Driver Behavior in the Presence of Pedestrians at Signalized Intersections Operating the Flashing Yellow Arrow

David Hurwitz
Oregon State University

Christopher M. Monsere
Portland State University, monsere@pdx.edu

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DRIVER BEHAVIOR IN THE PRESENCE OF PEDESTRIANS AT SIGNALIZED INTERSECTIONS OPERATING THE FLASHING YELLOW ARROW

Oregon ITE Technical Workshop
Portland, Oregon
February 4, 2013

Presenters:
David Hurwitz, Assistant Professor, OSU
Chris Monsere, Associate Professor, PSU
A brief history Flashing Yellow Arrow (FYA)

- 2000 - NCHRP and other research suggest FYA better for PPLT displays.
- 2003 - Oregon as early adopter.
- 2006 - ODOT has recommended the FYA on all state highways operating PPLT phasing since 2006.
- 2009 - MUTCD flashing yellow arrow (FYA) indication is replacing the CG signal indications for permissive movements in exclusive left turn lanes.

ODOT, 2012
Motivation for Our Work

• Add to the body of knowledge on driver behavior in response to the FYA in the presence of pedestrians.
  • Peds not significantly addressed in other aspects of FYA research

• Methodology
  • A simulator-based approach.
  • Used FYA locations were identified from historical crash data provided by installations in Washington County.
Oregon State Driving Simulator

Forward Projection

Rear Projection

Operators Station

Simulator in use
Eye Tracking

• Eye movement consists of fixations and saccades
  • Fixations are points that are focused on during a short period of time
  • Saccades are the quick eye movements between fixations
  • The majority of visual data is acquired from fixations
• The Mobile Eye-XG system records a fixation when the subject’s eyes have paused in a certain position for more than 100 milliseconds
Eye Tracking Raw Video
Simulated Environment
# Independent Variables

<table>
<thead>
<tr>
<th>Crossing Pedestrians</th>
<th>Opposing Vehicles</th>
<th>FYA Signal Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>No pedestrians</td>
<td>No vehicles</td>
<td>3-section dual-arrow vertical</td>
</tr>
<tr>
<td>1 pedestrian toward the subject</td>
<td>3 vehicles</td>
<td>4-section vertical</td>
</tr>
<tr>
<td>1 pedestrian away from subject</td>
<td>9 vehicles</td>
<td></td>
</tr>
<tr>
<td>Four pedestrians (2 each side)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Primary Data: Driver Glance Fixation Duration

<table>
<thead>
<tr>
<th>AOI Name</th>
<th>Fixation Count</th>
<th>Total Fixation Duration</th>
<th>Average Fixation Duration</th>
<th>First Fixation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay</td>
<td>9</td>
<td>3.4</td>
<td>0.378</td>
<td>15.02</td>
</tr>
<tr>
<td>FYA</td>
<td>7</td>
<td>3.11</td>
<td>0.444</td>
<td>16.02</td>
</tr>
<tr>
<td>Opposing Veh</td>
<td>8</td>
<td>2.72</td>
<td>0.34</td>
<td>24.34</td>
</tr>
<tr>
<td>OUTSIDE</td>
<td>27</td>
<td>6.19</td>
<td>0.229</td>
<td>14.29</td>
</tr>
<tr>
<td>Ped Towards</td>
<td>1</td>
<td>0.2</td>
<td>0.2</td>
<td>29.72</td>
</tr>
</tbody>
</table>
Hypotheses Explored

1. $H_0$: There is no difference in the proportion of drivers who fixate on areas where pedestrians are or may be present during permitted left-turn maneuvers at signalized intersections operating the FYA when pedestrians are present or not in the crosswalk.

2. $H_0$: There is no difference in the total duration of driver fixations during permitted left-turn maneuvers at signalized intersections operating the FYA with a 4-section vertical or a 3-section dual-arrow vertical configuration.

3. $H_0$: There is no difference in the location of the pedestrian in the crosswalk when the driver initiates a permitted left-turn maneuver at signalized intersections operating the FYA with a 4-section vertical or a 3-section dual-arrow vertical configuration.

4. $H_0$: There is no difference in the total duration of driver fixations during permitted left-turn maneuvers at signalized intersections operating the FYA with pedestrians walking towards, away, or from both sides.

5. $H_0$: There is no difference in the total duration of driver fixations during permitted left-turn maneuvers at signalized intersections operating the FYA with zero, 3, or 9 opposing vehicles.

6. $H_0$: There is no difference in the location of the pedestrian in the crosswalk when the driver initiates a permitted left-turn maneuver at signalized intersections operating the FYA with zero, 3, or 9 opposing vehicles.
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Research Hypothesis 1: Proportion of Fixations on Pedestrians

- $H_0$: There is no difference in the proportion of drivers who fixate on areas where pedestrians are or may be present during permitted left turn maneuvers at signalized intersections operating the FYA when pedestrians are present or not in the crosswalk.

Four Pedestrian Scenarios

- 1 ped walking toward subject
- 1 ped walking away from subject
- 2 peds away and 2 peds toward subject
- No peds present
Proportion of Fixations on Pedestrians: Results

- Fixations on Ped or Ped Area AOI tabulated
- R was used for proportion testing

<table>
<thead>
<tr>
<th>Ped Cases</th>
<th>Total</th>
<th>Did not Fixate</th>
<th>Fixated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Towards</td>
<td>152</td>
<td>10</td>
<td>142</td>
</tr>
<tr>
<td>Away</td>
<td>150</td>
<td>6</td>
<td>144</td>
</tr>
<tr>
<td>Both</td>
<td>309</td>
<td>16</td>
<td>293</td>
</tr>
<tr>
<td>None</td>
<td>158</td>
<td>62</td>
<td>96</td>
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<tr>
<th>Comparisons</th>
<th>Difference</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toward vs Away</td>
<td>2.6%</td>
<td>(-8.3%, 3.1%)</td>
<td>0.457</td>
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<tr>
<td>Both vs Toward</td>
<td>1.4%</td>
<td>(-6.5%, 3.7%)</td>
<td>0.690</td>
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<tr>
<td>Both vs Away</td>
<td>1.2%</td>
<td>(-0.3%, 5.7%)</td>
<td>0.748</td>
</tr>
<tr>
<td>None vs Toward</td>
<td>32.6%</td>
<td>(23.4%, 41.9%)</td>
<td>&lt; 0.001</td>
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<tr>
<td>None vs Away</td>
<td>35.2%</td>
<td>(26.3%, 44.1%)</td>
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Research Hypothesis 2: Fixations on FYA by Signal Configuration

$H_0$: There is no difference in the total duration of driver fixations during permitted left-turn maneuvers at signalized intersections operating the FYA with a 4-section vertical or a 3-section dual-arrow vertical configuration.

Two Signal Configuration
- 3-Section Dual-Arrow Vertical
- 4-Section Vertical

Seven Areas of Interest (AOI)
- Turn Bay
- Opposing Vehicles
- FYA Signal
- Ped Area
- Ped Both
- Ped Towards
- Ped Away
Fixations on FYA by Signal Configuration: Conclusions

- No significant difference were found in ATFD in any areas of interest (Welch’s (assuming unequal variance) two sample t-test.)
Fixations on FYA by Signal Configuration: Conclusions

• No significant difference were found in ATFD in any areas of interest.

This suggests that there is no difference in the amount of time a driver fixates on Pedestrians, Signal Heads, Opposing Vehicles, or the Turn Bay between a 4-section vertical or a 3-section dual-arrow.
Data Reduction: Pedestrian Location

• A secondary analysis of the data was performed using the raw video footage from the eye tracking camera.

• The location as described by Pedestrian Lane Number (PLN) was recorded at the moment when the driver initiated a left turn movement.
Research Hypothesis 5: Pedestrian Position by Signal Configuration

$H_0$: There is no difference in the location of the pedestrian in the crosswalk when the driver initiates a permitted left-turn maneuver at signalized intersections operating the FYA with a 4-section vertical or a 3-section dual-arrow vertical configuration.

Two Signal Configuration
- 3-Section Dual-Arrow Vertical
- 4-Section Vertical

4 Pedestrian Cases
- Towards Only
- Away Only
- Towards (with peds from both directions)
- Away (with peds from both directions)
Pedestrian Lane Locations by Signal Configuration

- Again, R Statistical Software used to perform Welch’s (assuming unequal variance) two sample t-test.

![Bar Chart]

<table>
<thead>
<tr>
<th>Ped Direction</th>
<th>Signal Configuration</th>
<th>Welch's two sample two tail t-test</th>
<th>4-section vs 3-section</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-section</td>
<td>3-section</td>
<td>p-value</td>
</tr>
<tr>
<td>Average Ped Position at Turn (PLN)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Away Only</td>
<td>0.724</td>
<td>1.079</td>
<td>0.007</td>
</tr>
<tr>
<td>Both Away</td>
<td>0.813</td>
<td>1.058</td>
<td>0.091</td>
</tr>
<tr>
<td>Toward Only</td>
<td>3.395</td>
<td>3.103</td>
<td>0.277</td>
</tr>
<tr>
<td>Both Towards</td>
<td>4.838</td>
<td>4.718</td>
<td>0.665</td>
</tr>
</tbody>
</table>
Simulator Validation

- SW Murray Boulevard and SW Walker Road in Beaverton, OR) for a 48-hour period between September 18th and 20th, 2012.
Simulator Validation

**Driver Stopping Location**

- **Simulator Data**
  - Before Crosswalk: 368
  - In Crosswalk: 84
  - After Crosswalk: 57

- **Field Data**
  - Before Crosswalk: 120
  - In Crosswalk: 26
  - After Crosswalk: 33

**Stopping Behavior**

- **Simulator Data**
  - Creep: 83
  - Creep & Stop: 58
  - Stop & Creep: 122
  - Full Stop: 246

- **Field Data**
  - Creep: 18
  - Creep & Stop: 14
  - Stop & Creep: 25
  - Full Stop: 122
Conclusions, and Limitations, Future Work

- 4% to 7% of drivers fail to fixate on pedestrians in conflicting crosswalks
- No statistical difference in glance durations for 4 or 3 section signal heads
- FYA and high pedestrian locations may require additional signal logic
- The current data over samples younger drivers. A larger, more diverse sample size could result in more robust results.
- Only fixation data was analyzed from the eye tracker. Saccades and glance sequence could be examined.
This project was funded by the Oregon Transportation Research and Education Consortium (OTREC).

Washington County Traffic Engineering provided matching funding as well as technical support (Stacy Shetler and Ed Anderson).

Kittelson & Associates, Inc. also provided technical support for the project (Shaun Quayle).
Questions?

Uh-oh --- this can’t be good.