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Driver Comprehension of Permissive Right-Turns with a Flashing Yellow Arrow (FYA)

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PSU TRANSPORTATION SEMINAR

OCTOBER 26, 2018

Research Team:

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Objectives

- Understand and assess driver comprehension and response to the FYA for right turns
- Develop an understanding of the safety and operational implications of using the FYA for permitted right-turns

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Research Methods

Oregon Driver Survey

- Determine driver comprehension for PPRT phasing alternatives.
- Identify potential factors for microsimulation and driving simulator study.

Oregon Driving Simulator Study

- Evaluate PPRT phasing alternatives for potential conflicts with active transportation through surrogate safety measures.

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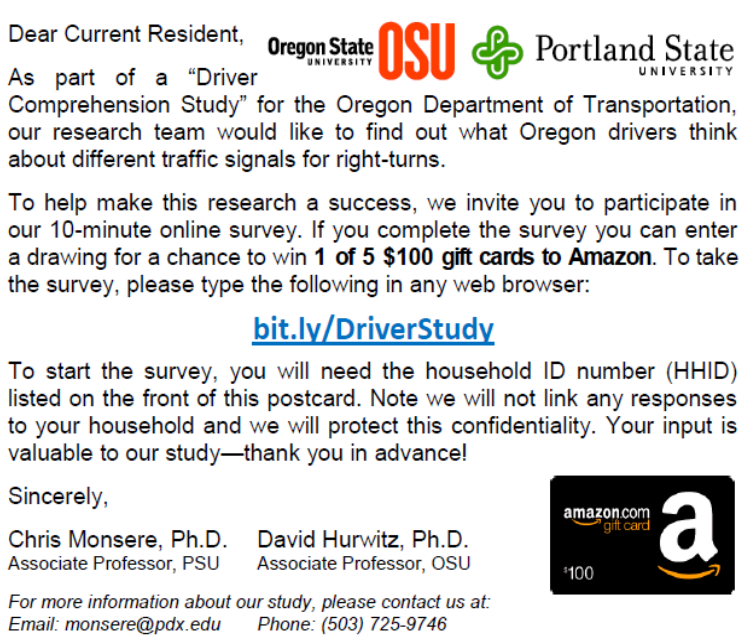
Survey

- Random sample of 10,000 address weighted by county population purchased from infoUSA
- Address cleanse = 9,872
- Pilot survey to OSU/PSU students and TAC
- Postcard distribution, mailed May 16 2016
- 5 $100 Amazon gift cards as incentive



Dear Current Resident,

As part of a "Driver Comprehension Study" for the Oregon Department of Transportation, our research team would like to find out what Oregon drivers think about different traffic signals for right-turns.

To help make this research a success, we invite you to participate in our 10-minute online survey. If you complete the survey you can enter a drawing for a chance to win **1 of 5 $100 gift cards to Amazon**. To take the survey, please type the following in any web browser:

bit.ly/DriverStudy

To start the survey, you will need the household ID number (HHID) listed on the front of this postcard. Note we will not link any responses to your household and we will protect this confidentiality. Your input is valuable to our study—thank you in advance!

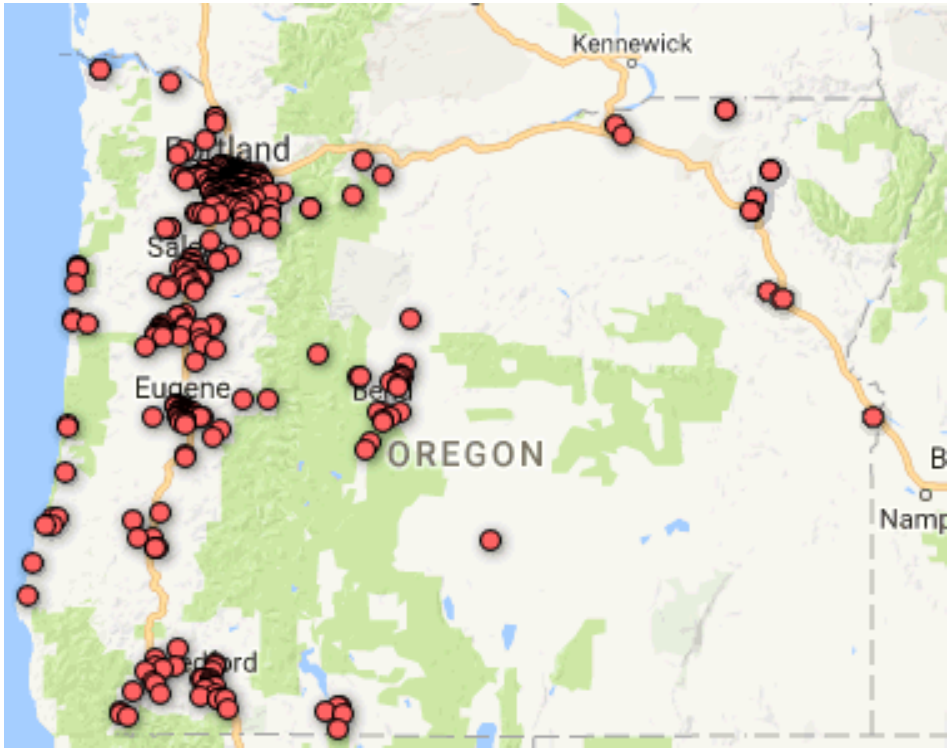
Sincerely,

Chris Monsere, Ph.D.
Associate Professor, PSU

David Hurwitz, Ph.D.
Associate Professor, OSU

For more information about our study, please contact us at:
Email: monsere@pdx.edu Phone: (503) 725-9746

Survey Responses



- 399 responses
- 4% response rate
- Overall, survey demographic
  - Older
  - Whiter
  - More educated
- 98% Oregon licensed drivers
- 50% drive 10+ times a week
- 95% 10+ years driving
- 2.5% color blind

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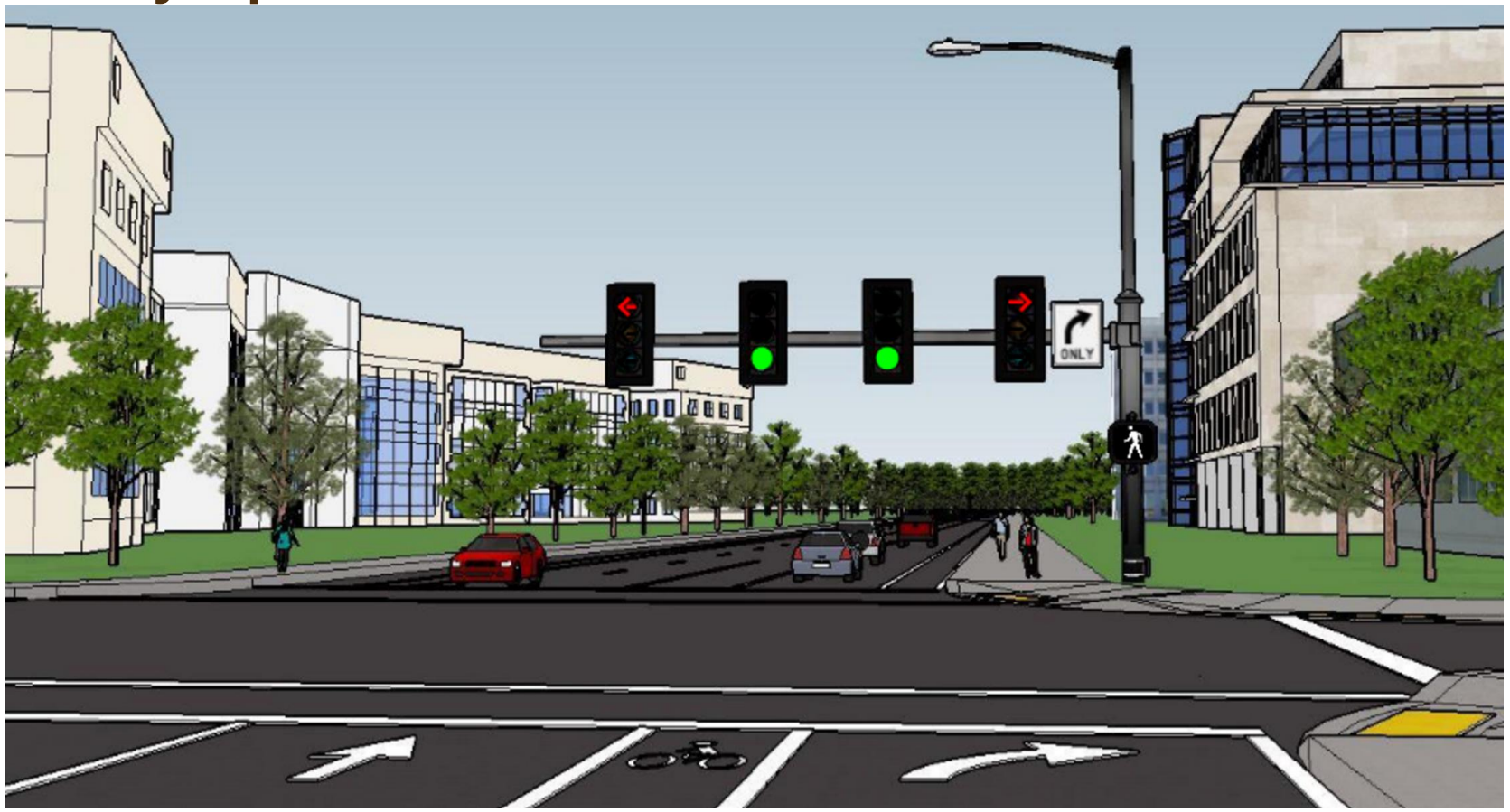
Survey Open Ended



*Imagine that you are approaching the intersection in **the lane farthest to the right and planning to TURN RIGHT**. What action would you take based on the current signal display?*
Please type your response in the box below and be as descriptive as possible

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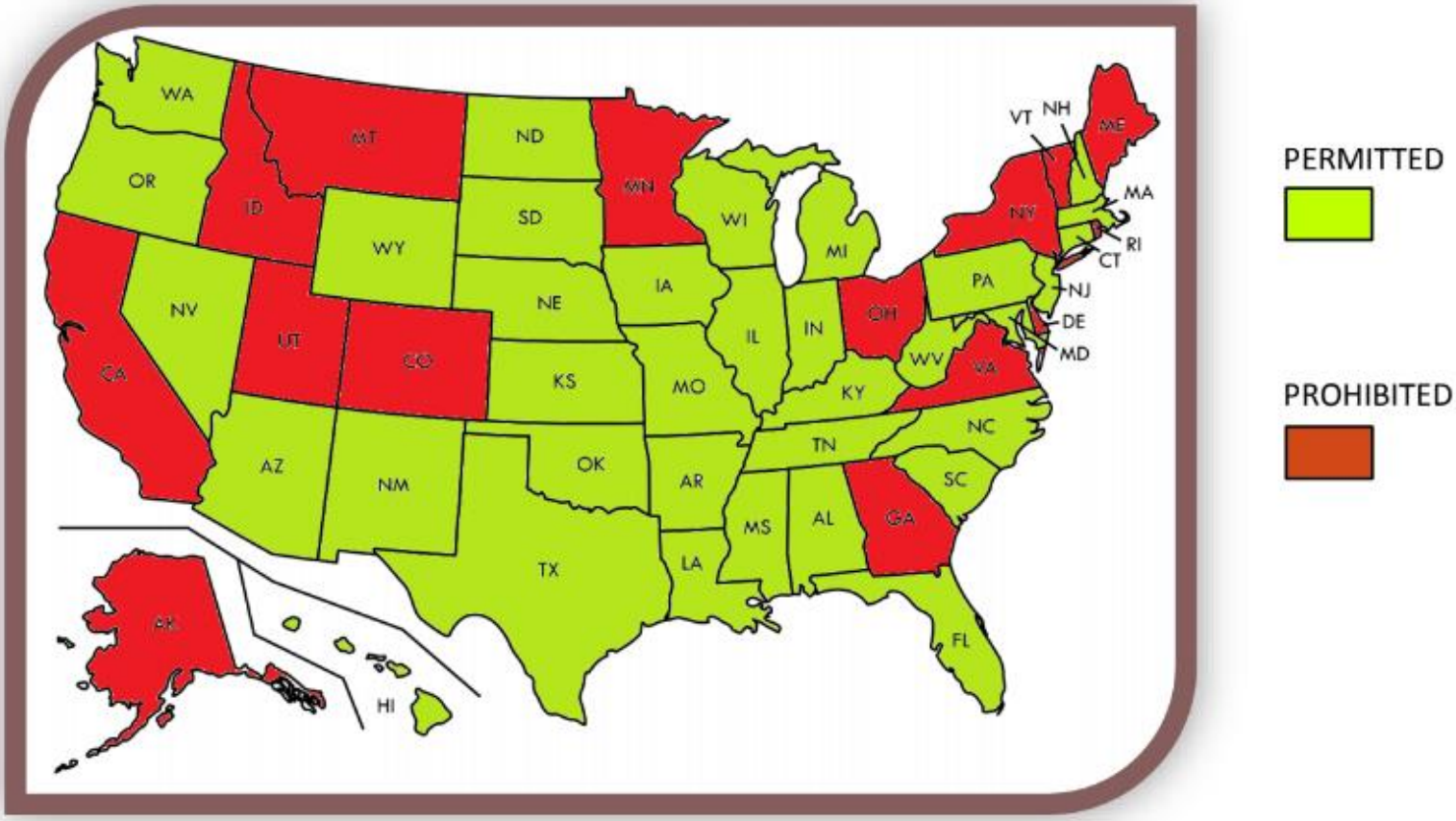
What Does Your State Say?

This table shows comparison of states that permit or prohibit right turns on red arrow. For the majority of the states that allow a left turn on red from a one-way street to another one-way street, the same ruling would apply for a left red arrow[1].

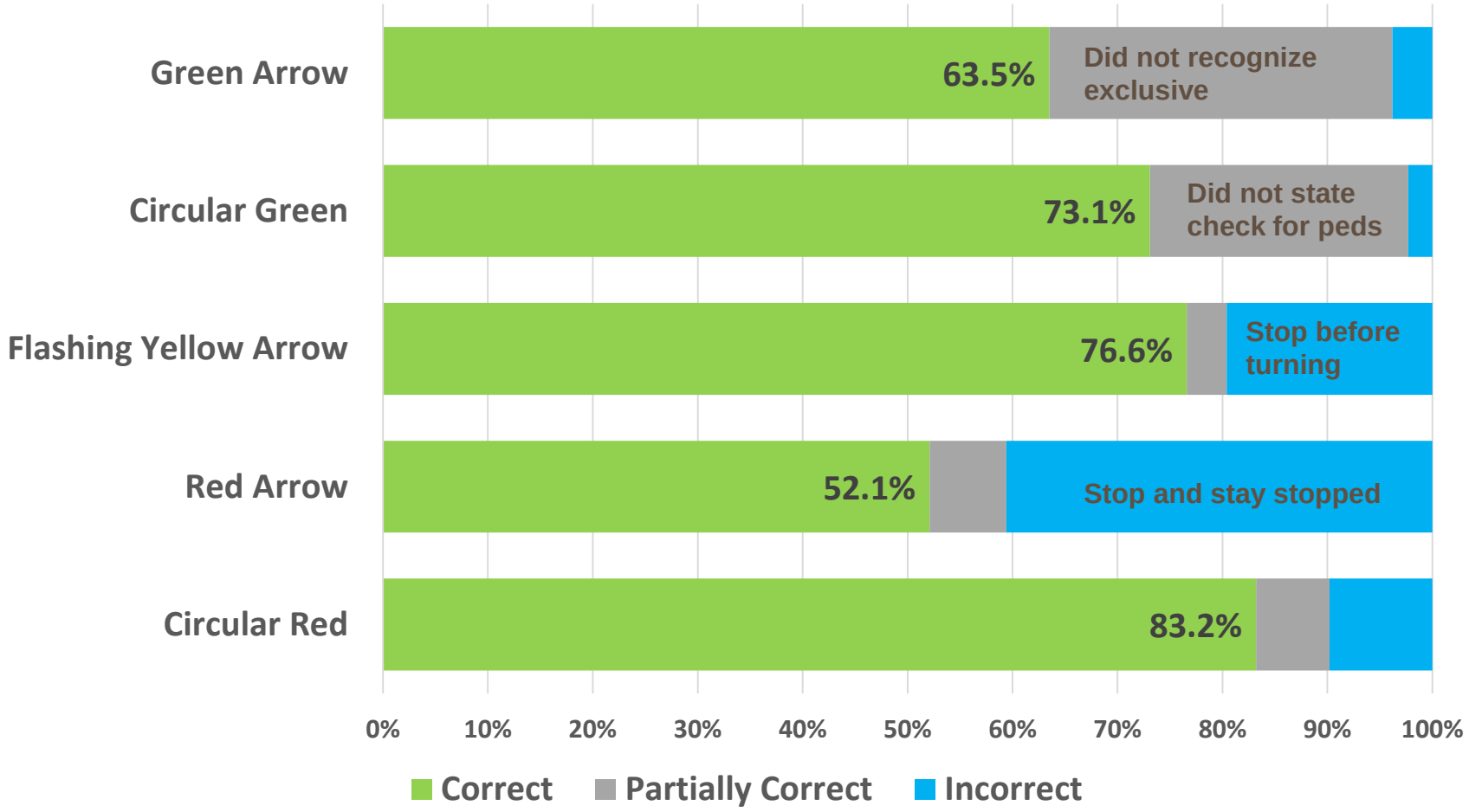


Source: "Right Turns on Red Arrow by State: Does your State Allow it" Sajid Hassan, Traffic Engineer NCDOT. 2016

Error Coding of Open Ended Survey Responses

if respondents indicated that they would…	Correct	Partially Incorrect	Incorrect
Steady Circular Green	Turn right with caution after yielding to pedestrians in the crosswalk	Turn right without stopping but failed to state that they would yield to pedestrians if present in the crosswalk	Stop before turning
Steady Green Arrow	Turn right without stopping recognizing that the steady green arrow indication means a protected movement (or) Indicated that they would watch for pedestrians who may cross against the pedestrian Don't Walk signal	Check for pedestrians and turn right (or) slow down and check for pedestrians and other cross traffic but did not recognize the protected movement in either case	Stop before turning
Steady Circular Red and Steady Red Arrow	Come to a complete stop and complete the turn when they found a safe gap or remained stopped if they failed to find a gap	Stop or turn right, without providing additional details	Stop and remained stopped until the green indication
Flashing Yellow Arrow	Turn right with caution after yielding to pedestrians in crosswalk	Turn right without stopping or failed to state that they would yield to pedestrians if present in the crosswalk	Stop before turning

Overall, n=399



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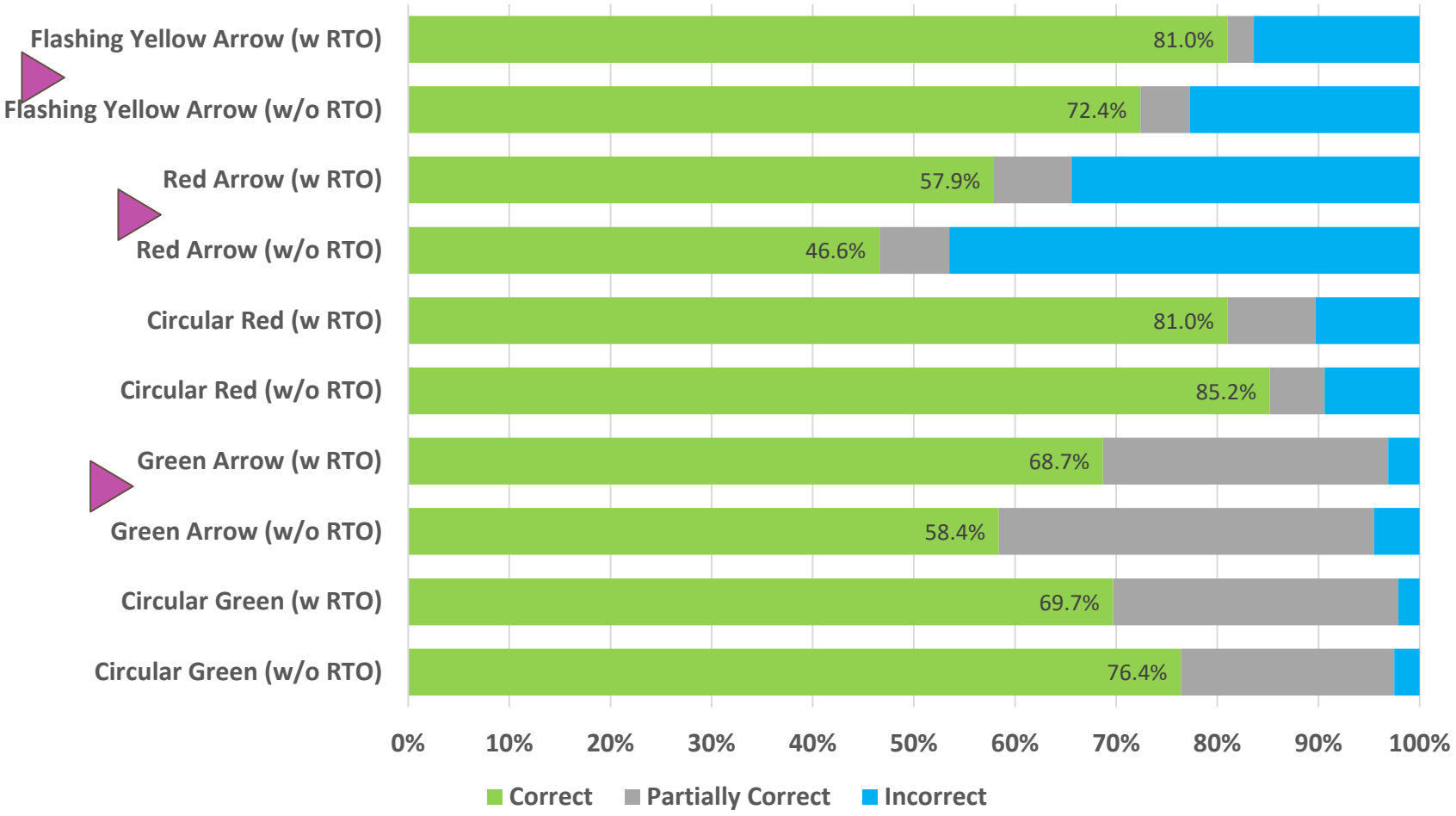
With and Without Right Turn Only Sign



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Statistically significant differences, p <0.05)

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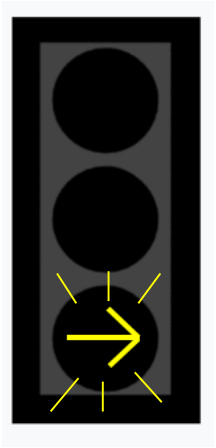
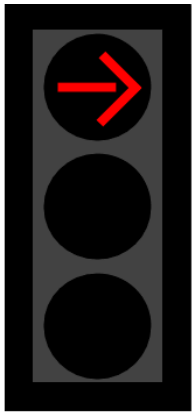
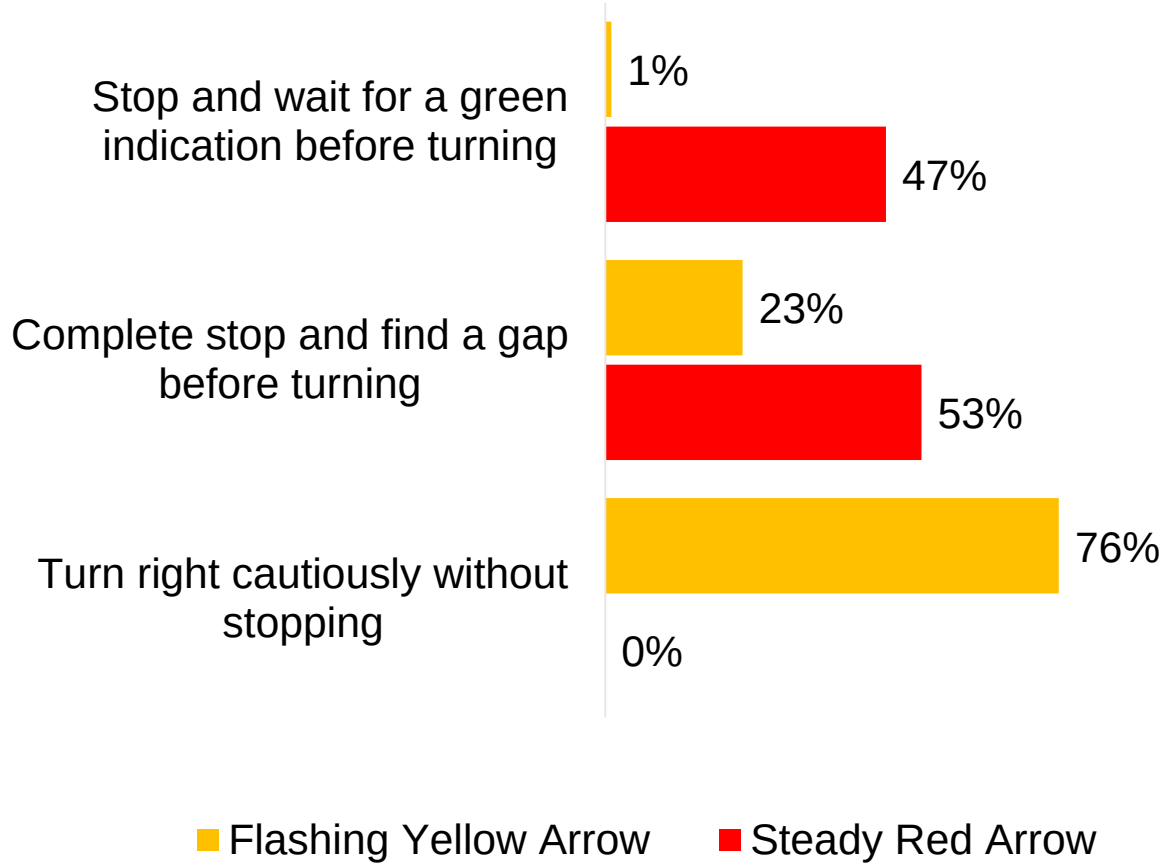
Steady Red and Flashing Yellow Arrow Multiple Choice







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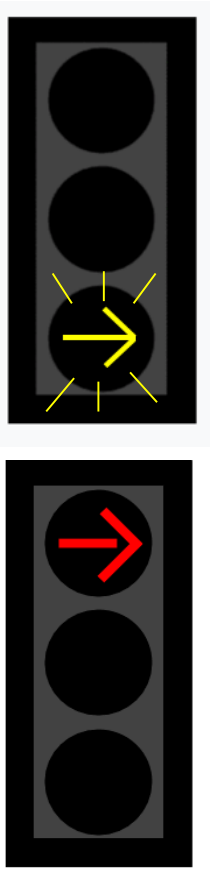
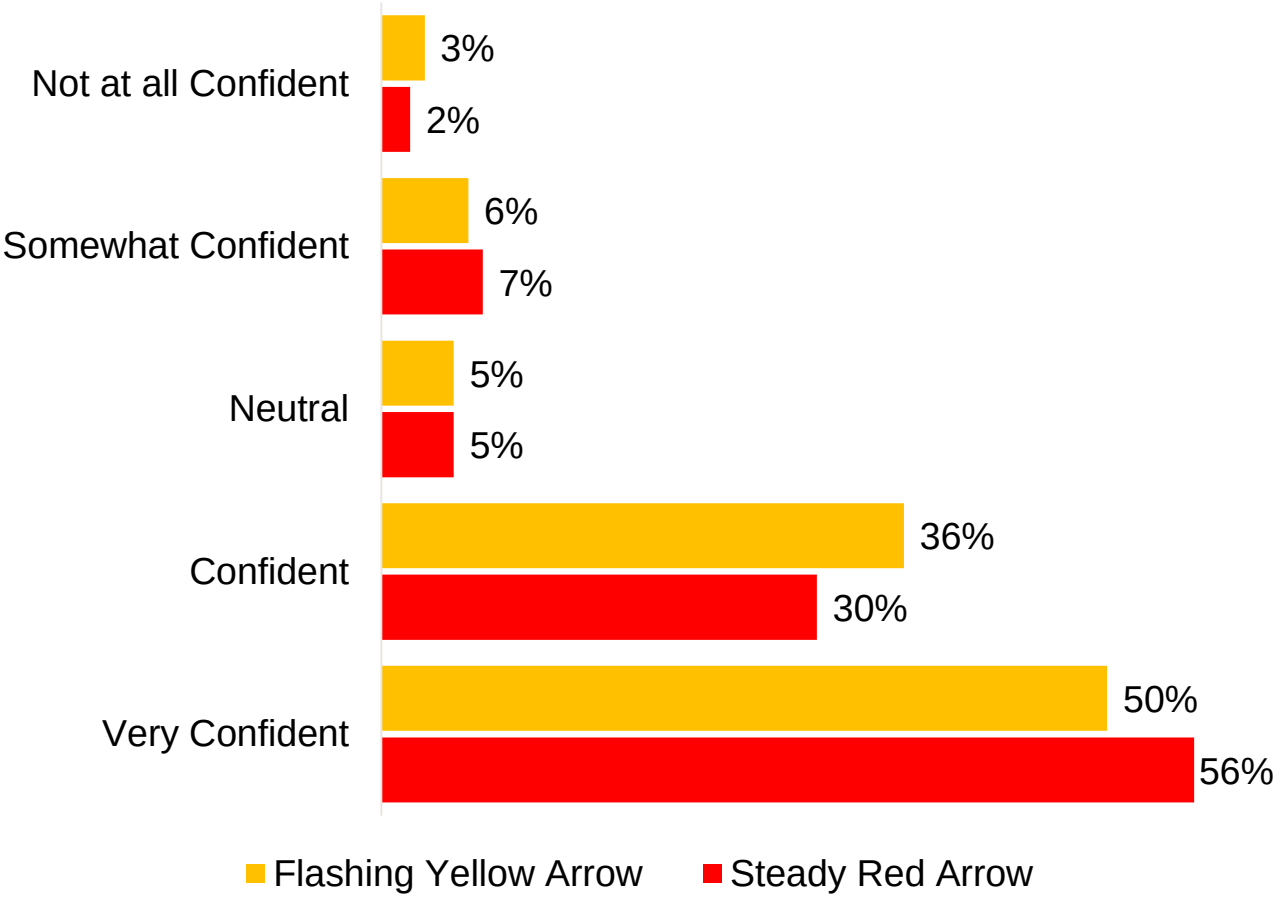
Steady Red and Flashing Yellow Arrow Multiple Choice





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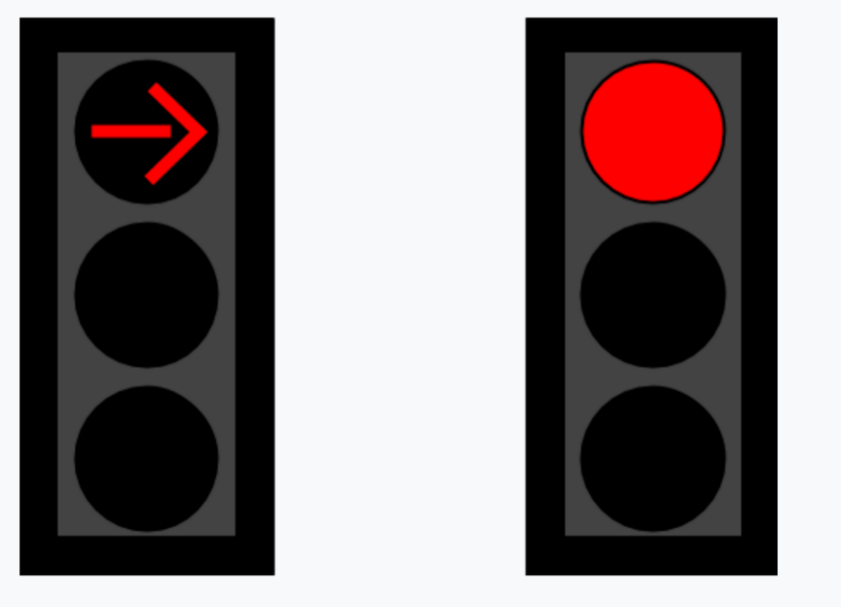
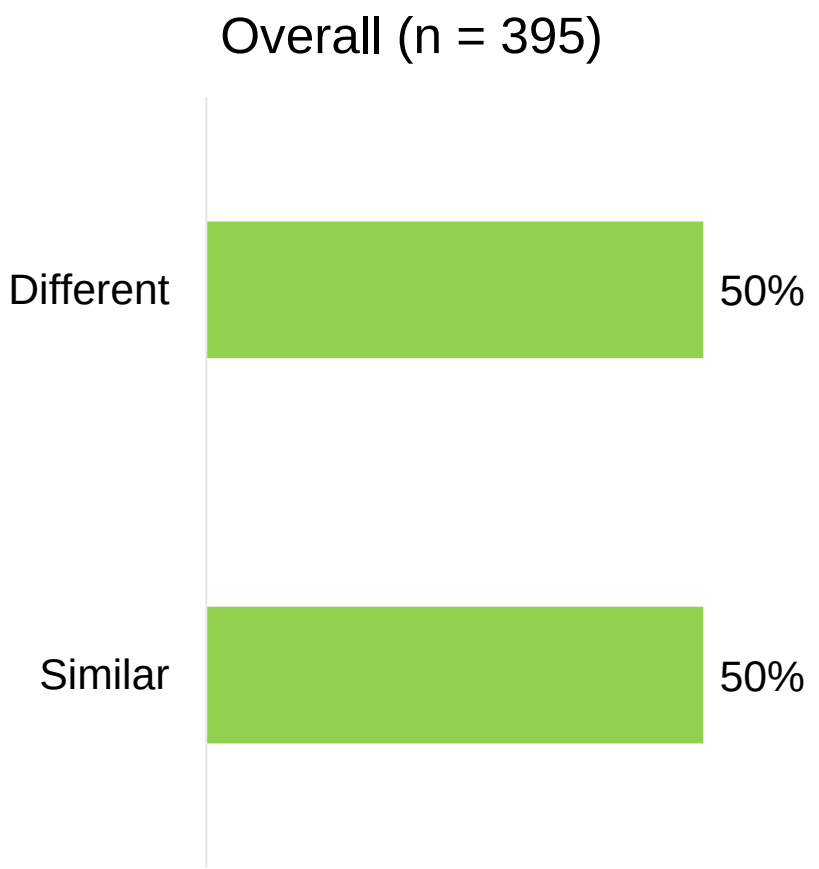
Red Ball and Red Arrow Comparison





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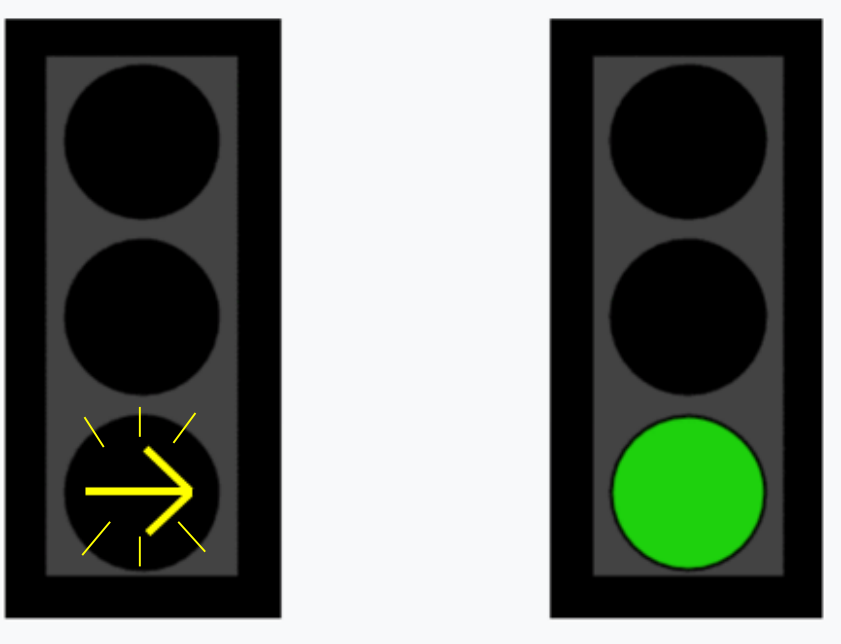
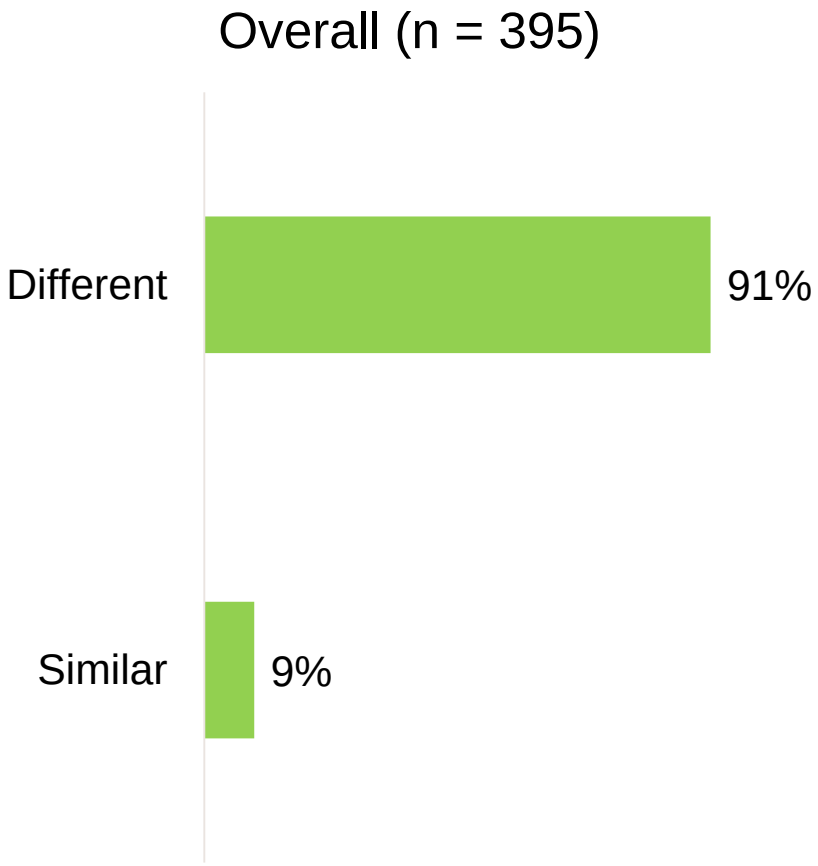
Green Ball and Flashing Yellow Arrow Comparison





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Primary Findings

- Good geographic coverage and number of responses
- Older drivers over-sampled
- Expected driver behavior with Steady Red Arrow not well understood
- FYA and CG
  - Both have good comprehension
  - FYA more incorrect, but fail safe (STOP)
  - CG more partially correct (fail to mention pedestrian)
  - CG and FYA strongly recognized “as different”

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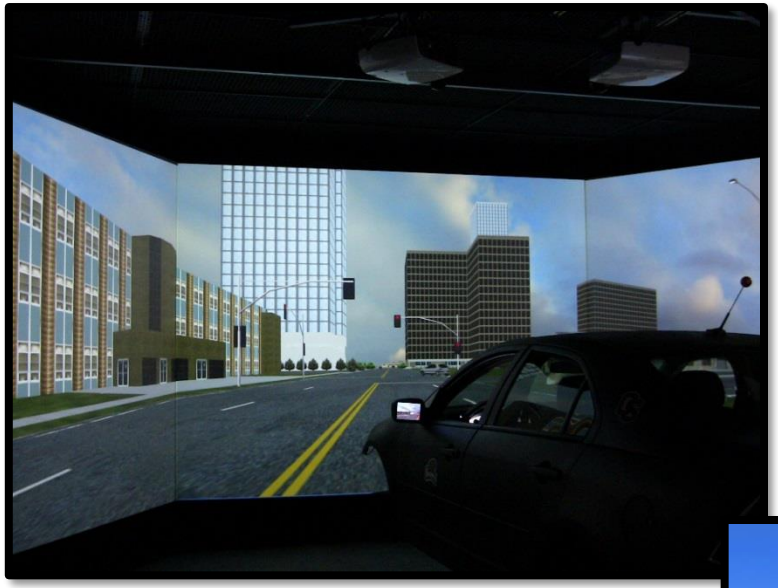
OSU Driving Simulator



View from outside the car

View from inside car
w/ ped crossing

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Independent Variables & Levels

VARIABLE	ACRONYM	CATEGORY	LEVEL	LEVEL DESCRIPTION	
Signal Head	SHA	Nominal (categorical)	1	CR: Circular Red	
			2	CG: Circular Green	
	SHB		1	SRA: Solid Red Arrow	
			2	SGA: Solid Green Arrow	
			3	FYA: Flashing Yellow Arrow	W: Walk interval
					C: Clearance walk interval
Geometry	G	Discrete	1	TB1: Right-turn bay length 1: 50 ft	
			2	TB2: Right-turn bay length 2: 100 ft	
Pedestrians	P	Discrete	1	No pedestrians crossing	
			2	Pedestrians crossing	

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Experimental Scenarios

T #	RT #	SIGNAL HEAD	BAY LENGTH (ft)	PEDESTRIAN
Grid 1				
6	1	FYAC	50	None
22	2	SGA	100	Pedestrian crossing
9	3	SRA	100	None
14	4	CG	50	Pedestrian crossing
Grid 2				
23	1	FYAW	100	Pedestrian crossing
8	2	CG	100	None
2	3	CG	50	None
18	4	FYAC	50	Pedestrian crossing
Grid 3				
19	1	CR	100	Pedestrian crossing
5	2	FYAW	50	None
7	3	CR	100	None
4	4	SGA	50	None
Grid 4				
20	1	CG	100	Pedestrian crossing
12	2	FYAC	100	None
10	3	SGA	100	None
21	4	SRA	100	Pedestrian crossing
Grid 5				
16	1	SGA	50	Pedestrian crossing
1	2	CR	50	None
11	3	FYAW	100	None
17	4	FYA	50	Pedestrian crossing
Grid 6				
3	1	SRA	50	None
13	2	CR	50	Pedestrian crossing
15	3	SRA	50	Pedestrian crossing
24	4	FYAC	100	Pedestrian crossing

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Intersection Layout

With 50 ft exclusive right turning bay

With 100 ft exclusive right turning bay

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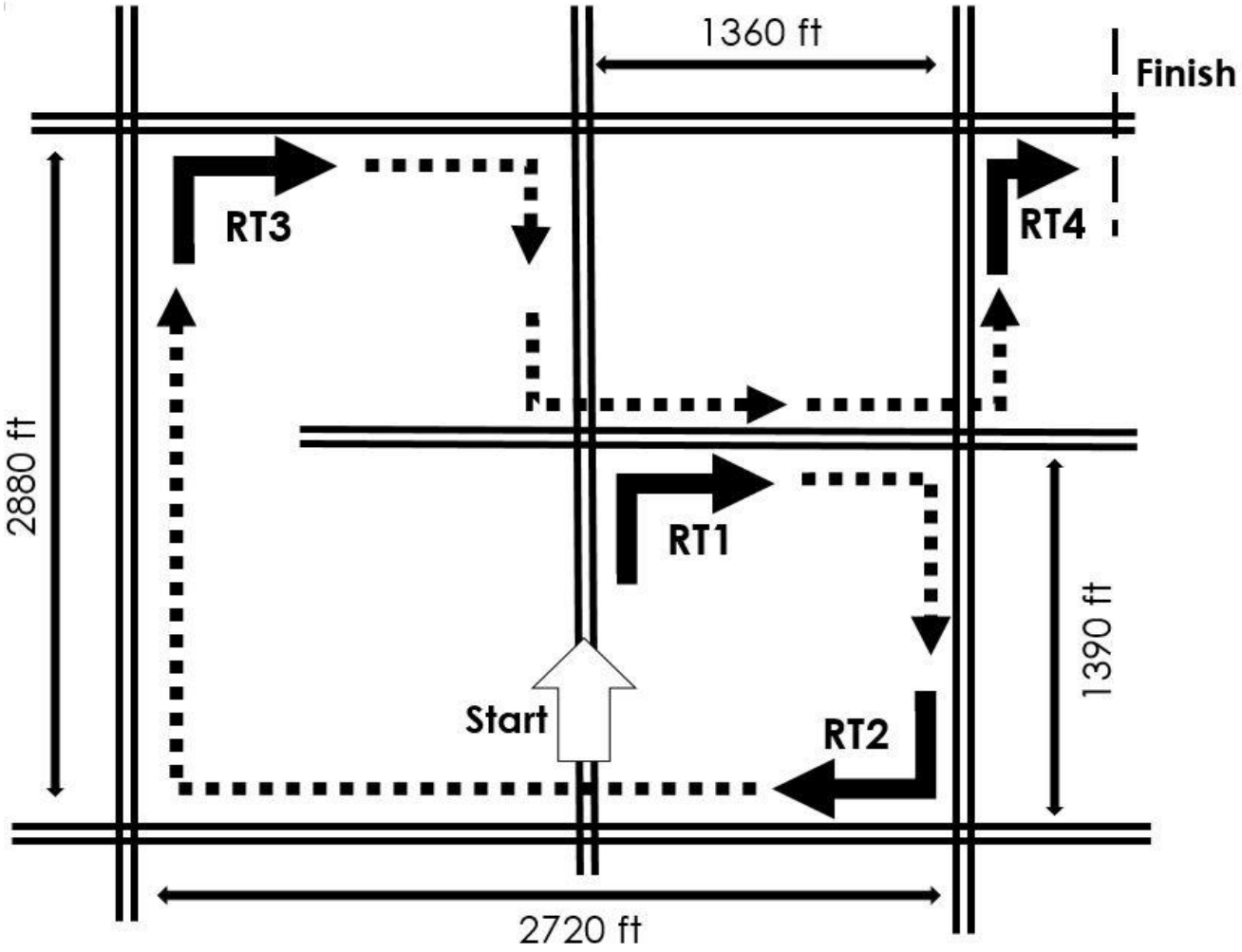
Example Experimental Trial w/ 4 Scenarios



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Experiment – Data Acquisition

Participants:

- 52 Participated
- 5 Simulator Sickness
- 1 calibration issue
- 46 Usable
- 1104 total-right turn scenarios

Data:

- Visual attention
- Observed driver behavior
- Position and speed of vehicles, and pedestrians
- Pre-post survey

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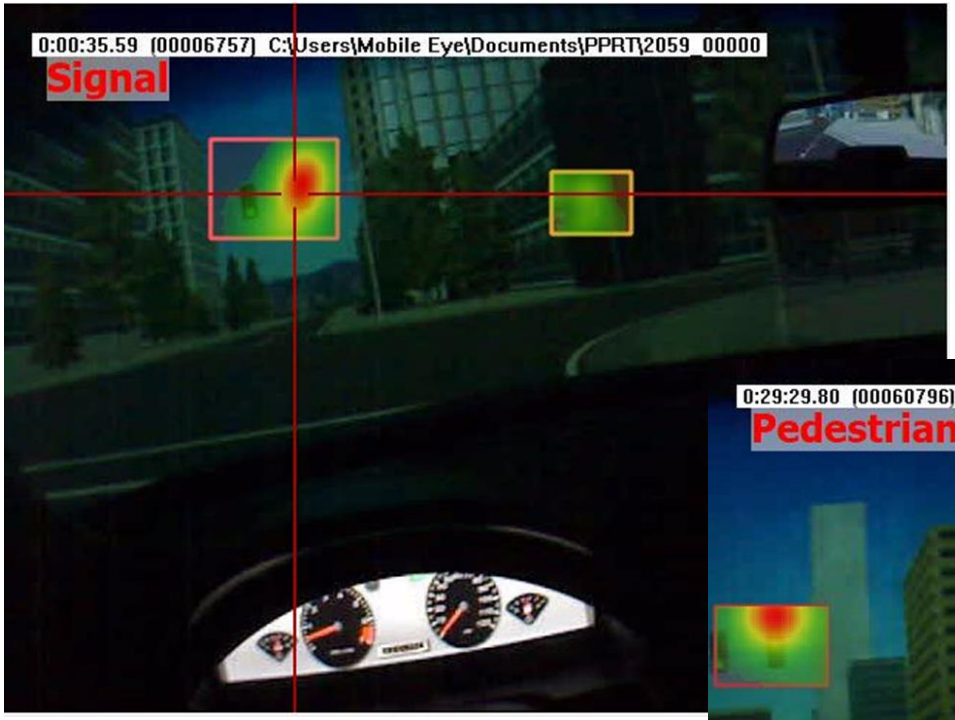
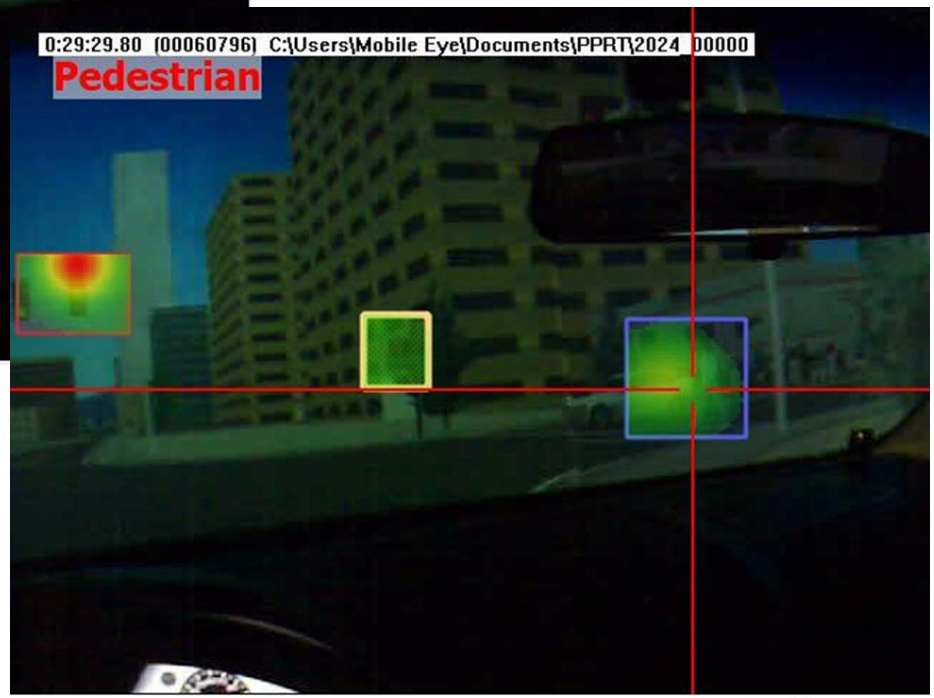
Visual Attention – Areas of Interest (AOIs)





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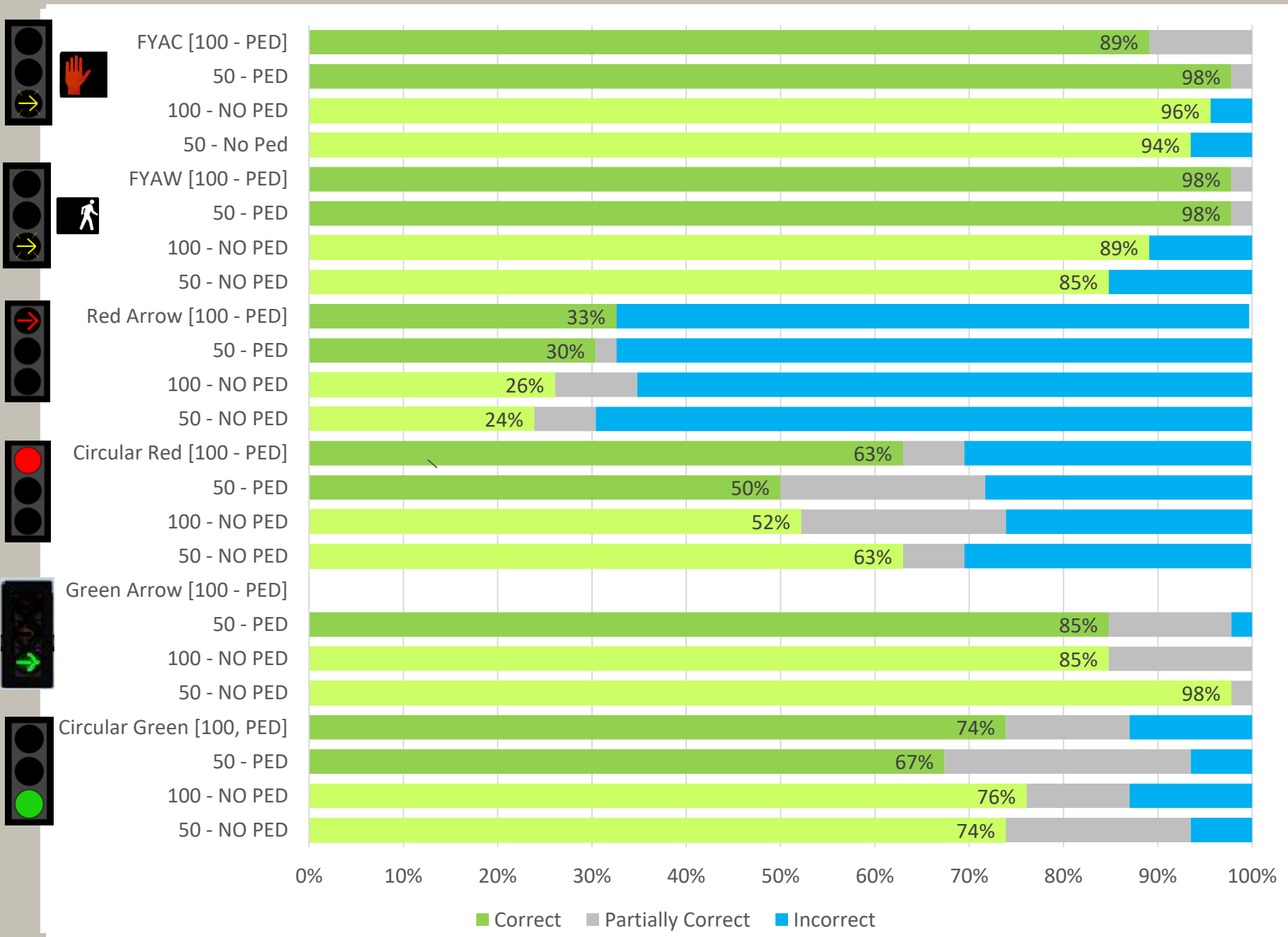
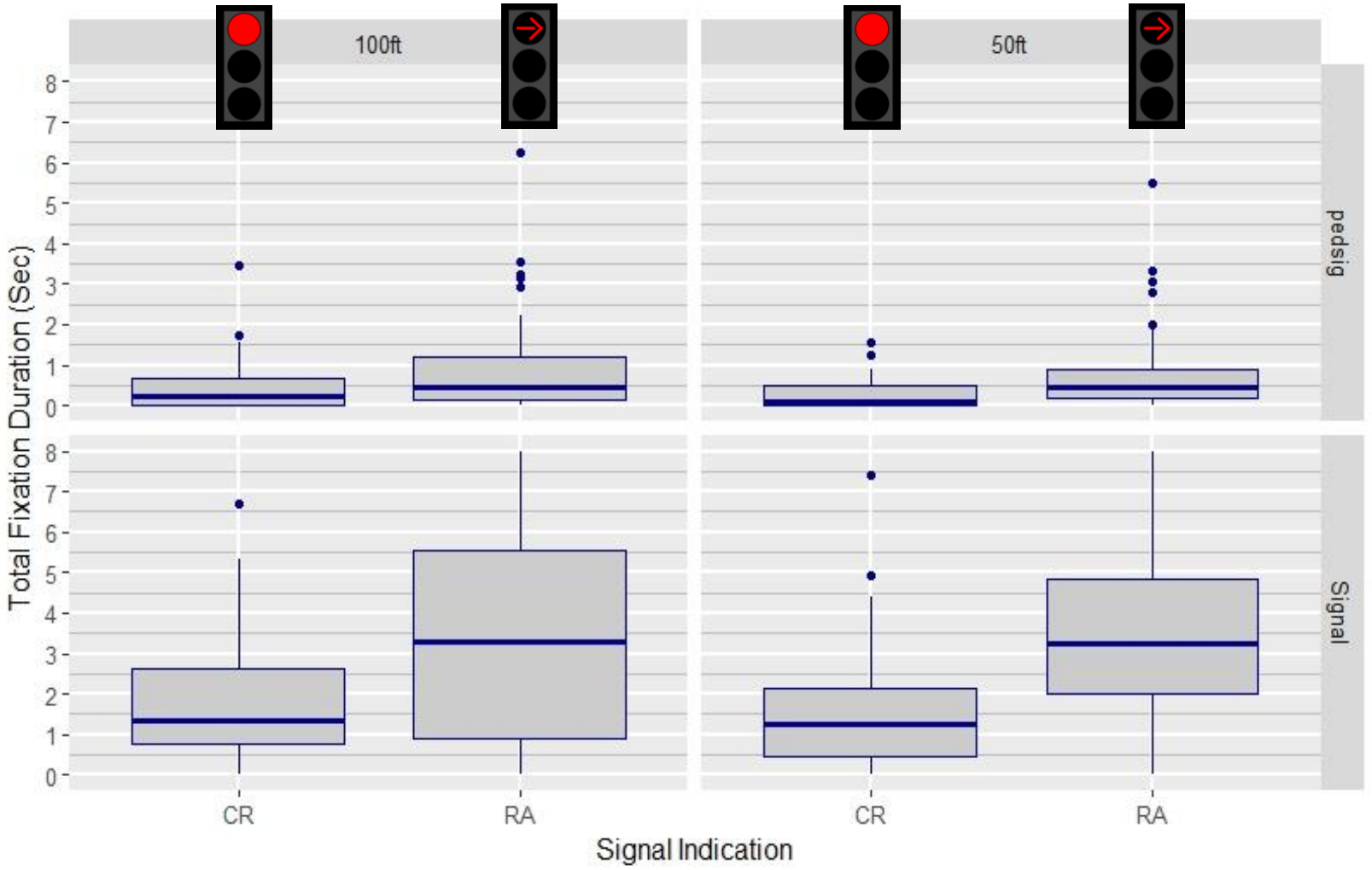
Error Coding of Observed Behavior

if respondents indicated that they would…	Correct	Partially Incorrect	Incorrect
Steady Circular Green	Turn right with caution after yielding to pedestrians (if present) in the crosswalk	Turn without checking for pedestrians even though the walk indication was displayed (or) not checking before turning but stopping once they saw a pedestrian	Stop before turning (vehicle speed < 1 mph) to check for pedestrians (or) A crash with a pedestrian
Steady Green Arrow	Turn right without stopping, recognizing that the SGA indicates a protected right-turn movement	Check for pedestrians and turn right (or) Slow down and check for pedestrians and other cross traffic but did not recognize the protected movement in either case	Stop before turning (some noted remain stopped until the signal display became green)
Steady Circular Red & Steady Red Arrow	Come to a complete stop (vehicle speed < 1 mph) and complete the turn when they find a safe gap	Turn right without coming to a complete stop (Vehicle speed > 1 mph)	Stop and remain stopped until the green indication
Flashing Yellow Arrow	Turn right with caution after yielding to pedestrians (if present) in crosswalk	Turn right without caution (vehicle speed >15 mph) (or) Not yielding when necessary	Stop before turning (vehicle speed < 1 mph) to check for pedestrians, (or) Remain stopped until the green indication


FYAC [100 - PED]
50 - PED
100 - NO PED
50 - No Ped
FYAW [100 - PED]
50 - PED
100 - NO PED
50 - NO PED
Red Arrow [100 - PED]
50 - PED
100 - NO PED
50 - NO PED
Circular Red [100 - PED]
50 - PED
100 - NO PED
50 - NO PED
Green Arrow [100 - PED]
50 - PED
100 - NO PED
50 - NO PED
Circular Green [100, PED]
50 - PED
100 - NO PED
50 - NO PED
89%
98%
96%
94%
98%
98%
89%
85%
33%
30%
26%
24%
63%
50%
52%
63%
85%
85%
98%
74%
67%
76%
74%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Correct
Partially Correct
Incorrect

Visual Attention – Total Fixation Duration (TFD)



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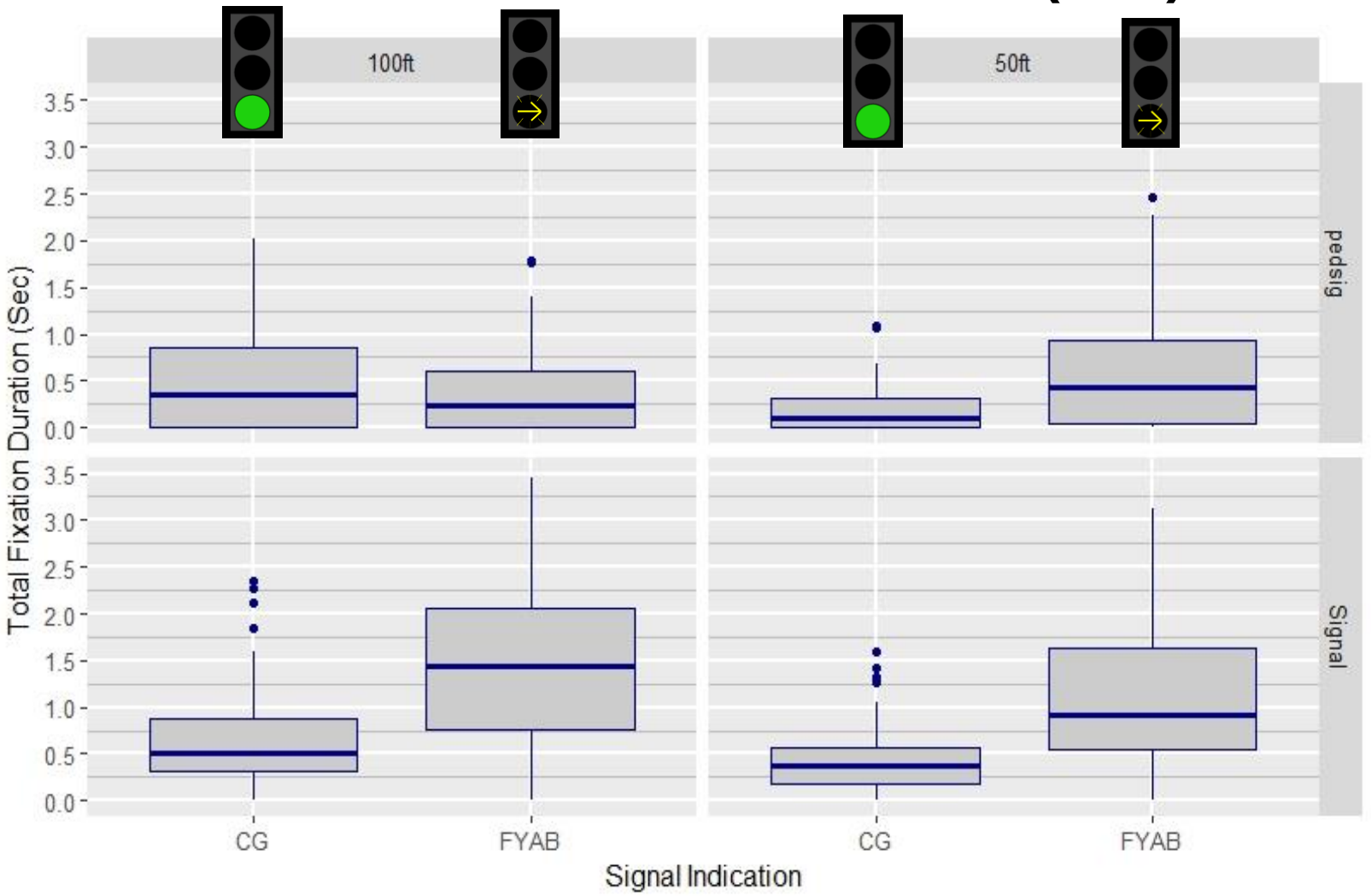
Visual Attention – Total Fixation Duration (TFD)



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Comparison: Indications that require driver yielding

- **Steady Circular Green**
  - Results between survey and driving simulator are consistent.
  - Survey (73%) and simulator (67 – 74%) simulator correct response.
  - Partially correct responses resulted from respondents failing to state in the survey (25% of the sample) or to demonstrate in the simulator (by near misses with pedestrians; 10%-19% of right turns) that they would yield to pedestrians

- **Flashing Yellow Arrow**
  - Results between survey and driving simulator are consistent.
  - Survey (77%) and simulator (84-95%) simulator correct response
  - Incorrect responses (stop) were fail-safe.
  - Evidence of better driver yielding to pedestrians.

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Comparison: Indications that require driver stop

- **Steady Circular Red**
  - Results between survey and driving simulator are not as comparable.
  - Correct survey responses (83%) were higher compared to the simulator experiment (50-63%) primarily dues to high “stop and stay stop” behaviors (could be carryover effect from RA.
  - Incorrect responses generally were a result of fail-safe actions.
- **Steady Red Arrow**
  - Results between survey and driving simulator are consistent.
  - Evidence of significant misunderstanding of the steady red arrow indication from both survey and simulator experiment as correct responses were 52% (survey) and 23-33% (simulator).
  - Only 50% of the survey respondents stated that both displays have the same meaning.

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Comparison of Results: Indications that communicate the movement is exclusive

- **Steady Green Arrow**
  - In survey, partially correct responses were coded if drivers indicated that they would check for pedestrians or other users before turning right (32%) but only 13% of drivers in the simulator experiment.
  - This is a fail-safe response.

Limitations of Research

Survey

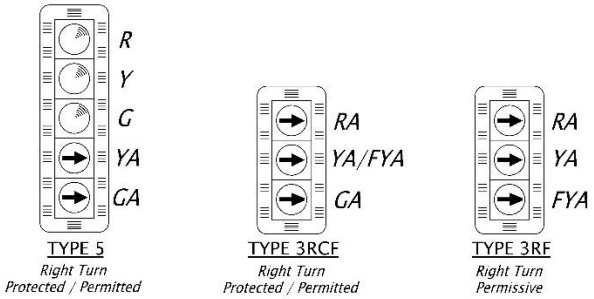
- Distribution of respondents in survey was biased toward white, men, and older population.
- Larger proportion of respondents were from southern Oregon (closer to CA), which has different laws for steady red arrow indication.

Simulator

- Potential for fatigue effects.
- Limited number and levels of variables were evaluated.

Recommendations for Practice

- Add language in the applicable ODOT documents, policies and manuals to require the use of the FYA in for protected permissive right turn operations and allow use of FYA for permissive right turn operations
- Add two new signal head types in the applicable ODOT documents, policies and manuals:



Color Indications. All Indications Are 12" Diameter.	
R	Red Circular Ball
Y	Yellow Circular Ball
G	Green Circular Ball
RA	Red Arrow
YA	Yellow Arrow
GA	Green Arrow
FYA	Flashing Yellow Arrow

- Recommend the use of R10-17a sign at locations using the STEADY RED ARROW (where RTOR is desired for efficiency)

R10-17a

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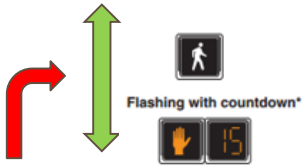
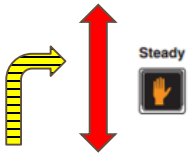
Options

1

Protected Right Turn
Pedestrian Don't Walk

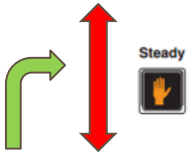


Steady Red Arrow during Pedestrian Walk and Clearance

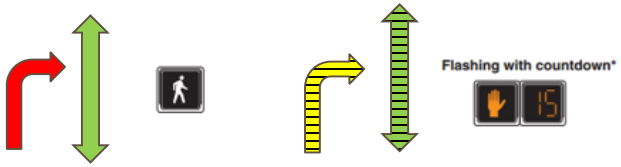


*If time remaining, FYA for right turns

2



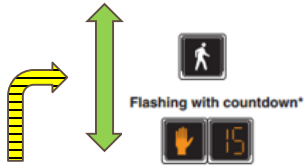
Protected Right Turn
Pedestrian Don't Walk



Steady Red Arrow during Pedestrian Walk and FYA during clearance

3

Protected Right Turn
Pedestrian Don't Walk



Flashing Yellow Arrow during Pedestrian Walk and Clearance

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Recommendations for Practice

- Due to better yielding and driver behavior, Oregon transportation agencies could potentially improve pedestrian safety at signalized intersections with high volumes of permissive right turns from exclusive right-turn lanes by using the FYA display in lieu of a STEADY CIRCULAR GREEN display.

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Acknowledgements

Oregon Department of Transportation (ODOT) and the Federal Highway Administration (FHWA) for funding this research.

The Technical Advisory Committee has provided valuable input throughout the project (Craig Black-ODOT, Scott Cramer-ODOT, Julie Kentosh-ODOT, Katie Johnson-ODOT, and Bikram Raghubansh-Clackamas County) and Mark Joerger, ODOT Research Coordinator.

Students at Oregon State University helped reduce data and code the simulator environment (Kayla Fleskes, MS, Ellie Simpson, MS, Hameed Aswad Mohammed, PhD, Hagai Tapiro, Post-Doctoral researcher, and Logan Scott-Deeter, undergraduate).

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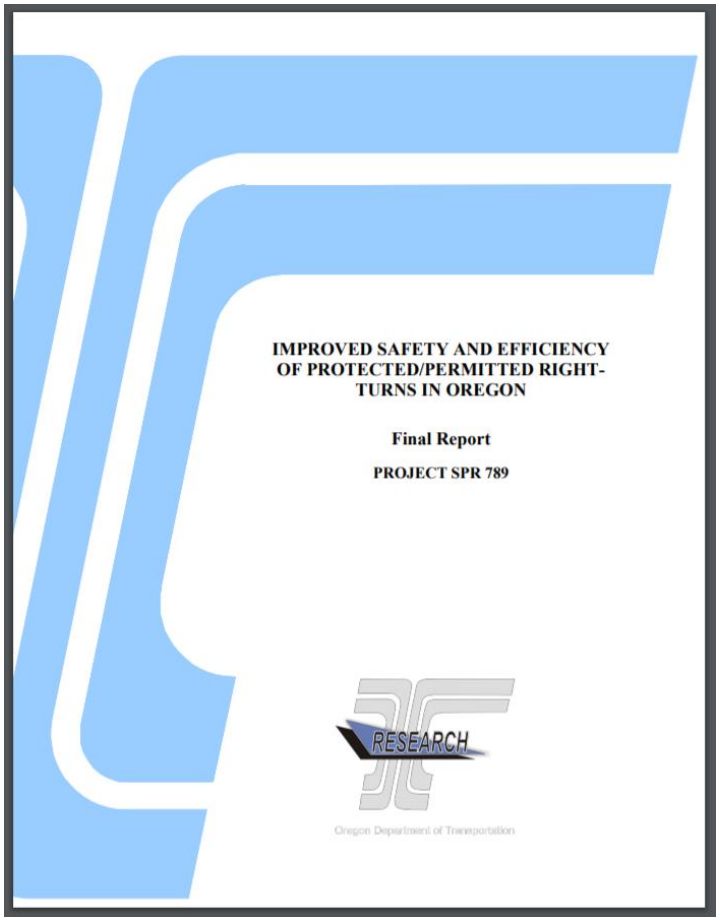
SPR 789 Final Report



Download the full report here

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Presentations and Papers:

- David Hurwitz, *ITE Western District Annual Meeting*, Keystone, CO, June 24-27, 2018.
- Chris Monsere and Sirisha Kothuri*, ITE Quad Conference*, Portland, OR, May 7-9, 2018.
- Sirisha Kothuri*, TRB Traffic Signal Systems Mid-Year Meeting*, Flagstaff, AZ, July 22-24, 2018.
- 2019 TRB Article (revise & resubmit)
- ASCE Journal of Transportation Article (in development)

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Questions?

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Associate Professor
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