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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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Citation Details

Hurwitz, David and Monsere, Christopher M., "Driver Behavior in the Presence of Pedestrians at Signalized Intersections Operating the Flashing Yellow Arrow" (2013). *Civil and Environmental Engineering Faculty Publications and Presentations*. 75.

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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:

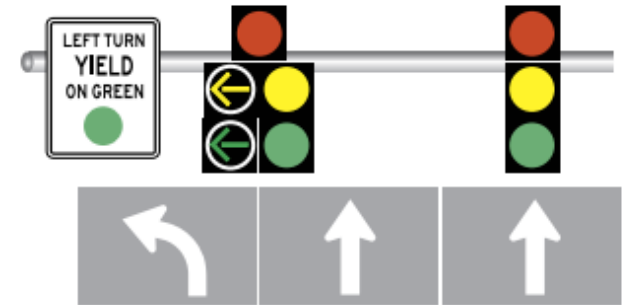
David Hurwitz, Assistant Professor, OSU

Chris Monsere, Associate Professor, PSU

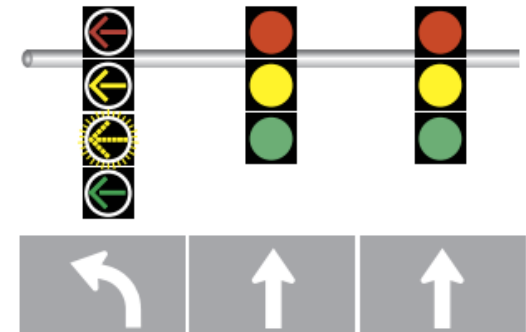
A brief history Flashing Yellow Arrow (FYA)

- 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.

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



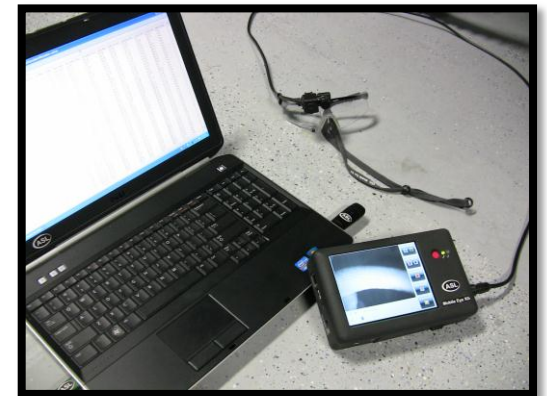
Simulator in use

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

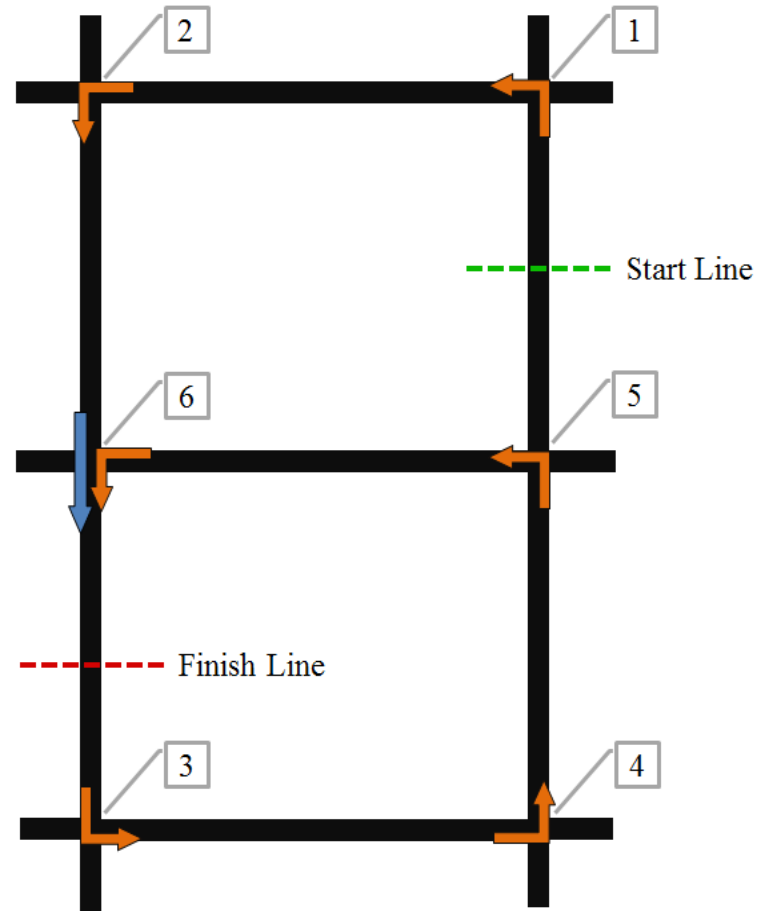


Computer & Control Unit

Eye Tracking Raw Video



Simulated Environment



Independent Variables

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)		

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 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.

Hypotheses Explored

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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

Ped Cases	Total	Did not Fixate		Fixated	
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

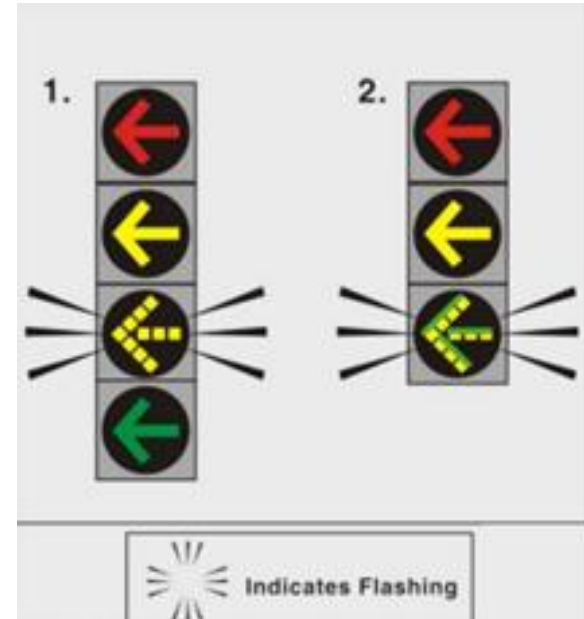
H_0 : There is no difference in the total duration of driver fixations during permitted left-turn maneuvers at signalized intersections operating the FYA with a 4-section vertical or a 3-section dual-arrow vertical configuration.

Two Signal Configuration

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

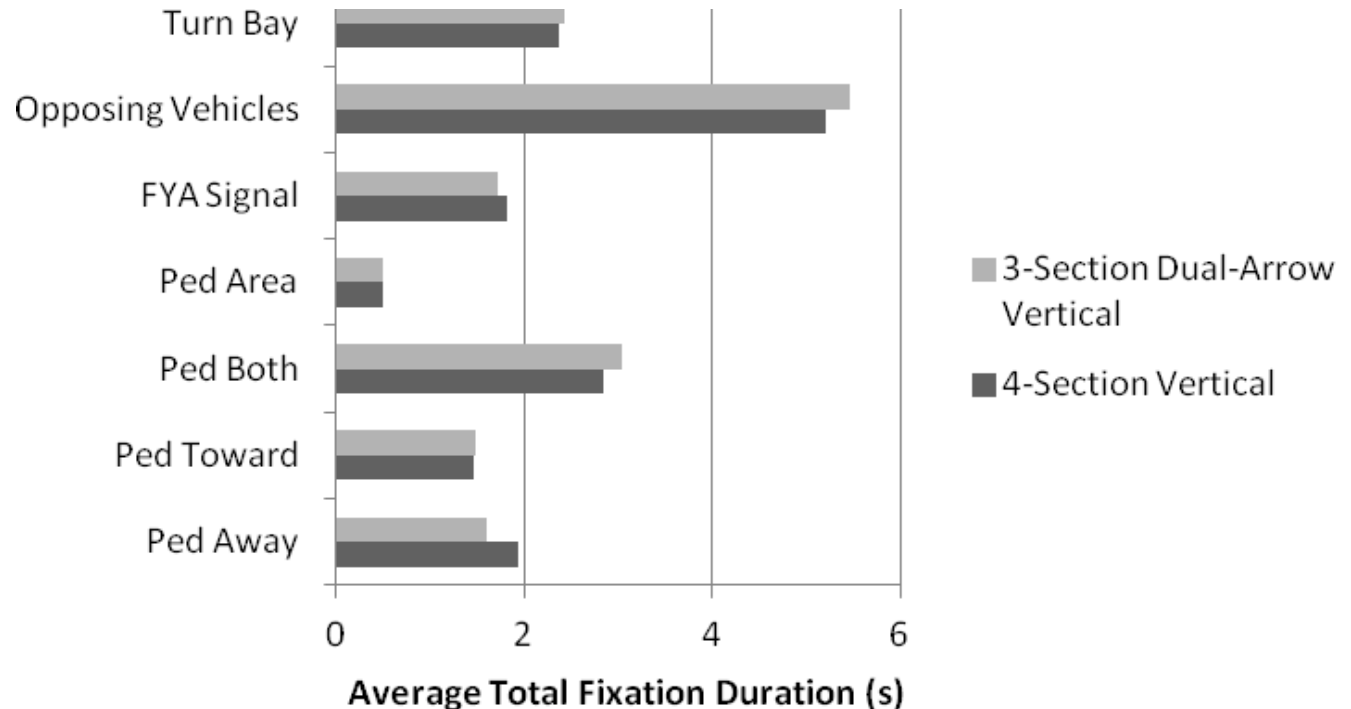
Seven Areas of Interest (AOI)

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



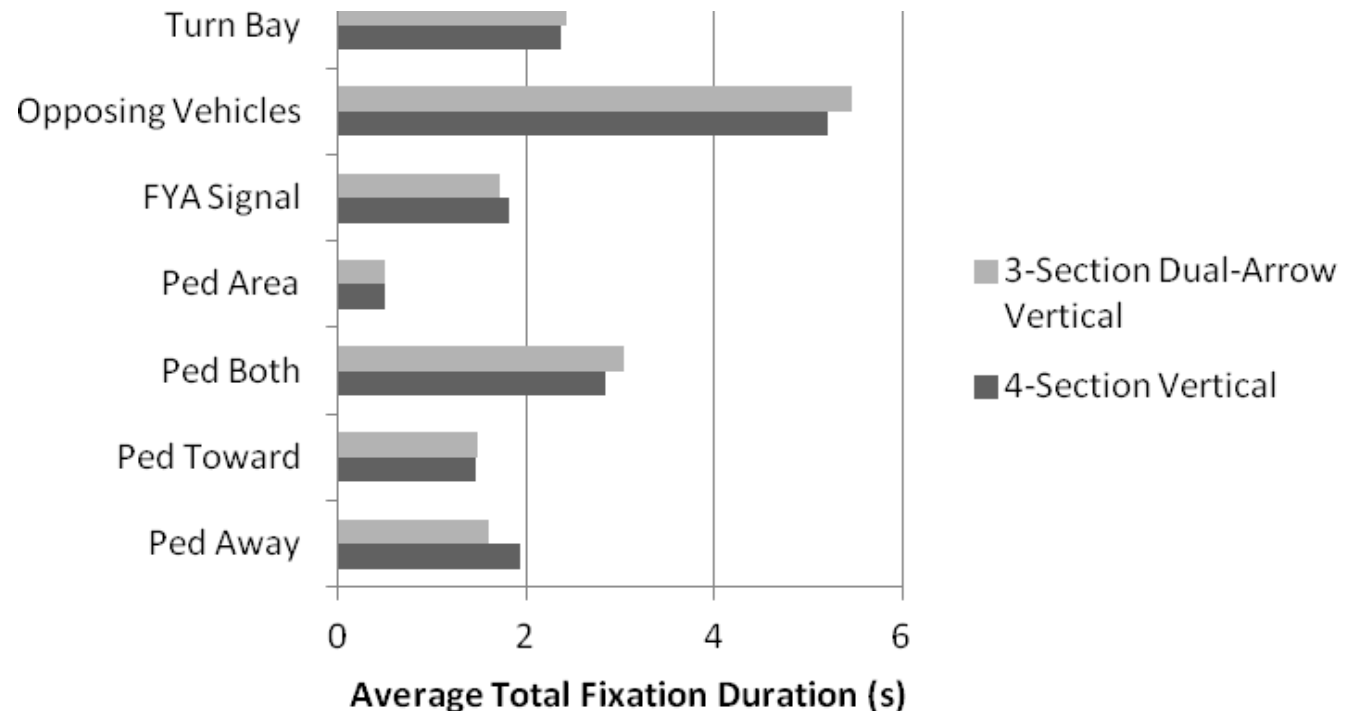
Fixations on FYA by Signal Configuration: Conclusions

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



Fixations on FYA by Signal Configuration: Conclusions

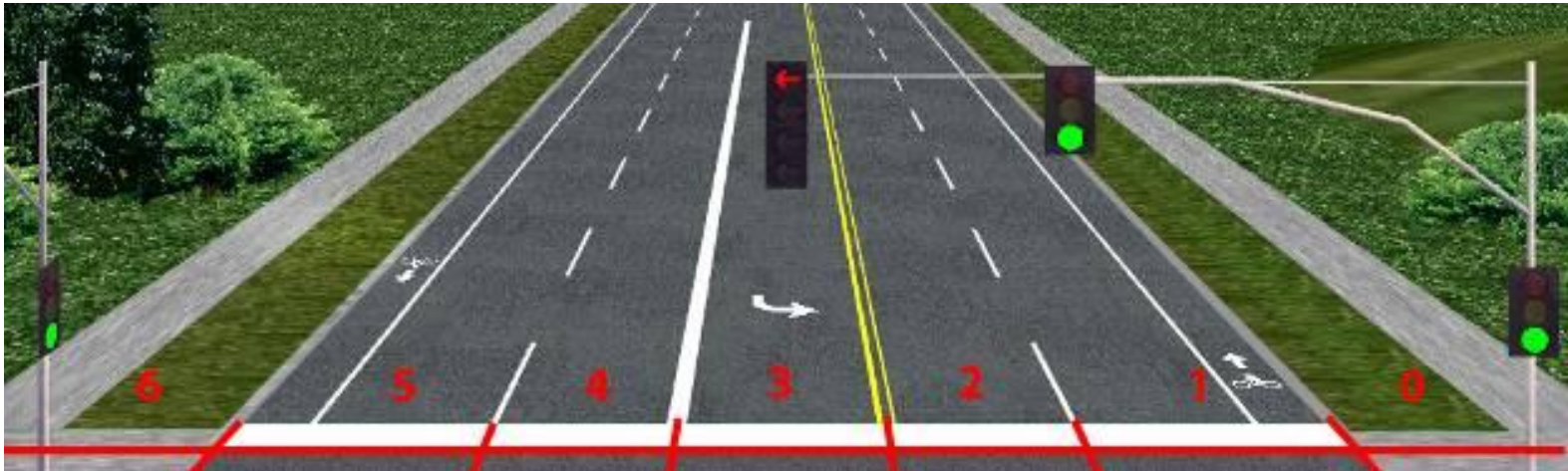
- No significant difference were found in ATFD in any areas of interest.



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 preformed 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

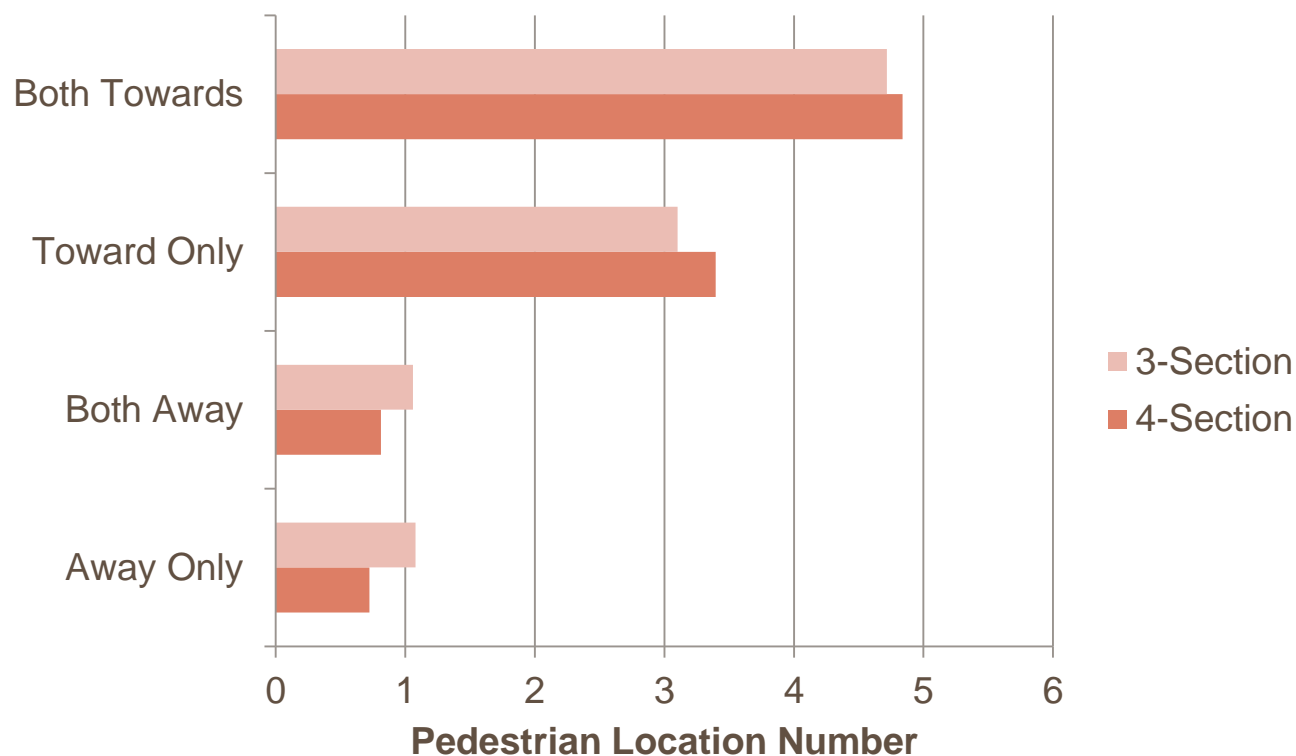
4 Pedestrian Cases

- 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 preform Welch's (assuming unequal variance) two sample t-test.



Ped Direction	Signal Configuration		Welch's two sample two tail t-test	
	4-section	3-section	4-section vs 3-section	
	Avg Ped Position at Turn (PLN)		p-value	Significant
Away Only	0.724	1.079	0.007	Yes
Both Away	0.813	1.058	0.091	No / Suggestive
Toward Only	3.395	3.103	0.277	No
Both Towards	4.838	4.718	0.665	No

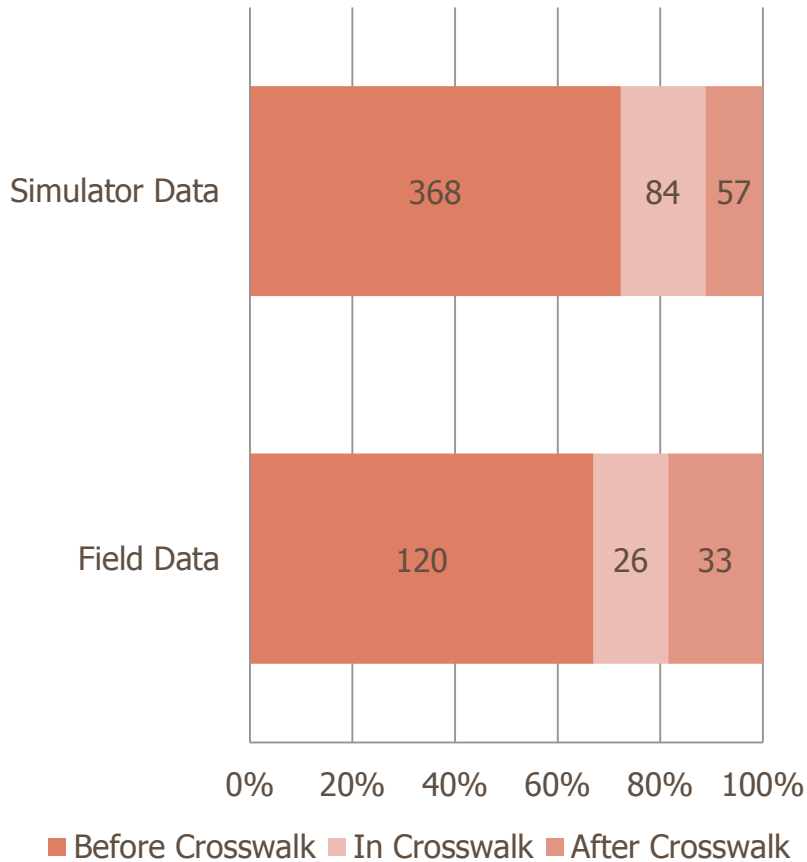
Simulator Validation



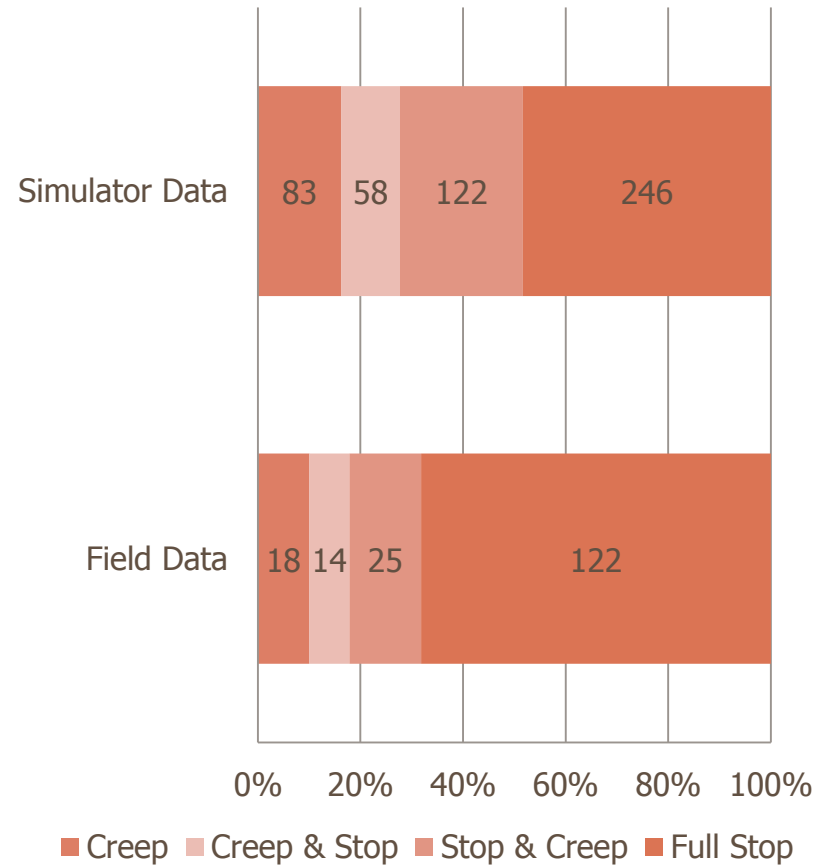
- SW Murray Boulevard and SW Walker Road in Beaverton, OR) for a 48-hour period between September 18th and 20th, 2012.

Simulator Validation

Driver Stopping Location



Stopping Behavior



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.

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).



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

Questions?



Uh-oh --- this can't be good.