

Assessing the Impact of Three Intersection Treatments in a Bicycling Simulator

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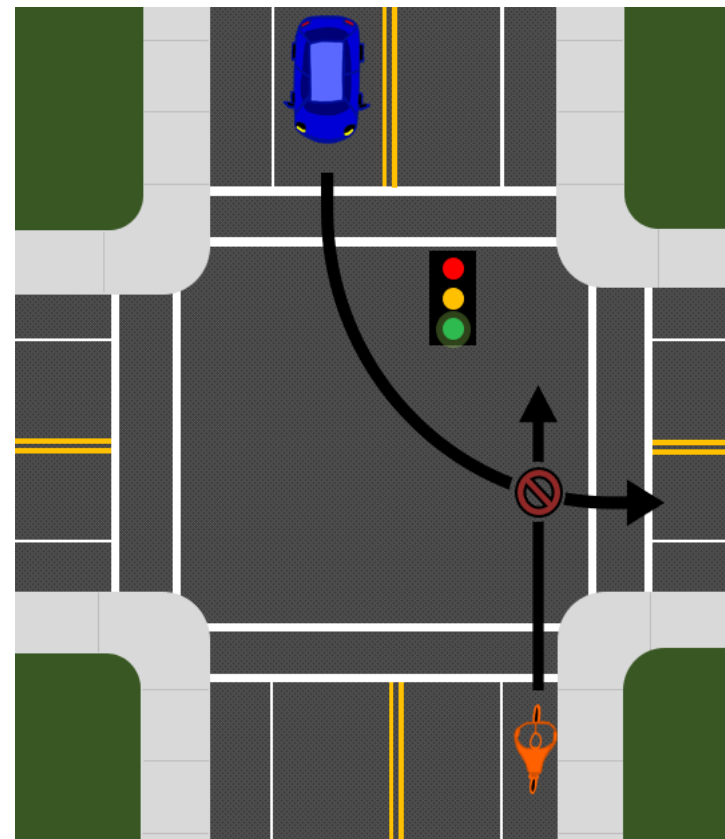
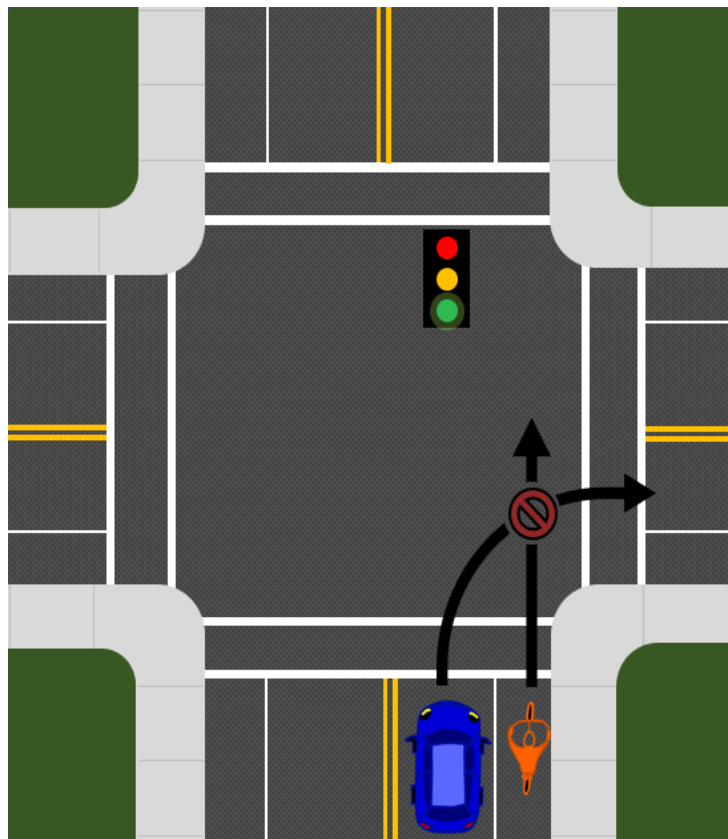
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Motivation

- There have been proven economic, health, and environmental benefits associated with biking (Simmons et al., 2015)
- 857 bicyclist fatalities in the US 2018 (NHTSA, 2020)
 - Due to crashes with vehicles
 - 79% occurred in urban environments
- Improved safety can promote more bicyclists
- Assess three treatments and their effectiveness at reducing right and left hook crashes

Right and Left Hook Crashes



Bike Box

- Adopted from the advanced stop bar
 - Common in European countries
- Provides bicyclist with a “waiting area”
 - Helps assist turning or through bicyclists
 - Makes cyclist more visible to motorists
- Unique pavement markings and geometry



Bike box in Portland, OR



R10-6a Sign

Bicycle Signal

- Dictates movement of bicyclists
 - Separate phase from vehicular signals
- Distinguishable by bicycle icon or housing unit color
- MUTCD guidelines require:
 - 8- or 12- inch diameter
 - Accompanied by R10-10B sign



Bicycle signal in Portland, OR



R10-10b Sign

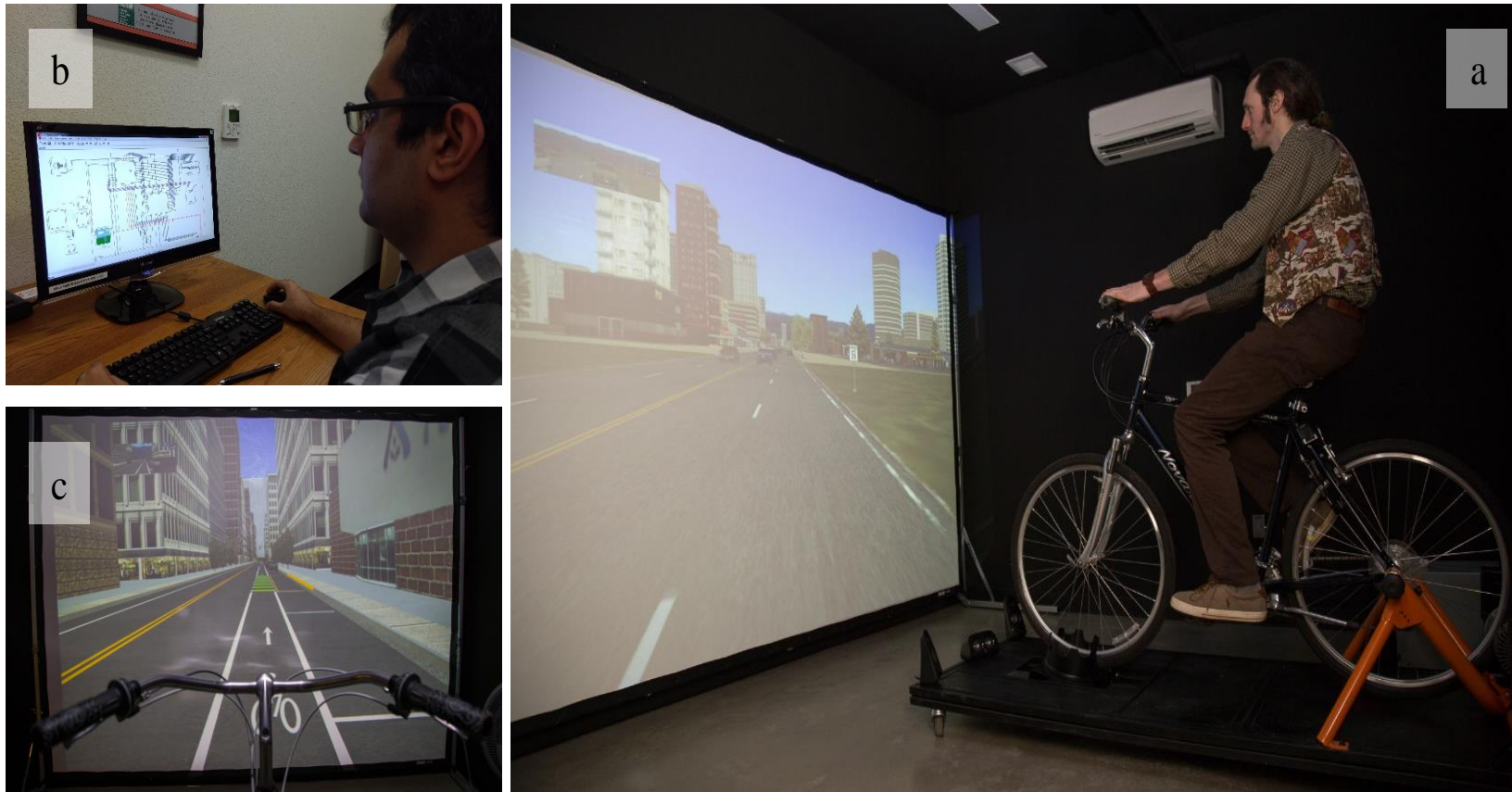
Mixing Zone

- Mixing zone with yield entry markings
- Brings the right-hook crash potential back from the intersection
 - Reduces mental load at intersection
- Allows bicyclists to claim the lane
 - Requires vehicles to yield to bicyclists
 - Provides opportunity to move away from turning side of the vehicle



Mixing zone in Portland, OR

OSU Bicycling Simulator



Experimental Equipment

- OSU Bicycling Simulator
 - Outputs instantaneous time-space data about rider
- ASL Mobile Eye XG
 - Provides fixation and saccade data
- Shimmer3 GSR Device
 - Measures skin conductance

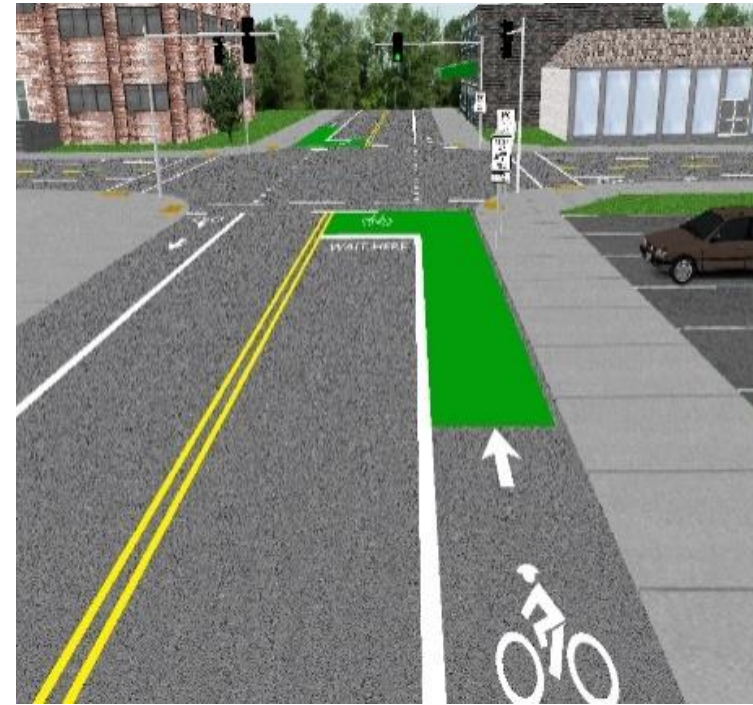


GSR (top) and eye tracking (bottom) equipment

Field to Simulator – Bike box



Bike box in real-world



Modeled for simulator

Field to Simulator – Bicycle Signal



Bicycle Signal in real-world



Modeled for Simulator

Field to Simulator – Mixing Zone



Mixing zone in real-world



Modeled for Simulator

Experimental Design

- Variables of Interest
 - Conflict type
 - Treatment
 - Stopping requirement
- Performance Measures
 - Survey
 - Lateral position
 - Conflict recognition
 - Level of stress

Independent Variable Levels

VARIABLE	CATEGORY	LEVEL	LEVEL DESCRIPTION
Type of Conflict	Nominal (categorical)	1	Right turning vehicle is arriving at intersection
		2	Right turning vehicle is waiting at intersection
		3	Left turning vehicle
		4	No conflicting vehicle
Intersection Treatment	Nominal (categorical)	1	Bike Box
		2	Bicycle Signal
		3	Mixing Zone
Stopping Requirement	Discrete	1	Red indication upon arrival
		2	Green indication upon arrival

Results – Pre Ride Survey

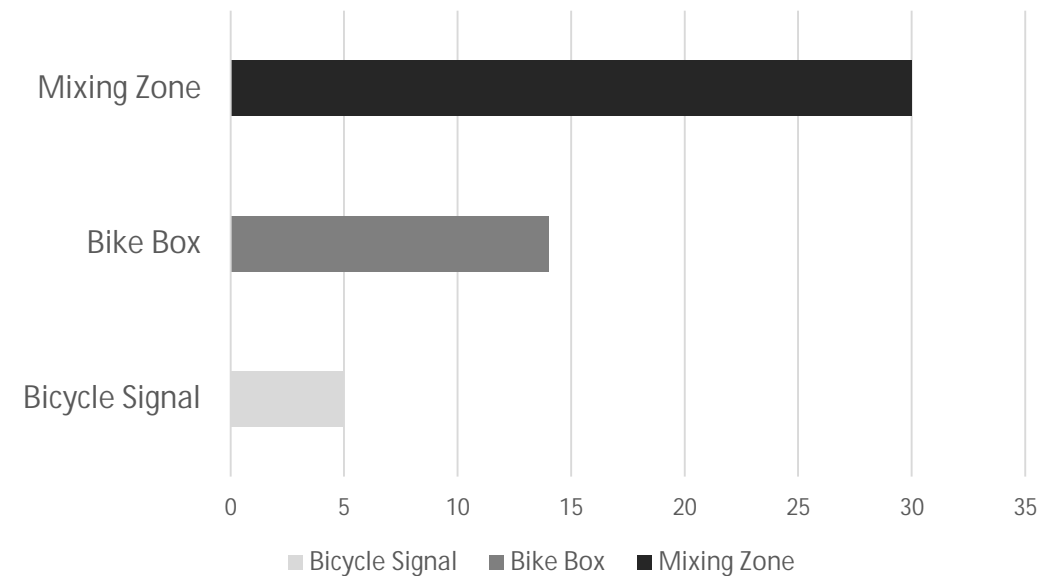
- 23 Female – 17 Male
- Well distributed in bicycling experience and frequency
- Majority of riders selected that they ride local
 - Local refers to riding around Corvallis, OR
 - Urban is a dense city environment
 - Rural is open land-use where majority is not buildings

Pre-ride survey response breakdown

Question	Response Options	# of Participants	% of Participants
How often do you ride a bike per week?	0 times	7	17.5
	1 time	10	25
	2-4 times	9	22.5
	5-10 times	11	27.5
	More than 10	3	7.5
How long do you ride a bike per week?	0-1 hour	18	45
	1-2 hours	7	17.5
	2-3 hours	6	15
	3-4 hours	2	5
	> 4 hours	7	17.5
What type of riding do you do?	Urban	8	20
	Rural	3	7.5
	Local	22	55
	None	7	17.5

Results – Post Ride Survey

- Majority of participants (90%) have not seen at least one treatment
 - Indicates potential for more promotion of newer treatments
- 69% were uncomfortable approaching an unfamiliar design
- Additional free response question
 - Asked for participants to indicate which treatment made them feel discomfort
 - Participants were allowed >1 answer



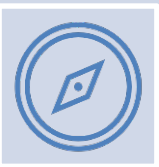
Participant response indicating discomfort traversing certain treatments

Results – Positioning

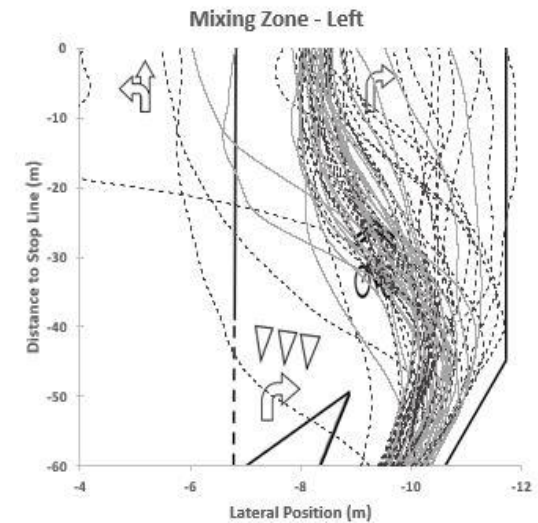
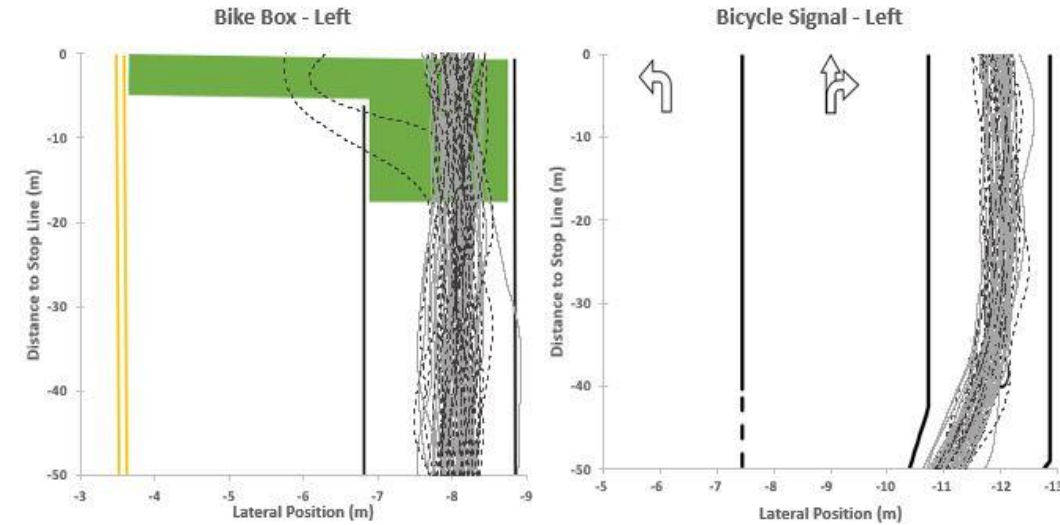


Visualizations show participant movements

- Dark/dotted line indicates red arrival
- Grey/solid line indicates green arrival



Assessed positioning using the offset from the center of lane



Statistical Analysis - Positioning

- Assessed positioning as offset from center of lane
 - Recommended by SAE Standards
- Average offset from lane center:
 - Mixing zone = 1.02 m
 - Bike box = 0.24 m
 - Bicycle signal = 0.17 m
- Repeated Measures ANOVA showed statistical significance
- Bonferroni Pairwise Comparison Test
 - Largest offset in Mixing zone

Statistical Analysis - Positioning

Bonferroni Comparison on Positioning

Treatment (i)	Treatment (j)	Estimate	SE	p-value	95% CI	
					Lower	Upper
Bike Box	Mixing Zone	0.782	0.153	<0.01*	0.399	1.166
	Bicycle Signal	-0.067	0.024	0.029*	-0.128	-0.005
Mixing Zone	Bike Box	-0.782	0.153	<0.01*	-1.166	-0.399
	Bicycle Signal	-0.849	0.160	<0.01*	-1.250	-0.448
Bicycle Signal	Bike Box	0.067	0.024	0.029*	0.005	0.128
	Mixing Zone	0.849	0.160	<0.01*	0.448	1.250

*Note: All measurements in meters

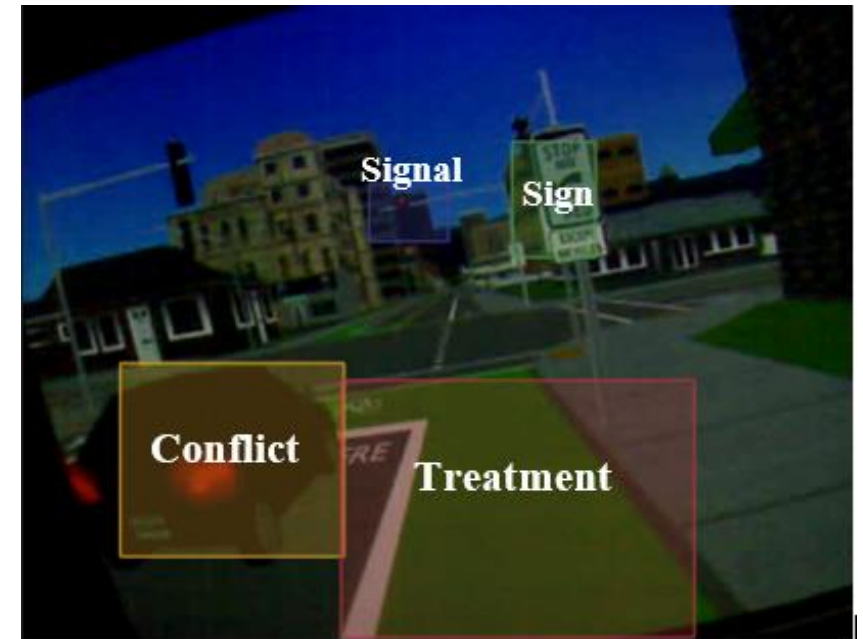
Results – Conflict Recognition



Visual attention was used to assess conflict recognition



Total Fixation Duration (TFD) on conflict vehicle



Results – Conflict Recognition

- Mixing zone resulted in largest TFD values
- Statistically significant result found from ANOVA test
 - P-value < 0.01
- Bonferroni Pairwise Comparison Test
 - Mixing zone had TFD values of 1.9 and 2.8 seconds more
 - Bicycle signal had lowest TFD values

Bonferroni test on Treatment type

Treatment (i)	Treatment (j)	Est.	SE	p	95% CI	
					Lower	Upper
Bike Box	Mixing Zone	-1.906	0.300	<0.01*	-2.686	-1.126
	Bicycle Signal	0.976	0.210	<0.01*	0.430	1.522
Mixing Zone	Bike Box	1.906	0.300	<0.01*	1.126	2.686
	Bicycle Signal	2.882	0.287	<0.01*	2.135	3.628
Bicycle Signal	Bike Box	-0.976	0.210	<0.01*	-1.522	-0.430
	Mixing Zone	-2.882	0.287	<0.01*	-3.628	-2.135

Recommendations

- All designs had positive and negative attributes
- Bicycle signal may be too safe
 - Did not require riders to perceive the potential conflict danger
- Mixing zone made participant feel uncomfortable
 - Although it promoted safe riding habits – participants did not enjoy
- Bike box provided a good balance of safety and functionality
 - No extreme findings – Improved safety without eliciting unsafe behaviors
- We recommend:
 - Bicycle signal be installed only when a clear need is present
 - Mixing zone be installed where fatal crashes occur
 - Bike box is the most versatile and can be installed most frequently

Acknowledgements

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