Final Report:

The Flashing Right Turn Signal with Pedestrian Indication: Human Factors Studies to Understand the Potential of a New Signal to Increase Awareness of and Attention to Crossing Pedestrians

BDV30-977-13

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Disclaimer

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

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

SI* (Modern Metric) Conversion Factors

Approximate Conversions to SI Units

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

FORCE and PRESSURE or STRESS				
lbf	pound force	4.45	newtons	N
lbf/in^2	pound force per square inch	6.89	kilopascals	kPa
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
^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

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16. Abstract. The flashing pedestrian indicator (FPI) is intended to alert turning drivers to the potential presence of pedestrians in the roadway, facilitate scanning in the likely direction of pedestrians, and encourage caution and yielding behavior in response to pedestrians. Task 1.1 assessed younger (21-35 years), middle-aged (50-64 years), and older (65+) drivers' ability to comprehend the intended message of this new signal. Participants were presented with static driving scenes, containing the FPI (as well as other signal states), and were asked to report the meaning of the FPI in open-ended and multiple choice formats. Task 1.2 presented a separate group of participants with similar scenes and participants were asked to imagine they were a right-turning driver. In this task, participants were asked to report the correct action (go, stop, yield to pedestrian). Pedestrian presence was manipulated, as well as whether the intersection featured an FPI. Results of Task 1.1 indicated that drivers quickly picked up on the meaning of the FPI. However, there was some confusion regarding the meaning of the FPI for drivers proceeding straight through the intersection rather than turning right (participants often thought that that the signal meant that drivers proceeding straight through the intersection should expect pedestrians as well). Task 1.2 indicated that, compared to a standard signal that did not feature an FPI, the FPI encouraged significantly more decisions to yield to pedestrians within a crosswalk both in timed and untimed responses. Participants were more likely to make a response to yield when the FPI was active even when no visible pedestrian was present. Furthermore, participants were slower in making their decision when no pedestrian was present. We interpret this pattern as indicating greater caution and search for pedestrians in the presence of the FPI. In general, few age differences were observed. Results suggested that the FPI is a promising signal with respect to comprehension, but additional research is needed to 1) further explore the source of, and potential solutions to, driver confusion uncovered in these studies, 2) evaluate driving behavior in response to the FPI, and 3) understand pedestrian response to the FPI. Additional laboratory and simulator studies are required before final recommendations can be made regarding implementation. Reported results provide insight into the design of these studies and the questions they should address.

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pedestrian, crosswalk, signalized intersection, older driver, aging road user, flashing yellow arrow	No restrictions

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Executive Summary

The reported two tasks (Task 1.1, Task 1.2) explored comprehension of a new signal: The flashing pedestrian indicator (FPI). This signal, which alternates between a yellow arrow and a symbol of a pedestrian, is intended to help alert drivers to the potential presence of pedestrians, to encourage drivers to scan for pedestrians, and to promote caution and yielding behaviors related to pedestrians within a crosswalk while a driver is making a turn at a signalized intersection. The ultimate goal of this research is to prevent pedestrian crashes, a goal that is especially relevant to the state of Florida given its above-average pedestrian fatality rate and its large and growing older adult population. Older adults are at greater risk as pedestrians compared to their younger counterparts for a number of reasons (decreased ability to sustain crash forces, slower walking speeds which increase exposure risk). Tasks support and inform the Florida Department of Transportation's (FDOT) Aging Road User Strategic Safety Plan.

Task 1.1 presented younger (21-35), middle-aged (50-64), and older (65+) drivers with driving scenes depicting various signal states, including the FPI, and participants were asked the meaning of these signals. In both open-ended and multiple choice formats, we found that participants easily understood the meaning of the FPI. The large majority of participants understood it to indicate the potential presence of a pedestrian. Most participants indicated that in response to the FPI, drivers should be cautious, scan for, or yield to pedestrians while making a turn.

Task 1.2 presented participants with scenes of an intersection, with a pedestrian either present or absent in the crosswalk immediately to the right. Participants were asked to imagine they were a driver turning right and to indicate what the correct action would be for various signal states (go, stop, yield). Critically, we manipulated whether the intersection contained or did not contain an FPI. Yielding decisions were increased significantly when the FPI was depicted compared to an equivalent situation in which a circular green signal was presented. This was true whether or not a visible pedestrian was present. The FPI also slowed responses when a pedestrian was absent, likely indicative of greater search for pedestrians.

Some participants were confused regarding the meaning of the FPI for drivers going straight through the intersection (participants often thought that drivers going straight would also need to be cautious of pedestrians). Our scenario featured a right-lane that served both as a through lane and as a lane that would allow a right-turn. This meant that the FPI and circular green were presented simultaneously in the same signal above this lane. The observed confusion may be diminished for intersections with a dedicated right-turn lane and additional research should explore this possibility. Further, participants often made a "yield" decision in response to the FPI even when no pedestrian was present. Observed confusion may impact traffic flow. The source of this confusion and potential solutions need to be addressed before implementation of the FPI can be recommended.

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

The FPI is a promising signal in that many drivers demonstrated comprehension. However, the reported studies raise important questions that need to be answered before final recommendations can be made regarding FPI implementation. We recommend additional studies that address confusion. In particular, whether confusion is unique to scenarios in which the FPI is located above a lane that allows both through traffic and a right turn. Confusion may be less for intersections that feature the FPI above a dedicated right-turn lane. We recommend studies of how roadway geometry impacts comprehension for drivers going straight through the intersection and drivers turning right. Supplemental signs and driver education (e.g., FPI tip cards) are other solutions that might be investigated to address confusion.

The reported studies are a first step in which driver comprehension and basic decision processes were tapped. Another necessary step is to evaluate driver behavior. This can be accomplished through a driving simulator study similar to other simulator studies that have examined driver/pedestrian interactions (e.g., Boot et al., 2014). Outcome measures can include whether the driver appropriately yields to crossing pedestrians when turning right and whether drivers respond inappropriately to the FPI (e.g., slowing or yielding) when driving straight through the intersection.

Finally, the response of the pedestrian is another important issue to consider. This is especially important as the FPI begins to mix together signals typically directed at drivers (yellow arrow) and signals typically directed at pedestrians (walk sign). Studies are needed to further explore pedestrian response to the FPI.

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Chapter 1. Introduction

Pedestrian Crash Risk

According to data from the National Highway Traffic Safety Administration (NHTSA), in 2012, pedestrians represented 14% of all traffic fatalities in the United States, an increase from 11% in 2003 (NHTSA, 2014). Florida was the state with the third highest absolute number of pedestrian fatalities (476) and fatalities per 100,000 population (2.46). Unfortunately, older pedestrians are at greater risk compared to their younger counterparts. Nationally, the fatality rate of individuals aged 75 to 84 was 2.70 fatalities per 100,000 population in 2012, compared to a rate of 1.51 across all age groups. Fatality rates were especially elevated for male pedestrians 85 years of age or older (4.02). Increased risk is likely due to greater fragility (a crash that might injure a younger pedestrian might kill an older pedestrian) and slower walking speeds that increase exposure risk (Charness et al., 2012; Langlois et al., 1997). Additionally, fear of falling may cause older pedestrians to both move more slowly and to attend to the ground rather than traffic around them while crossing (Avineri et al., 2012). Attempts to protect pedestrians from crashes by alerting drivers to their potential presence, as a result, are likely to differentially benefit older pedestrians (in addition to making the roadway safer for pedestrians of all ages).

Why do pedestrian crashes occur? A fundamental aspect of visual processing is that we can fail to notice seemingly obvious objects and events (such as a pedestrian entering the roadway) if we are not actively looking for them. This likely contributes in part to pedestrian crashes. The classic example is the experiment Simons and Chabris (1999) conducted, in which participants were asked to watch a video depicting two teams of basketball players, one wearing white and the other wearing black. Participants were asked to count the number of times the players dressed in white passed the ball. During this short video, a gorilla walked through the group of players, pounded its chest, and walked away, being fully visible for 5 seconds of the 75-second-long video. Surprisingly, 50% of participants failed to notice this unusual event despite it being easily observed by anyone asked to look for the gorilla. Of particular note is that instances of “inattentional blindness” have been observed in participants who directly fixated the unexpected event with their eyes, suggesting the problem in this particular case is often not one of looking (scanning), but seeing. Inattentional blindness has been proposed as a contributing cause in crashes and is consistent with numerous reports of drivers reporting not having seen pedestrians before a crash. If observers can fail to notice extremely salient and unusual events, they can also fail to notice pedestrians. By alerting drivers that they should expect pedestrians, these instances of inattentional blindness will likely be reduced. Scanning, however, may play an important independent role. A driver turning right may be biased to scan left for vehicles (Summala et al., 1996), and insufficient scanning to the right puts pedestrians crossing to the right at risk of being struck while crossing. Countermeasures that encourage scanning for pedestrians and the expectation that pedestrians may be present are likely to decrease instances in which drivers fail to yield to an unnoticed pedestrian.

A Proposed Solution

The Flashing Turn Signal Head with Pedestrian Indication (which we will abbreviate as Flashing Pedestrian Indicator, or FPI) has been one proposed solution to reduce pedestrian crashes at signalized intersections. The FPI alternates between a yellow arrow and pedestrian symbol (See Figure 1). Consider a right-turning driver. If the pedestrian button is pressed for the conflicting crosswalk (to the right), the Walk pedestrian signal would come up, and instead of a green arrow (in cases of a dedicated right-turn lane) or in addition to a circular green (in cases of a shared through/right-turn lane) the driver would see the FPI. This signal has two potential benefits. First, it can increase the awareness of pedestrians crossing or planning to cross, and second, it can encourage scanning to the right for pedestrians in and around the roadway. Based on the attention literature, this type of flashing/onsetting signal is one of the best methods to attract attention to a message (e.g., Yantis, 1993), and arrows have been found to reflexively orient attention in the direction they point (e.g, Galfano et al., 2012 ; Kuhn & Kingstone, 2009; Ristic et al., 2002; Tipples, 2002). Thus there is reason to believe that this new signal will be effective.

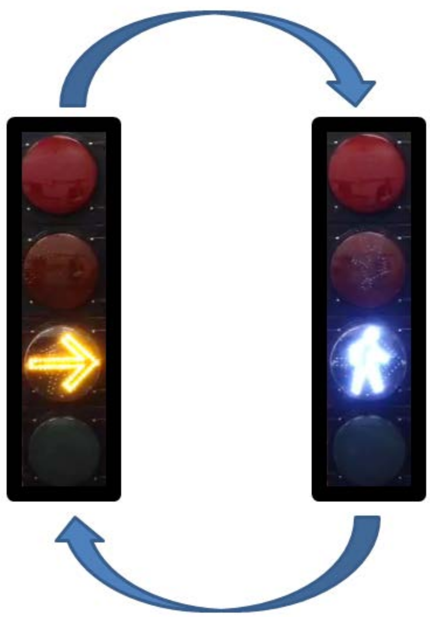

Figure 1. The Flashing Turn Signal Head with Pedestrian Indication (FPI).

However, as with any new traffic control device, it is important to understand whether drivers of all ages comprehend the meaning it is intended to convey (right turns are permissible but a pedestrian may be present, yield if appropriate). If this message is not conveyed, at best the countermeasure may not have its intended effect, and at worst drivers may misinterpret it in such a way that pedestrian risk is increased. For example, in one of our previous studies, some participants interpreted a solid yellow arrow as meaning “hurry up and turn” before the signal turns red (Boot et al., 2014). If the yellow arrow component of the proposed signal results in a rush to complete a turn, pedestrian risk might be increased rather than decreased. Thus two tasks (Task 1.1, 1,2) were conducted to better understand the reaction of drivers to the FPI.

Objectives and Supporting Tasks

An objective of Florida's *Aging Road User Strategic Safety Plan* (FDOT, 2006; available: http://www.safeandmobileseniors.org/FloridaCoalition.htm#Strategic_Plan) is to "improve the transportation environment to better accommodate the safety, access, and mobility of aging road users" (Objective 5.2) through "research that enhances and validates safety and mobility countermeasures" (Strategy 5.2.4). The research reported here advances this objective by studying younger (21-35), middle-aged (50-64), and older (65+) drivers in their comprehension of a novel traffic signal (Flashing Pedestrian Indicator) with the purpose of reducing pedestrian crashes. Older pedestrians are especially vulnerable to pedestrian crashes as a function of their decreased walking speeds and increased susceptibility to crash forces as a function of age-related changes. The Flashing Pedestrian Indicator (FPI) is intended to alert turning drivers to the potential presence of pedestrians, encourage scanning for pedestrians, and increase yielding behavior. One reported study (Task 1.1) examined younger, middle-aged, and older drivers' comprehension of the FPI, and one (Task 1.2) tested drivers' decisions in response to the FPI signal.

Chapter 2. Signal Comprehension and Driver Judgment Task

Task 1.1. Investigating Comprehension of the Flashing Pedestrian Indicator

This first task presented participants who had never seen the FPI previously with the FPI and other signal states and asked them for the meaning of the presented signal. We collected open-ended responses and then multiple-choice responses. Accuracy was emphasized for this task, not speed. The main goal was to provide a basic characterization of what the FPI meant to younger, middle-aged, and older drivers.

Method

Participants

A total of 15 younger (21 to 35 years, *M* = 23.4, *SD* = 1.9), 15 middle-aged (50 to 64 years, *M* = 58.9, *SD* = 4.1), and 15 older (65 and above years, *M* = 72.9, *SD* = 7.3) participants were recruited from the Tallahassee, FL area. All were licensed drivers. None of the participants tested in Task 1.1 or Task 1.2 had participated in previous studies in our laboratory involving a similar signal: the Flashing Yellow Arrow (FYA).

Materials

For this task, a survey was programmed to be run online (exclusively in Mozilla Firefox -- http://cognitivetask.com/fyp) using HTML, CSS, PHP, and JQuery. The motivation for this method of data collection was to be able to collect some data outside of the laboratory, especially since reaction time was not a factor for Task 1.1. All stimuli (1000 pixels x 564 pixels) were prepared in Google Sketchup, and signal states were added in Microsoft Paint (see Figure 2 for an example). Images were presented against a black background. For the creation of the Flashing Pedestrian Indicator animated GIFs, GifMaker.Me (http://gifmaker.me) was used, with a delay of 500 milliseconds between frames. Timing was derived from videos of the FPI provided by the Florida Department of Transportation.

Figure 2. Example of image from Task 1.1, in this case depicting the FPI in its arrow phase.

Images depicted an intersection from the point of view of a driver in the far right lane. This intersection had two through lanes and one dedicated left-turn lane in each direction. Since the right lane was not a dedicated right-turn lane, when the FPI was active the signal also depicted a circular green for traffic proceeding forward through the intersection (Figure 3). See supplemental materials for the full image of each scene presented to participants. An arrow above the signal mast pointed to the four headed signal furthest to the right to ensure participants knew which signal to which they were expected to respond.

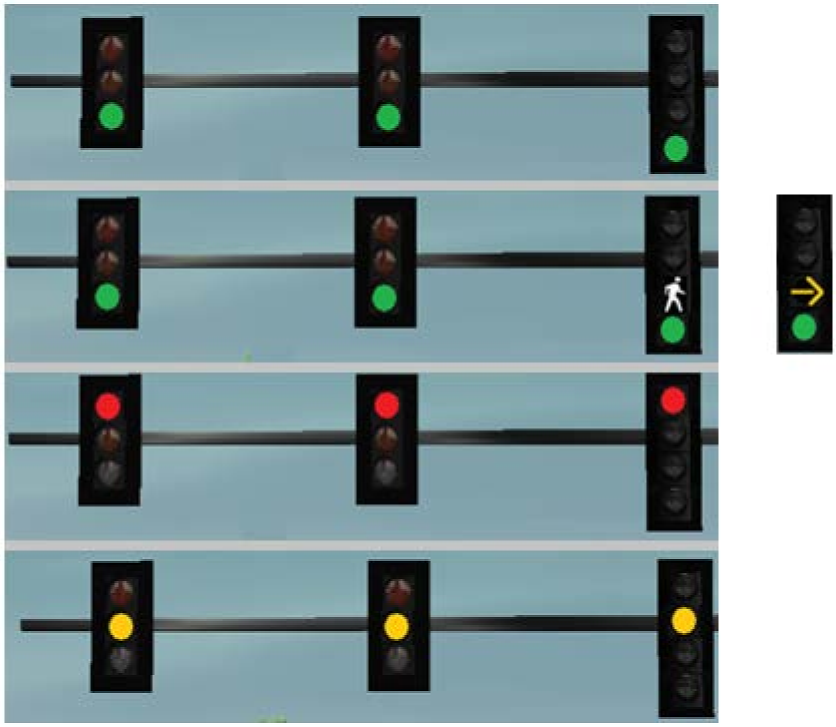

Figure 3. The signal states depicted in Task 1.1. Participants were asked to provide a meaning for each signal state, once for a driver turning right and once for a driver proceeding through the intersection. Note for the FPI (second row), the image was animated to cycle through the depiction of the walking pedestrian and the yellow arrow (500 ms each).

Procedure

The entire survey consisted of six sections: (1) informed consent; (2) open response questions related to signal states while turning right; (3) open response questions related to signal states while driving straight; (4) multiple choice questions related to each signal while turning right; (5) a section asking participants for their opinion on the signal after being informed about its meaning; (6) a section containing demographic questions. These procedures are described in more detail below.

Those that agreed to the consent form continued on to the full survey while those that did not agree were thanked for their time. For the second section, participants were asked to interpret the meaning of each signal for a right-turning driver. Responses were collected via a text box underneath the image of the signal. Participants were asked to be as detailed as possible. The third section was essentially the same as the second, except that participants were asked to interpret the meaning of the signal for a driver going straight rather than turning right. In the fourth section, participants were asked again to interpret the meaning of the each presented signal state for a right-turning driver, but were given multiple options and were asked to check each option that applied. Options were based on information from the 2014 Florida Driver's Handbook and also discussions with FDOT regarding the intended meaning of the FPI. The options available were: (1) Come to a complete stop at the marked stop line or before moving into the cross-walk or intersection; (2) Go - but only if the intersection is clear; (3) A driver should prepare to yield to a pedestrian (if present); (4) A pedestrian is likely present; (5) A right turning driver should scan to the right for pedestrians; (6) Stop if you can safely do so, The light will soon be red; (7) A right turn is allowed. These options were randomly shuffled, to control for response-order effects. For sections two through four presented above, signals were presented in the order of: (1) Green; (2) Yellow; (3) Red; (4) FPI. In the fifth section, an animation of the FPI was shown, below a block of text explaining the signal. Below that, participants were asked to give their opinion of the signal, including any concerns they may have. Since both Task 1.1 and Task 1.2 collected this data, we provide a combined analysis of these data at the end of this report. The final section of the survey asked participants both demographic questions and questions related to their current driving habits (i.e. weekly driving distance, and frequency).

Results

Appendix A depicts whether or not participants used specific words in their responses. First, we explored the answers to open ended questions in which participants were asked to provide the meaning of different signals. We begin with the scenario of primary interest: the meaning of the FPI for right-turning drivers. Two coders scored the answer of each participant for whether any part of the answer corresponded to the following categories: (1) the driver has right-of-way; (2) a pedestrian has right-of way; (3) a right turn is allowed; (4) a pedestrian is likely present; (5) the driver should scan or watch for pedestrian; (6) the driver should yield to a pedestrian if present; 7) the driver should slow or be cautious. In making the judgment of whether or not a driver thought a pedestrian might likely be present, we used any mention of a pedestrian as indicating awareness of potential pedestrians. Reported data represent an average of the proportion of participants providing an answer that falls in one of the previously mentioned categories across the two raters. Figure 4 depicts these results, in contrast to responses made when only the green circular of the signal above the right turn lane was active.

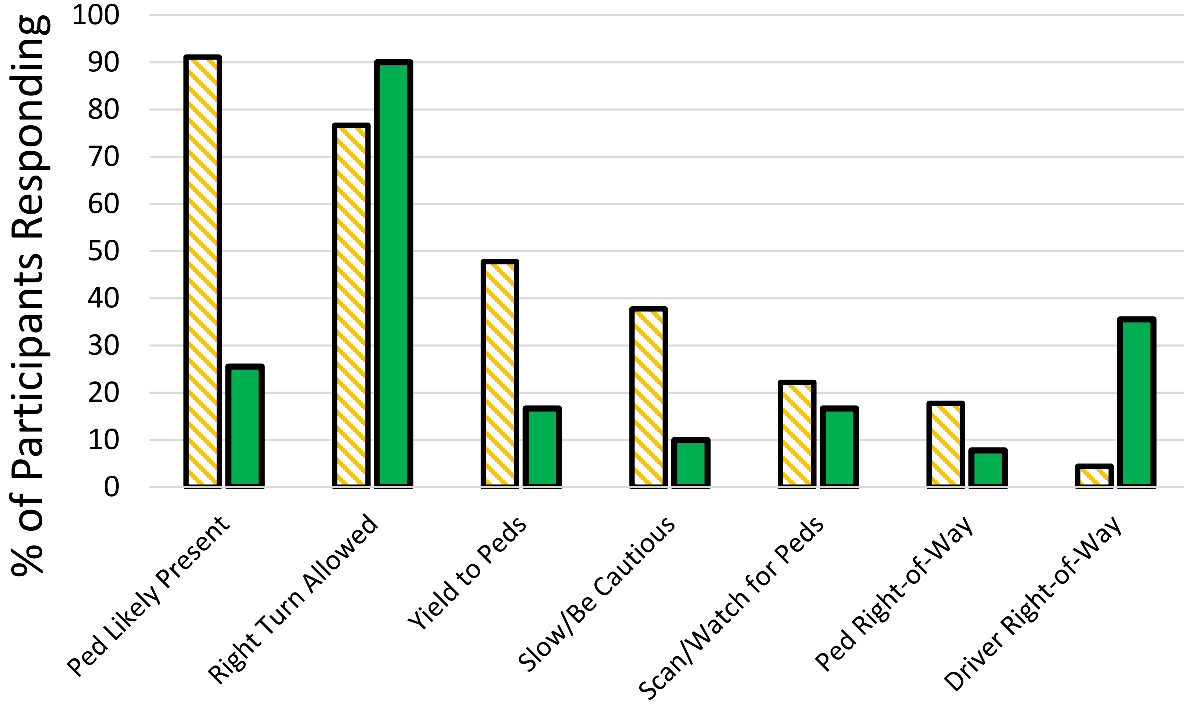

Figure 4. Responses for drivers turning right. Proportion of participants whose open-ended answers fell into each response category when the signal depicted the FPI (yellow/white bars) vs. only a circular green.

Encouragingly, over 90% of participants interpreted the signal as relating to a pedestrian likely being present. Close to half (48%) provided answers indicating that the driver should yield to pedestrians present. Fifty-four percent of participants indicated that they should scan for, slow, or be cautious in the presence of pedestrians. Few participants misinterpreted the FPI to mean that the driver had right-of-way. The two participants who made this response stated the meaning as "that you have the right away, but be safe about pedestrian walking" and "to watch out for pedestrians even if it is my right of way." Both responses clearly indicate an awareness of potential pedestrians present and a need to be cautious. We also examined whether the distribution of responses was similar for younger, middle-aged, and older drivers was roughly similar, and found this to be the case (Figure 5).

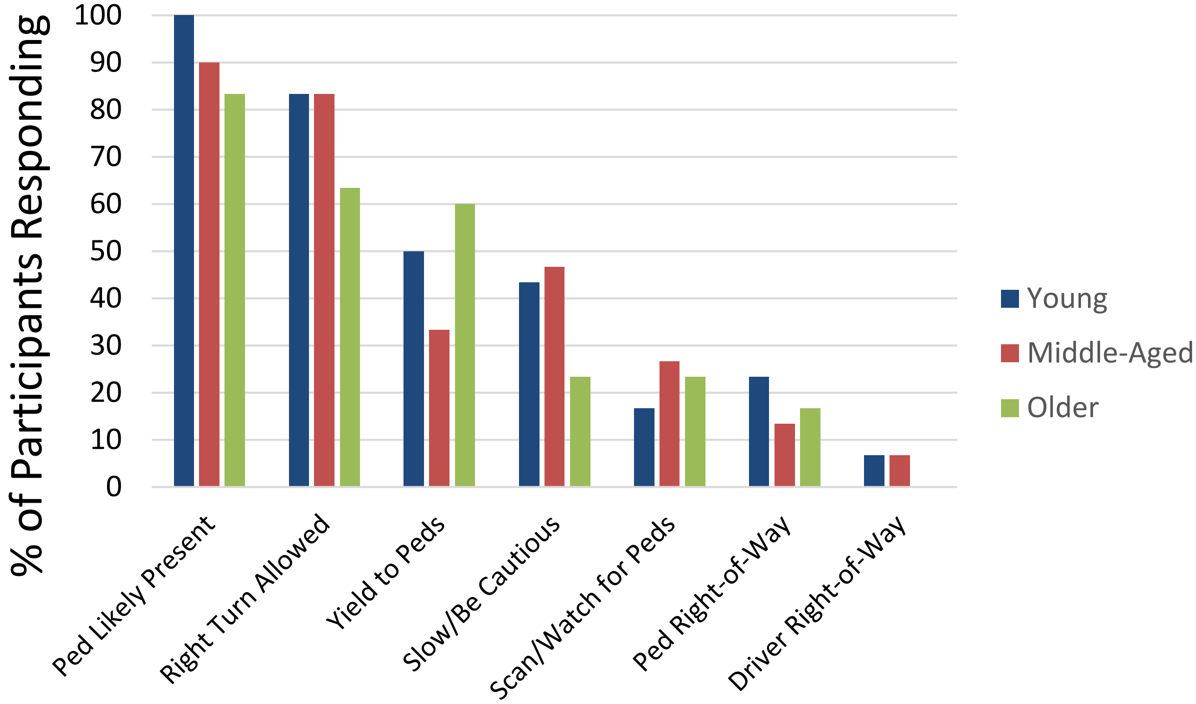

Figure 5. Responses for drivers turning right as a function of age.

However, when presenting drivers with the same scenario, and asking the driver the meaning of the scenario for a driver going straight through the intersection, participants sometimes misinterpreted the signal as though the FPI applied to them as well (that they too needed to watch for pedestrians). Figure 6 depicts interpretation of the FPI and the circular green state for drivers going straight through the intersection. In general, the FPI seemed to engender caution even for drivers not turning right. Figure 7 depicts a relatively similar distribution of responses across age groups, with some evidence for middle-aged and older drivers giving more cautious responses compared to younger drivers (more scan for pedestrian and slow/be cautious responses especially).

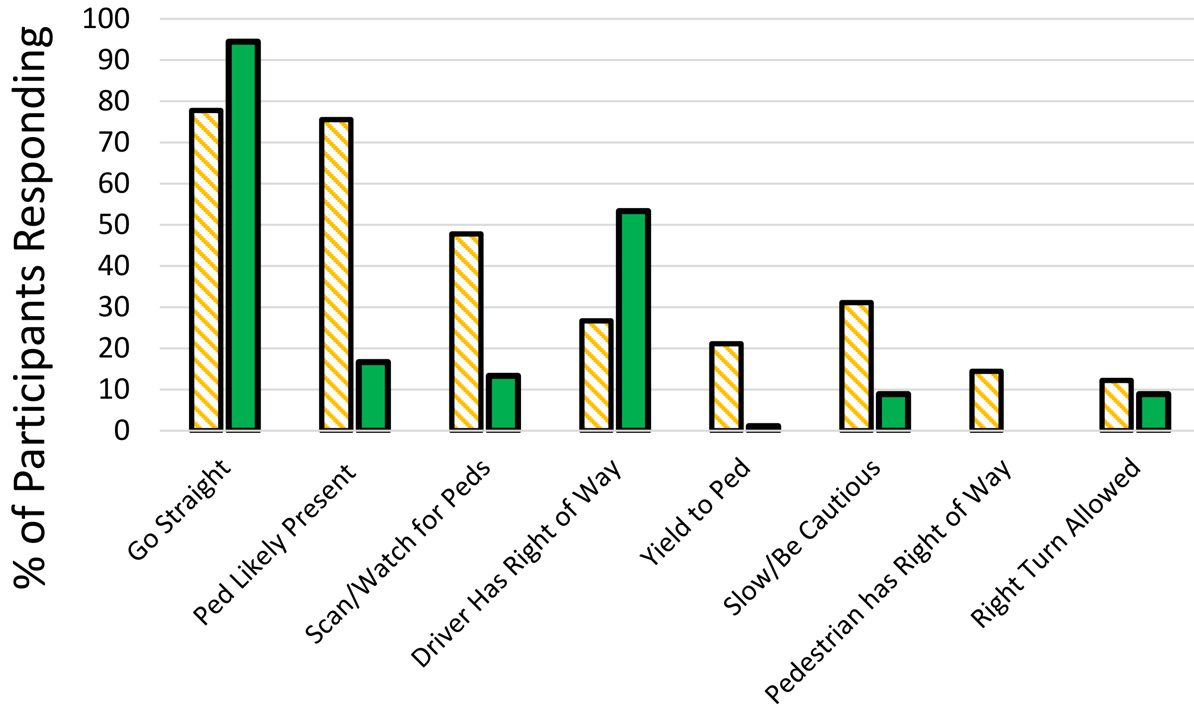

Figure 6. Responses for drivers going straight. Proportion of participants whose open-ended answers fell into each response category when the signal depicted the FPI (yellow/white bars) vs. only a circular green.

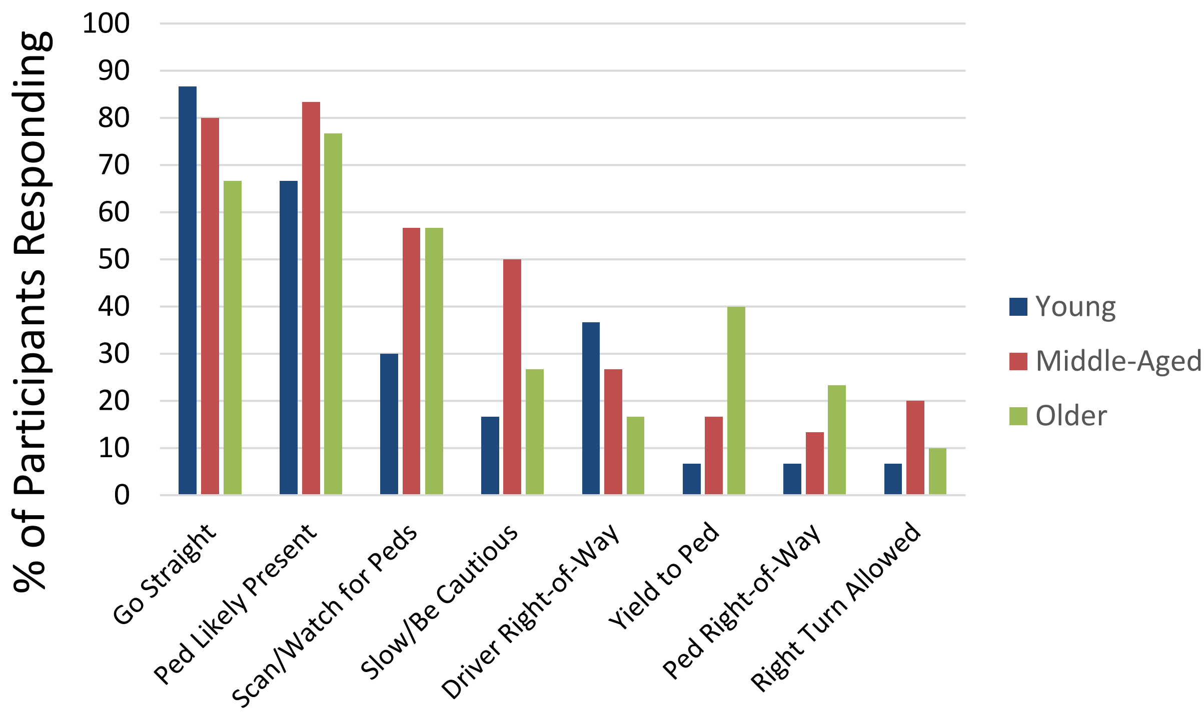

Figure 7. Responses for drivers going straight as a function of age.

In general, the open-ended responses appear to confirm that most participants understood the message of the FPI well. Next, we explored multiple choice responses. Participants were asked, when presented with each signal state, to select all choices that applied. Within Figure 6, we present the percent of participants who made a particular response for each signal state, including the FPI. Note that the "Go" category corresponds to the response "Go, but only if the intersection is clear."

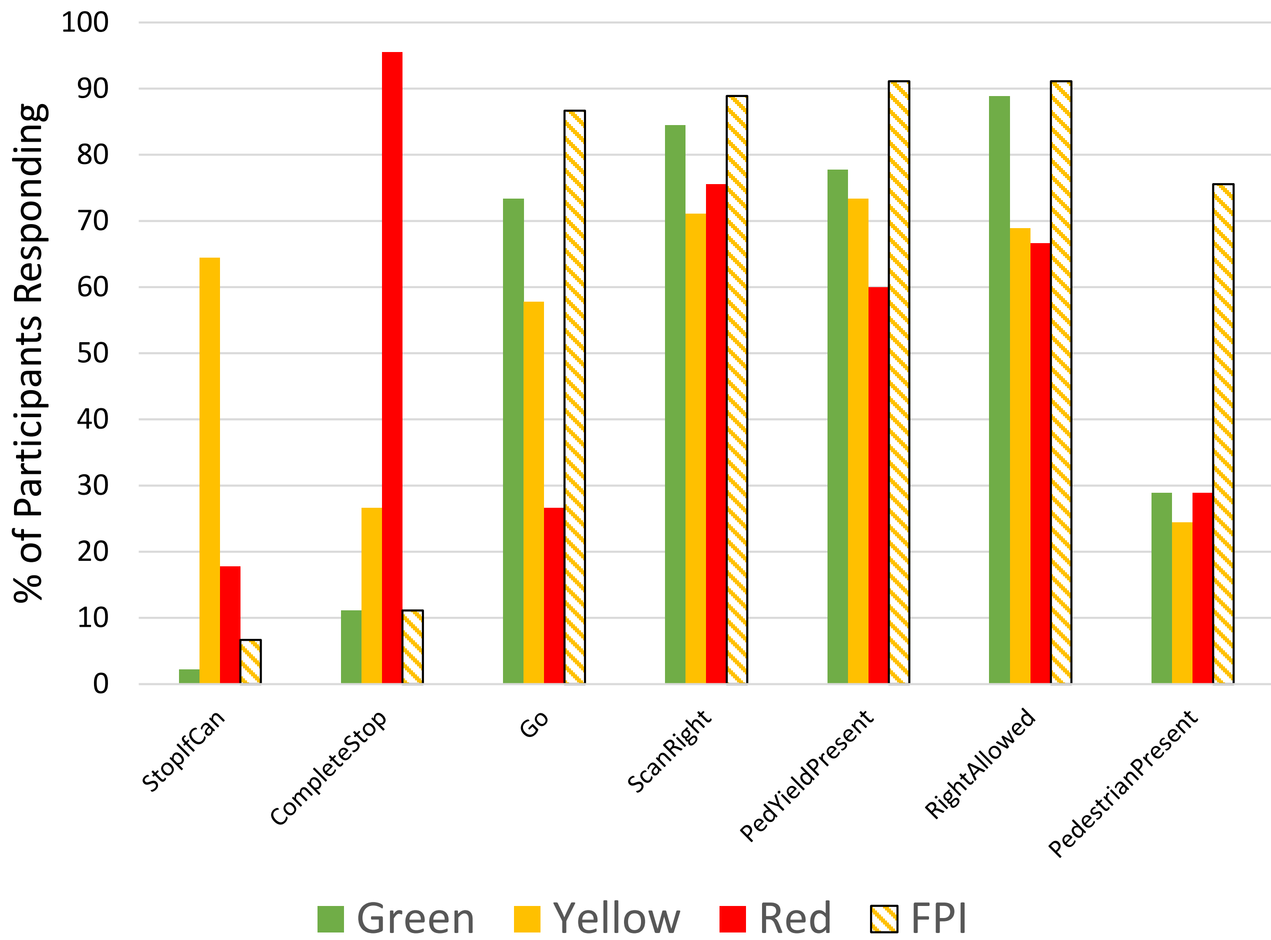

Figure 8. Percentage of participants whose multiple choice answers fell into each response category when participants were asked the meaning of each signal for a right-turning driver.

Of critical importance, greater than 75% of participants understood the FPI to mean that a pedestrian may be present (far greater than any other signal; see the last set of columns to the right of Figure 8). Greater than 90% understood it to indicate that a driver should yield should a pedestrian be present. Although technically not the meaning of the green, yellow, and red signals, it is somewhat encouraging that a high percentage of participants indicated that a right-turning driver should yield to pedestrians and scan for participants under these conditions as well. Not surprisingly, almost all drivers indicated a complete stop should be made at the stop bar for a red signal. For a yellow signal, a mixture or responses were made, reflective of the fact that a yellow signal can mean different things depending on the context (stop if you can do so, or go if there is enough time to complete the turn). In addition to the message that a potential pedestrian was present, that they should yield if necessary, and that they should scan to the right, participants also understood that they could make a right turn in the presence of the FPI (go and right-turn allowed responses). Responses to the FPI were similar across age groups (Figure 9).

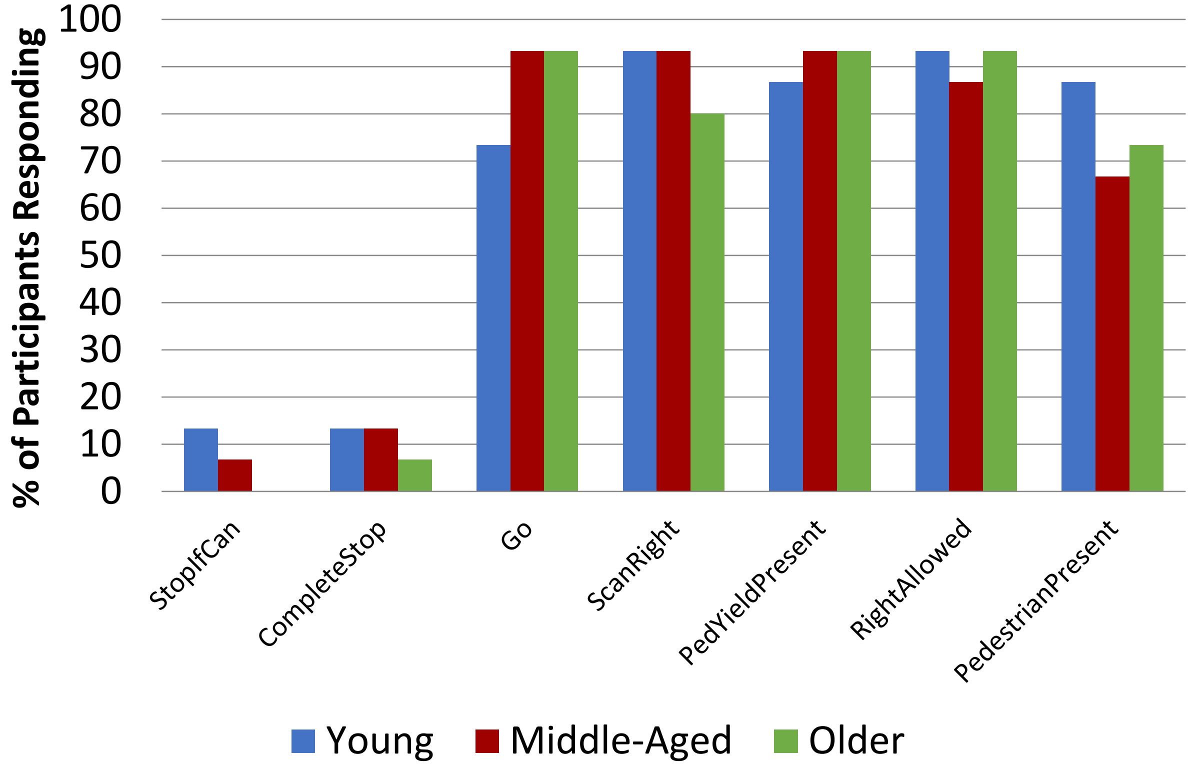

Figure 9. Percentage of participants whose multiple-choice answers fell into each response category when participants were asked the meaning of the FPI for a turning driver as a function of age.

Conclusions

The FPI conveyed crucial information: most participants understood that it meant pedestrians may be present, and most indicated that they should either be cautious, scan, or yield to potential pedestrians in the roadway while turning right. In the specific case of intersections without a dedicated right-turn lane, some confusion may result for drivers proceeding straight through the intersection. This confusion may be less likely to occur for intersections with a dedicated right-turn lane. The FPI was interpreted in such a way that it may engender caution and scanning for pedestrians even for drivers proceeding straight through the intersection. Comprehension across age groups was similar.

Task 1.2. Driver Judgment Task

Task 1.1 focused on comprehension of the FPI. Task 1.2 asked drivers to report the correct action of a right-turning driver in response to the FPI and other signal states. Critically, we also included scenarios that featured an intersection that did not contain an FPI (the signal furthest to the right had three signal heads rather than four and simply depicted a circular green). In both these situations (FPI vs. 3-signal circular green), the Walk Signal was active for pedestrians crossing the side street. First we asked participants to make untimed judgments, and then participants completed a speeded version of the same task. In some scenes, a pedestrian was in the crosswalk that would intersect with the path of a right-turning driver, and sometimes the crosswalk was empty.

Method

Participants
A total of 15 younger (21 to 35 years, *M* = 25.7, *SD* = 3.4), 15 middle-aged (50 to 64 years, *M* = 58.2, *SD* = 4.8), and 16 older (65 and above years, *M* = 72.6, *SD* = 4.5) participants were recruited from the Tallahassee, FL area. All were licensed drivers.

Materials
For this task, a two-part experiment was programmed in PsychoPy (Peirce, 2007; version 1.81), a Python-based experimental software package. All stimuli (1200 pixels x 673 pixels) were rendered in Google Sketchup, with different combinations of the following factors: signal head (3 or 4), pedestrian present or absent. The position and appearance of the pedestrian varied, making the task more difficult. Signal colors were added in Microsoft Paint as they were in Task 1.1. This resulted in 11 unique images (see Figure 10 for an example). All stimuli were presented against a black background as they were in Task 1.1. Responses were collected with a button box, created by the Department of Psychology Machine Shop at Florida State University. The button box has three response buttons, labeled from left to right as: “Go”, “Stop”, and “Yield to Pedestrian.” These response options were also presented on-screen within white rectangles with black text, so participants could remain fixated on the stimuli.

Figure 10. Sample stimulus for Task 1.2. Note the pedestrian to the right in the crosswalk.

Procedure
For the first part of this experiment, accuracy in responding to the stimuli as a right-turning driver was emphasized, not speed. The five stimuli presented in this block appeared in the following order across all participants: (1) three signal head, green light, no pedestrian present; (2) three signal head, green light, pedestrian present; (3) four signal head, red light, no pedestrian present; (4) four signal head, flashing pedestrian indicator, no pedestrian present; (5) four signal head, flashing pedestrian indicator, pedestrian present.

For the second part of this experiment, there were two nearly identical blocks of trials, combined into one master list of 40 trials, then randomly ordered. In one block of 20 trials (before randomization), when the flashing pedestrian indicator was the signal depicted, the arrow would appear first, and in another block of 20 trials, the pedestrian was shown as the first frame in the animation. In this part of the experiment, speed was emphasized.

After completing the five accuracy trials and 40 reaction time trials, participants were asked to complete a short-form of the survey from Task 1.1 (http://cognitivetask.com/fypi_opinion), only including the sections about their opinion and demographics.

Results
First, we focus on accuracy with and without speed pressure. Recall that the first part of the task simply asked participants to respond with the correct answer to each image, taking as much time as needed. We focus on the critical comparison of interest: When the FPI was present, compared to a 3-signal-head circular green. We considered an

accurate response to be “yield” when a pedestrian was present, and “go” when a pedestrian was absent. As can be seen from Figure 11, participants were more likely to make a correct decision to yield when the FPI was presented in the case of a pedestrian being present compared to a circular green ($\chi^2(1) = 5.00$, $p < 0.05$).

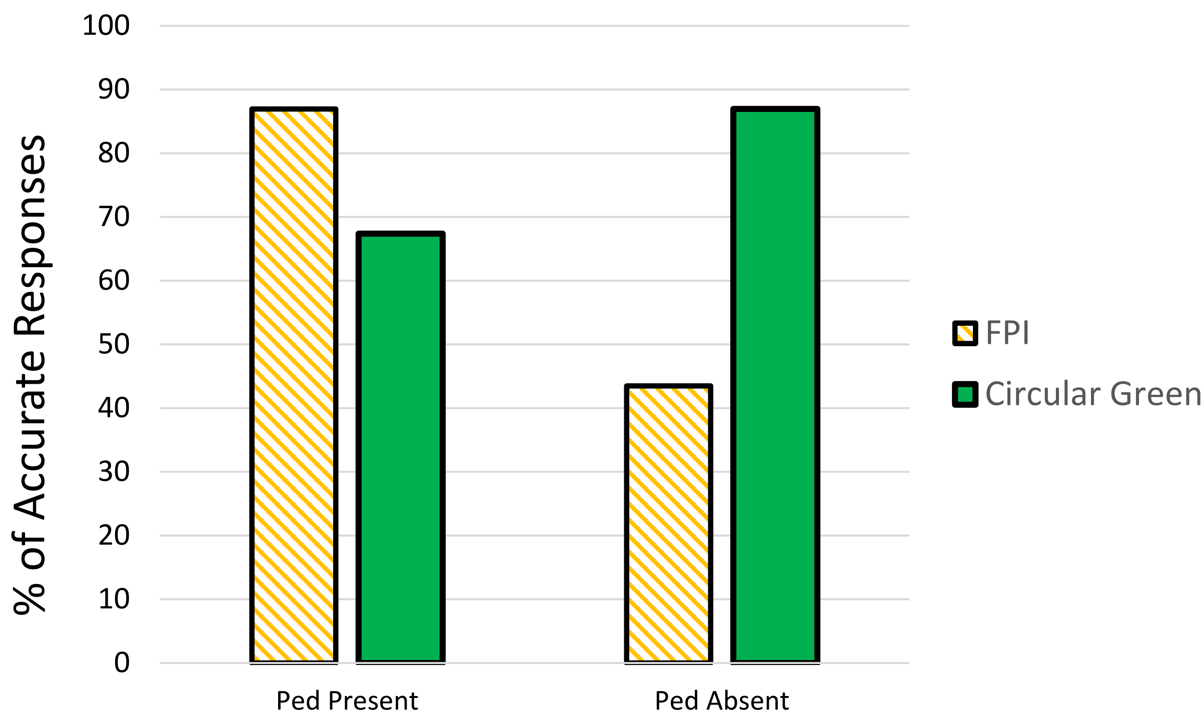

Figure 11. Untimed responses. Percent of participants who made the correct response for each signal for a right-turning driver as a function of pedestrian presence in the crosswalk.

The inverse was true when a pedestrian was absent (participants performed less accurately when the FPI was presented ($\chi^2(1) = 5.00$, $p < 0.05$). Out of the 26 error responses, all fell into the “yield” category.

Next, we turn to the speeded decision task. In this case, each image was presented to participants 4 times, with the position and appearance of the pedestrian being variable in images with a pedestrian present. As can be seen from Figure 12, a similar pattern is observed. When a pedestrian was present, participants were more accurate when the FPI was presented (more yielding responses) compared to the circular green signal ($F(1, 45) = 15.12$, $p < 0.001$). When a pedestrian was absent participants were more accurate when a circular green was present ($F(1, 45) = 26.05$, $p < 0.001$). Similar to the untimed response portion of this task, errors were such that participants were more likely to make a “yield” response, even when no pedestrian was in the crosswalk. Of the 132 errors across all participants and trials, 94% of these errors were the “yeild” response, and the remaining were the “stop” response.

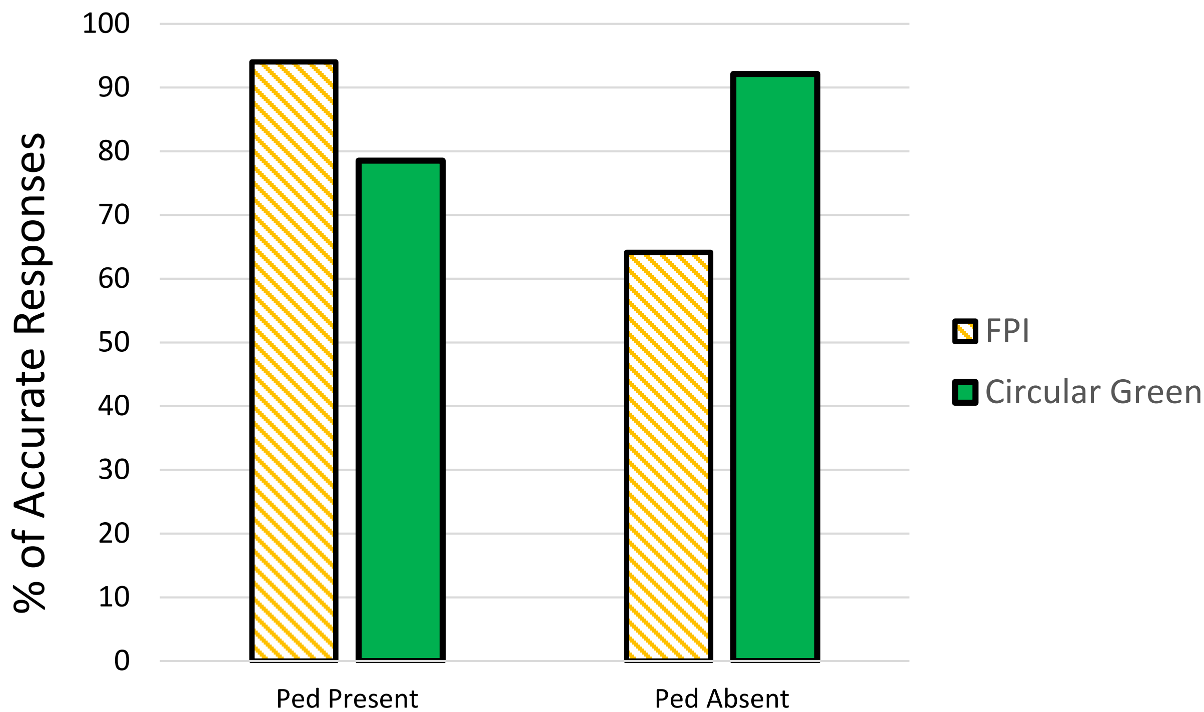

Figure 12. Speeded responses. Percent of participants who made the correct response for each signal for a right-turning driver as a function of signal type and pedestrian presence in the crosswalk.

Next we examined the response times in the speeded task. Figure 13 depicts these data. Response times were comparable when a pedestrian was present between when participants were presented with the FPI vs. a circular green ($F(1, 45) = 00.00$, $p = .99$). However, when a pedestrian was not present, participants took more time to make their response when presented with an FPI compared to a circular green signal ($F(1, 45) = 10.91$, $p < 0.01$). We interpret this slowing as participants taking additional time to check for the presence of pedestrians.

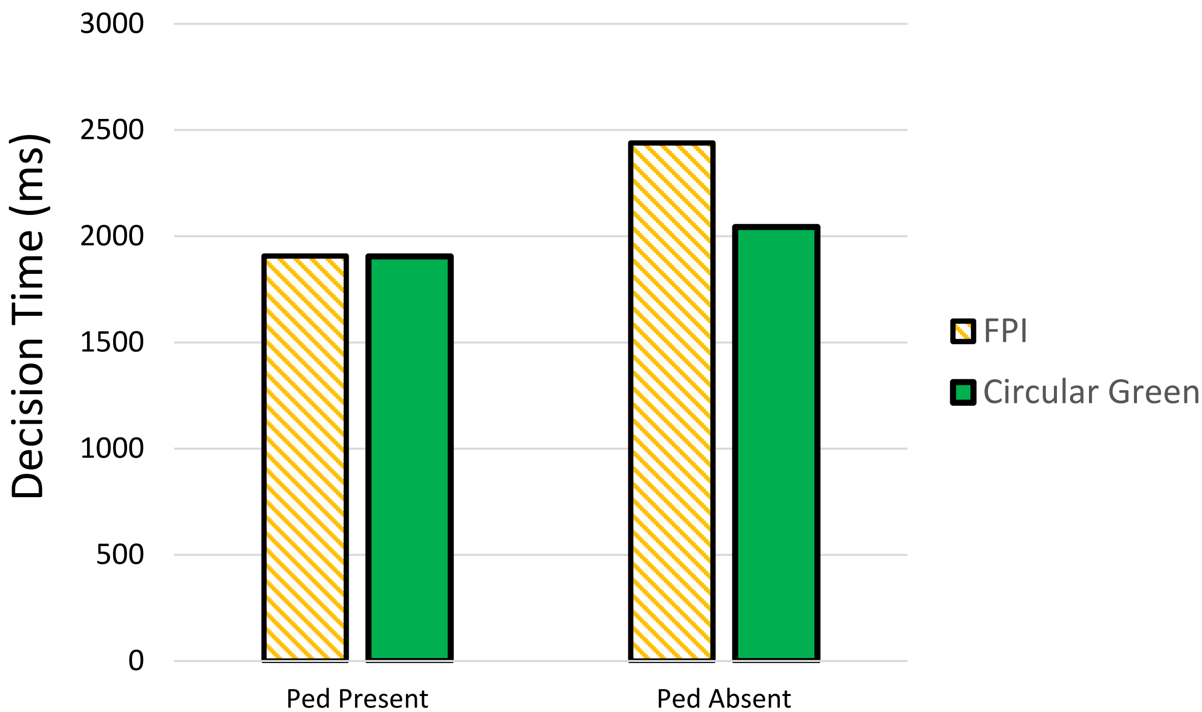

Figure 13. Speeded responses. Decision time of participants as a function of signal type and pedestrian presence in the crosswalk.

Finally, we explored age effects, first in the untimed judgment task (accuracy), and then in the timed judgment task (both response time and accuracy). The pattern of untimed and speeded judgment accuracy was remarkably consistent across age groups (Figures 14 and 15). For the timed judgments, which included multiple presentations of varying images, accuracy data were entered into an ANOVA with signal type and pedestrian presence as within-participant factors, and age (younger, middle-aged, older) as a between participant factor. This revealed a significant signal type by pedestrian interaction ($F(1, 43) = 27.58$, $p < 0.001$). As noted before, participants were more likely to make an accurate yielding response in the FPI condition when a pedestrian was present. However, they were less accurate at making a “go” response when a pedestrian was absent. In other words, there was a bias toward safety, participants were more likely to make a yield response to the FPI compared to a circular green in the absence of a pedestrian even though the intersection was clear. There was no effect of age, nor did age interact with any other variable (all p values > 0.30). Thus younger, middle-aged, and older adults responded very similarly.

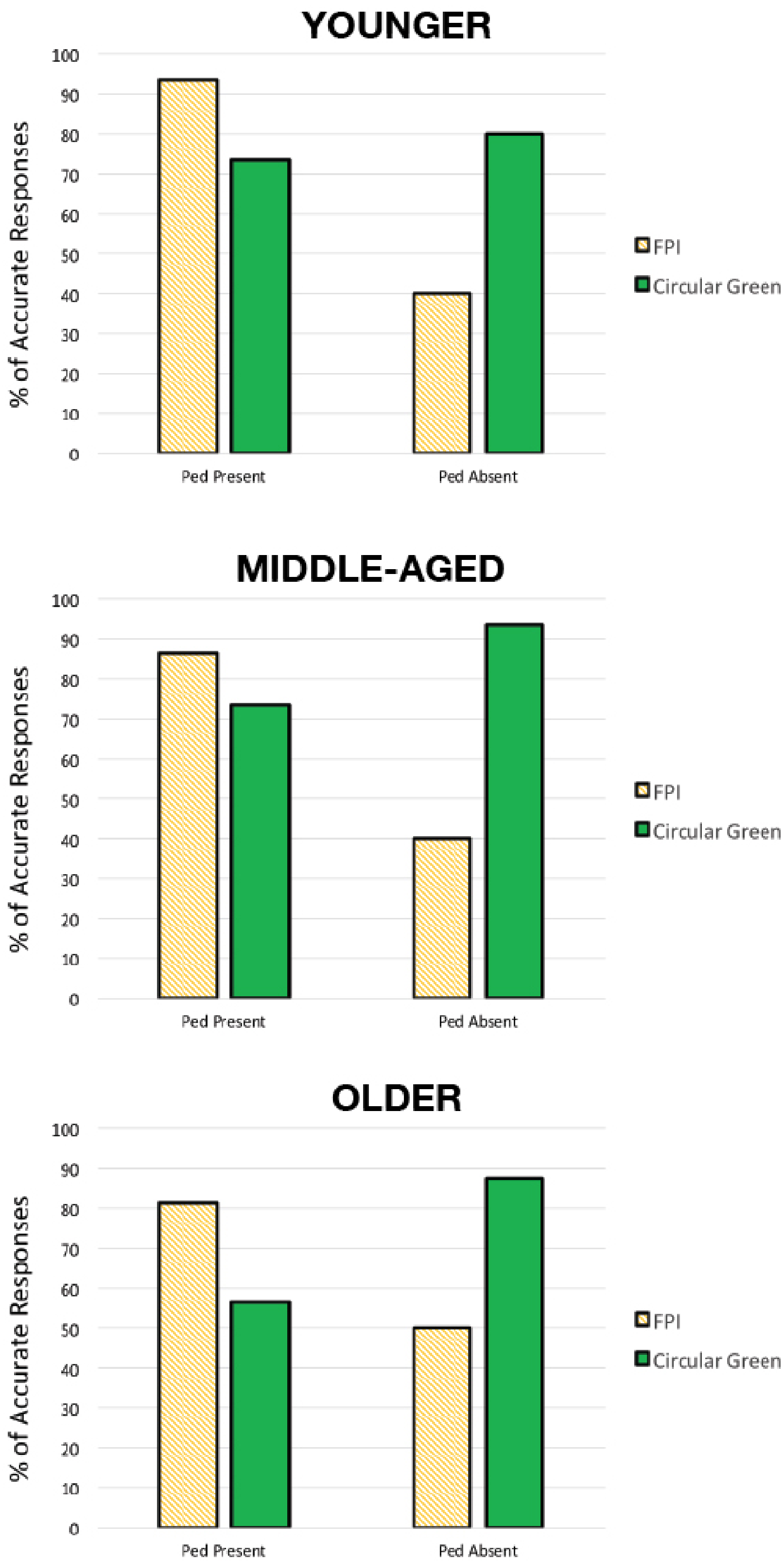

Figure 14. Untimed response accuracy as a function of age, signal type, and pedestrian presence.

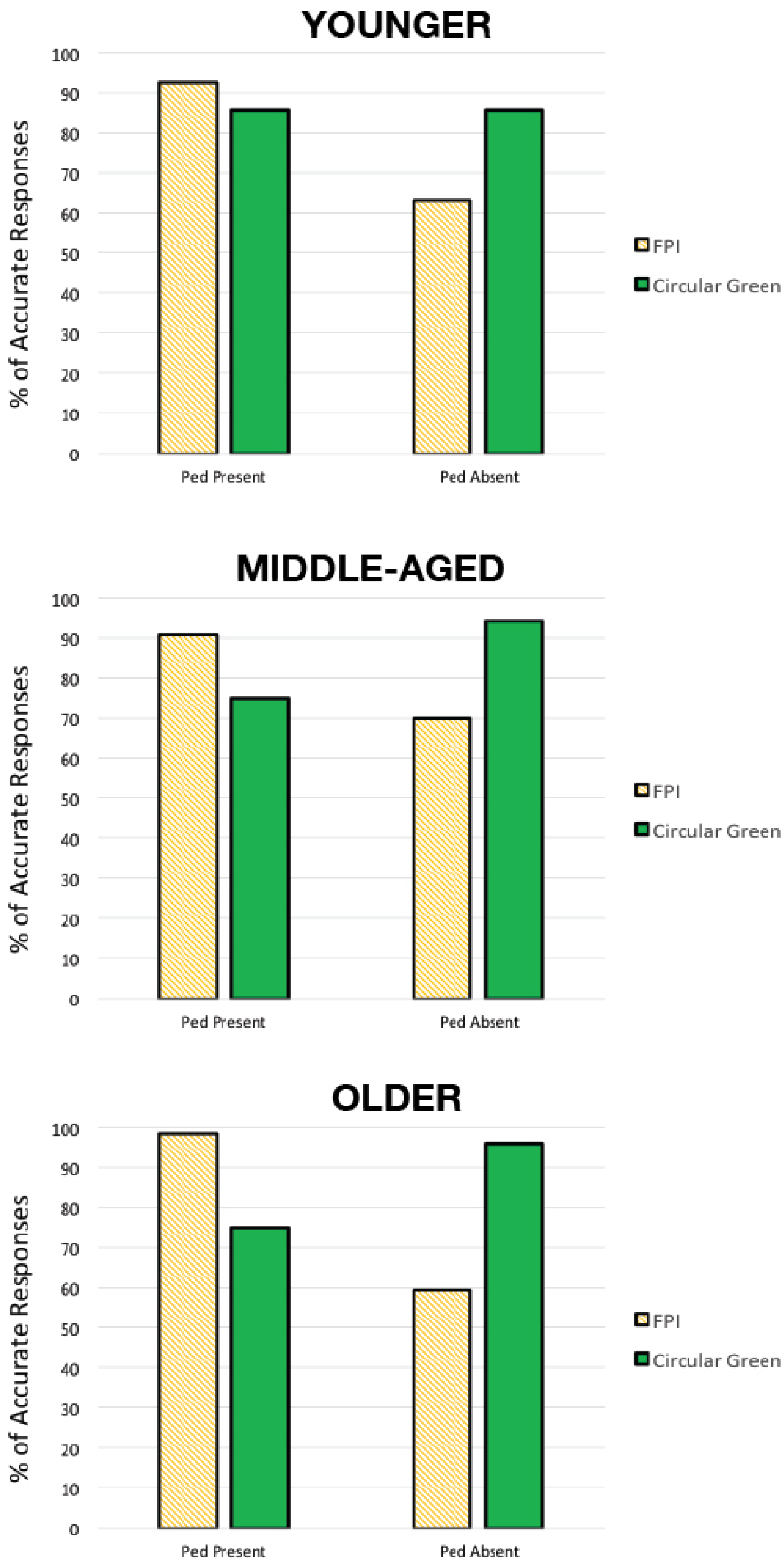

Figure 15. Speeded response accuracy as a function of age, signal type, and pedestrian presence.

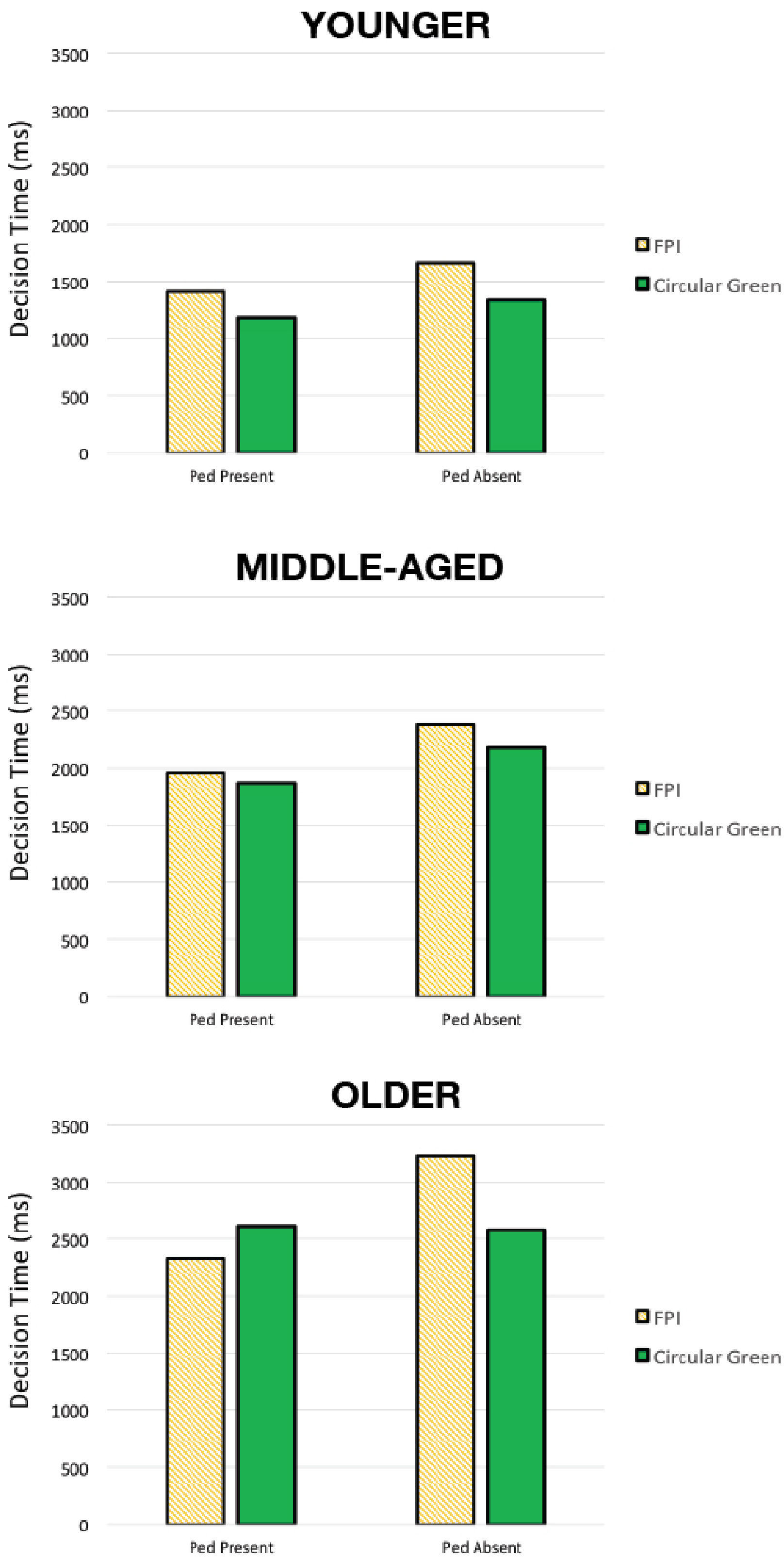

Figure 16. Speeded response decision time as a function of age, signal type, and pedestrian presence.

We also examined decision time (Figure 16). There was an effect of age, with older adults being slower compared to younger adults ($F(2, 43) = 11.17$, $p < 0.001$), a signal by pedestrian presence interaction ($F(1, 43) = 8.23$, $p < 0.01$), and also a signal by age by pedestrian presence interaction ($F(2, 43) = 4.24$, $p < 0.05$). To further explore the nature of this interaction, we ran separate ANOVAs for pedestrian present and absent conditions. The initial three-way interaction appeared to be driven by a trend for an interaction between age and signal type in the pedestrian absent condition, with older adults delaying their decision longer in the FPI condition compared to the circular green condition compared to other age groups (signal by age interaction: $F(2, 43) = 2.69$, $p = 0.08$, see Figure 15). When a pedestrian was present, the only significant effect or trend involved older adults responding more slowly in general ($F(2, 43) = 7.31$, $p < 0.01$). Results may indicate that older adults are especially receptive to the message of the FPI and search longer for potential pedestrians when a pedestrian is absent.

Conclusions

In Task 1.2, the decision to yield was increased when the FPI was present compared to a circular green signal which would typically be presented at a non-FPI intersection. A potential drawback might be that even in the absence of a pedestrian in or near the crosswalk, participants often still made a yield response. This abundance of caution, even in the absence of a visible pedestrian may still serve as protection for pedestrians who may not be immediately be visible due to environmental conditions (nighttime, poor visibility due to inclement weather). Caution in these cases was inferred from both by a tendency for participants to make a yield response and also slower decision times overall, which likely indicated increased scanning or searching for pedestrians. However, this caution may have a negative impact in terms of traffic flow that should be considered. Younger, middle-aged, and older adults responded to the FPI similarly in most cases.

Driver Opinions and Comments

After both Task 1.1 and 1.2, participants were asked to give their impressions of the new signal. They were shown the FPI again and given the following text to read:

“The image below represents a new traffic signal that Florida is considering. It alternates between a flashing yellow arrow and pedestrian symbol. The purpose of this new signal is to alert right-turning drivers to the potential presence of pedestrians in the crosswalk. The pedestrian activates this signal by pushing the call button. When this signal is present, the right-turning driver should scan to the right, watch for pedestrians, and yield to pedestrians in the crosswalk**. What do you think of this new signal? Please express your comments and concerns in the box below:”**

All responses are provided in the supplemental materials. We coded each response for instances of positive and negative comments. Overall, 74% of participants made at least one positive comment about the FPI. Positive comments often related to the necessity of such a signal, the fact that it would encourage safety, and the fact that it was easy to understand. As an example, one participant claimed that "It's clear what the intent is and would serve as a reminder of the potential for pedestrians." Another participant stated that "The new signal is helpful, because if gives additional visual information to warn of pedestrians." Forty-six percent of participants mentioned something negative or a concern that they had regarding the FPI. A common theme was a question of whether the FPI is needed since drivers should already know to yield to pedestrians, even in the absence of additional countermeasures encouraging them to do so. For example, one participant responded, "I think [it] is unnecessary because if you are a responsible driver you always are going to look for pedestrians and if you are not, the new flashing light will mean nothing." Another participant stated, "Doesn't do anything new. Those have always been the rules. Hard to believe a driver would be so clueless to obey this signal when he wouldn't otherwise yield to a pedestrian." These negative comments might be interpreted as a lack of awareness of pedestrian risk in general and an overconfidence in drivers' ability to see pedestrians and an overestimation of pedestrian visibility. Other comments related to potential distraction by the flashing signal (7% of participants), and some participants were worried about potential driver confusion (16%). Some participants suggested educational materials to better inform drivers regarding FPI meaning. Only 16% of participants *only* made negative comments regarding the FPI without also mentioning something positive as well. Results suggest that in general many drivers would be receptive to the FPI, and that educational materials such as FDOT tip cards may address some of the participants' concerns. Educational materials might also highlight pedestrian risk in Florida and nationwide to help convince drivers of the utility of the FPI.

Chapter 3. Summary of the Studies

Benefit of the Project

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

Task 1.1. & Task 1.2

Both tasks indicated that the FPI is largely well understood, and may be a promising signal to explore further with the aim of reducing pedestrian crash risk. In no instance did participants seem to misunderstand the meaning of the FPI such that this misunderstanding would likely result in increased pedestrian crash risk. If anything, the FPI might have resulted in an overabundance of caution in some situations (e.g., for a driver going straight through the intersection, for a driver encountering the FPI without a pedestrian clearly visible). It should be noted that this may in fact be a situation drivers encounter since a pedestrian may call for the walk signal and either change his or her mind, or cross before the walk sign is presented. Unnecessary caution and scanning for pedestrians, even for drivers proceeding straight through the intersection, might impact traffic flow.

Specific Recommendations Based on Study Findings

Although promising in terms of comprehension, not all participants understood the message of the FPI in certain situations. Results allow for the recommendation of specific studies to further evaluate the FPI before a decision can be made regarding implementation.

1) We recommend additional laboratory based studies similar to the ones reported here that manipulate roadway geometry. Specifically, these studies would manipulate whether or not the FPI is placed above a dedicated right-turn lane or not. Part of the reason for this confusion may be the mixing of signals directed to right-turning drivers (FPI) and drivers going straight (circular green). Studies might also examine the impact of supplemental signs and driver education (e.g., FPI tip cards). A previous study has found that tip cards can reduce confusion regarding the flashing yellow arrow and similar effects might be observed for the FPI.
2) Given the initially promising results reported here with respect to comprehension, we recommend studies of driver behavior in response to the FPI, informed by the reported results and the laboratory-based study described above. Specifically, this question is well-suited for a driving simulator study. Not only can such a study measure *appropriate* yielding behavior during simulated driving for drivers turning right, it can also assess *inappropriate* behaviors (e.g., braking) in response the FPI for drivers passing straight through the intersection. A previous study examining yielding behavior in response to pedestrians within different crosswalk types might be used as a model for such a study (Boot et al., 2014).

3) The reported tasks and the recommended studies described above focus on the driver. However, a complete picture of the appropriateness of the FPI must also consider pedestrian reactions. This is a potentially important issue because the FPI includes a signal (walk sign) that is traditionally meant for pedestrians. We recommend additional studies that assess comprehension of the FPI from the perspective of pedestrians intending to cross.

The reported studies provide important information required to shape the design and direction of studies necessary to make a final recommendation regarding the implementation of the FPI.

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Appendix A. Word Frequency Matrices for Task 1.1, Open-Ended Responses

In these graphs, words used in open-ended responses are shown on the y-axis, and participants are on the x-axis. This style graph helps to quickly see commonly used words across participants.

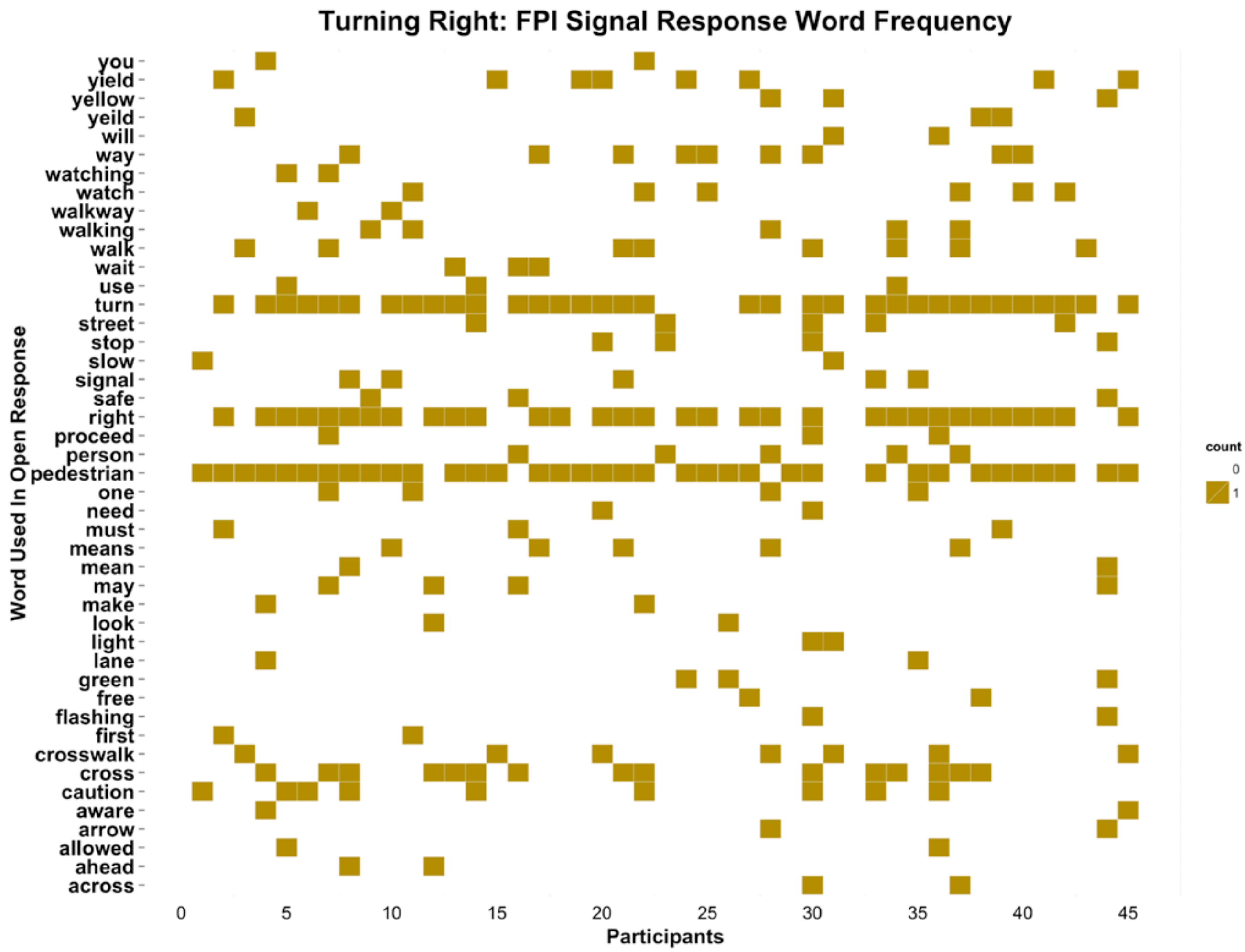

Figure 17. Use of target words for the FPI signal (y-axis), when participants (x-axis) were told to imagine they are a driver turning right. To see patterns across participants, look across a row for a given word.

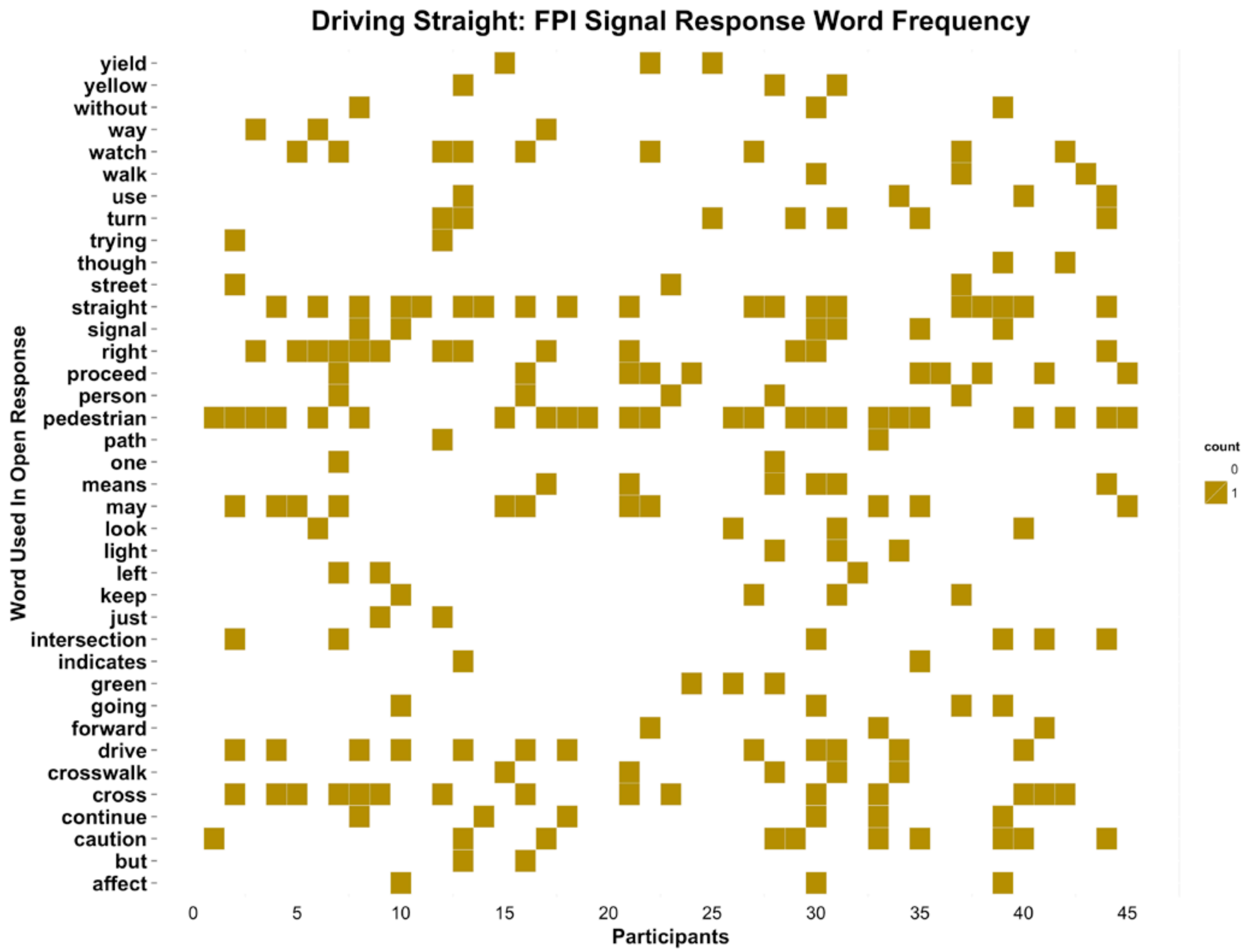

Figure 18. Use of target words for the FPI signal (y-axis), when participants (x-axis) were told to imagine they are a driver driving straight. To see patterns across participants, look across a row for a given word.

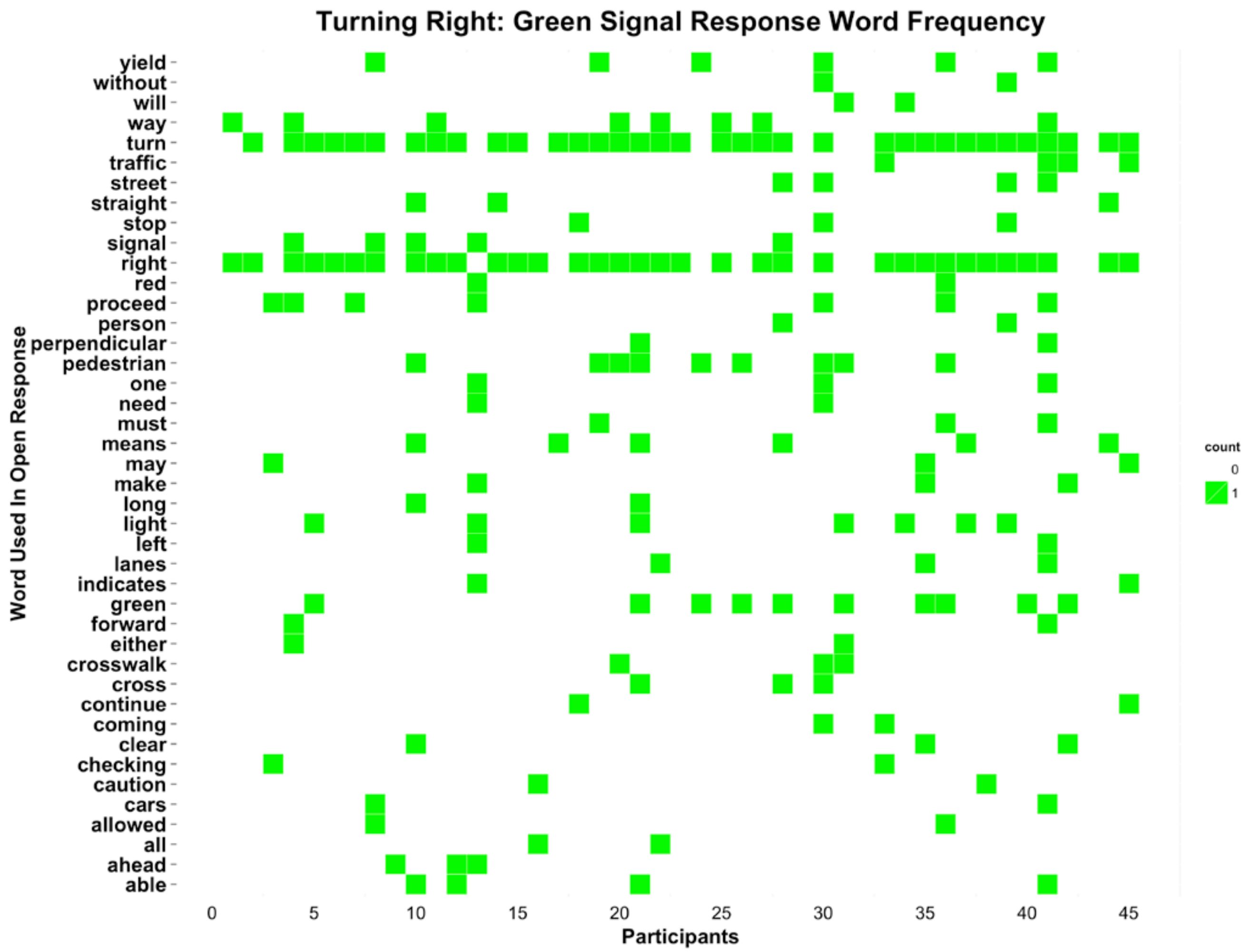

Figure 19. Use of target words for the Green-circular signal (y-axis), when participants (x-axis) were told to imagine they are a driver turning right. To see patterns across participants, look across a row for a given word.

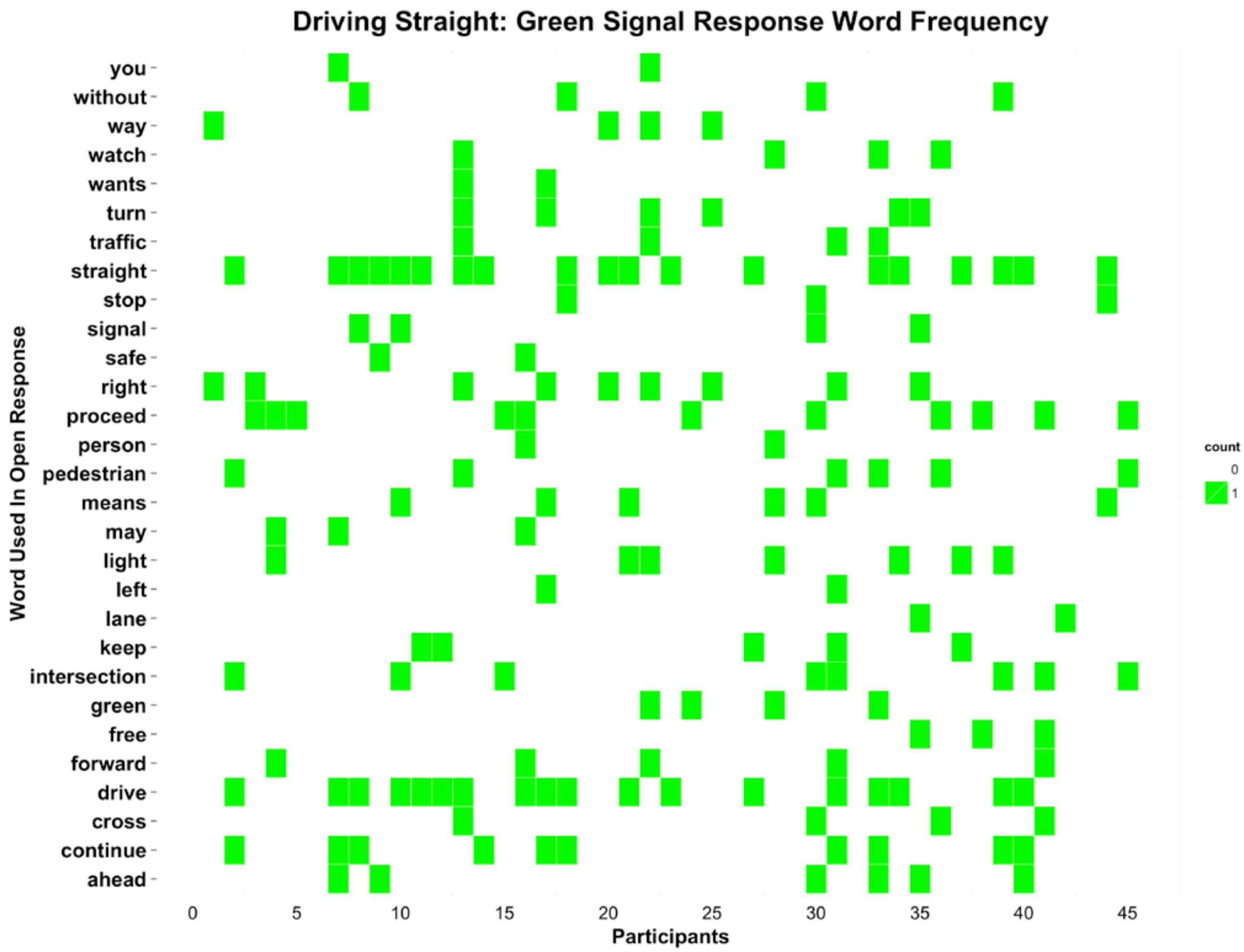

Figure 20. Use of target words for the Green-circular signal (y-axis), when participants (x-axis) were told to imagine they are a driver driving straight. To see patterns across participants, look across a row for a given word.

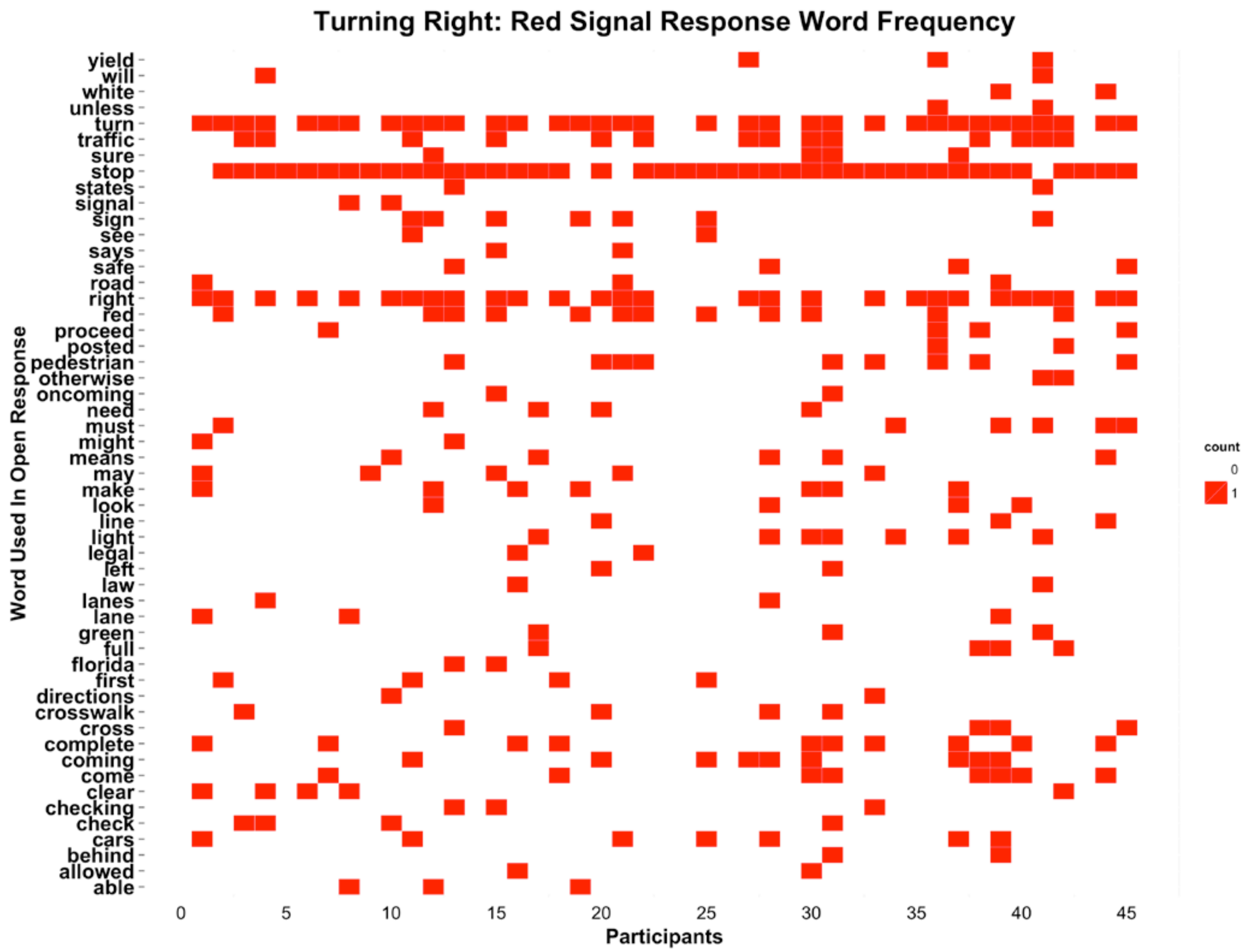

Figure 21. Use of target words for the Red-circular signal (y-axis), when participants (x-axis) were told to imagine they are a driver turning right. To see patterns across participants, look across a row for a given word.

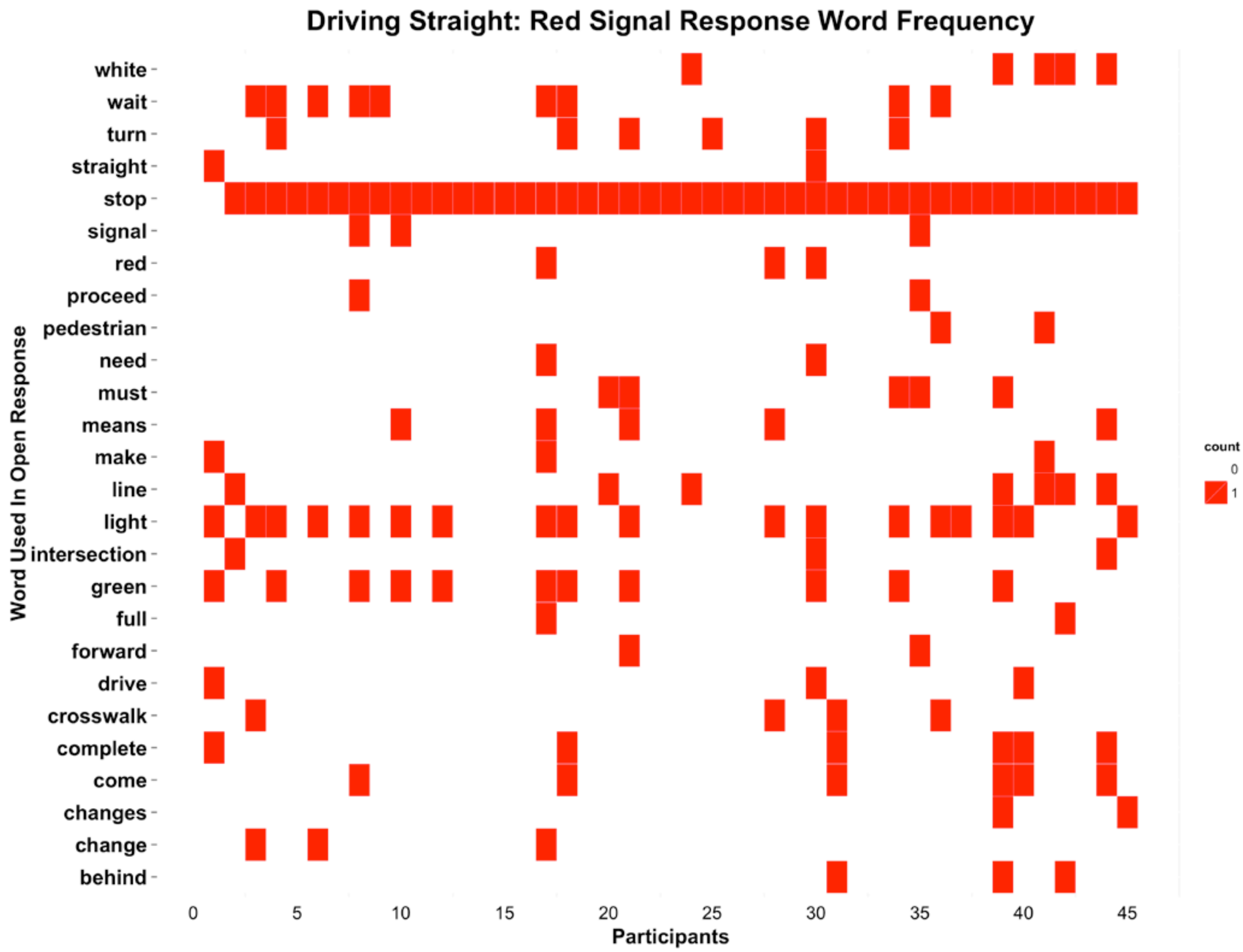

Figure 22. Use of target words for the Red-circular signal (y-axis), when participants (x-axis) were told to imagine they are a driver driving straight. To see patterns across participants, look across a row for a given word.

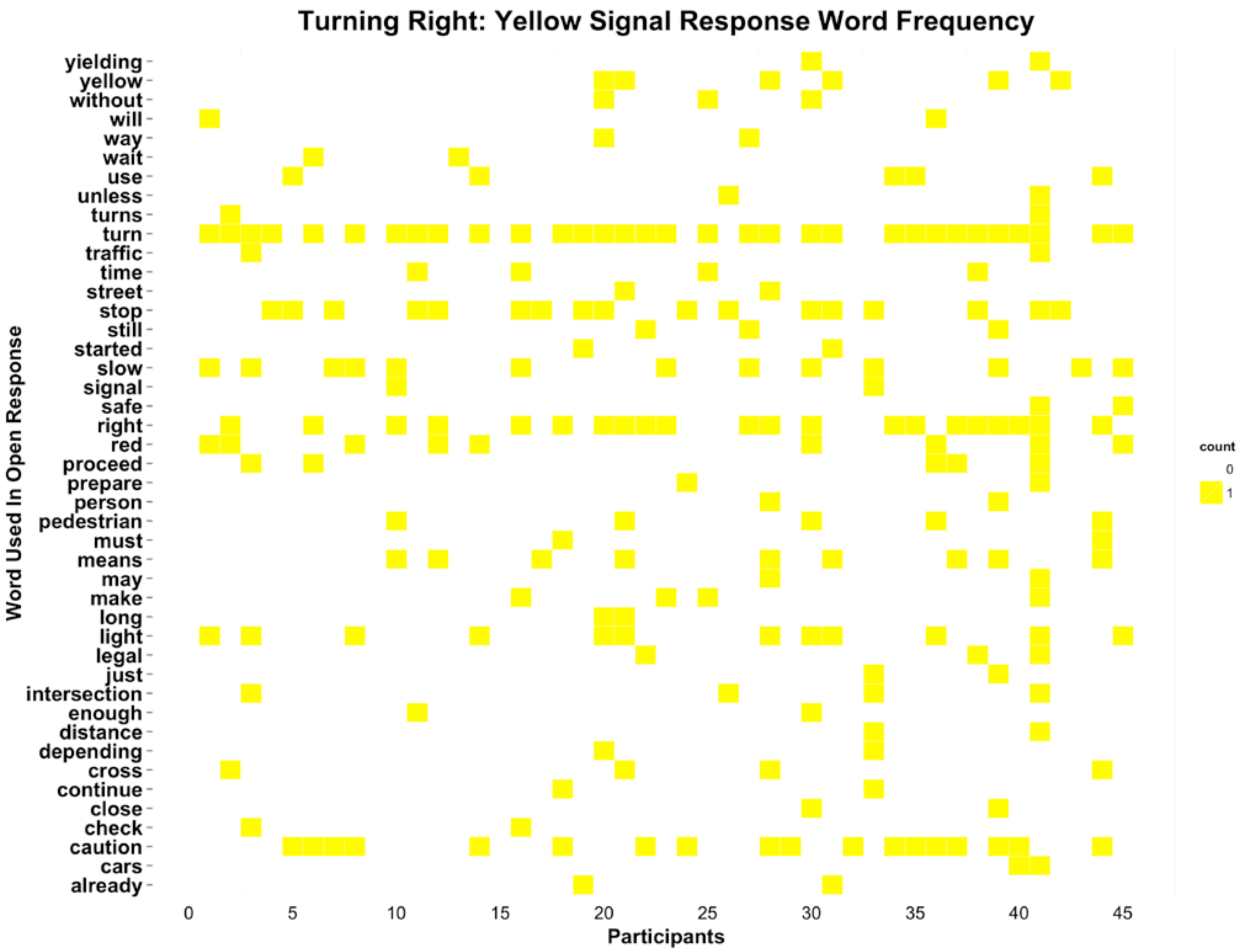

Figure 23. Use of target words for the Yellow-circular signal (y-axis), when participants (x-axis) were told to imagine they are a driver turning right. To see patterns across participants, look across a row for a given word.

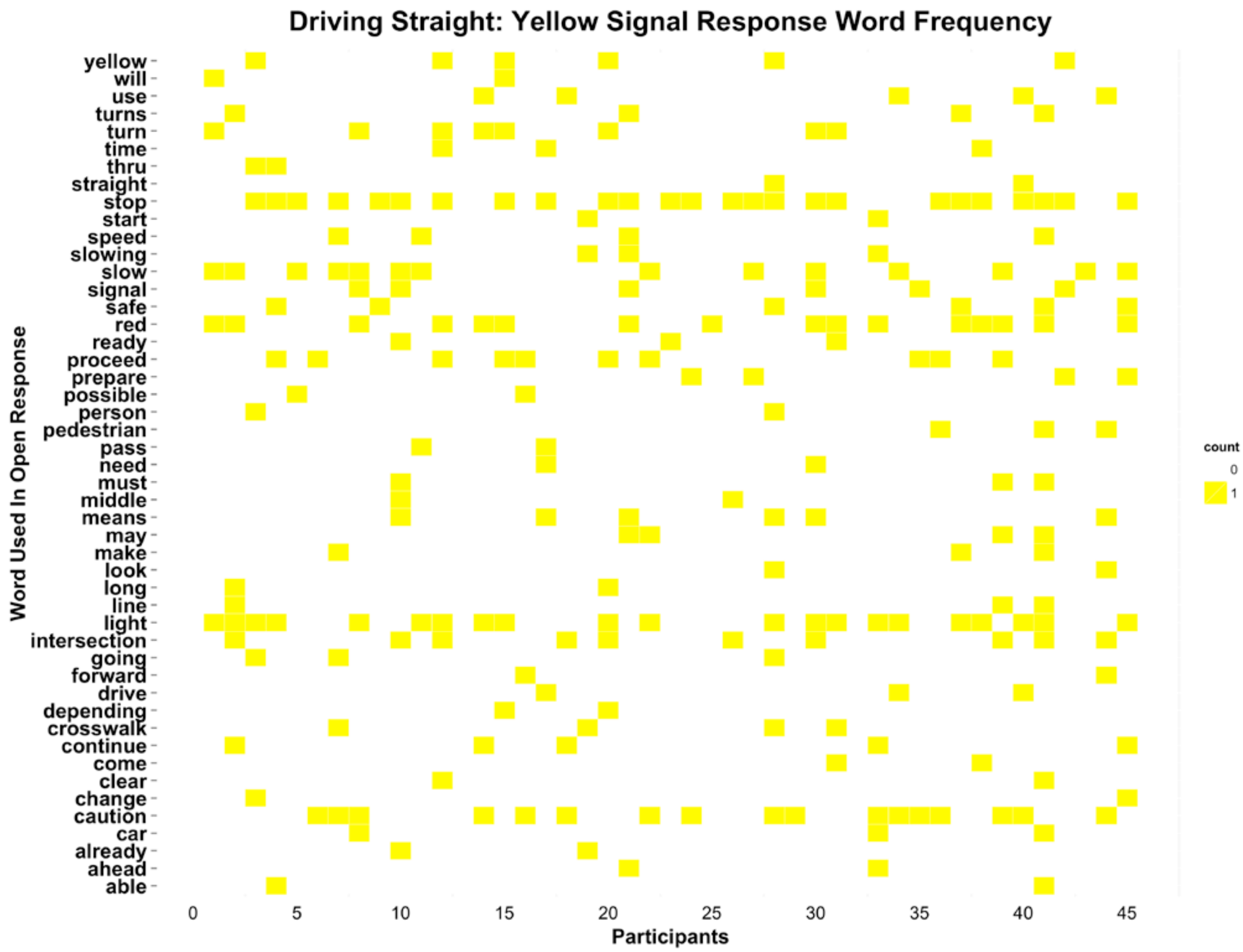

Figure 24. Use of target words for the Yellow-circular signal (y-axis), when participants (x-axis) were told to imagine they are a driver driving straight. To see patterns across participants, look across a row for a given word.