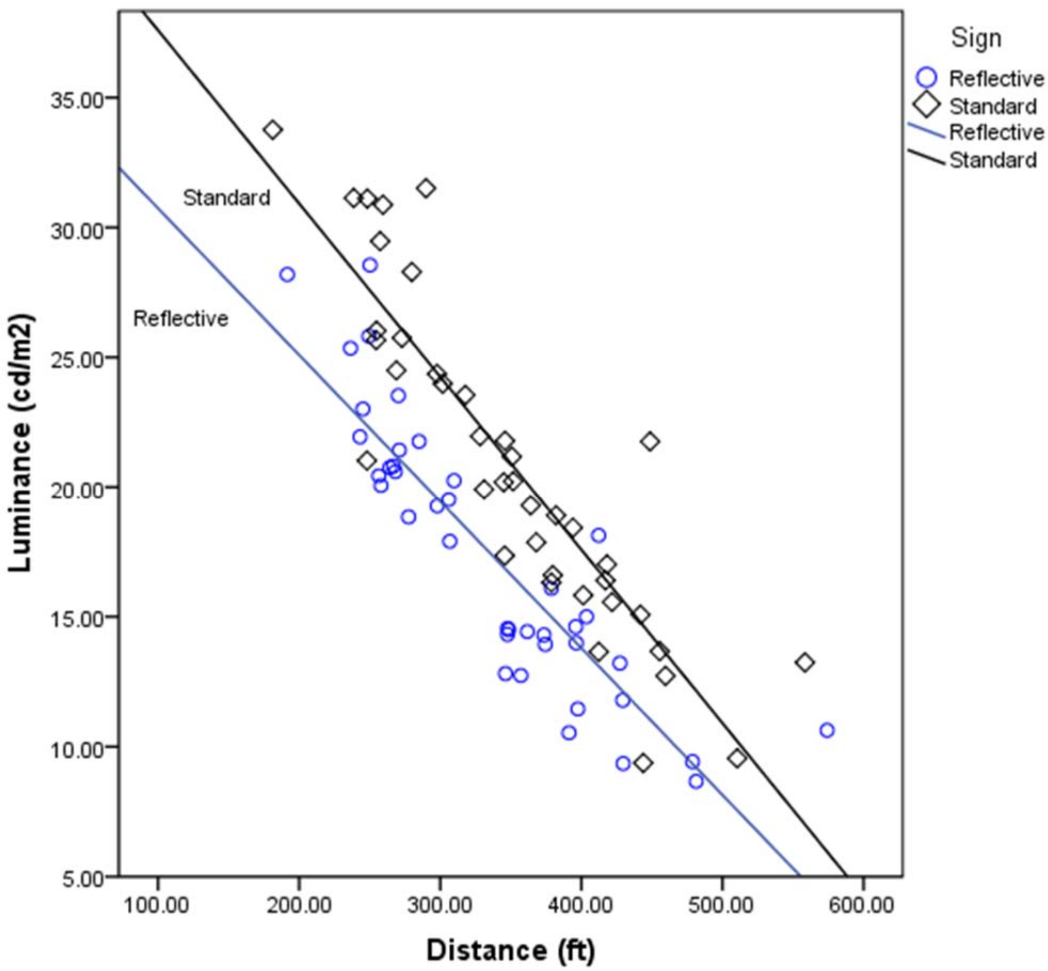

Figure 47. Luminance as a function of distance and sign type.

Conclusions

In terms of legibility distance, the results suggest the existence of an advantage for the standard sign over the retroreflective ones for middle-aged and older drivers but not for younger ones. Hence we would recommend using the standard sign sheeting when normal (illuminated) conditions prevail. From the luminance values shown in Table 6, however, we could infer that under a power failure condition the reflective sign would be expected to be at an advantage. The fact that there were no significant differences in accuracy between the two sign types suggests that these results are not purely due to an accuracy-distance trade-off. In addition, because no participant was able to read any of the signs at the furthest distance allowed (765 ft), a ceiling effect could be ruled out in explaining the lack of significant difference between the two signs for the younger drivers. Furthermore, the standard sign's advantage in legibility distance is best explained by its greater level of measured luminance.

Chapter 6. Observational and Field Studies on the Efficacy of Pedestrian Signal Buttons using Varying Types of Feedback

Task 5: Efficacy of Pedestrian Signal Buttons that Provide Feedback.

In 2009, an estimated 59,000 pedestrians were injured and another 4,092 were killed in traffic crashes across the United States. That same year, Florida reported the highest rate of pedestrian fatalities: 2.51 per 100,000 residents (NHTSA, 2009). Although pedestrian fatalities represent a relatively small proportion of injuries and fatalities in traffic crashes, 3% of all injuries and 12% of fatalities, this type of crash may be an easy target for reducing the overall number of traffic injuries and fatalities. One report notes that a sizeable proportion of pedestrian-vehicle conflicts, as much as 43%, were judged to have been caused solely by the pedestrian, compared to 35% for drivers (Campbell, Zegeer, Huang, & Cynecki, 2003).

According to reports, about 40 percent of all pedestrian-vehicle crashes occur at intersections (Lord, Smiley, & Haroun, 1998), so understanding pedestrian behavior at intersections could be particularly useful in developing programs to reduce the number of pedestrian injuries and fatalities. It has been noted that pedestrian compliance at signalized intersections is quite low, with estimates ranging from 50% (Zegeer, Opiela, & Cynecki, 1983) to below 20% (Huang & Zegeer, 2001). It is possible that low compliance rates with pedestrian signals may be one contributing factor to pedestrian-vehicle crashes at intersections.

Why do pedestrians fail to cross with the signal when one is available? Studies have identified a number of contributing factors, such as the length of time pedestrians must wait before crossing (Van Houten, Ellis, & Kim, 2007) and the amount of vehicle traffic present (Bush, 1986; Garder, 1989; Yagil, 2000; Van Houten, Ellis, Sanda, & Kim, 2006). Another factor that could also affect pedestrian compliance is whether or not they believe the pedestrian signal is operating correctly; if pedestrians do not believe the signal is working, they might be less likely to wait until the pedestrian signal changes to “walk”.

In the current project, we conducted two studies to evaluate the effect of signal button feedback on pedestrian crossing behavior. In our first study we observed and recorded the behaviors of pedestrians at several intersections in Tallahassee. The aim of this initial study was first to evaluate the advantage, if any, of pedestrian buttons that provide auditory feedback compared to those that do not, as well as identify other factors that might also affect pedestrian behavior. Because effects on compliance do not necessarily address the question of whether providing positive feedback directly affects pedestrians’ confidence that a button is operating correctly, we conducted a second field study where this question could be specifically evaluated.

Task 5: Observational Study

Method

Intersections Observed

Only intersections located in Tallahassee’s downtown area were used due to their relatively high pedestrian traffic compared to other parts of the city, allowing us to obtain a more diverse sample that included pedestrians of all ages. We selected several intersections that were balanced on as many factors as possible given the set of locations available. These factors, which were selected because other research suggested that they were relevant to pedestrians' crossing behavior at intersections, included the type of pedestrian button (auditory feedback or no feedback), size of intersection (3 lanes or less versus 4 or more), and estimated pedestrian and vehicle traffic (high or low traffic). After evaluating and piloting several locations, eight intersections were chosen for the observations (see Table 7, Figure 48).

Table 7. Intersections observed. Street 1 is the crossing that was being observed. Average daily traffic (ADT) data retrieved from: http://www.talgov.com/pubworks/traffic_cnts/index.cfm

	Intersection	Button Feedback	Size	ADT Street 1	ADT Street 2	Sessions
1	S. Monroe / E. Madison	No	Large	27,485	4,857	3
2	S. Monroe / Gaines	No	Large	22,485	25,110	3
3	Gadsden / Park	No	Small	7,873	5,912	5
4	Apalachee / S. Monroe	No	Large	30,967	29,210	4
5	S. Monroe / Jefferson	Yes	Large	30,042	N/A	3
6	Call / S. Monroe	Yes	Small	4,022	30,042	5
7	S. Monroe / Tennessee	Yes	Large	32,359	32,401	4
8	Duval / St. Augustine	Yes	Small	7,247	N/A	4

Figure 48. Locations of observed intersections

Procedure

Eight research assistants from the Aging Driving and Pedestrian Safety (ADAPtS) lab were trained on our coding scheme. Coders were trained by the lead field supervisor, and practiced recording observations at an intersection near the Florida State University campus for several sessions before collecting data. The information coded during each session is listed in Table 9.

There were always two experimenters present during any observation session so that agreement between raters could be examined. Observers were situated at opposite ends of the intersection; so that they both had a clear view of the pedestrian signals (see Figure 49). To assure that the data coded by each observer could be matched during data entry, coders recorded the exact time at the beginning of each cycle when a pedestrian was present. Observations for a given cycle were only considered valid for inclusion in analyses if both observers reported data.

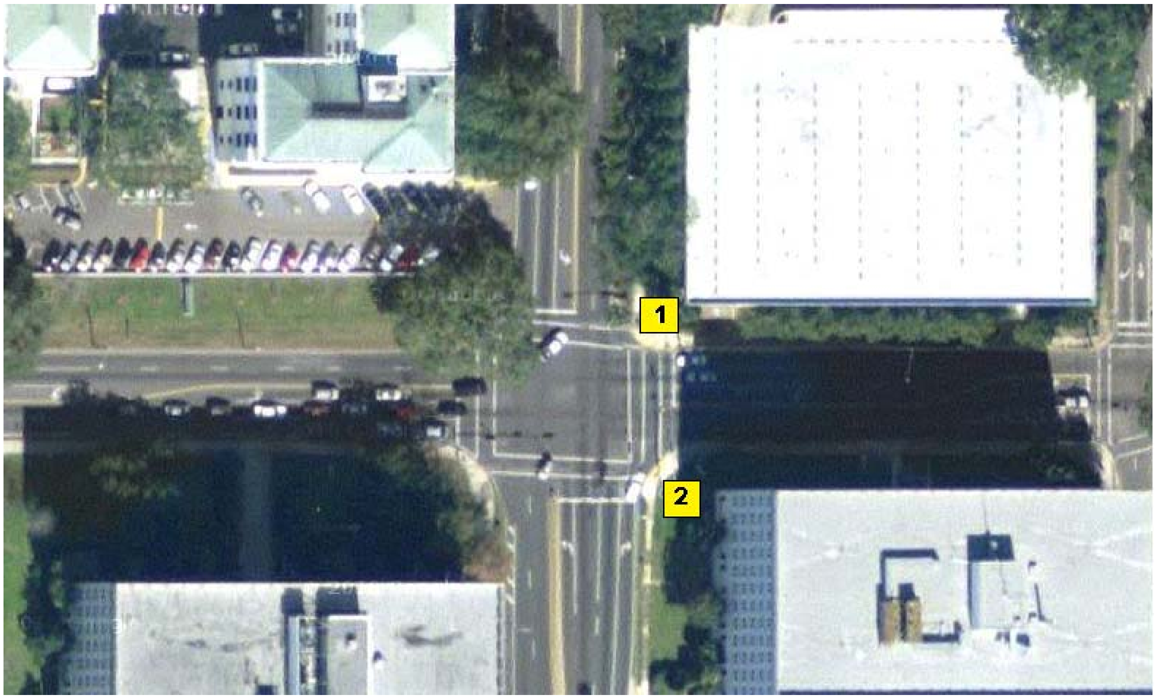

Figure 49. Observer locations for sessions at S. Monroe and Gaines. Image retrieved from Google Maps: http://tinyurl.com/2bzp4yw

Observation sessions, each lasting for one and a half hours, took place on weekdays during three time periods likely to have a significant amount of pedestrian traffic. The observation times are as follows: Morning, from 7:00 a.m. to 8:30 a.m., Lunch, from 11:30 a.m. to 1:00 p.m., and Afternoon, from 4:00 p.m. to 5:30 p.m. Each intersection was observed at least once for each time block, while other intersections may have been observed several times during each to compensate for their lower pedestrian traffic. The number of observations for each intersection is given in the last column of Table 8.

Our goal was to have approximately the same number of observations across intersections with each signal button type. However, due to the substantially lower pedestrian traffic at smaller intersections, we were only able to equate the number of observations across button types for large intersections. The total number of observations across large and small intersections for each signal button type is given in Table 8.

Table 8. Total number of pedestrians observed for each signal button type at large and small intersections.

	Feedback	**No Feedback**	**Total**
Large Intersections	249	234	437
Small Intersections	188	26	260
Total	437	260	**697**

Table 9. Information recorded for each observation session.

Intersection Information – Collected in advance of each observation session	
Location	Street names/travel directions, which corner of intersection was being observed
Physical Features of Intersection	Signal button type, number of lanes, presence of refuge island, if buttons were labeled
Date/Day/Time of observation	
Weather conditions	e.g. temperature, overcast/clear
Environmental/Behavioral Observations – Recorded by observers during session	
Number of pedestrians present	Coded time of arrival during cycle (Don't Walk, Walk, Countdown)
Total number of cars stopped	Vehicles stopped at street pedestrian is crossing
Number of cars making right turns	Number of vehicles waiting to turn right on red while pedestrian is crossing
Illegal left turns	Noted if vehicles made illegal left turns into path of pedestrian
Pedestrian Behavior – Recorded for each pedestrian present during a cycle	
Signal Button Use	Number of times pedestrian pressed the signal button
Age Group (estimated)	Child, Younger Adult/Teenager, Middle Adult, Older Adult
Time of Arrival	Time during cycle when pedestrian arrived (e.g. Walk, Don't Walk, Countdown)
Wheeled Pedestrian	Whether pedestrian was on a bike, skateboard, using a wheelchair, etc…
Signal Compliance	Coded whether pedestrian entered intersection during the "Walk" phase, countdown, or "Don't Walk" phase
Complete Cross	Whether compliant pedestrians were able to cross in the time allowed, before the "Don't Walk" phase began
Walking Speed	Coded as "walk", "run", "speed up during cross"
Special Circumstances	Pedestrian/vehicle conflict, emergency vehicle, vehicle collision, vehicle ran light
Notes	Coders noted any special circumstance not explicitly requested on coding sheet

Results

Due to the small number of observations for small intersections overall, as well as the uneven number of observations across feedback and non feedback buttons at those intersections, some analyses will include only large intersections. However, as other studies have reported that few pedestrians tend to use crossing signals at small intersections with light traffic, the results for large intersections are the most useful for evaluating the efficacy of auditory feedback buttons.

Button Use

Across all cycles observed where a pedestrian was present, the button was pressed by at least one pedestrian 63% of the time, which is consistent with what has been reported in other studies (e.g. Zegeer, Opiela, & Cynecki, 1983), with some reporting rates lower than 20% (e.g. Huang & Zegeer, 2001). While a numerically larger percentage of pedestrians chose to activate the signal at intersections where buttons that gave auditory feedback were installed, this difference did not reach statistical significance, $X^2(1, N = 297) = 1.62$, $p = .20$ (see Figure 50). In accordance with other studies, we found that pedestrians were significantly more likely to activate the signal at large intersections with heavy traffic than at smaller intersections with very light traffic, $X^2(1, N = 297) = 21.53$, $p < .001$ (see Figure 51).

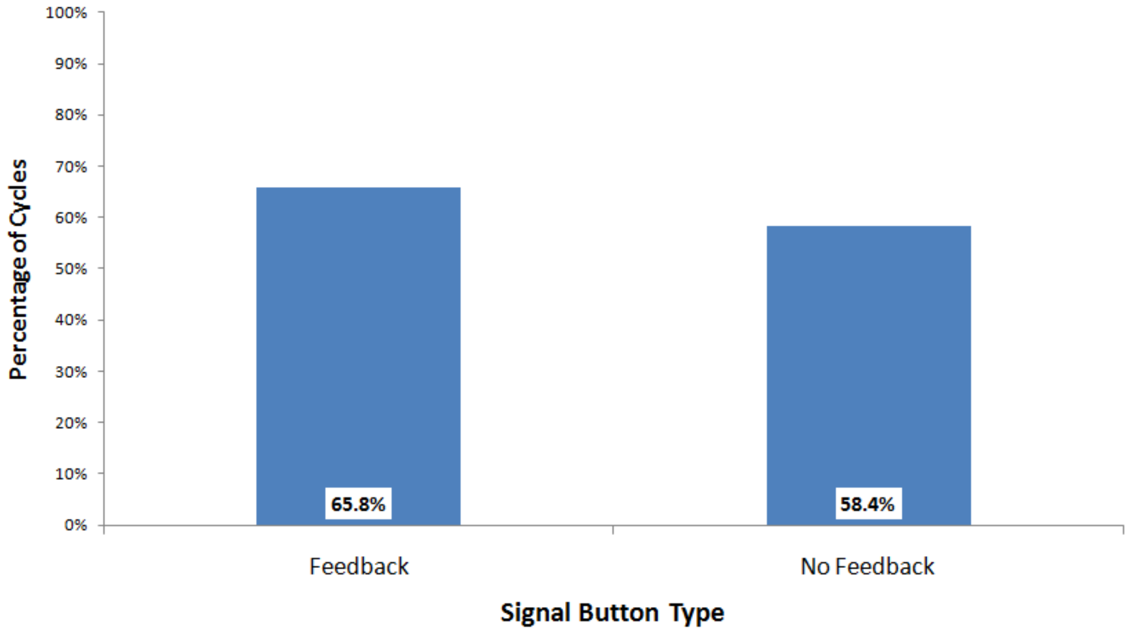

Figure 50. For each button type, out of the total number of cycles where a pedestrian was present, percentage where the signal button was pressed at least once

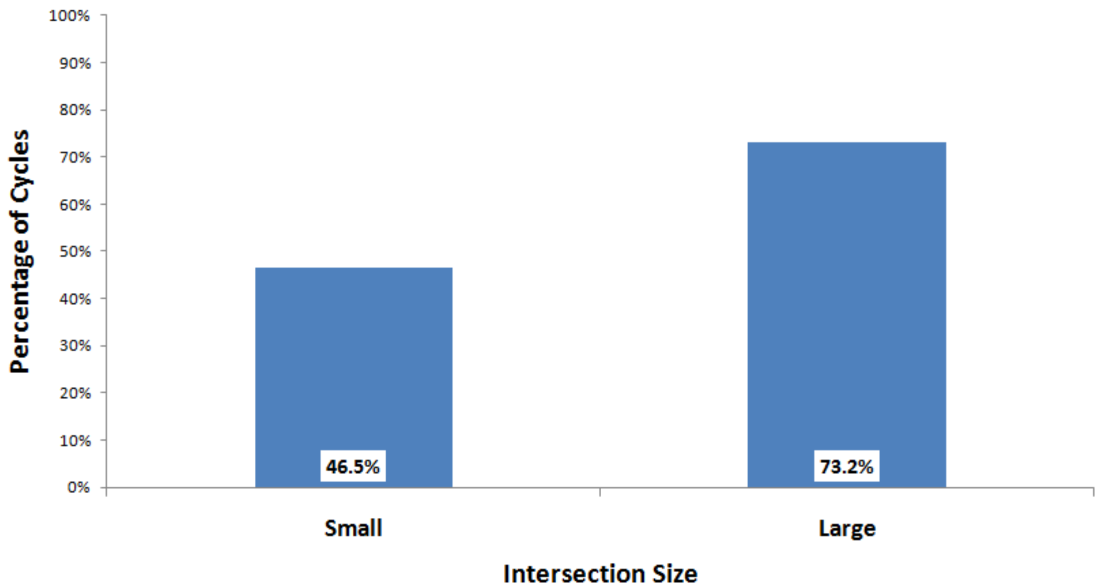

Figure 51. For cycles where a pedestrian was present, the button was pressed at least once on a greater percentage of cycles for large than for small intersections

We also examined button use by age group. However, due to the smaller number of pedestrians observed at small intersections, we do not have a sufficient sample size to make comparisons between age groups for small intersections. Because of this, the analysis was constrained to only large intersections. For large intersections, though there were slight differences in the frequency of button use across signal type for older and younger adults, this difference did not reach statistical significance for any age group (see Figure 52).

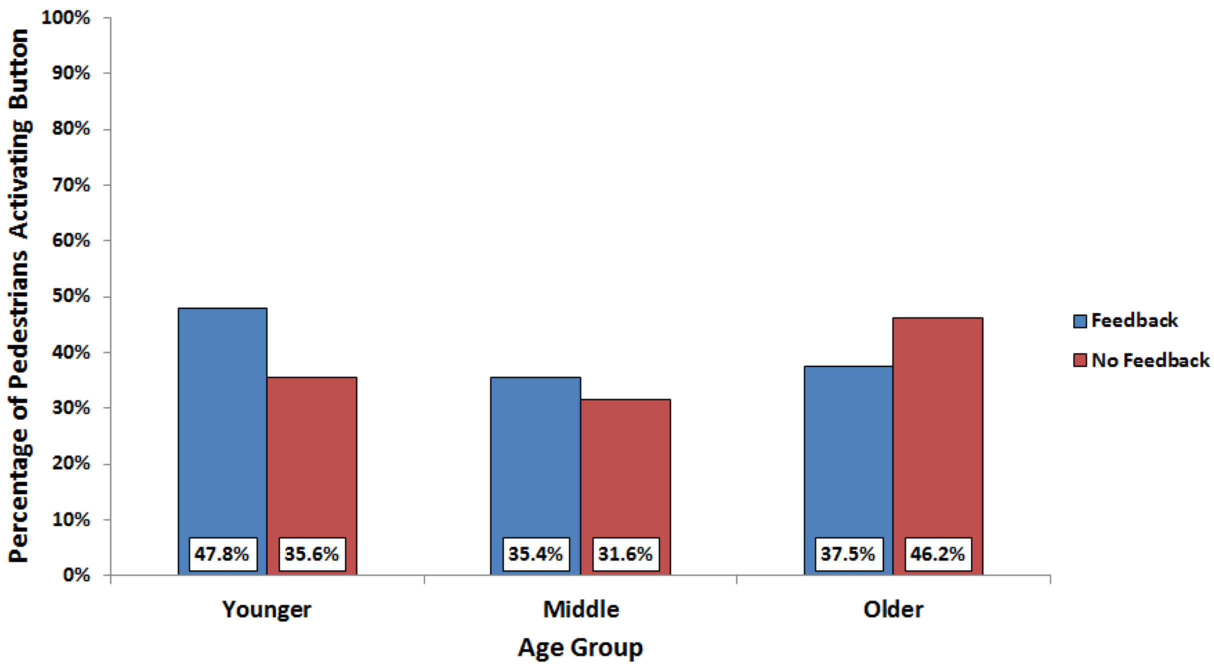

Figure 52. Percentage of pedestrians in each age group that pressed the signal button at least once for feedback and non feedback signals

Compliance

Next, we examined compliance with the pedestrian signals overall and by button type for large and small intersections. Compliance was defined as having entered the intersection during the "Walk" phase. Pedestrians that entered the intersection during the countdown or "Don't Walk" phases were counted as noncompliant.

For large intersections, pedestrians were no more likely to comply with the signal when the signal button provided feedback than when it did not, $X^2(1, N = 451) = .11$, $p = .75$ (see Figure 53). Compliance rates for each age group were then tested against the average compliance across all age groups, which was 78%. The compliance rate of 68% for younger adults was significantly lower than the group average, $p < .001$, while the compliance rate of 82% for middle adults was significantly higher than the group average, $p = .05$. Older adults compliance rate did not differ from the group average, $p = .33$ (see Figure 54).

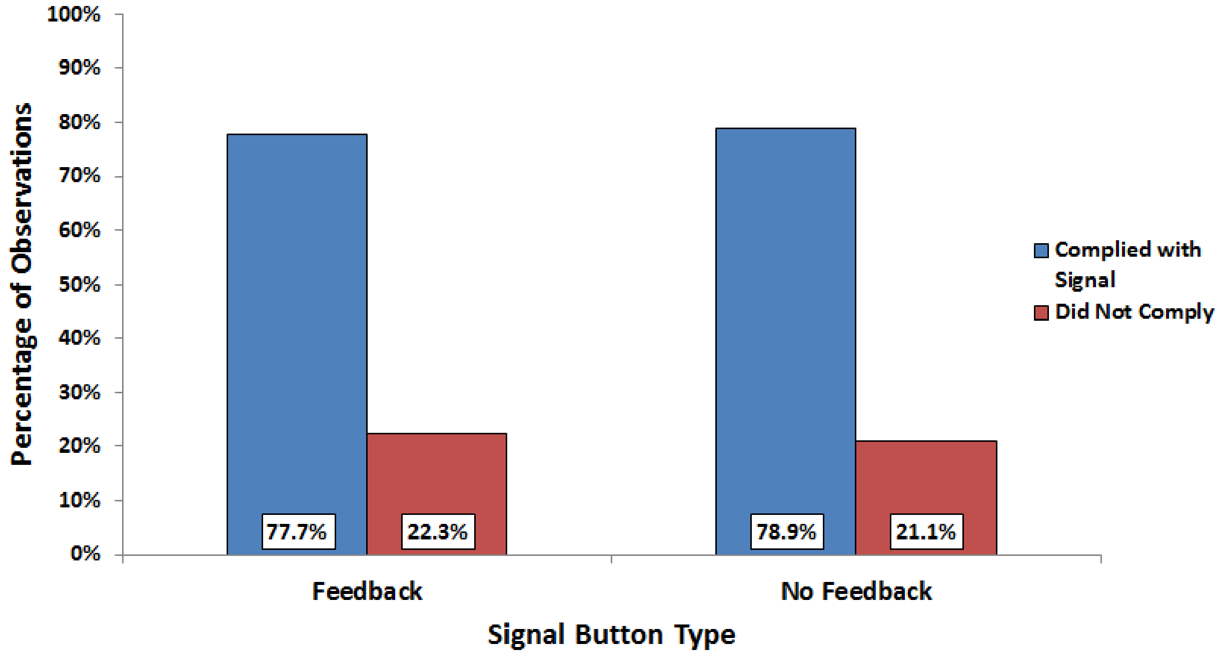

Figure 53. Percentage of pedestrians that complied with the signal for intersections with feedback and non feedback signal buttons

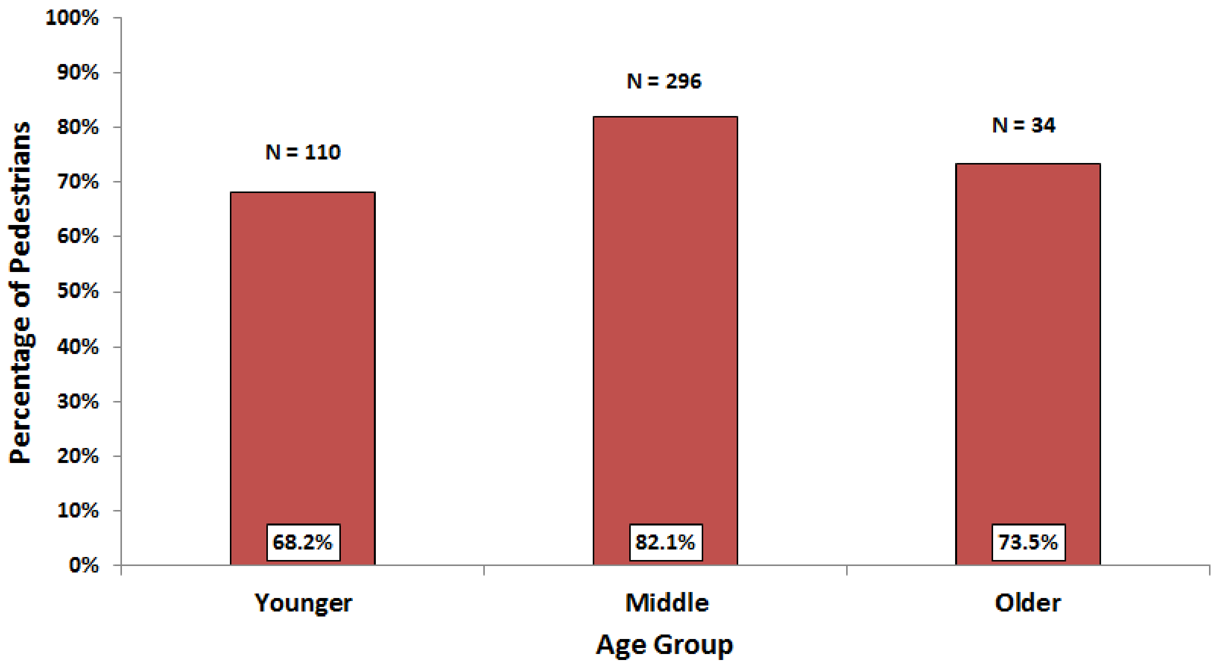

Figure 54. Percentage of pedestrians in each age group that complied with the signal for large intersections.

Previous studies have suggested that pedestrians sometimes fail to comply with the signal because they believe the signal button does not work. Multiple button presses by the same pedestrian during a single cycle may be an indication that the person is not confident that their request to cross has been registered and may believe that the pedestrian signal is not working properly (or may represent play behavior). It is possible that buttons that provide auditory feedback reduce this source of pedestrian noncompliance. To examine this possibility, we first compared the incidence of pedestrians pressing the signal button more than once across both signal types, and then went on to examine compliance as a function of whether pedestrians pressed the signal button once or multiple times. For large intersections, people were no more likely to press the signal button more than one time when feedback was given than they were when no feedback was given, $X^2(1, N = 172) = .72$, $p = .40$ (see Figure 55).

In addition, pedestrians who pressed the button multiple times were equally likely to comply with the signal when compared to those who pressed the button only once or not at all, $X^2(2, N = 439) = .14$, $p = .93$. Compliance was near 78% in all cases. Pedestrians who did not press the button at all were most often present during cycles where multiple pedestrians were crossing, which is the most likely reason for their high rate of compliance.

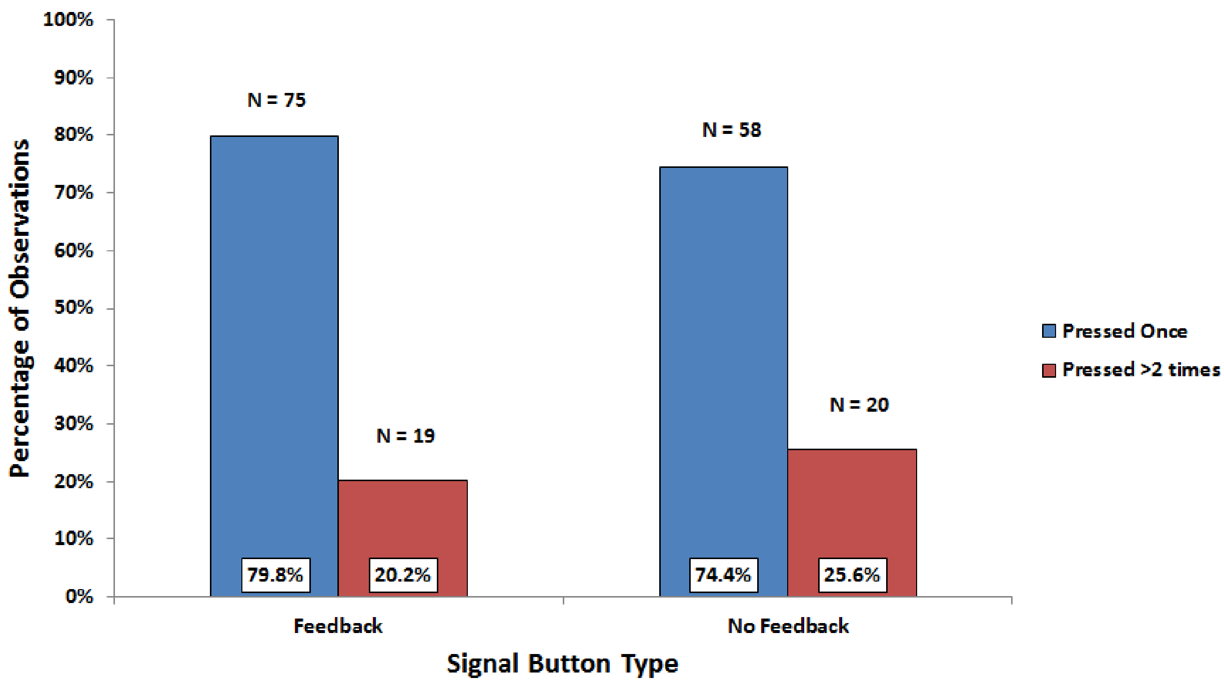

Figure 55. Percentage of pedestrians that pressed the button once or multiple times by button type.

Conclusions

Consistent with other studies, we found that pedestrians were more likely to use the pedestrian signal button at large intersections with heavy traffic than at smaller intersections with light traffic (Bush, 1986). For large intersections, where pedestrians were most likely to use the signal to cross, we found no evidence of differences in button use or compliance with pedestrian signals between intersections where a feedback button was installed versus those with a standard, non feedback button.

Overall, we observed high rates of compliance with pedestrian signals, with compliance for large intersections of 78%. We also found differences in compliance across age groups, with lower than average compliance for younger adults and higher than average compliance for middle aged adults.

Other work has suggested that pedestrians may sometimes fail to comply with the signal because they believe that it is not operating and so do not wait for the pedestrian signal to change. In studies that have found increased compliance following the installation of signal buttons that provide feedback, some have also reported that fewer pedestrians press the signal button multiple times after feedback buttons are installed. This has been taken as an indication that feedback buttons feedback signal buttons reassure pedestrians that their desire to cross has been registered making them less likely to believe the pedestrian signal is broken, which should reduce the number of noncompliant pedestrians. We recorded instances of multiple button presses in the current study and did not find any reduction in multiple button presses between feedback and non feedback intersections, nor did we find that multiple button presses were related to noncompliance. However, it is possible that this may be a result of the high overall rate of compliance in our study.

The current results do not suggest that pedestrian signal buttons that provide auditory feedback have a significant effect on compliance with pedestrian signals. Instead, our results suggest that other factors, such as how busy an intersection is, wait time, or the age of the pedestrian have a stronger effect on signal button use and compliance.

Task 5: Experimental Field Study: Pedestrian Crossing Attitudes for Signal Buttons with Varying Feedback Modes

The above study examined behavior of pedestrians crossing at intersections that may have been very familiar and so pedestrians may have been habituated to the form of feedback at the particular intersection. Where type of pedestrian signal button may have its strongest effect is in the case of unfamiliar intersections where people are less likely to be able to judge the conditions for safe crossing. In this study, we experimentally manipulated the type of button to be pressed and asked pedestrians to rate their confidence that the button press had been registered and the likelihood that they would wait for a crossing signal before crossing.

Method

Design

The Task 5 field study used a 3 x 2 mixed model design where pedestrian signal button type (no feedback, auditory feedback, vibrotactile + auditory feedback)and age group (younger, middle, older) was the only between subjects factor.

Participants

Participants were 66 adults, which included 21 younger (Mean Age = 21.67, SD = .86), 24 middle (Mean Age = 58.17, SD = 4.80), and 23 older (Mean Age = 72.35, SD = 4.61) adults (see Table 10). All participants in the Task 5 field study had also completed the Task 3 field study during the same experimental session. They were paid $25 for the combined sessions.

Table 10. Age and gender composition for Study 5.

Age Group	Male	Female	Total
Younger	10	11	21
Middle	6	18	24
Older	12	11	23
Totals	**28**	**40**	**68**

Materials

The types of buttons installed are a standard, non-feedback push button (Pelco Products, Inc. Model# P.N. SE-2061-08), the auditory "chirp" feedback unit (Polara Engineering, Inc., Bulldog Series: http://www.polara.com/Bulldog_Specifications.html), and the vibro-tactile and auditory "talking" feedback unit (Polara Engineering, Inc., Navigator: http://www.polara.com/Navigator.html).

Procedure

Participants were instructed to press each signal button and immediately rate their confidence that the button press has been registered by the signal. Following the confidence rating for each button, participants also rated the likelihood that they would be willing to wait for the signal if they were crossing an intersection equipped with that type of button. The order in which the buttons are presented was counterbalanced across participants. This was done to control for potential order effects. For example, participants that press and rate the standard, non-feedback push button first may give that button a higher rating than they would if they had rated one of the feedback buttons first.

After participants have rated all three buttons on these two questions, they answered questions about the frequency at which they travel as a pedestrian and indicate which factors that they believe influence their crossing decisions, such as the amount of traffic, size of intersection, wait time until walk signal, presence or absence of feedback, presence of walk signal, and whether or not they are in a rush. Participants were also given the opportunity to provide any additional information they felt was relevant, and this information, if any, was also recorded by the experimenter.

Results

Participants' Routine Use of Pedestrian Signals

Participants in the current study represented a range of experience with pedestrian signal equipped intersection (see Figure 56). Participants' self-reported frequency of crossing intersections equipped with pedestrian signals differed across age groups (see Table 11). Overall, younger participants tended to report more experience with signal-equipped intersections, with only six out of 21 participants reporting that they crossed signal-equipped intersections once a week or less and 12 out of 21 participants reporting that they did this three times a week or more. In contrast, most middle (19 out of 24) and older adult (20 out of 23) participants reported that they crossed signal-equipped intersections once a week or less.

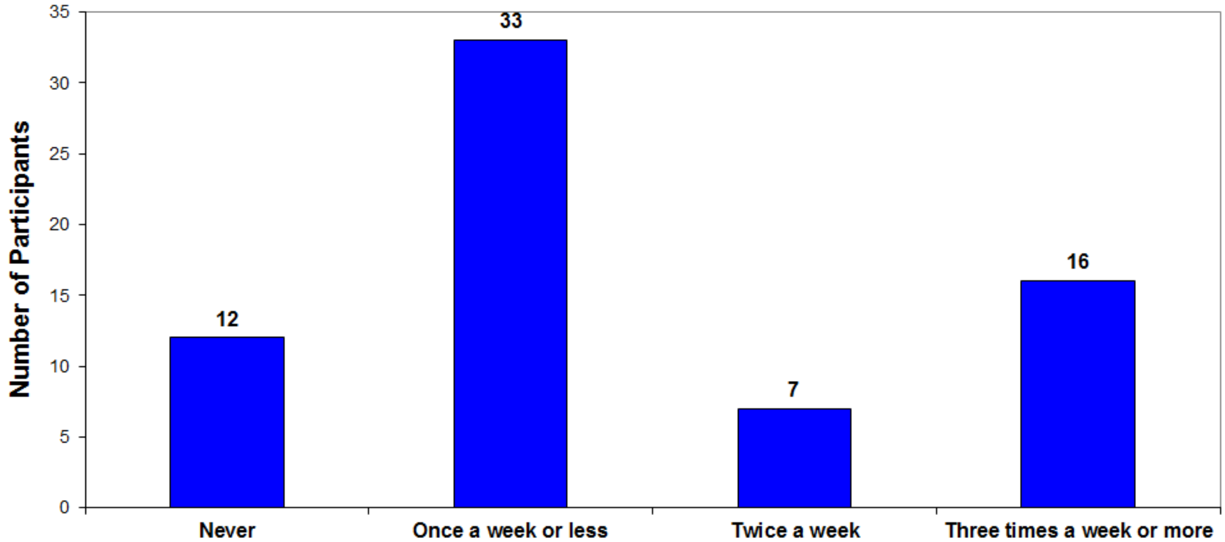

Figure 56. Total number of participants endorsing each response option for the question: How often do you cross streets where pedestrian signals are installed?

*Table 11. Participants' self-reported frequency of crossing intersections equipped with a pedestrian signal. * Indicates significance at < .05*

	Younger	Middle	Older	X^2
Once a week or less	6	19	20	8.13*
Three or more times a week	12	3	1	12.88*

Self-Reported Compliance with Signals

Participants in the current study reported high rates of compliance with pedestrian signals, and self-reported compliance significantly differed across age groups. Only 2 out of 68 participants, both younger adults, reported that they never wait for the "walk" signal before crossing, and 14 out of 68 reported that they sometimes wait for the "walk" signal (see Figure 57).

Overall, consistent with observed rates of compliance in the Task 5 observational study, younger adults reported lower rates of compliance than middle or older adults. While only three younger adult participants (14%) reported that they always wait for the "walk" phase, 12 middle adult participants (50%) and 13 older adult participants (57%) reported that they always wait for the "walk" phase, $X^2(2, N = 28) = 6.50$, $p = .04$ (see Table 12).

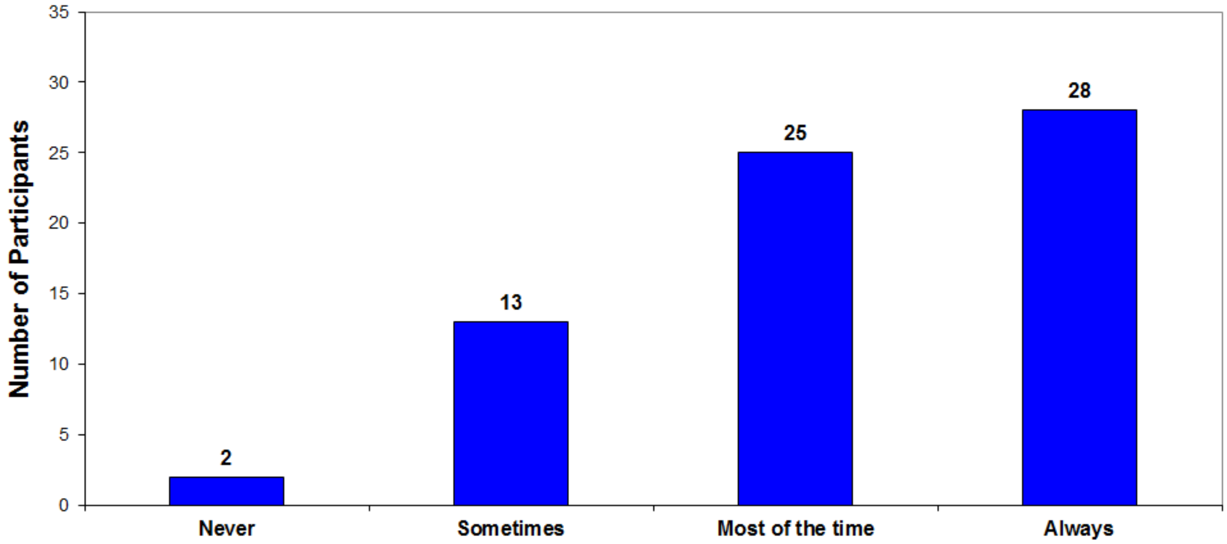

Figure 57. Total number of participants endorsing each response option for the question: When crossing a street with a pedestrian signal, do you typically wait for the walk signal before crossing?

*Table 12. Self-reported compliance at intersections equipped with pedestrian signals. * Indicates significance at < .05*

	Younger	Middle	Older	X^2
Never	2	0	0	n/a
Sometimes	9	3	1	8.00*
Most of the time	7	9	9	.32
Always	3	12	13	6.50*
Total:	**21**	**24**	**23**	

Factors Affecting Compliance

Previous studies have reported that the amount of traffic present at an intersection showed a strong relationship to pedestrian signal compliance (e.g. Garder, 1989; Yagil, 2000), and studies conducted in larger cities with heavier traffic tend to report higher rates of compliance (e.g. VanHouten et al., 2006; Miami, FL) than do studies conducted in smaller cities with relatively light traffic (e.g. Huang & Zegeer, 2001; Windsor, Ontario). Consistent with these findings, as well as with the results of the Task 5 observational study, nearly all participants in the current study reported that the amount of traffic present was the most important factor they considered when deciding whether or not to wait for the "walk" signal before crossing (see Figure 58). The number of participants reporting that the amount of traffic was the most important factor did not differ across age groups, $X^2(2, N = 43) = .33$, $p = .85$, (see Table 13).

Participants also provided ratings of how important they felt each factor was when considering whether or not they would wait for the "walk" phase before crossing an intersection (see Figure 59). The two factors that were rated as most important to participants when deciding whether or not to comply with a pedestrian signal were the amount of traffic and the size of the intersection (distance to cross).

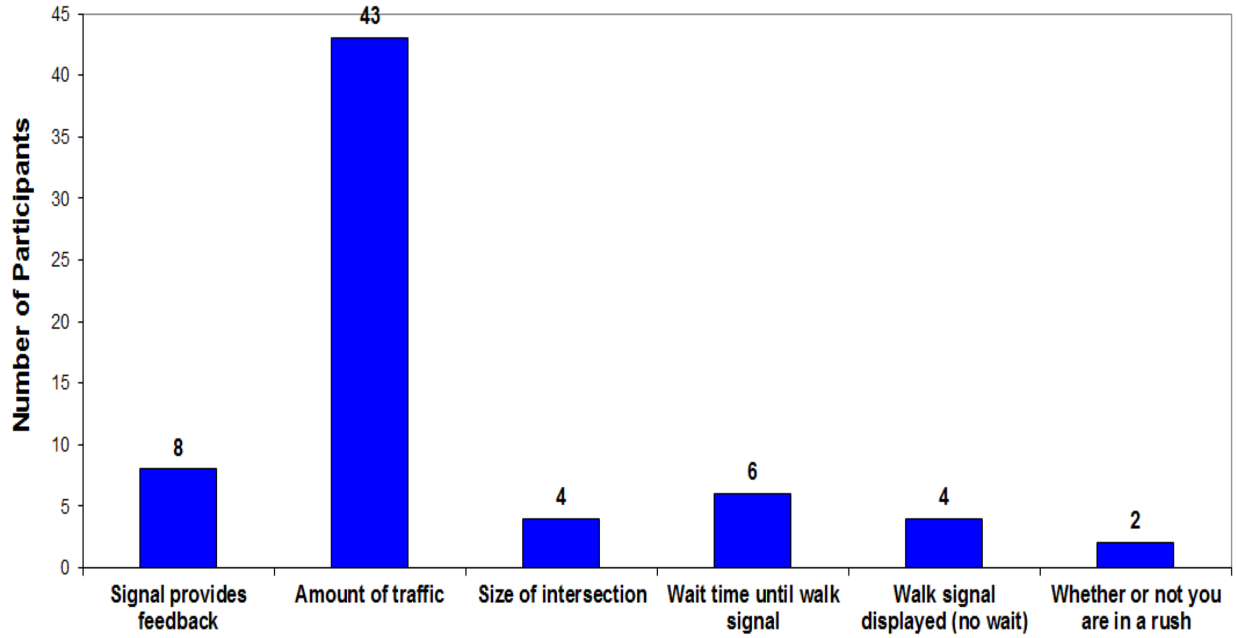

Figure 58. Responses to the question: what factor most strongly influences your decision to cross with or without using the pedestrian signal?

Table 13. Number of participants in each age group that selected each choice as the most important factor in deciding whether to comply with the pedestrian signal. There were no significant differences between age groups.

	Younger	Middle	Older	X^2
Feedback signal button	1	5	2	3.25
Amount of traffic	13	16	14	.33
Size of intersection (distance to cross)	0	1	3	1.00
Wait time until walk signal	5	0	1	2.67
Walk signal displayed / No wait	1	1	2	.50
In a hurry	1	0	1	0

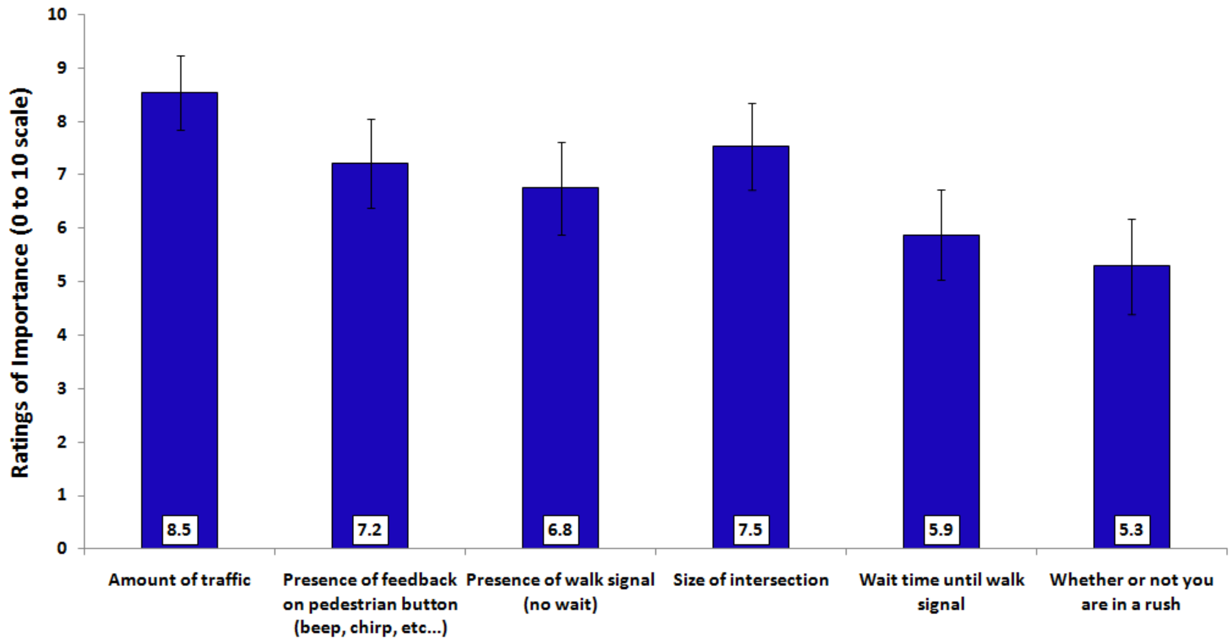

Figure 59. Average ratings for individual factors related to compliance. Error bars show the 95% confidence interval.

Self-Reported Reasons for Multiple Button Presses

In the current study, the most frequently reported reason for pressing a pedestrian signal button multiple times was that participants were not confident that their request to cross had been registered (see Figure 60). Neither participants' self-reported tendency to press signal buttons more than once reasons for pressing signal buttons more than once, nor the frequency of reporting common reasons for doing so differed significantly across age groups (see Table 14).

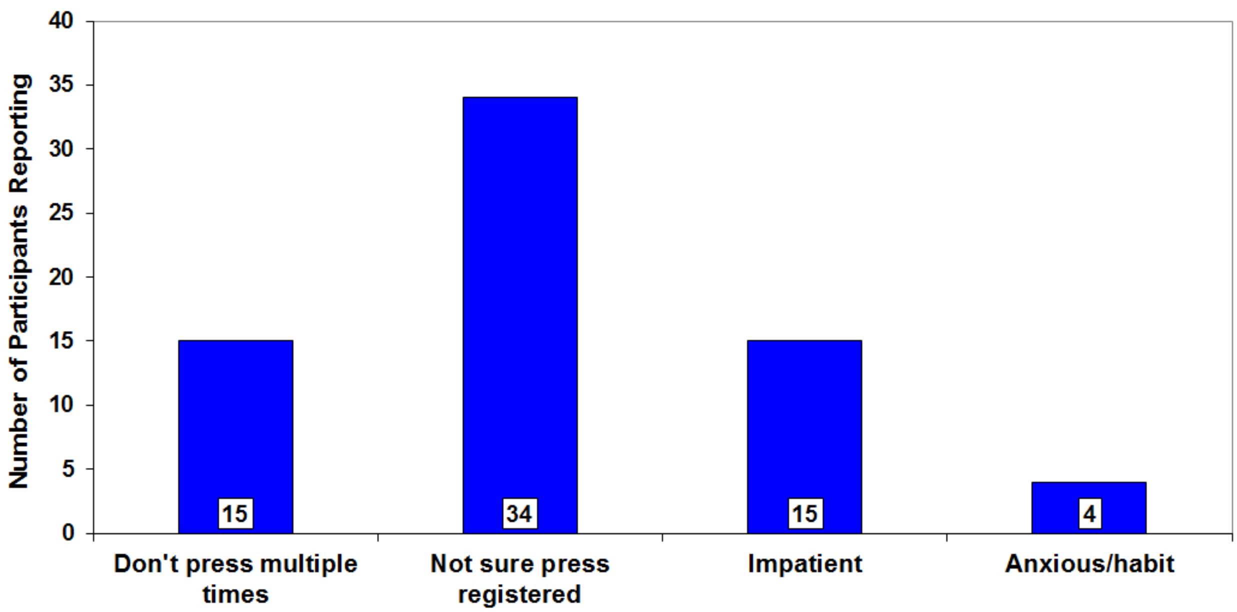

Figure 60. Frequency of participants' most commonly reported reasons for multiple signal button presses.

Table 14. Frequency of reported reasons for pressing pedestrian signal buttons more than once.

	Younger	Middle	Older	X^2
Do not press multiple times	3	6	6	1.20
Not confident button is working	11	14	9	1.12
Impatient	6	4	5	.40
Other (e.g. bored, anxious, habit)	1	0	3	1.00

Confidence that button was pressed for button type

Because confidence ratings were not normally distributed, Friedman's test, a nonparametric alternative to the repeated measures ANOVA, was used to compare participants' confidence ratings for each signal button type. As predicted, participants were significantly more confident when signal buttons provided feedback than when they did not, $X^2(2, N = 66) = 28.58$, $p < .001$ (see Figure 61).

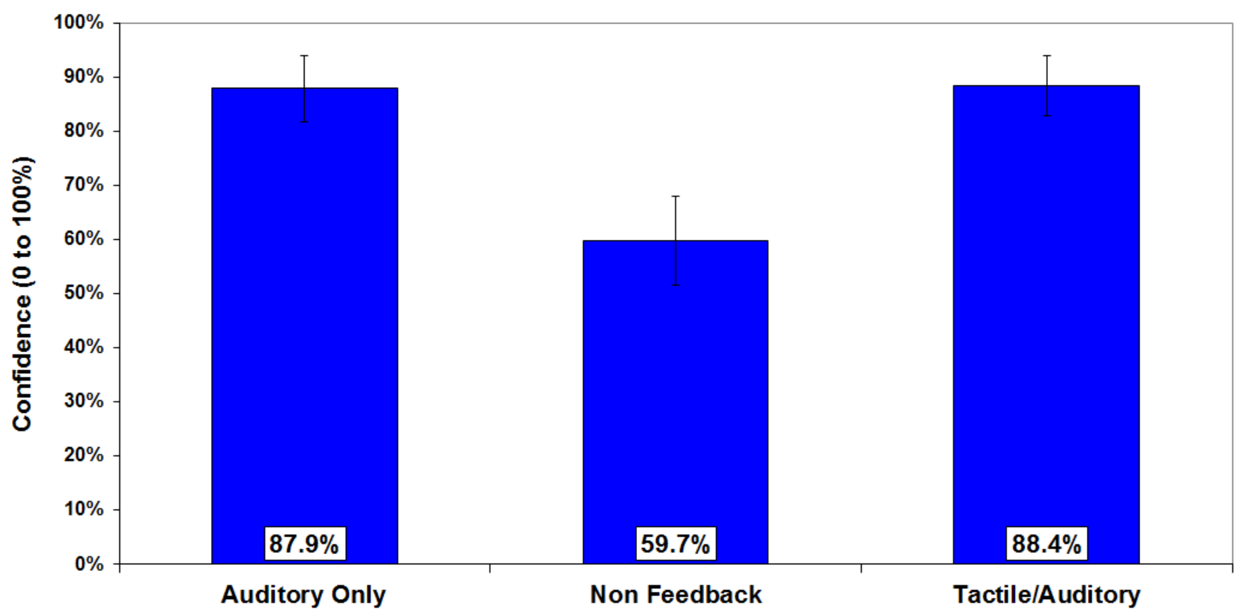

Figure 61. Average confidence that button presses were registered by signal button type. Error bars show the 95% confidence interval.

Wilcoxon Signed-Ranks Tests were conducted to examine differences in median confidence ratings between signal button types. Median confidence ratings were significantly higher for the auditory feedback, $z = -4.19$, $p < .001$, and the tactile/auditory feedback buttons, $z = -4.68$, $p < .001$, compared to the standard, non-feedback button, but there was no difference in median confidence ratings between the two buttons that provided feedback, $z = -.29$, $p = .77$.

Additional tests were conducted to determine whether the observed differences in confidence ratings between button types differed across age groups. While the overall pattern of results was similar across all three age groups, younger adults' confidence judgments did not differ significantly between button types. Confidence ratings were significantly higher for buttons that provided feedback for middle and older adults (see Table 15).

*Table 15. Average confidence ratings by age group and button type. * Indicates significance at < .05, ** Indicates significance at < .001*

	Auditory Only	Standard	Tactile + Auditory	X^2
Younger	94.3%	70%	91.3%	4.31
Middle	87%	53.1%	91.1%	20.80**
Older	83.8%	57.1%	83.5%	6.86*

Analyses were conducted to determine whether the order in which buttons were rated influenced participants' confidence ratings. Buttons that provided feedback received significantly higher ratings than the standard non feedback button in conditions where the auditory only button was presented first, $X^2(2, N = 23) = 12.38$, $p = .002$, as well as in conditions where the button that provided vibrotactile and auditory feedback button was presented first, $X^2(2, N = 22) = 20.94$, $p < .001$. However, participants' ratings did not differ significantly between feedback and non-feedback buttons when the standard, non-feedback button was presented first, $X^2(2, N = 21) = 4.04$, $p = .13$ (see Figure 62).

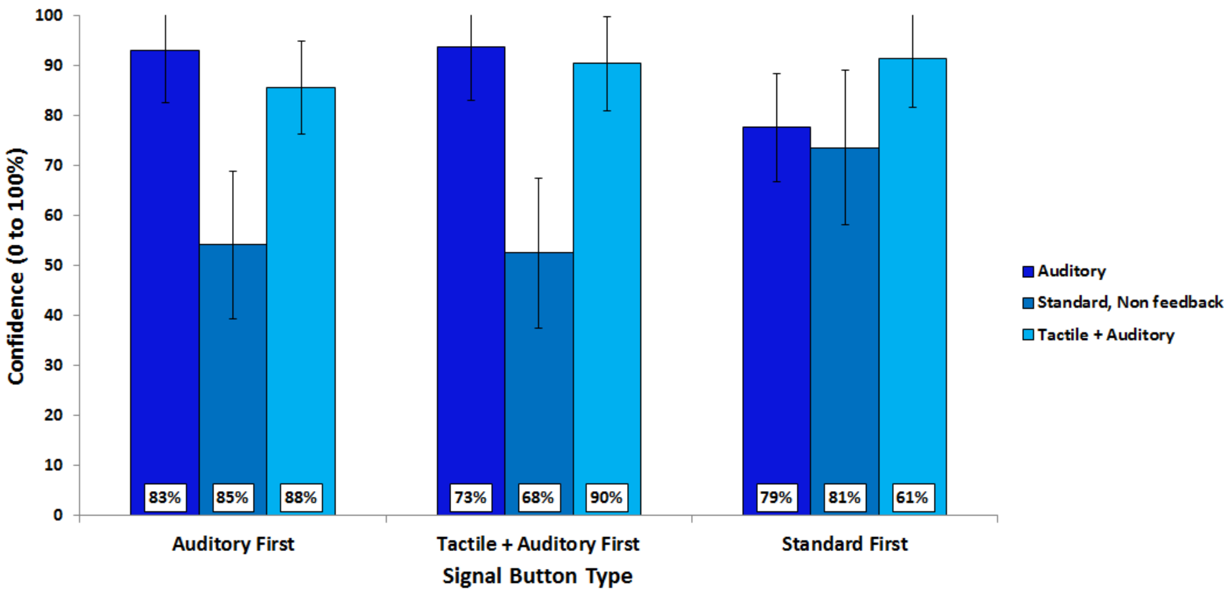

Figure 62. Average confidence rating by button type and presentation order. Error bars show the 95% confidence interval.

Compliance Ratings

Participants' ratings of their willingness to comply differed significantly between button types, $X^2(2, N = 68) = 6.10$, $p = .05$, following a similar pattern to what was observed for confidence ratings (see Figure 63). As with confidence ratings, median compliance ratings were significantly higher for the auditory feedback, $z = -2.82$, $p = .005$, and the tactile/auditory feedback buttons, $z = -2.11$, $p = .04$, compared to the standard, non-feedback button, but there was no difference in median confidence ratings between the two buttons that provided feedback, $z = -.58$, $p = .56$. Finally, compliance ratings showed a moderate correlation with confidence ratings, suggesting that participants' confidence that their button press may relate to their willingness to comply with the signal (see Table 16). However, because compliance ratings were collected immediately following confidence ratings, it is possible that this correlation only reflects participants' tendency to use their confidence ratings as an anchor point for their compliance ratings.

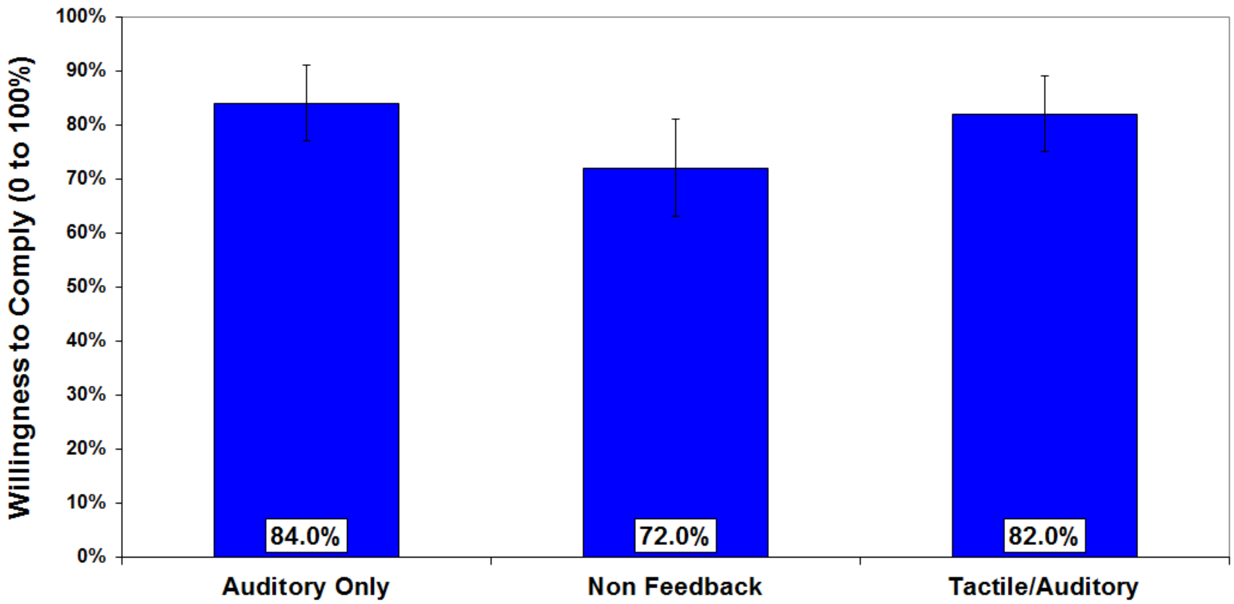

Figure 63. Average self-reported willingness to comply by signal button type. Error bars show the 95% confidence interval.

Table 16. Correlation between confidence and compliance ratings for each button type.

	Correlation (n = 66)	*p*
Auditory Only	.32	.01
Standard, Non feedback	.40	.001
Tactile + Auditory	.33	.007

Conclusions

Previous work has suggested that compliance with pedestrian signals may be increased when buttons provide feedback (VanHouten, Ellis, Sanda, & Kim, 2006, but see also Huang & Zegeer, 2001). One reason why feedback buttons may be effective in increasing compliance is that feedback indicates that the signal is operating correctly and one's desire to cross has been registered, which may in turn increase pedestrians' willingness to wait for the "walk" (Jones & Peppiatt, 1996). Although our study did not directly evaluate the effect of feedback on participants' willingness to wait for the signal to change, we did find that both participants' confidence that their desire to cross was registered, as well as their self-reported willingness to comply with the signal, were reliably higher when buttons provided feedback than when they did not.

Consistent with findings from other studies, as well as from the Task 5 observational study, younger adults reported lower rates of compliance with pedestrian signals and were also more likely to report that they crossed intersections equipped with a pedestrian signal three or more times a week. In contrast, most older and middle aged adults reported that they crossed signal controlled intersections once a week or less but reported higher levels of compliance than did younger adults.

Further large-scale studies need to establish whether pedestrian-vehicle crashes vary with the type of feedback provided to the pedestrian at intersections and with the age of pedestrian in order to verify whether installing the more expensive feedback signals may reduce crashes. We conclude that signals with auditory or auditory and tactile feedback do make a difference in both the confidence that a signal button was registered and the reported willingness of pedestrians to wait for a signal change following a button press. However, given the observational study results, there may not be a significant impact on crossing behavior and on crash rates.

Chapter 7. A Field Evaluation of Character Legibility for 16.8” versus 18” Message Panels

Task 6 Field Study of 16.8” versus 18” DMS Character Legibility

Upon close inspection of a DMS sample panel from Daktronics, Jeff Morgan, an FDOT engineer, noticed that the character height, measured from LED to LED was less than the accepted NEMA standard 18”. Instead, it measured approximately 16.8” inches in height. Consequently, the question arose if the sign could produce similar viewing and legibility characteristics of a true 18” character sign. In response, the manufacturer has claimed that the design of the panel “blooms” to compensate for the 1.2” and therefore creates a perceptual equivalent of a larger 18” character size. Daktronics, the manufacturer of the 16.8” DMS sign, provided technical literature as well as some basic observations to back this claim. In support of this, Mace et al. (1994) found that increased luminance can compensate for the small size of some signs. However, it may still be the case that side-effects arise when the 16.8” character blooms to appear the same height as the 18” standard, such as increased blurriness or lower accuracy on legibility tests. Accordingly, Schieber (1994) found that increased blurriness leads to lower sign legibility distances.

This study was intended to detect the differences, if any, between a Daktronics Vanguard VF-2020 series panel using 16.8 inch characters and a Precision Solar Controls SMC-1000-ST sign using true 18 inch characters under field conditions.

Method

Design

Before the experiment, participants were given a Snellen eye-test at the facility testing for far vision in an attempt to control for visual acuity. A minimum of 20/40 vision was required for the completion of the study. A 2 x 2 x 2 x 3 design was used with sign type (blooming vs. standard), task type (pattern matching vs. letter naming), and distance (far vs. near) as within-subjects variables, and age (younger, middle, and older aged adults) as a between-subjects variable. Distance was blocked within task type, and sign type was blocked within distance. Across participants, there were a total of 35 character pairs used including 4 for practice. Each character pair was programmed into both signs, but participants never saw the same character pair on both signs. The order of presentation for sign type, task type, and distance was counterbalanced across participants. Character pairs were randomly selected.

Participants

Twenty-one younger (M=23 yr), middle-aged (M=60 yr) and older (M=72 yr) were paid $15 to participate. As in previous studies, participants were prescreened to determine eligibility.

Equipment

We relied on the expertise of FDOT engineers and administrators in the selection and supply of equipment for Task 6, as no budget was allotted for such acquisitions. The goal for the design in this task was to obtain two panels with identical specifications except for a small difference in character height. However, because no single manufacturer makes both a sub 18” and true 18” character DMS panel, and manufacturers vary greatly on sign panel configuration, this could not be obtained. Thus, some factors that could have been controlled with proper equipment were neglected due to the unavailability of options. Figure 64 shows the final experimental set up.

Figure 64. Photograph showing the setup of the field. 16.8" sign on the left, 18" sign on the right.

16.8" Character Panel: Daktronics Vanguard VF-2020

A 9 x 15 pixel housing was graciously supplied by Mike Weinberg at Daktronics when informed of the scope of the study. FDOT did have one bench unit on hand, but the housing was determined inadequate due to a lack of a polycarbonate sheet with UV inhibitors and semi-gloss black Hynar 500 resin, which were both outfitted on the new panel. The original LED panels were reused and powered by a Vanguard VF-3000 control unit.

18" Character Panel: Precision Solar Controls SMC-1000-ST

Due to the inability to obtain a DMS unit with similar specifications, a full-sized solar and battery powered PCMS unit was used. The FDOT Traffic Engineering and Research Lab (TERL) and David Wilfong of Precision Solar Controls supplied a sign for comparison, as this unit measured exactly 18" from LED to LED, and contained no lamps or bulbs over the LED's. The PCMS sign contained 24 characters, each of 5 x7 pixels. Characteristics are shown in Tables 17 and 18 below.

Because the blooming effect depends in part on the brightness of the display (i.e. signs must be brighter in order to "bloom"), the decision was made to conserve ecological representativeness of the study and not artificially lower the brightness of the Daktronics DMS panel to make it equivalent to the PCMS unit. Rather, both the PCMS and DMS units were set up according to manufacturers' specifications for normal operating conditions.

*Table 17. This diagram shows the general specifications of the two types of Variable Message signs compared in Task 6. *Exact Intensity not listed, e.g., 3000 cd/m² is an estimate.*

	Daktronics Vanguard VF-2020	**PCS PCMS Unit**
Intensity:	9200 cd/m^2	3000 cd/m^2
Pixel configuration:	5 x7	5 x 7
LED configuration:	8 Pixel Cluster	5 Pixel Cluster
Space between characters:	3 & 5/8"	2 & 1/8"
Power source:	In-Line AC	Solar / Battery
Matrix Type	Full Matrix	Character Matrix
Character height:	16.8"	18"

Table 18. Luminance measures taken under field conditions. Measures are in cd/m^2

	Daktronics Vanguard VF-2020	**SMC-1000-ST PCMS Unit**
Single pixel	23,105	2581
65 feet	938	2753
135 feet	741	2516

As the DMS panel was a 9 x 15 pixel unit, it could display up to three 5 x 7 characters at once. However, this means that there would be no more space between characters than there are for pixels of an individual character (see Figure 65).

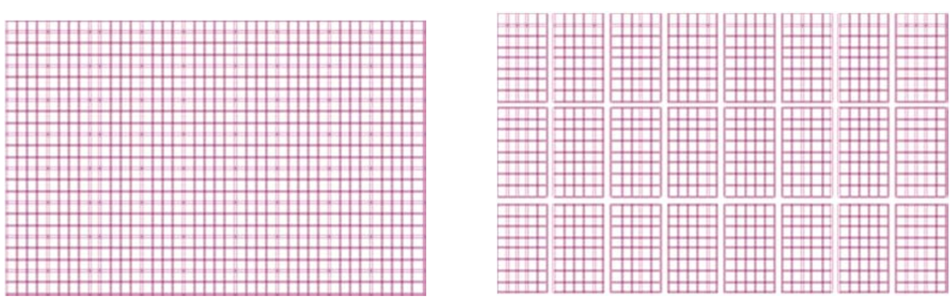

Figure 65. Images displaying the difference between a Full Matrix (left) and a ~~Modular~~ Character Matrix (right) screen type. Character layout is adjustable on a Full Matrix but constrained on a CharacterMatrix. The Full Matrix DMS panel was programmed to imitate the layout of the Character PCMS unit as much as possible.

To create spacing similar to the PCMS sign (the PCMS sign is a character display, so character space in non-adjustable; a one-pixel character space was programmed into the control unit by Derek Vollmer. While this spacing prevented one problematic confound, it meant that we were forced to drop one letter from the stimuli and display two characters only with a one-pixel space between them. The PCMS displayed the same, and in order to compensate for the additional backing of the PCMS unit, the character pair was displayed in the lower left corner (See Figure 66).

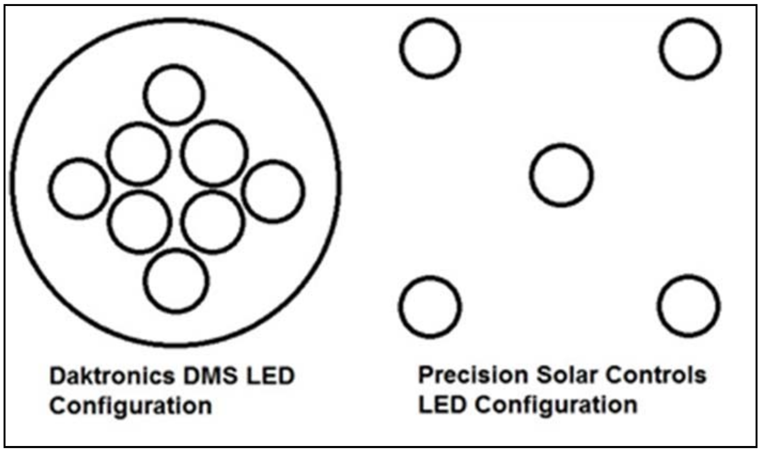

Figure 66. Picture showing differences in LED configurations of both sign types. On the Daktronics model (left), each pixel was contained in the housing. The bloom of the LEDs is intended to “fill” this circle. The PCMS sign (right) had no such housing. Note: Figure is an approximate illustration.

Configuration

Both signs were elevated approximately 5 feet, 3 inches above the concrete slab, and the units were set to their maximum brightness. Distances were used to mirror the visual angle of a character on the Snellen Eye-Test. The 18” character was used as the standard for calculating the visual angle. For example, a person with 20/20 vision can read a character with a .0833 degree of visual angle. Therefore, with an 18” character, a person with 20/20 vision should be able to read an 18” character from 1031 feet. For the near distance, a similar calculation was used, but for an individual with 20/30 vision. An 18” character at 773 feet produces a visual angle of .1111 degrees, so this distance was used. Again, the near distance was 773 feet, and the far distance was 1031 feet (see Figure 67).

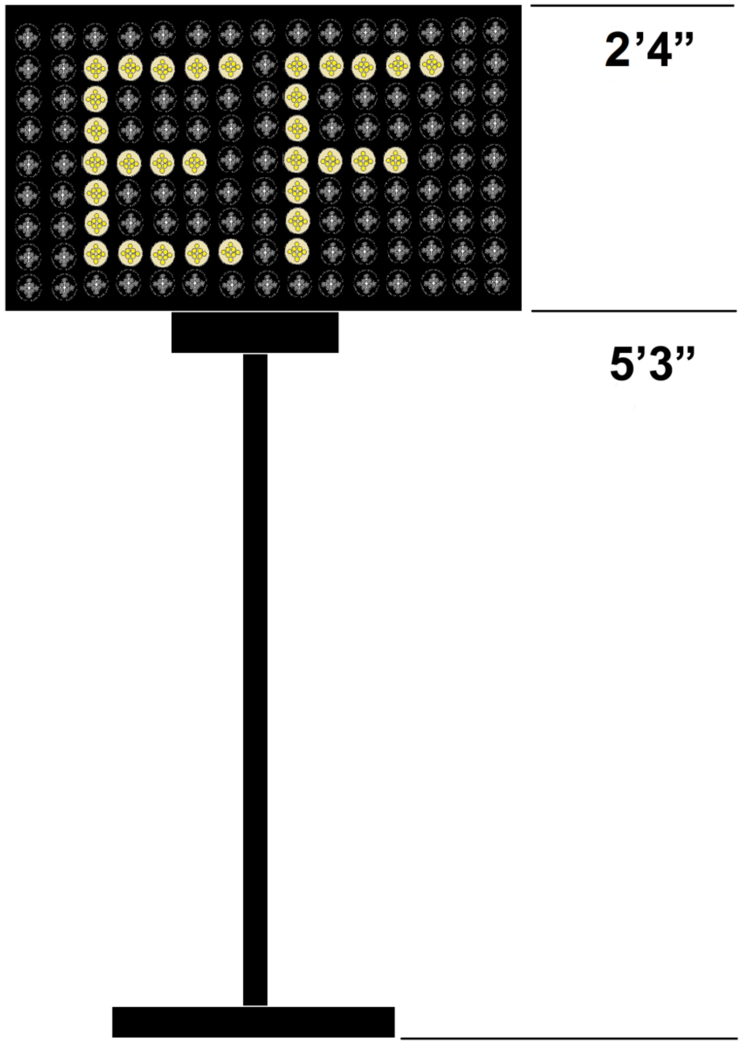

Figure 67. A diagram of the DMS sample unit, mounted 5’3” from the ground. PCMS sign was set to the same height

Procedure

At the beginning of the session, participants completed the vision screening. For the vision screening, participants stood 20 feet from the Snellen eye chart and were instructed to begin reading at the line of characters corresponding to a visual acuity of 20/40 and continue reading each line down until they could no longer read the characters. Once the eye exam had been administered, participants began the sign legibility task.

The sign legibility task consisted of two parts, a pattern matching task and a letter naming task. Both tasks consisted of two blocks of trials, one from a near viewing distance of 773 feet and one from a far viewing distance of 1031 feet. In the pattern matching task, participants were asked if the letter pair that was read to them matched the letter pair displayed on one of the signs at the end of the track (see Figure 68). In the letter naming task, participants were instructed to read the letter pair displayed on one of the signs at the end of the track. (Items were displayed on only one sign at a time, and the other sign was always blank during a trial). The order in which tasks were completed was balanced between participants so that half of the participants completed the pattern matching task first and the letter naming task second, and the remaining participants completed the letter naming task first and the pattern matching task second.

Following the pattern matching and letter naming tasks, participants were asked a series of debriefing questions. First, participants were asked to rate the sharpness of each sign's display on a 1 to 10 scale (1 = very blurry, 10 = very sharp). Next, participants were asked to rate the brightness of each sign, also on a 1 to 10 scale (1 = least bright, 10 = brightest). Finally, participants were asked which of the two signs they found easiest to read.

Figure 68. Overview of field setup for Task 6

Results

Sign reading and sign matching data were combined to increase power for detecting effects of conditions. Before conducting the following analyses, all variables were screened for normality, homogeneity of variance, and multivariate outliers. It was found that the scores for accuracy and confidence were moderately skewed in the negative direction. As a consequence, the scores for these variables were reflected, which is the process of subtracting each score of a variable from the sum of the maximum score for that variable and a constant (in this case, 1). The square roots of the reflected scores were then calculated and used as a substitute for the true scores. By doing this, the distributions for both variables became acceptable. To determine the extent to which these corrections changed the results of the significance tests for the analyses, analyses for both variables in their corrected and un-corrected forms were conducted. For sign viewing accuracy, it was found that the transformed variables had no effect on any of the significance tests; therefore, the main analysis on sign viewing accuracy was conducted using the original scores. For sign viewing confidence, the sign type by distance interaction, which was significant for the analysis using the original scores, $F(1, 60) = 7.78$, $p = .007$, $\eta^2_p = .115$, was found not to be significant for the analysis using the transformed scores, $F(1, 60) = .43$, $p = .52$, $\eta^2_p = .01$, $1 - \beta = .10$. As a consequence, the main analysis for confidence was conducted using the transformed scores.

Accuracy

To determine whether reading accuracy varied across sign type and distance, a mixed ANOVA was employed using sign type (blooming vs. standard) and distance (773 ft vs. 1031 ft) as within-subjects factors, and age group as a between-subjects factor. The results revealed a main effect of age group, $F(2, 60) = 8.29$, $p = .001$, η^2_p

= .22. Follow-up tests of this main effect revealed a significant difference of about 15% between younger and older-aged adults in favor of younger-aged adults, $F(1, 60) = 15.94$, $p < .001$, 95% CI [.22, 66], $\eta^2_p = .21$, as well as a significant difference of about 30% between older and middle-aged adults in favor of middle-aged adults, $F(1, 60) = 7.21$, $p = .009$, 95% CI [.08, .52], however, there were no differences between middle and younger-aged adults, $F(1, 60) = .17$, $p = .20$, 95% CI [-.08, .37], $\eta^2_p = .03$, $1 - \beta = .25$ (see Figure 69).

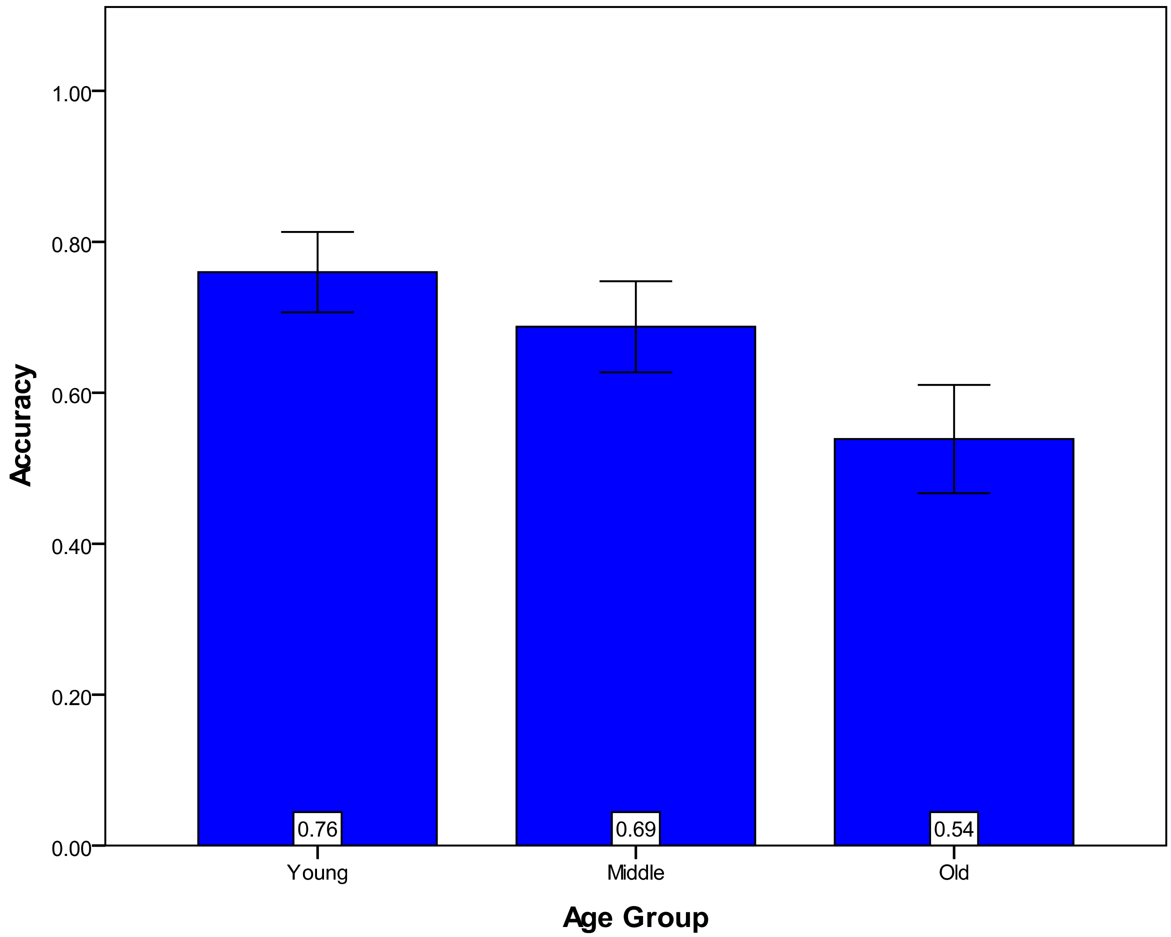

Figure 69. Accuracy as a function of age group (error bars represent 95% confidence intervals).

There were also significant main effects of sign type and distance, though these were qualified by their two-way interaction. At the nearest distance to the signs (773 ft), the difference between the two sign types was significant with a difference in accuracy of about 10% in favor of the blooming sign, $F(1, 60) = 8.96$, $p = .004$, 95% CI [-.16, -.03], $\eta^2_p = .13$. At the furthest distance from the signs (1031 ft), the sign type difference was still significant, with a difference in accuracy of about 20% in favor of the blooming sign, $F(1, 60) = 40.91$), $p < .001$, 95% CI [-.26, -.14], $\eta^2_p = .41$ (see Figure 70).

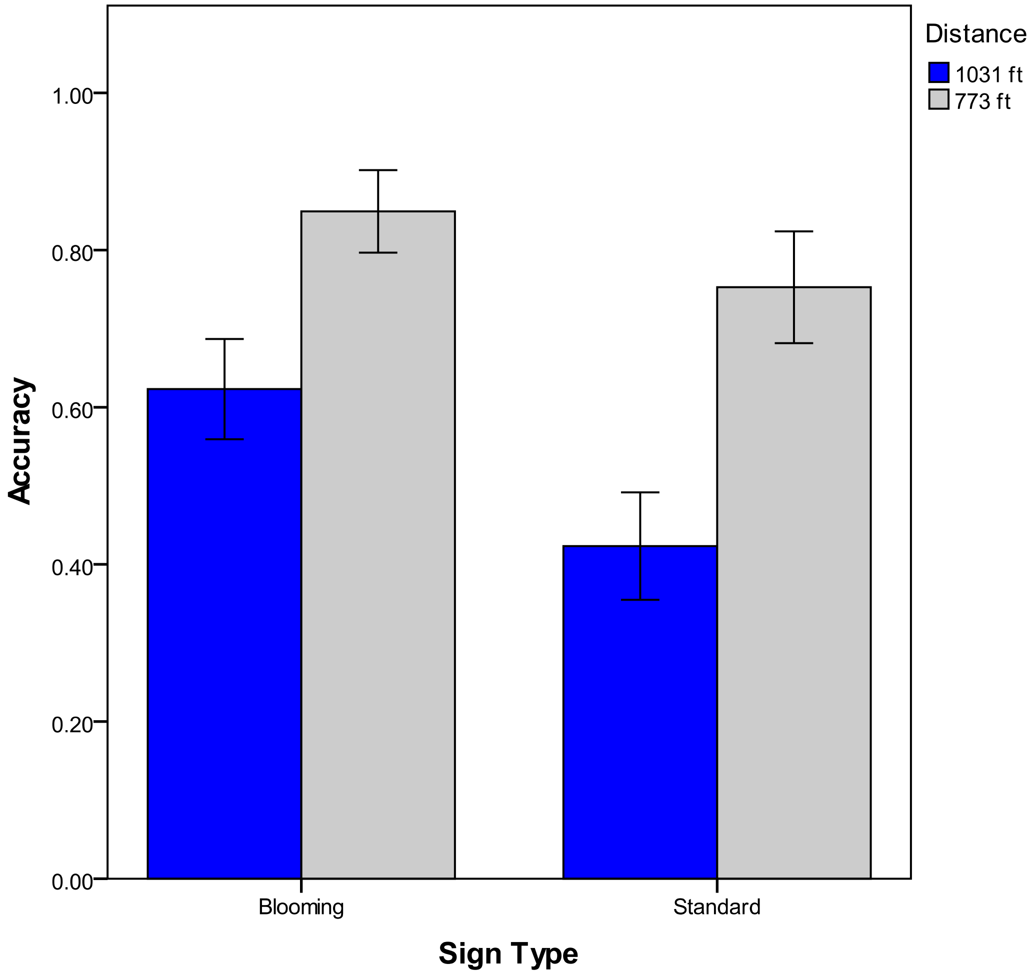

Figure 70. Accuracy as a function of distance and sign type (error bars represent 95% confidence intervals).

Confidence rating.

Sign type, distance, and age group were submitted to a mixed ANOVA with sign type and distance as within-subjects factors and age group as a between-subjects factor. The ANOVA revealed a main effect for distance, $F(1, 60) = 222$, $p < .001$, 95% CI [2.37, 3.10], $\eta^2_p = .13$, with participants reporting less confidence in their judgments at the farthest distance (see Figure 71).

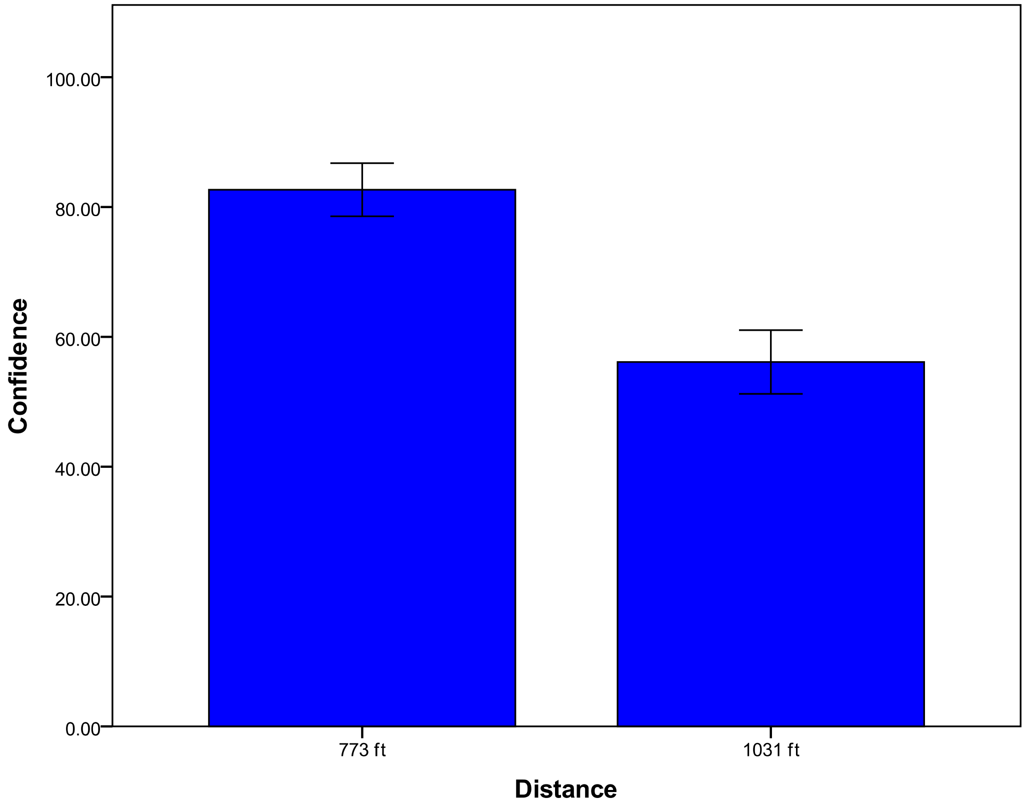

Figure 71. Confidence as a function of distance (error bars represent 95% confidence intervals).

The ANOVA also revealed main effects for age group and sign type, which were qualified by their interaction. Follow-up tests of the interaction revealed higher confidence judgments for the blooming sign over the standard for younger $F(1, 20) = 11.04$, $p = .003$, 95% CI [.36, 1.58], $\eta^2_p = .36$, middle, $F(1, 20) = 12.11$, $p = .002$, 95% CI [.44, 1.77], $\eta^2_p = .38$, and older-aged adults, $F(1, 20) = 35.3$, $p < .001$, 95% CI [1.35, 2.81], $\eta^2_p = .64$. In addition, it was revealed that the difference between sign types significantly differed between younger and older-aged participants, $F(1, 60) = 6.02$, $p = .02$, 95% CI [-2.02, -.206], as well as between older and middle-aged participants, $F(1, 60) = 4.63$, $p = .04$, 95% CI [-1.88, -.07], $\eta^2_p = .07$, with older-aged participants showing a greater difference in confidence judgments between sign types in both cases (see Figure 72).

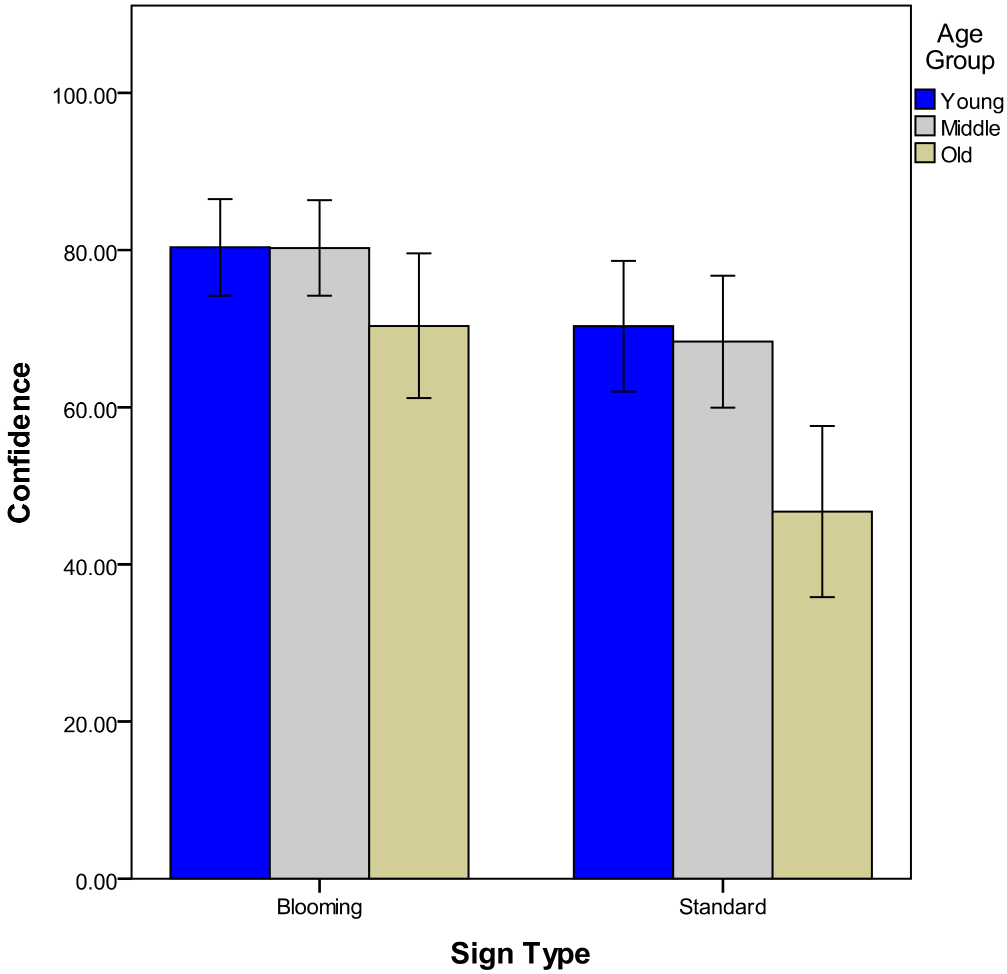

Figure 72. Confidence as a function of age group and sign type (error bars represent 95% confidence intervals).

Conclusions

Overall, the results suggest the existence of an advantage for the more brightly illuminated "blooming" sign over the standard. Not only were participants more confident when it came to identifying that sign, they were more accurate in their judgments of it as well. In addition, it appears that the advantage for the "blooming" sign stays fairly steady across the three age groups included in the study, though it is reduced with younger and middle-aged adults. As expected, older participants made more errors when it came to correctly identifying the sign information and this error rate increased with greater distance.

In short, this particular blooming 16.8" sign design gives a viewing advantage over the standard 18" character sign. Likely, the reason is the greater intensity of the pixels. Here the values were rated at 9000 cd/m 2 for the 16.8" character size sign compared to 3000 cd/m 2 for the 18" character PCMS sign. For equivalence in performance it may be possible to use less than triple the intensity though this would have to be established with another study.

Chapter 8. Summary of the Studies

Benefit of the Project

This project has provided relevant data using a human factors approach to aid the formulation of policy and recommendations for the Safe Mobility for Life Program. Some of the findings with relevant policy implications are:

1) Current MUTCD recommendations for multi-phase messages with DMS and PCMS signs appear to work equally well with drivers of all ages, though there were some trends suggesting that alternative orders and compatible positioning may better serve older driver decisions to merge left or right.
2) More expensive fluorescent sheeting warning signs are legible at a greater distance than standard sheeting only when drivers use low headlamp beams and these results hold for drivers of all ages.
3) No advantage was found for using supplemental pedestal signals at intersections in aiding driver stopping decisions. Adding such pedestal signals would be expected to be costly and have little return on investment.
4) Standard sheeting improves the legibility for illuminated overhead street signs compared to reflective sheeting, with a stronger benefit expected for middle-aged and older drivers and no benefit expected for younger drivers.
5) Pedestrian compliance with traffic signals at city intersections in Tallahassee is not influenced by whether pedestrian crossing buttons provide enhanced feedback about their activation. Size of intersection and traffic intensity are the most likely influences for compliance. Middle-aged pedestrians were more likely to comply with signals than younger pedestrians. Pedestrian confidence that a button press resulted in activation is higher with enhanced feedback pedestrian crossing buttons only for middle-aged and older pedestrians.
6) At least one 16.8” character DMS device has a legibility advantage over a standard 18” character sign, probably because of its increased pixel brightness relative to the comparison sign. However, we cannot conclude that a blooming effect accounts for the better performance of the 16.8” sign given the greater brightness of the pixels in that sign.

Specific Recommendations Based on Study Findings

1) Further investigation is warranted to determine optimal ordering of multi-phase messages with DMS and PCMS signs. Trends favored some experimental orders compared to MUTCD-recommended ones particularly with older drivers. A more realistic task, using a driving simulator or field study, is a logical next step in assessing compliance behavior as a function of sign location and message order.
2) It should be advantageous to replace warning signs with standard sheeting with fluorescent sheeting in urban environments where drivers are most likely to be using low headlamp beams at night. It would be reasonable to conduct a public education campaign to remind drivers to use high beams at night in rural settings, (and to remember to dim them for oncoming traffic) to ensure that standard sheeting warning signs are maximally legible. However, before such a campaign is initiated, research is needed to determine the prevalence of high versus low beam use at night and whether the benefits of using high beams may be

outweighed by the costs to older drivers who recover effective night vision more slowly when exposed to high intensity light.

3) Supplemental pedestal signals should have a very low priority for deployment and might be considered a reasonable investment only in the case to enhance intersections with unusually low visibility of signalized intersection due to obstructions that cannot easily be alleviated.
4) Standard sheeting should be adopted in preference to reflective sheeting in illuminated overhead street signs.
5) A public education campaign aimed at younger pedestrians may be warranted and beneficial to improve compliance with pedestrian signals.
6) Further research will be necessary to determine if PCMS 16.8” character signs are as effective as 18” character signs when luminance for the pixels is equivalent.

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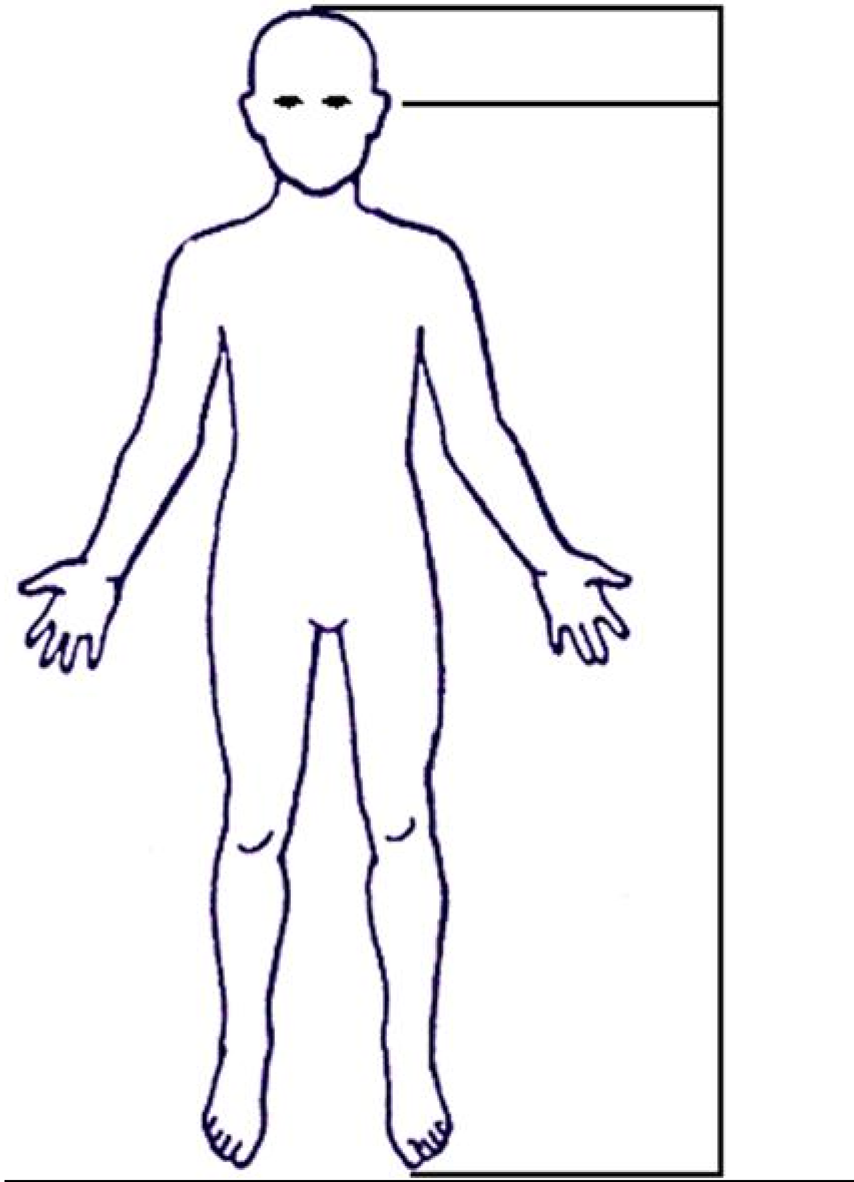
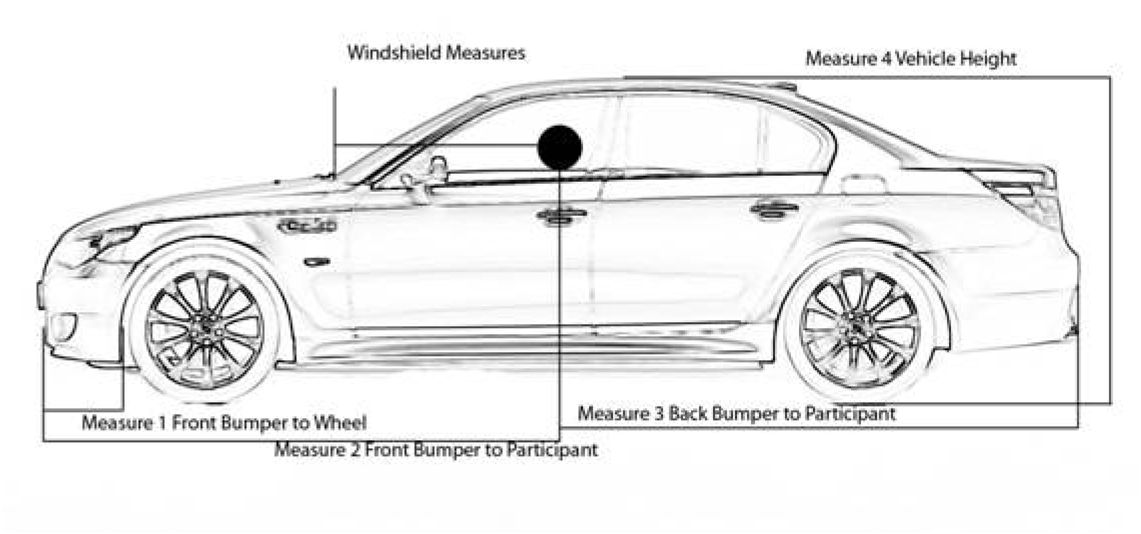
Appendix A. Participant and car measurements for Task 2.



Description. This diagram depicts the measurements gathered on participants outside of their vehicles. Total height and height to eyes was obtained.



Description. This diagram shows the measurements obtained on the cars and the participants in the cars for task 3 field study.

Appendix B. Additional Tables for Task 2

	Mean	*SD*	*Accuracy*	*n*
Yield Ahead, Standard	688	228	.96	119
Yield Ahead, Fluorescent	739	207	.97	122
Stop Ahead, Standard	781	216	.96	121
Stop Ahead, Fluorescent	795	251	.97	119
Signal Ahead, Standard	773	202	.99	120
Signal Ahead, Fluorescent	772	228	.96	119

Overall performance data for individual signs in Task 2 field. Includes all age groups. Distances (for accurate trials) are in feet.

	Mean	*SD*	*Accuracy*	*n*
Standard Beam Headlights				
Yield Ahead, Standard	648	212	.94	54
Yield Ahead, Fluorescent	717	195	.97	59
Stop Ahead, Standard	773	222	.96	56
Stop Ahead, Fluorescent	780	284	.98	57
Signal Ahead, Standard	735	200	1.00	57
Signal Ahead, Fluorescent	763	238	.98	55
High Beam Headlights				
Yield Ahead, Standard	725	238	.98	56
Yield Ahead, Fluorescent	760	217	.98	58
Stop Ahead, Standard	789	212	.97	58
Stop Ahead, Fluorescent	810	210	.96	55
Signal Ahead, Standard	813	199	.98	55
Signal Ahead, Fluorescent	781	220	.95	58

Overall performance data for individual signs in Task 2 field. Includes all age groups. Distances (for accurate trials) are in feet.

	Mean	*SD*	*Accuracy*	*n*
Younger Adults				
Standard Beam Headlights				
Yield Ahead, Standard	716	197	1.00	22
Yield Ahead, Fluorescent	802	169	1.00	23
Stop Ahead, Standard	811	228	1.00	22
Stop Ahead, Fluorescent	871	325	1.00	21
Signal Ahead, Standard	770	162	1.00	22
Signal Ahead, Fluorescent	855	178	1.00	21
High Beam Headlights				
Yield Ahead, Standard	846	211	.95	22
Yield Ahead, Fluorescent	890	195	1.00	22
Stop Ahead, Standard	891	176	1.00	22
Stop Ahead, Fluorescent	909	175	.95	22
Signal Ahead, Standard	923	179	1.00	22
Signal Ahead, Fluorescent	901	192	1.00	22
Middle Adults				
Standard Beam Headlights				
Yield Ahead, Standard	597	240	1.00	12
Yield Ahead, Fluorescent	684	206	1.00	12
Stop Ahead, Standard	790	240	1.00	12
Stop Ahead, Fluorescent	807	238	1.00	14

Signal Ahead, Standard	768	241	1.00	13
Signal Ahead, Fluorescent	724	267	1.00	12
High Beam Headlights				
Yield Ahead, Standard	653	281	1.00	14
Yield Ahead, Fluorescent	633	169	1.00	14
Stop Ahead, Standard	673	245	.93	14
Stop Ahead, Fluorescent	704	181	1.00	14
Signal Ahead, Standard	748	175	1.00	14
Signal Ahead, Fluorescent	649	207	.93	14
Older Adults				
Standard Beam Headlights				
Yield Ahead, Standard	596	198	.85	24
Yield Ahead, Fluorescent	656	188	.92	26
Stop Ahead, Standard	725	208	.91	25
Stop Ahead, Fluorescent	676	242	.96	24
Signal Ahead, Standard	682	209	1.00	25
Signal Ahead, Fluorescent	690	255	.95	24
High Beam Headlights				
Yield Ahead, Standard	665	195	1.00	23
Yield Ahead, Fluorescent	718	205	.96	24
Stop Ahead, Standard	760	185	.96	24
Stop Ahead, Fluorescent	771	225	.95	22
Signal Ahead, Standard	740	187	.95	23
Signal Ahead, Fluorescent	742	199	.91	24

Performance data for individual signs in Task 2 field for younger, middle, and older adults. Distances (for accurate trials) are in feet.