



# **Driver Reactions to the Flashing Yellow Arrow in the Presence of Pedestrians**

ITE Western District Annual Meeting  
Phoenix, Arizona  
July 15<sup>th</sup>, 2013

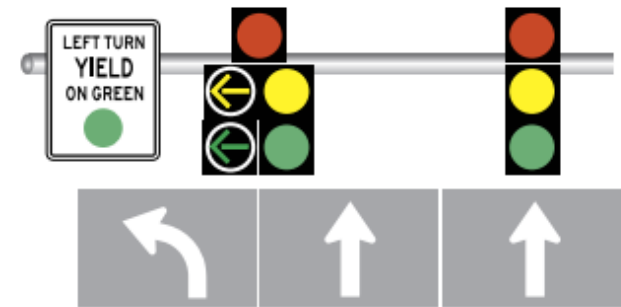
Authors: Hurwitz, David ; Tuss, Halston; Marnell, Patrick – Oregon State University  
Monsere, Chris; Paulsen, Kirk – Portland State University

Presenter: Pat Marnell

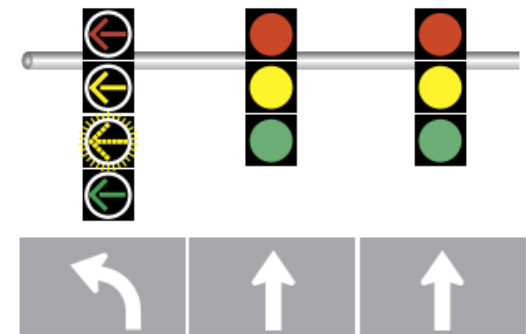
# A brief history Flashing Yellow Arrow (FYA)

- 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.

TRADITIONAL – FIVE SECTION SIGNAL



FLASHING YELLOW ARROW SIGNAL



*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



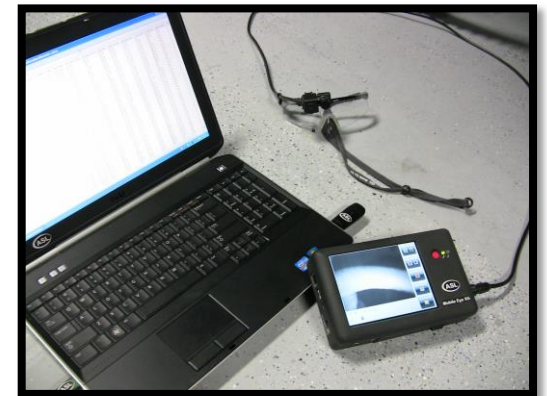
Simulator in use

# 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

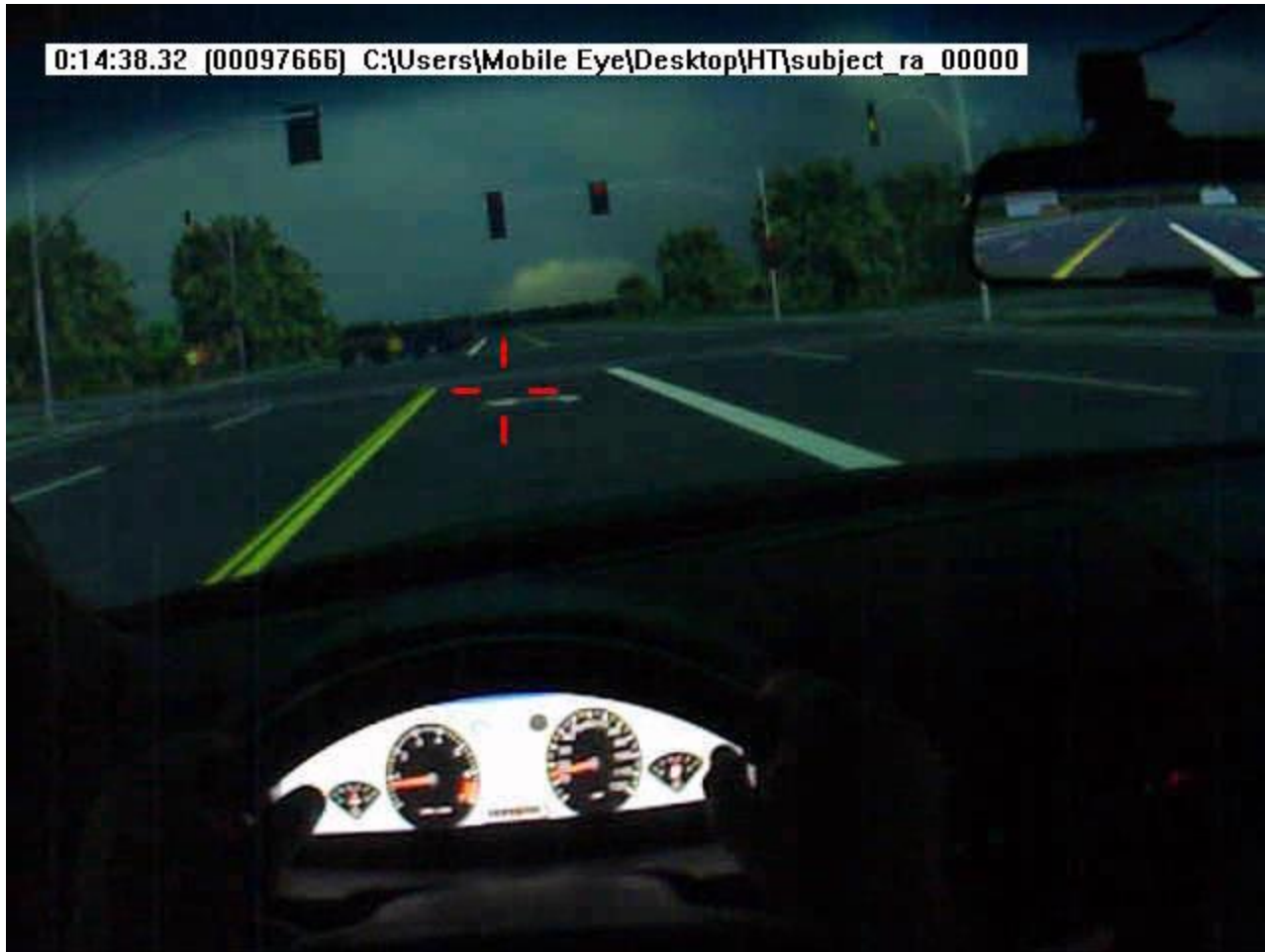


Scene & Eye Camera

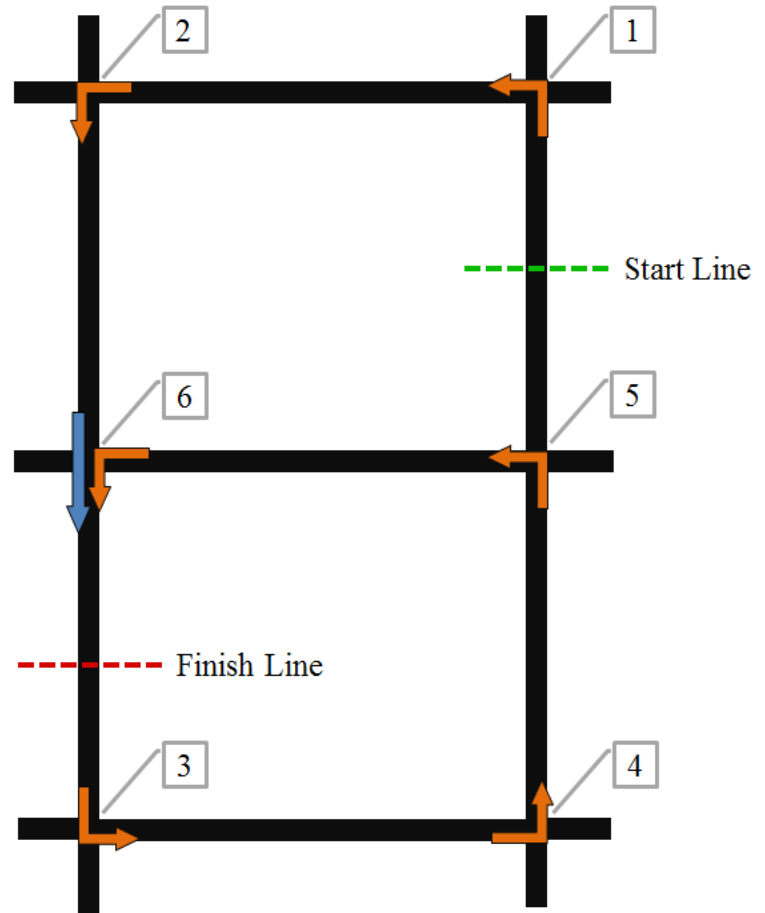


Computer & Control Unit

# Eye Tracking Video Screen Capture



# Simulated Environment



# Independent Variables

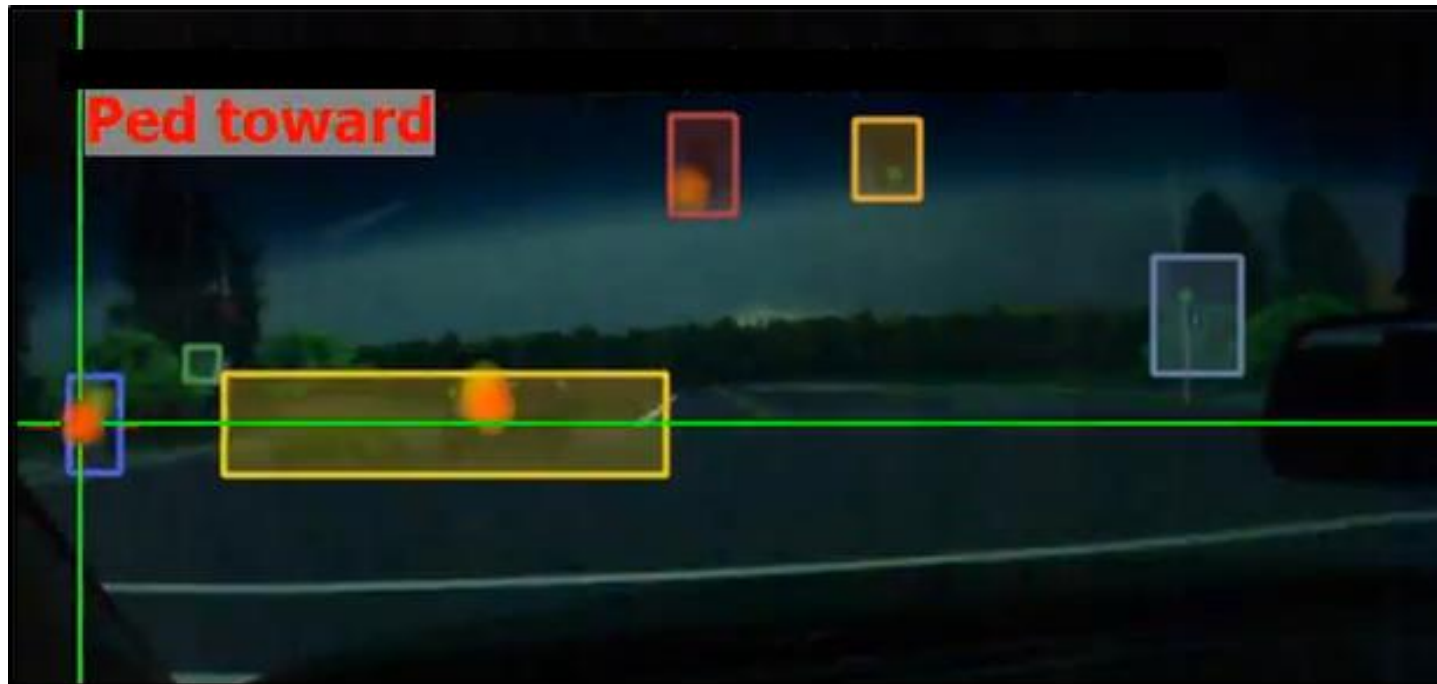
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| Crossing Pedestrians            | Opposing Vehicles | FYA Signal Configuration      |
|---------------------------------|-------------------|-------------------------------|
| No pedestrians                  | No vehicles       | 3-section dual-arrow vertical |
| 1 pedestrian toward the subject | 3 vehicles        | 4-section vertical            |
| 1 pedestrian away from subject  | 9 vehicles        |                               |
| Four pedestrians (2 each side)  |                   |                               |

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# Primary Data: Driver Glance Fixation Duration



| AOI Name     | Fixation Count | Total Fixation Duration | Average Fixation Duration | First Fixation Time |
|--------------|----------------|-------------------------|---------------------------|---------------------|
| Bay          | 9              | 3.4                     | 0.378                     | 15.02               |
| FYA          | 7              | 3.11                    | 0.444                     | 16.02               |
| Opposing Veh | 8              | 2.72                    | 0.34                      | 24.34               |
| OUTSIDE      | 27             | 6.19                    | 0.229                     | 14.29               |
| Ped Towards  | 1              | 0.2                     | 0.2                       | 29.72               |

# Hypotheses

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 total duration of driver fixations during permitted left-turn maneuvers at signalized intersections operating the FYA with zero, 3, or 9 opposing vehicles.

# 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 (**both**)
- No peds present (**none**)



# Proportion of Fixations on Pedestrians: Results

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

| Ped Cases | Total | Did not Fixate |            | Fixated |            |
|-----------|-------|----------------|------------|---------|------------|
|           |       | Count          | Percentage | Count   | Percentage |
| Towards   | 152   | 10             | 7%         | 142     | 92%        |
| Away      | 150   | 6              | 4%         | 144     | 95%        |
| Both      | 309   | 16             | 5%         | 293     | 89%        |
| None      | 158   | 62             | 39%        | 96      | 65%        |

| Comparisons    | Difference | 95% CI         | p-value |
|----------------|------------|----------------|---------|
| Toward vs Away | 2.6%       | (-8.3%, 3.1%)  | 0.457   |
| Both vs Toward | 1.4%       | (-6.5%, 3.7%)  | 0.690   |
| Both vs Away   | 1.2%       | (-0.3%, 5.7%)  | 0.748   |
| None vs Toward | 32.6%      | (23.4%, 41.9%) | < 0.001 |
| None vs Away   | 35.2%      | (26.3%, 44.1%) | < 0.001 |
| None vs Both   | 34.1%      | (25.6%, 42.5%) | < 0.001 |

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# Research Hypothesis 2: Fixations on FYA by Signal Configuration

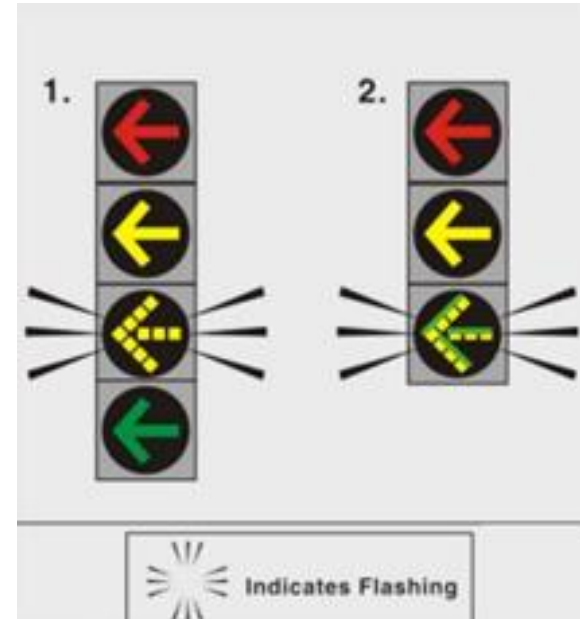
$H_0$ : There is no difference in the total duration of driver fixations during permitted left-turn maneuvers at signalized intersections operating the FYA with a 4-section vertical or a 3-section dual-arrow vertical configuration.

## Two Signal Configuration

- 3-Section Dual-Arrow Vertical
- 4-Section Vertical

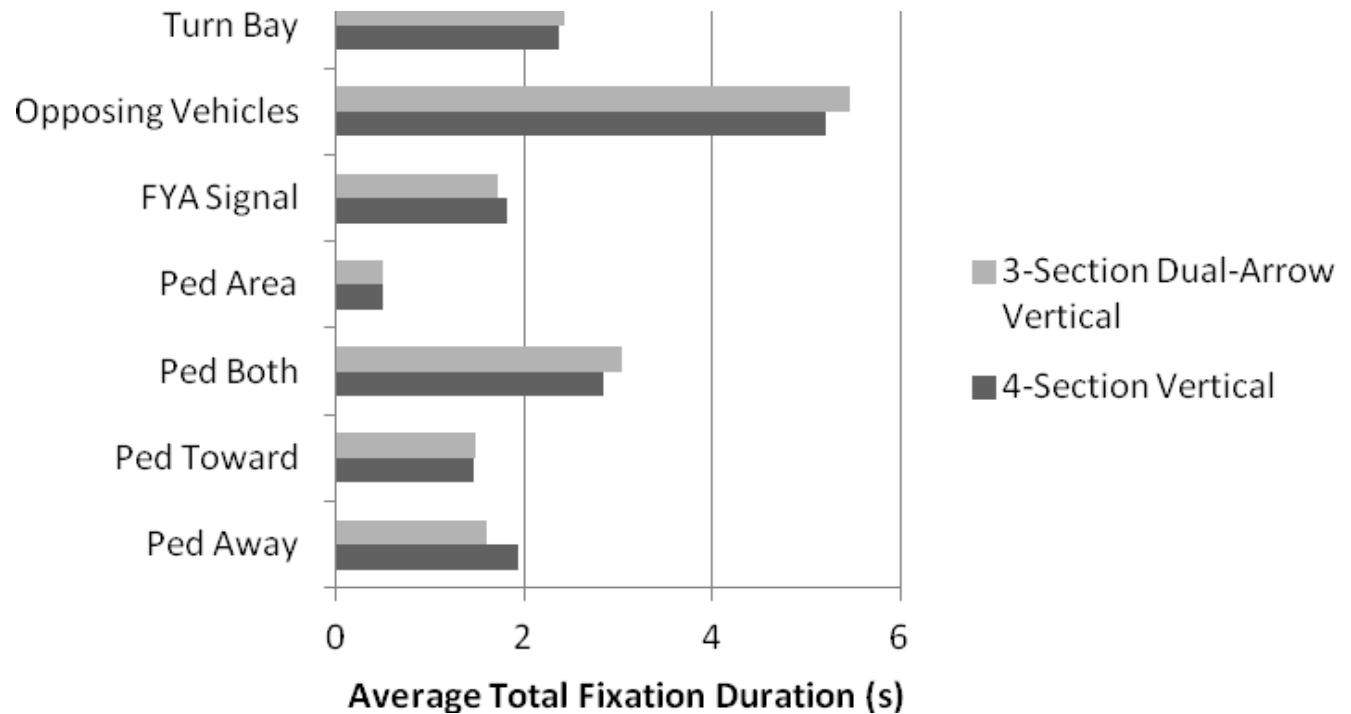
## Seven Areas of Interest (AOI)

- Turn Bay
- Opposing Vehicles
- FYA Signal
- Ped Area
- Ped Both
- Ped Towards
- Ped Away



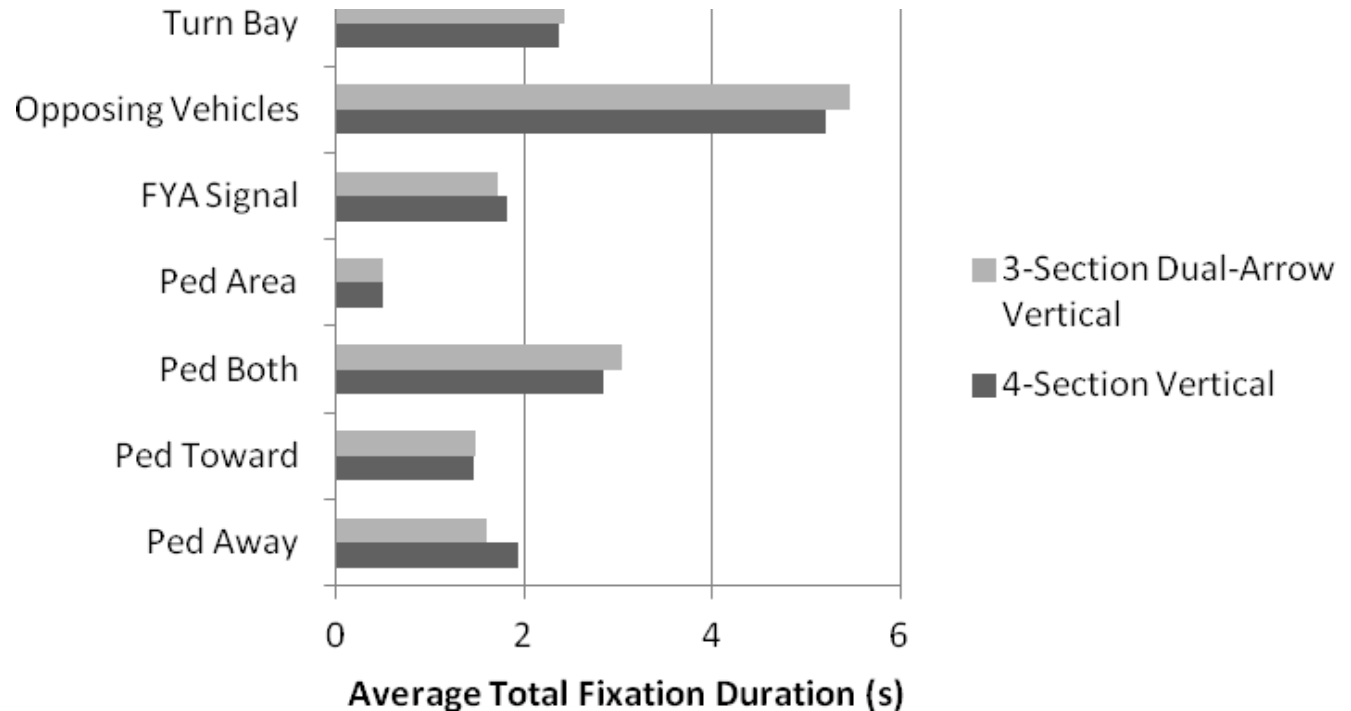
# Fixations on FYA by Signal Configuration: Conclusions

- No significant difference were found in ATFD in any areas of interest (Welch's two sample t-test.)



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- No significant difference were found in ATFD in any areas of interest (Welch's two sample t-test.)



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.



# Research Hypothesis 3: Fixations on FYA by Opposing Vehicle Volume

$H_0$ : 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.

## Seven Areas of Interest (AOI)

- Turn Bay
- Opposing Vehicles
- FYA Signal
- Ped Area
- Ped Both
- Ped Towards
- Ped Away

## Three Vehicle Volumes

- Zero Vehicles
- 3 Vehicles
- 9 Vehicles



# Fixations on FYA by Opposing Vehicle Volume: Results

- Again, R Statistical Software used to perform ANOVA analysis and family-wise comparisons with Tukey's Honest Significant Difference

| Areas of Interest | Mean Opposing Vehicle Volume |       |       | ANOVA   | Tukey's Honest Significant Differences multiple comparisons of means with 95% family-wise confidence level |                               |         |                               |                      |                              |     |
|-------------------|------------------------------|-------|-------|---------|--|-------------------------------|---------|-------------------------------|----------------------|------------------------------|-----|
|                   | No Veh                       | 3 Veh | 9 Veh |         | All  | <i>No Veh</i> vs <i>3 Veh</i> |         | <i>No Veh</i> vs <i>9 Veh</i> |                      | <i>3 Veh</i> vs <i>9 Veh</i> |     |
|                   | ATFD (sec)                   |       |       |         |  | p-value                       | Sig     | p-value                       | Sig                  | p-value                      | Sig |
| Ped Away          | 2.435                        | 1.504 | 1.328 | < 0.001 | < 0.001  | <b><u>Yes</u></b>             | < 0.001 | <b><u>Yes</u></b>             | 0.762                | No                           |     |
| Ped Toward        | 2.570                        | 1.310 | 0.678 | < 0.001 | < 0.001  | <b><u>Yes</u></b>             | < 0.001 | <b><u>Yes</u></b>             | 0.037                | <b><u>Yes</u></b>            |     |
| Ped Both          | 4.334                        | 2.758 | 1.670 | < 0.001 | < 0.001  | <b><u>Yes</u></b>             | < 0.001 | <b><u>Yes</u></b>             | 0.010                | <b><u>Yes</u></b>            |     |
| Ped Area          | 0.536                        | 0.512 | 0.404 | 0.145   | 0.964  | No                            | 0.333   | No                            | 0.511                | No                           |     |
| FYA Signal        | 2.150                        | 1.538 | 1.622 | 0.012   | 0.001  | <b><u>Yes</u></b>             | 0.007   | <b><u>Yes</u></b>             | 0.880                | No                           |     |
| Opposing Vehicles | N/A                          | 3.845 | 6.833 | N/A     | N/A  |                               | N/A     |                               | < 0.001 <sup>†</sup> | <b><u>Yes</u></b>            |     |
| Turn Bay          | 2.296                        | 2.394 | 2.479 | 0.313   | 0.842  | No                            | 0.554   | No                            | 0.882                | No                           |     |

<sup>†</sup>No multiple comparisons required. The *P*-value reflects a 2-sided Welch's 2-sample *t*-test. Significant *P*-values are shown in bold type.

# Fixations on FYA by Opposing Vehicle Volume: Results

- Again, R Statistical Software used to perform ANOVA analysis and family-wise comparisons with Tukey's Honest Significant Difference

| Areas of Interest | Mean Opposing Vehicle Volume |       |       | ANOVA   | Tukey's Honest Significant Differences multiple comparisons of means with 95% family-wise confidence level |                               |              |                               |                      |                              |     |
|-------------------|------------------------------|-------|-------|---------|--|-------------------------------|--------------|-------------------------------|----------------------|------------------------------|-----|
|                   | No Veh                       | 3 Veh | 9 Veh |         | All  | <i>No Veh</i> vs <i>3 Veh</i> |              | <i>No Veh</i> vs <i>9 Veh</i> |                      | <i>3 Veh</i> vs <i>9 Veh</i> |     |
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| Ped Away          | 2.435                        | 1.504 | 1.328 | < 0.001 | < 0.001  | <b>Yes</b>                    | < 0.001      | <b>Yes</b>                    | 0.762                | No                           |     |
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# Fixations on FYA by Opposing Vehicle Volume: Conclusions

- Significant differences found between No Veh and 3 Veh for AOIs Ped Towards, Ped Away, and Ped Both, and FYA Signal
- Significant differences found between No Veh and 9 Veh for AOIs Ped Towards, Ped Away, and Ped Both, and FYA Signal
- Significant differences found between 3 Veh and 9 Veh for AOIs Ped Towards and Ped Both, and Opposing Vehicles.

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Opposing traffic affects fixations on pedestrian, except between moderate and heavy levels of traffic for pedestrian walking away from driver.

Drivers fixate longer on the FYA when no vehicles are present

## 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
- Drivers spend less time focusing on peds when more opposing vehicles are present
- 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.

# Acknowledgments



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).



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

## More Information from this Study

**Improved Pedestrian Safety At Signalized Intersections Operating the Flashing Yellow Arrow Final Report OTREC-RR-13-02**  
**<http://otrec.us/project/484>**



Questions?