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

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

PSU TRANSPORTATION SEMINAR
OCTOBER 26, 2018

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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
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.
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
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
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.
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. 

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

<table>
<thead>
<tr>
<th>if respondents indicated that they would...</th>
<th><strong>Correct</strong></th>
<th><strong>Partially Incorrect</strong></th>
<th><strong>Incorrect</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steady Circular Green</strong></td>
<td>Turn right with caution after yielding to pedestrians in the crosswalk</td>
<td>Turn right without stopping but failed to state that they would yield to pedestrians if present in the crosswalk</td>
<td>Stop before turning</td>
</tr>
<tr>
<td><strong>Steady Green Arrow</strong></td>
<td>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</td>
<td>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</td>
<td>Stop before turning</td>
</tr>
<tr>
<td><strong>Steady Circular Red and Steady Red Arrow</strong></td>
<td>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</td>
<td>Stop or turn right, without providing additional details</td>
<td>Stop and remained stopped until the green indication</td>
</tr>
<tr>
<td><strong>Flashing Yellow Arrow</strong></td>
<td>Turn right with caution after yielding to pedestrians in crosswalk</td>
<td>Turn right without stopping or failed to state that they would yield to pedestrians if present in the crosswalk</td>
<td>Stop before turning</td>
</tr>
</tbody>
</table>
Overall, n=399

Green Arrow
- 63.5% Did not recognize exclusive

Circular Green
- 73.1% Did not state check for peds

Flashing Yellow Arrow
- 76.6% Stop before turning

Red Arrow
- 52.1% Stop and stay stopped

Circular Red
- 83.2%
With and Without Right Turn Only Sign

Statistically significant differences, p <0.05)
Steady Red and Flashing Yellow Arrow Multiple Choice

- **Stop and wait for a green indication before turning**
  - Steady Red Arrow: 47%
  - Flashing Yellow Arrow: 1%

- **Complete stop and find a gap before turning**
  - Steady Red Arrow: 53%
  - Flashing Yellow Arrow: 23%

- **Turn right cautiously without stopping**
  - Steady Red Arrow: 0%
  - Flashing Yellow Arrow: 76%
Steady Red and Flashing Yellow Arrow Multiple Choice

- Very Confident: 56%
- Confident: 30%
- Somewhat Confident: 7%
- Neutral: 5%
- Not at all Confident: 3%

- Flashing Yellow Arrow: 50%
- Steady Red Arrow: 56%

*Portland State University*
Red Ball and Red Arrow Comparison

Overall (n = 395)

- Different: 50%
- Similar: 50%
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”
OSU Driving Simulator

View from outside the car

View from inside car w/ ped crossing
## Independent Variables & Levels

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>ACRONYM</th>
<th>CATEGORY</th>
<th>LEVEL</th>
<th>LEVEL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal Head</strong></td>
<td>SHA</td>
<td>Nominal (categorical)</td>
<td>1</td>
<td>CR: Circular Red</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>CG: Circular Green</td>
</tr>
<tr>
<td></td>
<td>SHB</td>
<td></td>
<td>3</td>
<td>FYA: Flashing Yellow Arrow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>W: Walk interval</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C: Clearance walk interval</td>
</tr>
<tr>
<td><strong>Geometry</strong></td>
<td>G</td>
<td>Discrete</td>
<td>1</td>
<td>TB1: Right-turn bay length 1: 50 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>TB2: Right-turn bay length 2: 100 ft</td>
</tr>
<tr>
<td><strong>Pedestrians</strong></td>
<td>P</td>
<td>Discrete</td>
<td>1</td>
<td>No pedestrians crossing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Pedestrians crossing</td>
</tr>
</tbody>
</table>
## Experimental Scenarios

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

With 50 ft exclusive right turning bay

With 100 ft exclusive right turning bay
Example Experimental Trial w/ 4 Scenarios
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

Portland State University

Oregon State University
Visual Attention – Areas of Interest (AOIs)
## Error Coding of Observed Behavior

<table>
<thead>
<tr>
<th>if respondents indicated that they would...</th>
<th>Correct</th>
<th>Partially Incorrect</th>
<th>Incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Steady Circular Green</strong></td>
<td>Turn right with caution after yielding to pedestrians (if present) in the crosswalk</td>
<td>Turn without checking for pedestrians even though the walk indication was displayed (or) not checking before turning but stopping once they saw a pedestrian</td>
<td>Stop before turning (vehicle speed &lt; 1 mph) to check for pedestrians (or) A crash with a pedestrian</td>
</tr>
<tr>
<td><strong>Steady Green Arrow</strong></td>
<td>Turn right without stopping, recognizing that the SGA indicates a protected right-turn movement</td>
<td>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</td>
<td>Stop before turning (some noted remain stopped until the signal display became green)</td>
</tr>
<tr>
<td><strong>Steady Circular Red &amp; Steady Red Arrow</strong></td>
<td>Come to a complete stop (vehicle speed &lt; 1 mph) and complete the turn when they find a safe gap</td>
<td>Turn right without coming to a complete stop (Vehicle speed &gt; 1 mph)</td>
<td>Stop and remain stopped until the green indication</td>
</tr>
<tr>
<td><strong>Flashing Yellow Arrow</strong></td>
<td>Turn right with caution after yielding to pedestrians (if present) in crosswalk</td>
<td>Turn right without caution (vehicle speed &gt;15 mph) (or) Not yielding when necessary</td>
<td>Stop before turning (vehicle speed &lt; 1 mph) to check for pedestrians, (or) Remain stopped until the green indication</td>
</tr>
</tbody>
</table>
Visual Attention – Total Fixation Duration (TFD)
Visual Attention – Total Fixation Duration (TFD)

[Box plots showing total fixation duration for CG and FYAB at 100ft and 50ft.]
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.
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 due 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.
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:

<table>
<thead>
<tr>
<th>Color Indications</th>
<th>All Indications Are 12” Diameter.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Red Circular Ball</td>
</tr>
<tr>
<td>Y</td>
<td>Yellow Circular Ball</td>
</tr>
<tr>
<td>G</td>
<td>Green Circular Ball</td>
</tr>
<tr>
<td>RA</td>
<td>Red Arrow</td>
</tr>
<tr>
<td>YA/FYA</td>
<td>Yellow Arrow</td>
</tr>
<tr>
<td>YA</td>
<td>Green Arrow</td>
</tr>
<tr>
<td>FYA</td>
<td>Flashing Yellow Arrow</td>
</tr>
</tbody>
</table>

• Recommend the use of R10-17a sign at locations using the STEADY RED ARROW (where RTOR is desired for efficiency)
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 Clearance
   and FYA during clearance

3. Protected Right Turn
   Pedestrian Don’t Walk
   Flashing Yellow Arrow during Pedestrian Walk and Clearance
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.
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).
Presentations and Papers:


- 2019 TRB Article (revise & resubmit)

- ASCE Journal of Transportation Article (in development)
Questions?

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