ALLUSION 2

Understanding Vulnerable Road User Interpretation of eHMI on Multiple Highly Automated Vehicles

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OBJECTIVES

Learnings from Study 1 that were applied in Study 2:

Pattern: Changed from 3 to 2 levels
Location: Windshield
Colors: White and Amber

Included small Law Enforcement cohort to look at teal colors and understand perspective from their experience on the force and being on patrol.

- True baseline
- Scenarios Specific Changes
- Only pedestrian scenarios
- Both vehicles always cross the pedestrian's path
- More mid-block scenarios

RESEARCH QUESTIONS

Presence of eHMI

- Does the presence of multiple AVs with and without eHMI affect participants crossing decisions?

Type of eHMI

- How do colors (i.e., white and amber) of eHMI impact the decision-making of pedestrians?

Interpretation of eHMI Function

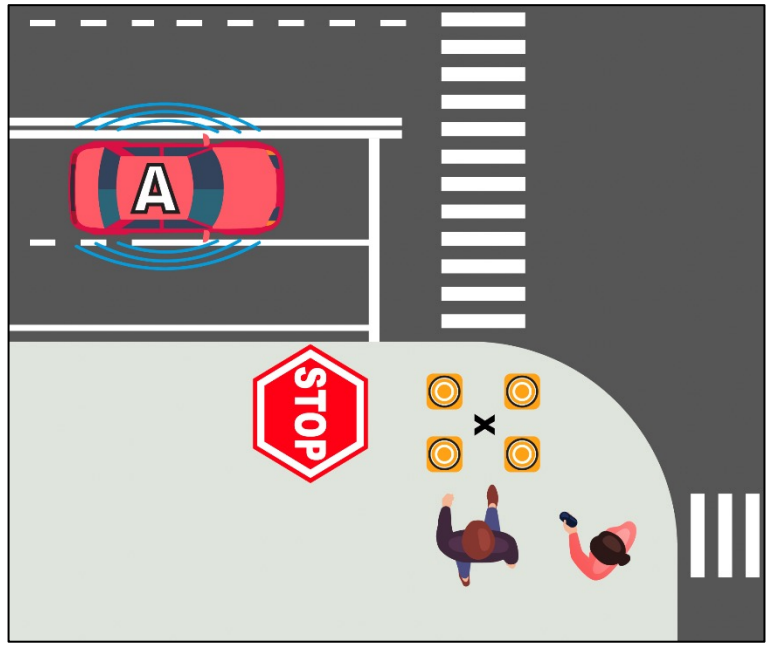
- Does an external communication display reduce confusion for other road users regarding the intention of the AV to slow/stop or go?
- Is an eHMI that provides two levels of information (i.e., yielding and driving) more understandable/interpretable than an eHMI with three levels (i.e., driving, yielding, and ready)?
- What are law enforcement officers' preferences across lightbar color conditions (i.e., white, amber, teal)?

STUDY VARIABLES

Group	Variable	Levels	Description
Vehicles	Light Bar Color	2	1) White 2) Amber
Scenario	Passenger	4	1) Scenario 1 2) Scenario 2 3) Scenario 3 4) Scenario 4

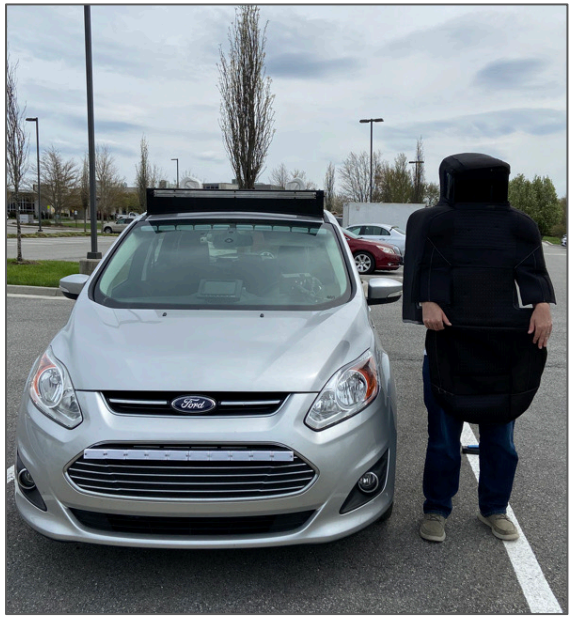
PARTICIPANT DECISION MAKING

- **Safe Crossing Box**
  - Box outlined with four cones and a ‘X’ on the pavement
  - Participant will be standing outside the box, and the moderator will provide instructions
  - When the participant deems it is safe to cross the street, they will step inside the box
  - When ever they feel uncomfortable, or that they would not cross the street they will exit the box



SEAT-SUIT

- To simulate a fully self-driving experience without using an actual autonomous vehicle
- Creates the illusion of a fully autonomous vehicle, which is necessary to test and evaluate real-world encounters and behaviors.



Seat-Suit A

Seat-Suit B

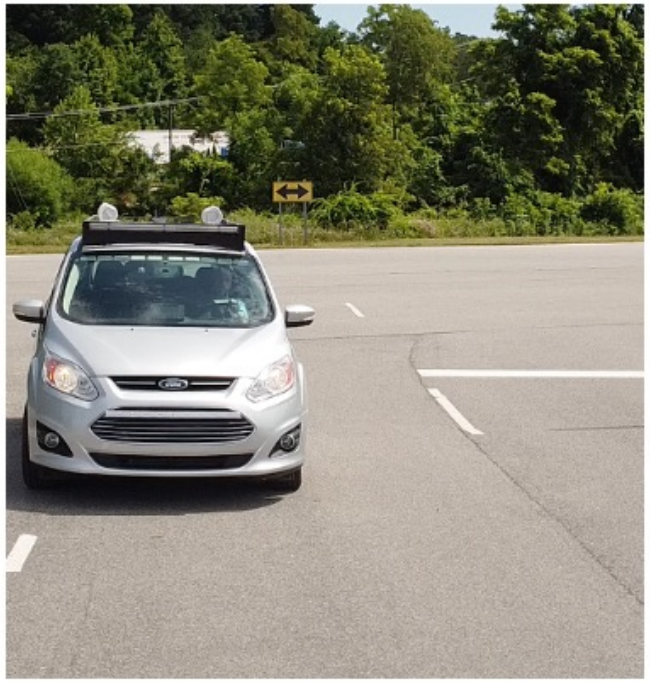
LIGHT PATTERNS TESTED

TWO PATTERNS:
(1) Yielding: Out to In
(2) Drive: Solid

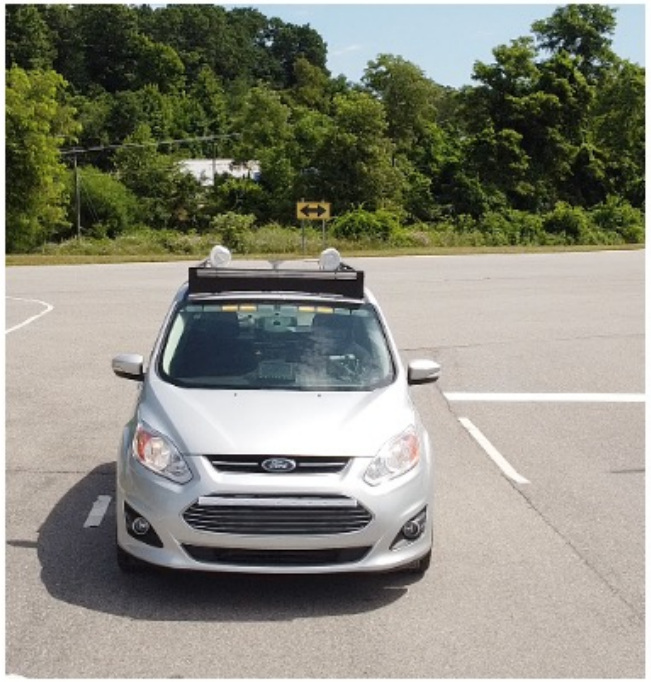
Same light patterns on both vehicles.

Light Pattern Sequence

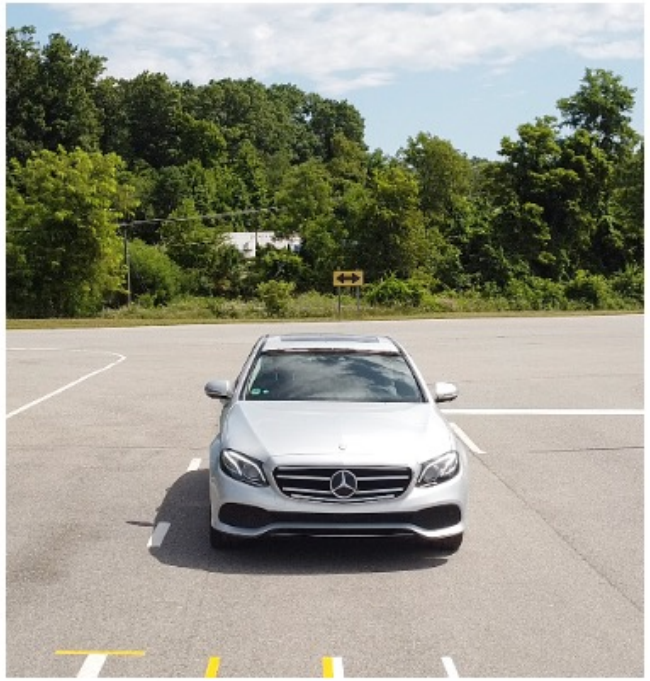
COLOR CONDITION



White Windshield



Amber Windshield



White Windshield

TESTED SCENARIOS

SAME CONSTRAINTS:

- 2 vehicles crossed pedestrians intended path
- 3 trials for each scenario, total of 12 exposures
- 1 trial was used as a baseline, where the eHMI was turned off
- Data collected for every scenario:
  - Crossing-decision
  - Glance
  - Distance
  - Qualitative feedback
  - Survey Data

Scenario Number	Setting	Scenario Type	Speed
1	Intersection	Vehicle Right Turn at a 4-way stop	10 mph
2		Both Vehicles Proceed Straight	10 mph
3	Mid block	Straight Crossing Path at a 1-way stop	20 mph
4		Straight Crossing Path at Midblock	30 mph

SCENARIO 1: Vehicle Right Turn at 4-way stop

APPROACH SPEED – 10 MPH

SCENARIO OVERVIEW

- Participant will be acting as a pedestrian. The participant will never enter roadway will vehicles are navigating intersection.
- Participant will stand on the side of the road utilizing the decision box.
- Vehicles will start at 25 mph and then at 100-foot markings from the intersection the 'AV's' will not press the gas and decelerate to 10 mph.
- 'AV A' will arrive first and come to a complete stop. After 'AV A' comes to a complete stop, the participant will then decide to cross the street or not.
- 'AV A' will take turn with further apex and enter farthest lane to maximize distance between VRUs
- Then 'AV B' will arrive and stop at the stop sign.
- 'AV A' will proceed first followed by 'AV B'.

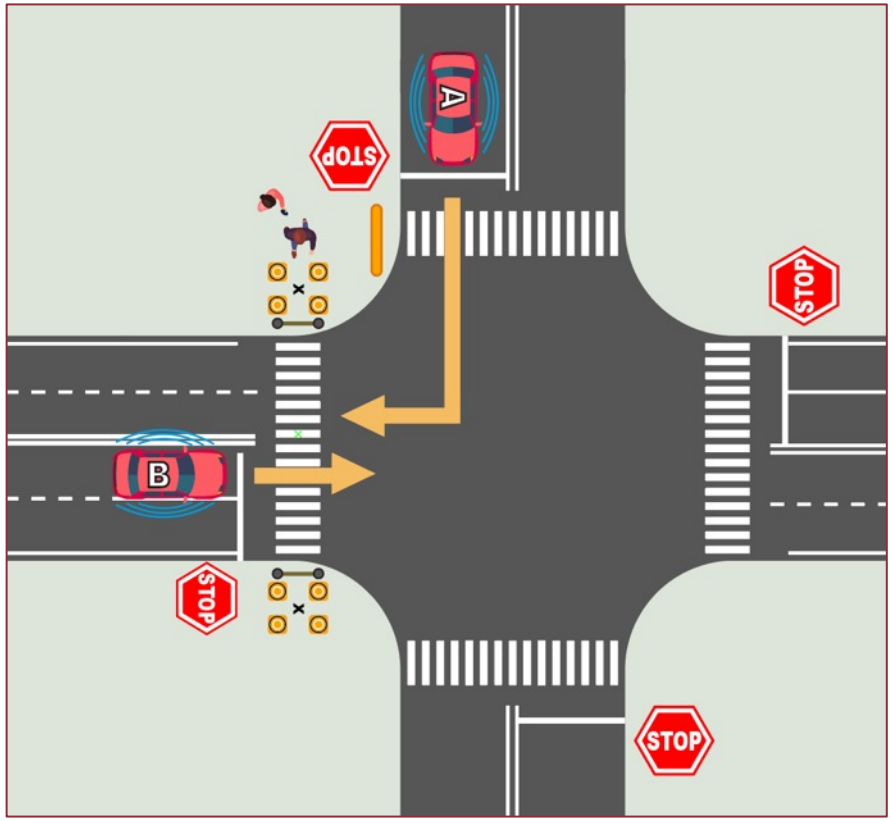
REPEATED THREE TIMES TO SWITCH LIGHT LOCATIONS. VEHICLES WILL STAY IN THE SAME LOCATION.

SCRIPT

- Let's say you are a pedestrian deciding if you would want to cross the street where Highly Automated Vehicles are operational. You will not actually cross the street. Step into the box whenever you feel that you would cross the street. When you would not cross the street step outside the box. Do you have questions before we begin?

RISK MITIGATION

- All vehicles are required to come to a complete stop.
- Barricades will be placed between the participant and any moving vehicles.
- The Mercedes vehicle ('AV B') is equipped with AEB.
- The participant and moderator will be at least one car lane width away from the 'AV' negotiation.
- A jersey barrier will be placed in-between the participant and 'AV A' making the right-hand turn.



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SCENARIO 2: 2 Vehicle Straight Crossing Path at 4-way stop

APPROACH SPEED – 10 MPH

SCENARIO OVERVIEW

- Participant will be acting as a pedestrian. The participant will never enter roadway will vehicles are navigating intersection.
- Participant will stand on the side of the road utilizing the decision box.
- Vehicles will start at 25 mph and then at 100-foot markings from the intersection the 'AV's' will not press the gas and decelerate to 10 mph.
- After the 'AV A' comes to a complete stop, the participant will then decide to cross the street or not.
- 'AV A' will arrive first and come to a stop.
- Then 'AV B' will arrive and stop at the stop sign.
- 'AV A' will proceed first followed by 'AV B'.

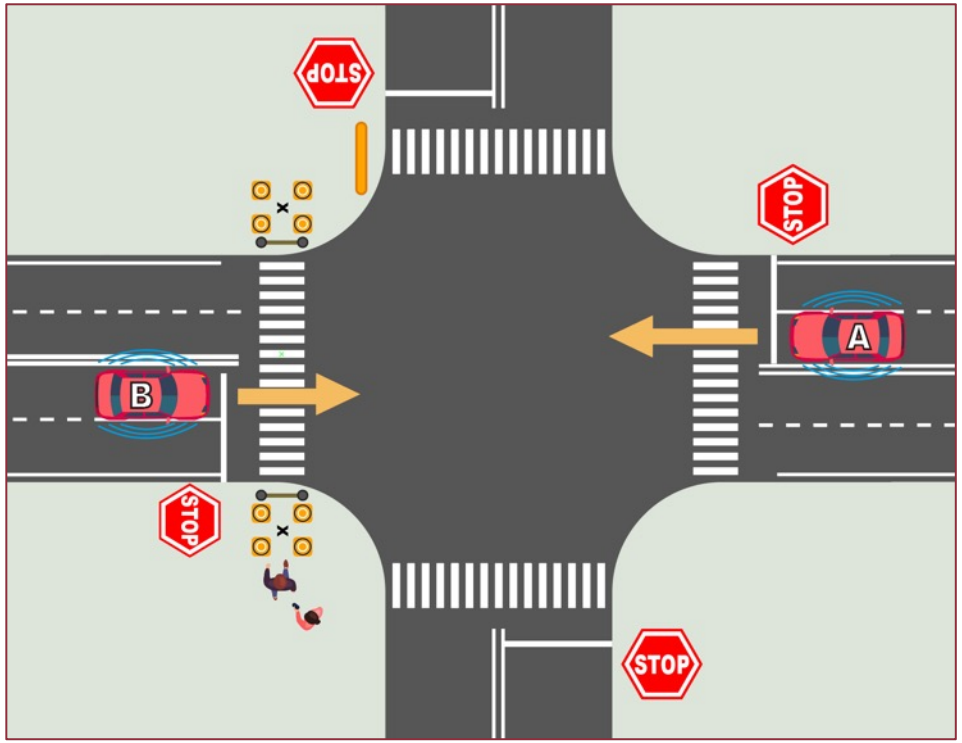
REPEATED THREE TIMES TO SWITCH LIGHT LOCATIONS. VEHICLES WILL STAY IN THE SAME LOCATION.

SCRIPT

- Let's say you are a pedestrian deciding if you would want to cross the street where Highly Automated Vehicles are operational. You will not actually cross the street. Step into the box whenever you feel that you would cross the street. When you would not cross the street step outside the box. Do you have questions before we begin?

RISK MITIGATION

- All vehicles are required to come to a complete stop.
- Barricades will be placed between the participant and any moving vehicles.
- The Mercedes vehicle ('AV B') is equipped with AEB.
- The participant and moderator will be at least one car lane width away from the 'AV' negotiation.



SCENARIO 3: 2 Vehicle Straight Crossing Path at 1-way stop

APPROACH SPEED – 10 MPH

SCENARIO OVERVIEW

- Participant will be acting as a pedestrian. The participant will never enter roadway will vehicles are navigating intersection.
- Participant will stand on the side of the road utilizing the decision box.
- Vehicles will start at 25 mph and then at 100-foot markings from the intersection the 'AV's' will not press the gas and decelerate to 10 mph.
- 'AV B' will approach the intersection first and come to a complete stop.
- Then 'AV A' will proceed down the roadway and drive straight through while 'AV B' remains stopped at the stop sign.
- After 'AV A' is clear from the roadway and has passed, then 'AV B' will make a left turn and proceed down the roadway.

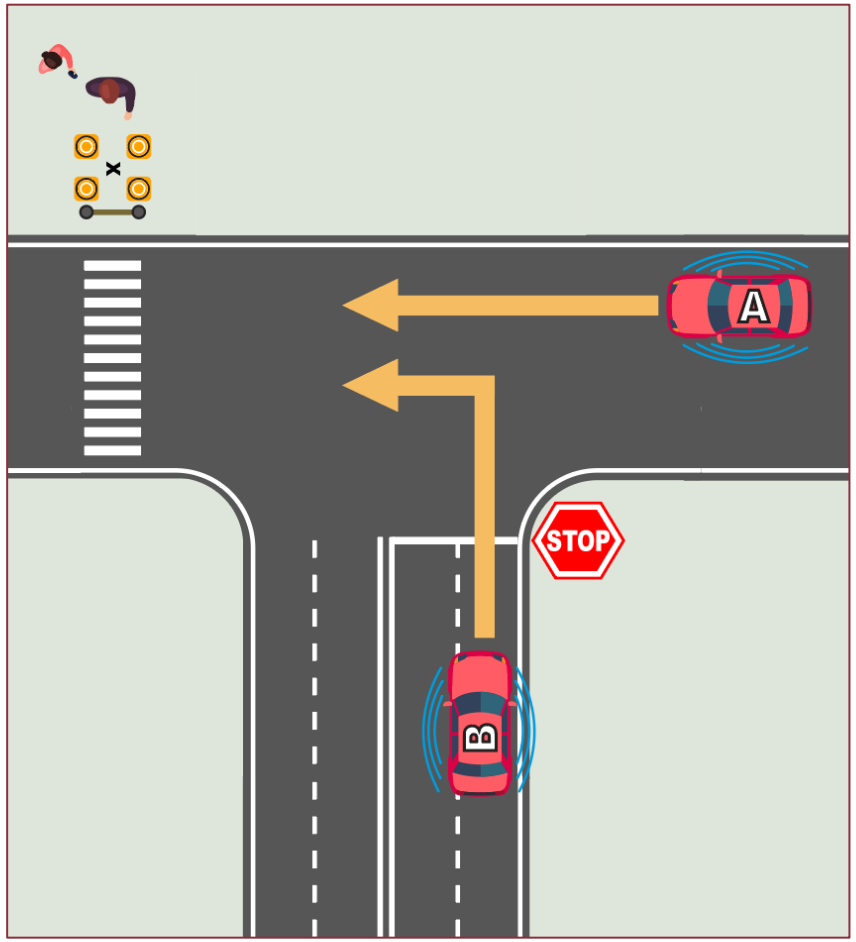
REPEATED THREE TIMES TO SWITCH LIGHT LOCATIONS. VEHICLES WILL STAY IN THE SAME LOCATION.

SCRIPT

- Let's say you are a pedestrian deciding if you would want to cross the street where Highly Automated Vehicles are operational. You will not actually cross the street. Step into the box whenever you feel that you would cross the street. When you would not cross the street step outside the box. Do you have questions before we begin?

RISK MITIGATION

- 'AV B' is required to come to a complete stop.
- Barricades will be placed between the participant and any moving vehicles.
- The Mercedes vehicle ('AV B') is equipped with AEB.
- The participant and moderator will be at least one car lane width away from the 'AV' negotiation.



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SCENARIO 4: 2 Vehicle Straight Crossing Path at Midblock

CONSTANT SPEED – 30 MPH

SCENARIO OVERVIEW

- Participant will be acting as a pedestrian. The participant will never enter roadway while vehicles are navigating intersection.
- The participant will not be informed of the meaning of the light bar and will not cross in this scenario.
- Vehicles will start at 30 mph and remain at that constant speed.
- 'AV A' and 'AV B' will arrive to the cross point at the same time. They will both procced straight without stopping for this midblock scenario.

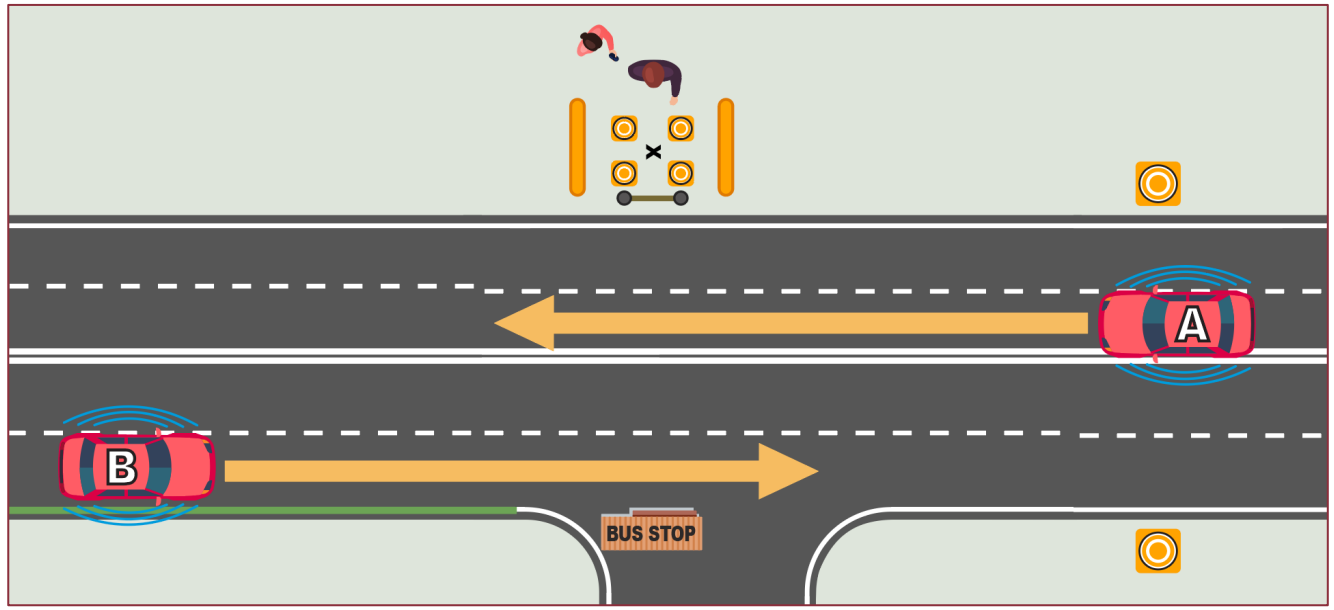
REPEATED THREE TIMES TO SWITCH LIGHT LOCATIONS. VEHICLES WILL STAY IN THE SAME LOCATION.

SCRIPT

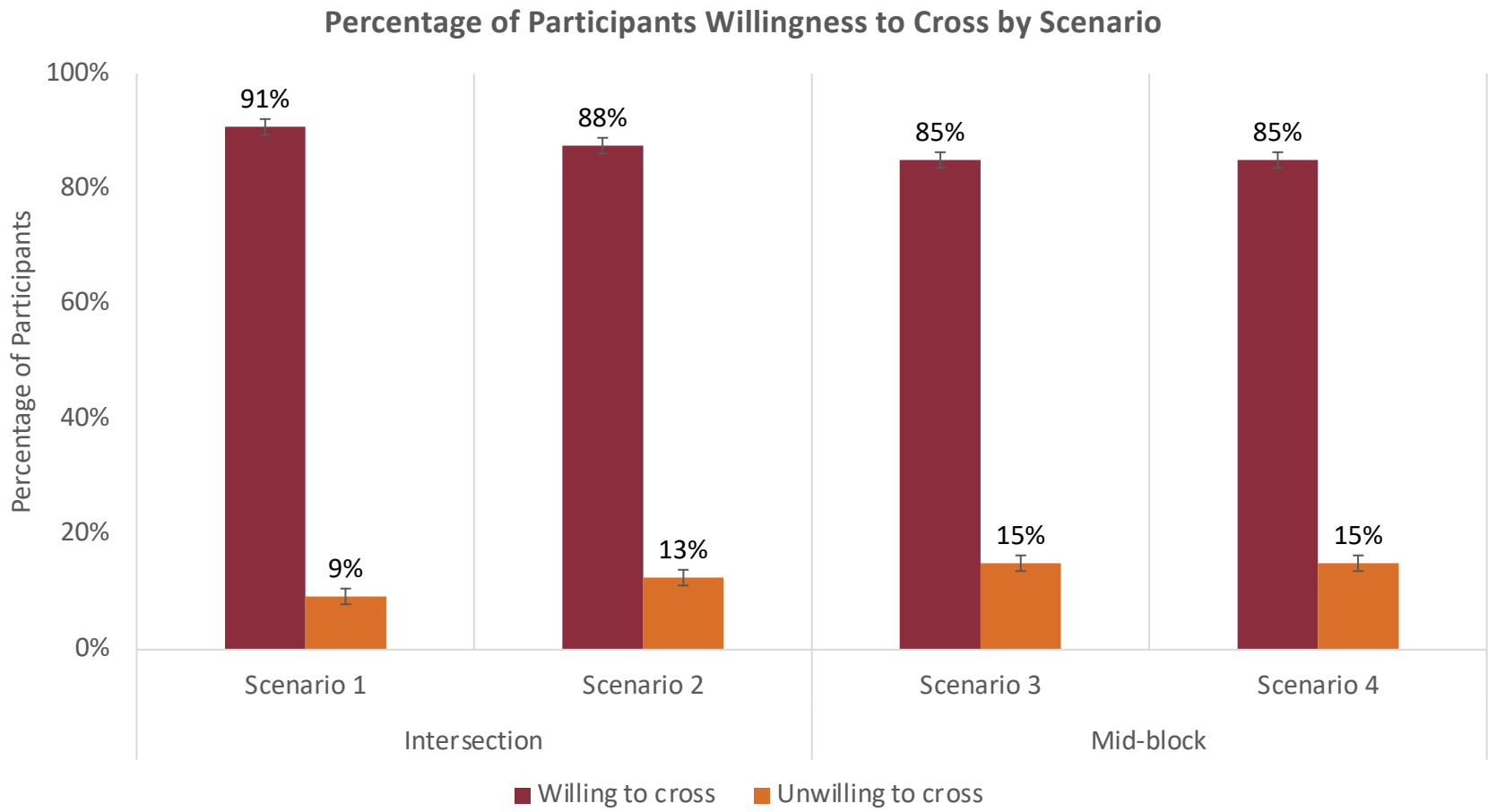
- Let's say you are a pedestrian deciding if you would want to cross the street where Highly Automated Vehicles are operational. You will not actually cross the street. Step into the box whenever you feel that you would cross the street. When you would not cross the street step outside the box. Do you have questions before we begin?

RISK MITIGATION

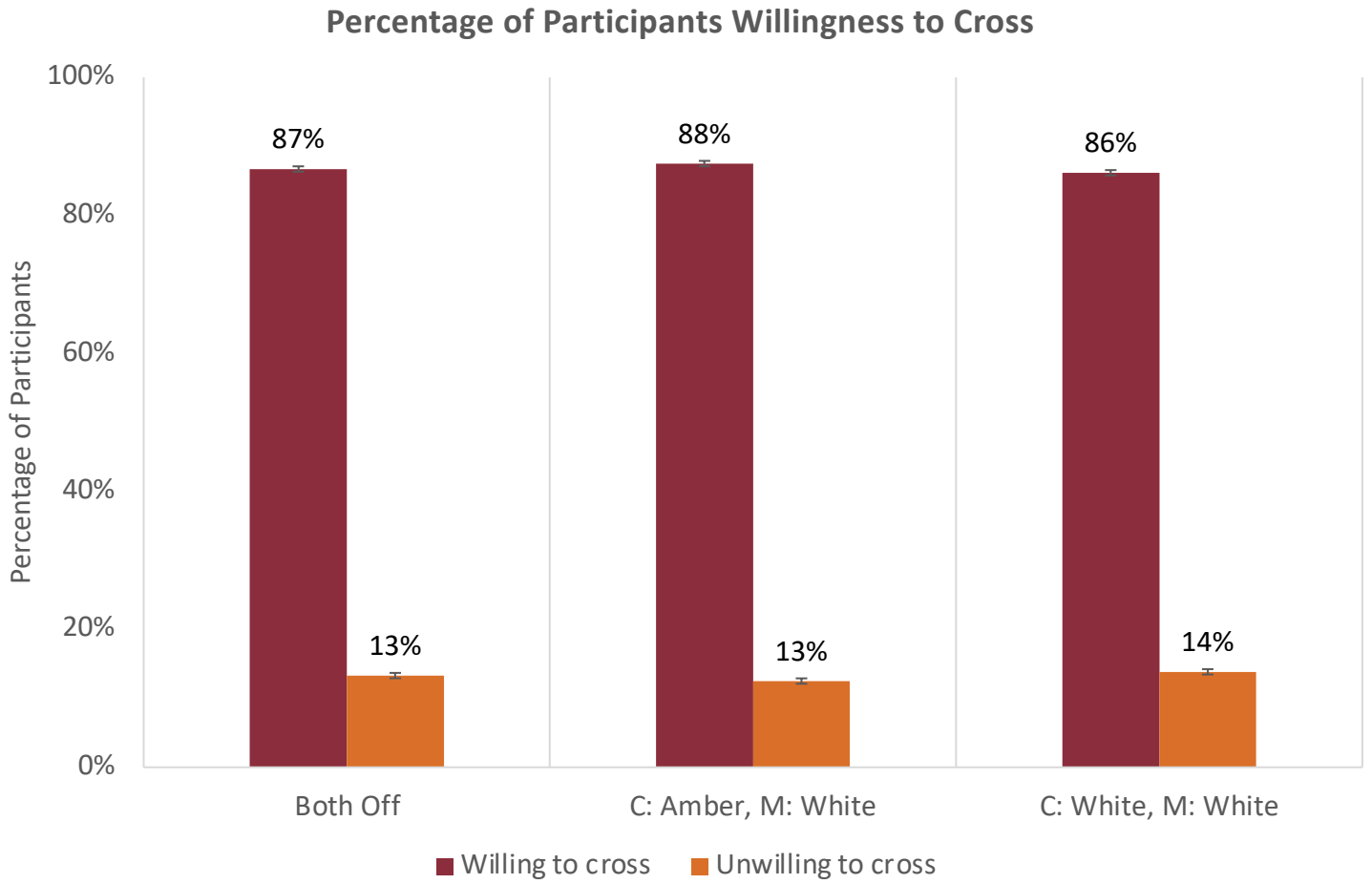
- Barricades will be placed between the participant and any moving vehicles.
- The Mercedes vehicle ('AV B') is equipped with AEB.
- The participant and moderator will be at least one car lane width away from the 'AV' negotiation.



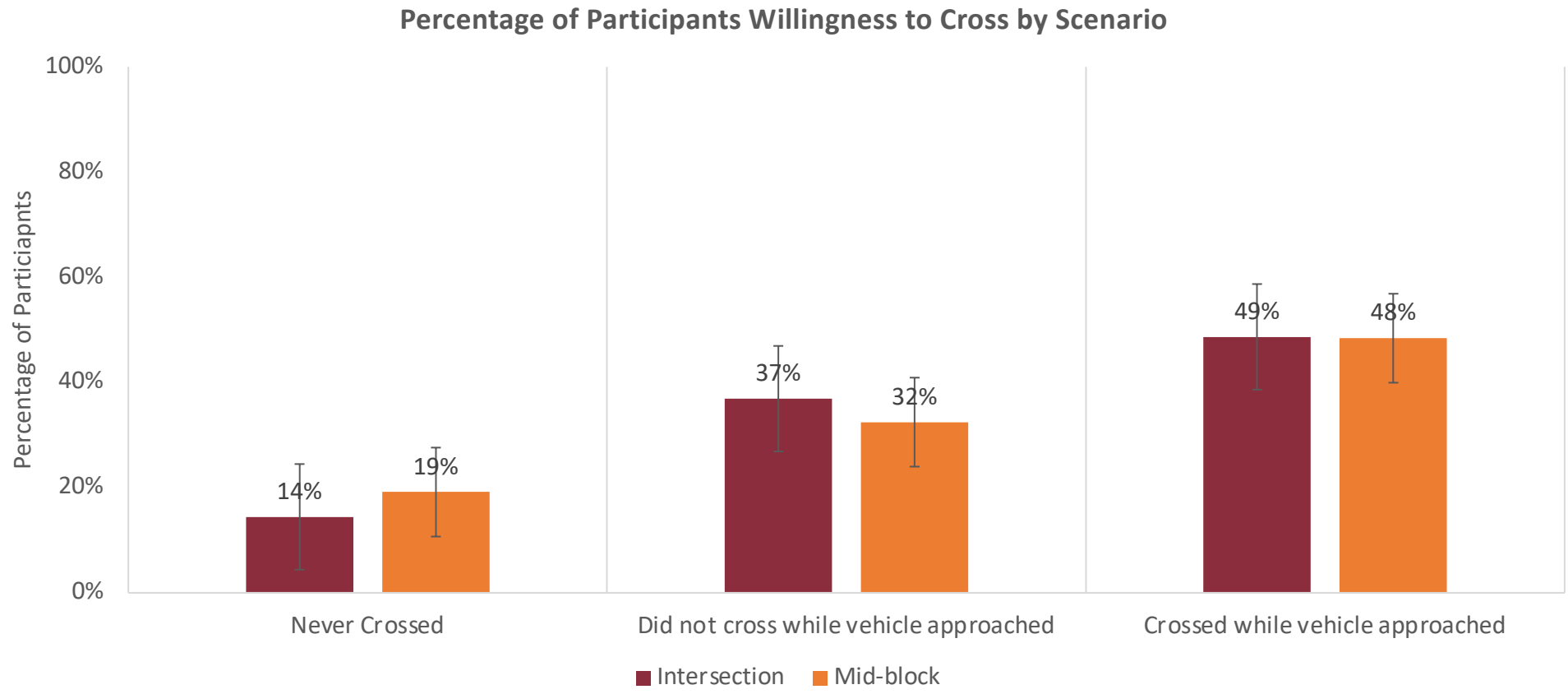
CROSSING DECISION: By Scenario



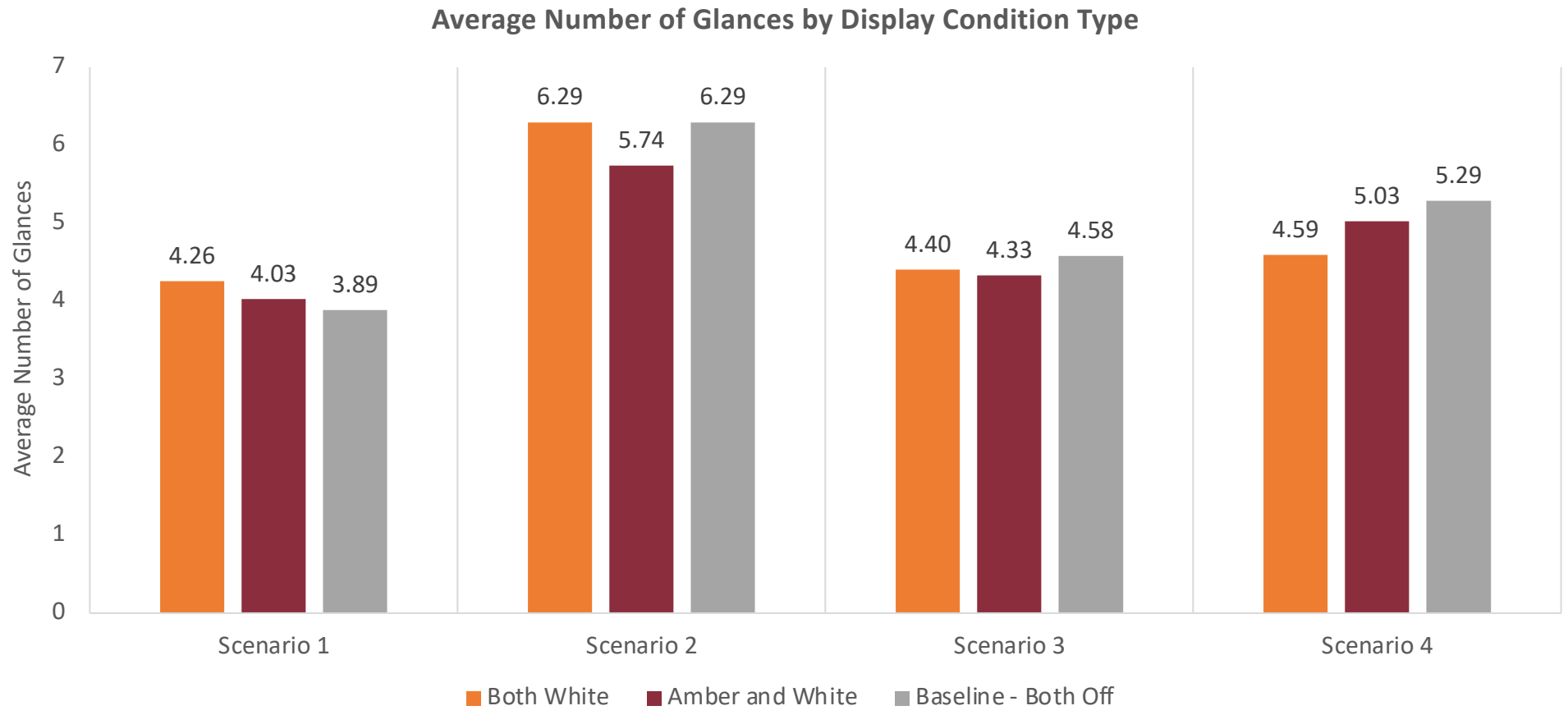
CROSSING DECISION: By Condition



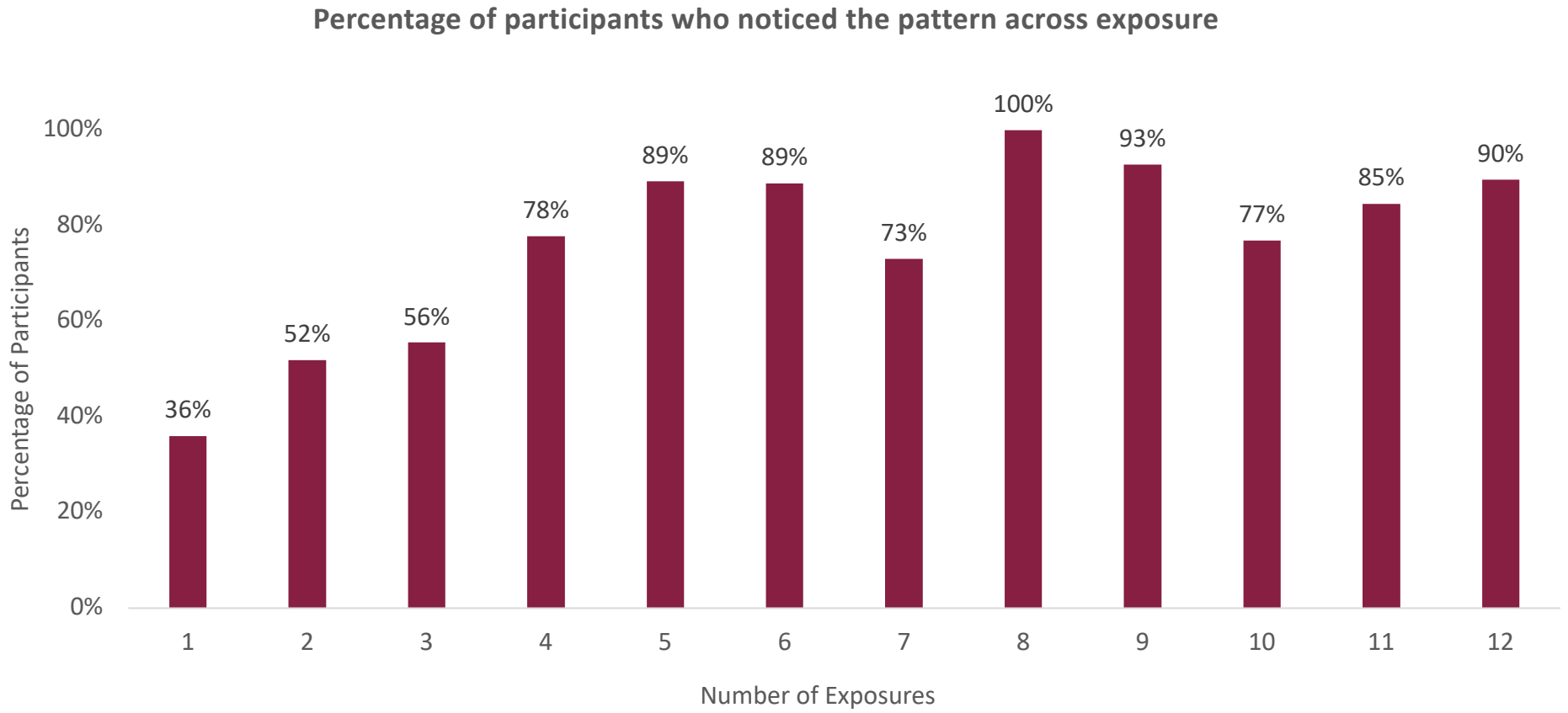
CROSSING DECISION: By Location



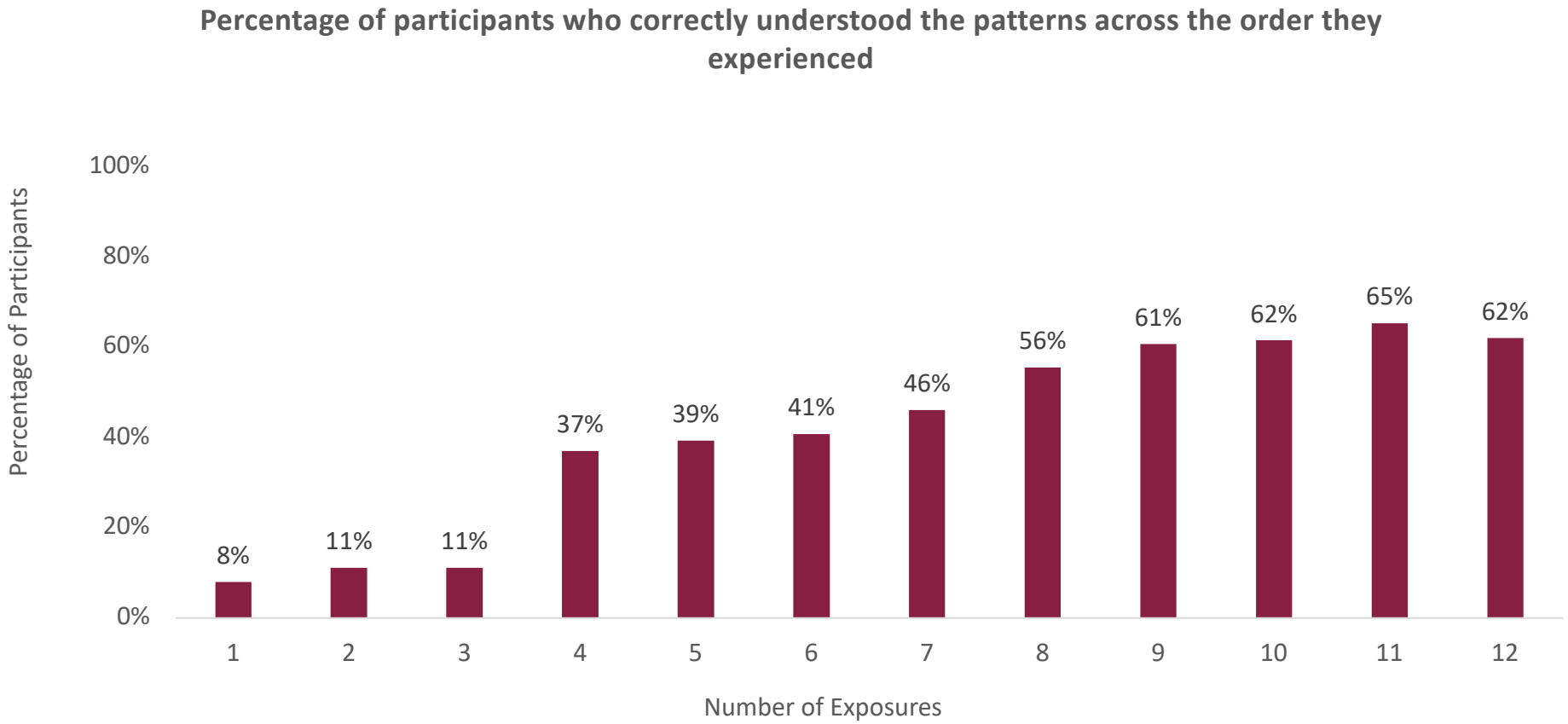
GLANCES: By Condition



NOTICE PATTERN

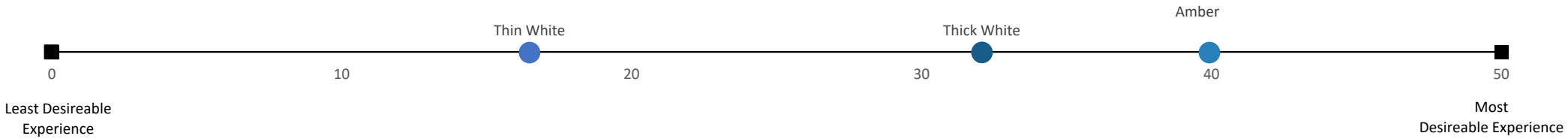


UNDERSTAND THE PATTERN



Desirability

Now that you've seen different systems, we want to understand which type of feedback is best for you personally. I would like for you to rate the systems you just experienced in terms of how it aligned with your most desired experience on a scale of 0 to 50, where 0 = least desired and 50 = most desired. You may choose any number between 0 and 50.



CONCLUSION

Presence of eHMI

- Multiple vehicles increased task complexity and created a hierarchy of attention.
- Relied more on vehicle kinematics and distance over the display.

Type of eHMI

- Participants wanted the vehicle to provide some physical cue or change in behavior.
- Expect eHMI to be standardized across vehicles if they are deployed.

Interpretation of eHMI

- Training and time with the eHMI are desired for easier predictability and transparency of AVs behavior.
- Light bar patterns contradict other real-world applications.
- Over time participants stated that they felt more comfortable relying on the eHMI to make crossing decisions.
- The relative size of the eHMI, the vehicle's distance, and the external environment impacted the visibility of the eHMI.

CONCLUSION

Law Enforcement Officer Cohort

- Aid in accident reconstruction
- Need to be informed of the eHMIs presence and taught its function
- Potential for confusion with other emergency type vehicles
- Reiterated the need for standardization