Allusion Project Overview

Alexandria Rossi Alvarez
Dr. Charlie Klauer
Kevin Grove

VIRGINIA TECH
TRANSPORTATION
INSTITUTE

Overview

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- Study Design
- Scenario Overview

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- Qualitative Analysis
- Patterns
- Crossing Decision by Scenario
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- Crossing Decision by Condition
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Background

BACKGROUND

- Common driving pedestrian scenarios
- Test communication devices
- Currently most research is subjective data and not performance based
- Aim to use performance decision metrics with supplemental qualitative data

LITERATURE REVIEW:

- Most research uses Augments and Virtual Reality, and laboratory type settings
- Not many studies that are an actual roadway environment
  - Slider device study to measure participants' willingness to cross the street (Day, Debargha et al.)
- External validity issues

Objectives & Research Questions

External Communication Impact

1. Does head-pose and decision-making behavior change once a participant understands what the vehicles are communicating?
2. How many exposures to vehicle external communication does it take for participants to understand the meaning of the displays?

Light Bar Factors

1. Does the location of vehicle external communication influence head-pose behavior and decision-making?
2. Does the color of vehicle external communication influence head-pose and decision-making?
3. Is there an influence on head-pose or decision-making when the vehicle external communication is communicating when the vehicle is yielding, stopped, or about to proceed?

Testing Scenarios

1. Does the objective data collected across these scenarios correlate to the qualitative information collected?
2. Doe these testing scenarios provide reliable human performance data, specifically in measures of decision-making and head-pose?

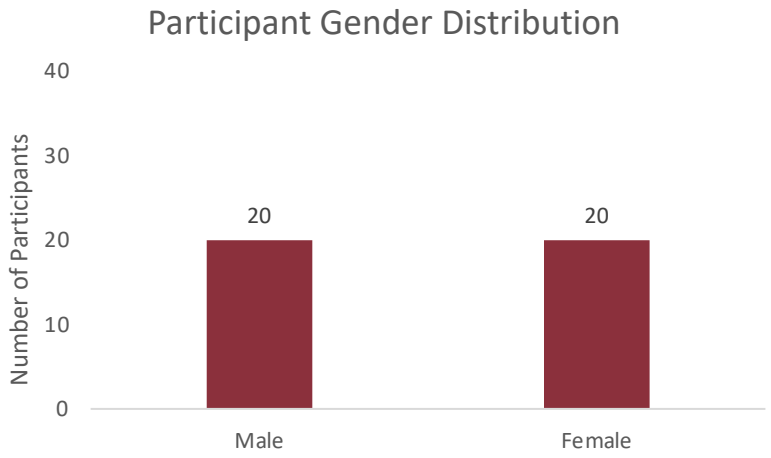
Study Design

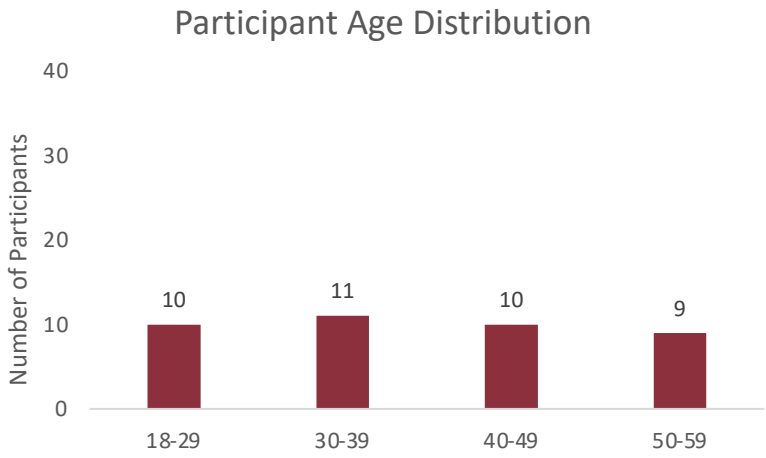
STUDY DESIGN

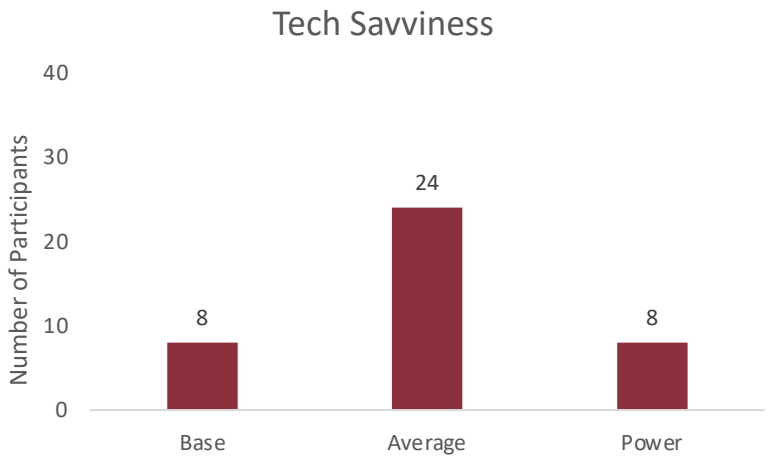
- 40 participants
- With-in subject design
- Two pseudo highlight automated vehicles
- Assessed external communication for an HAV from both a pedestrian and passenger perspective
- Pedestrian scenarios, participants had to decide when they would or would not cross the street

Participant Vehicle with COVID-19 Dividers.

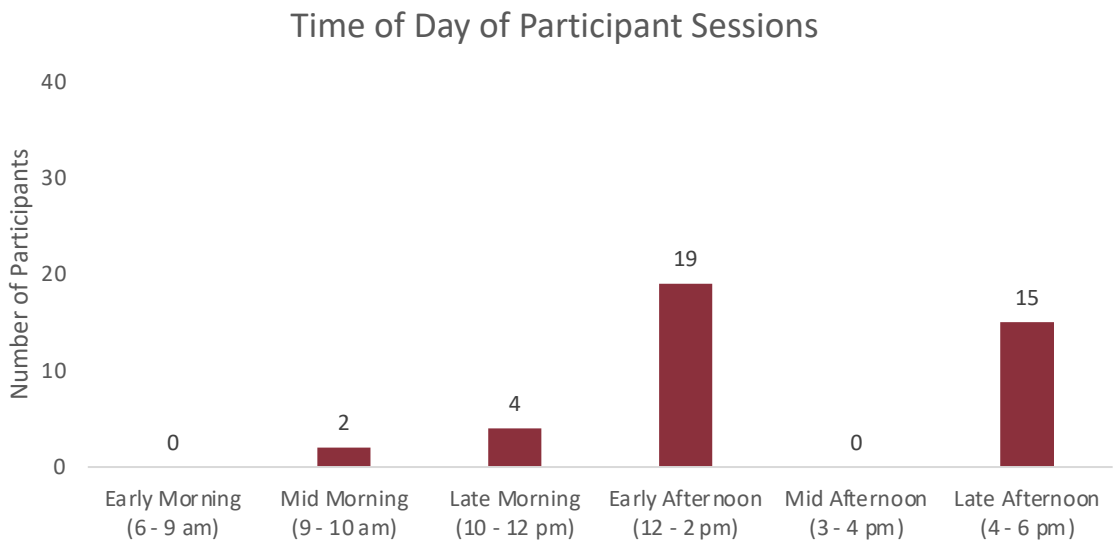
Participant Demographics

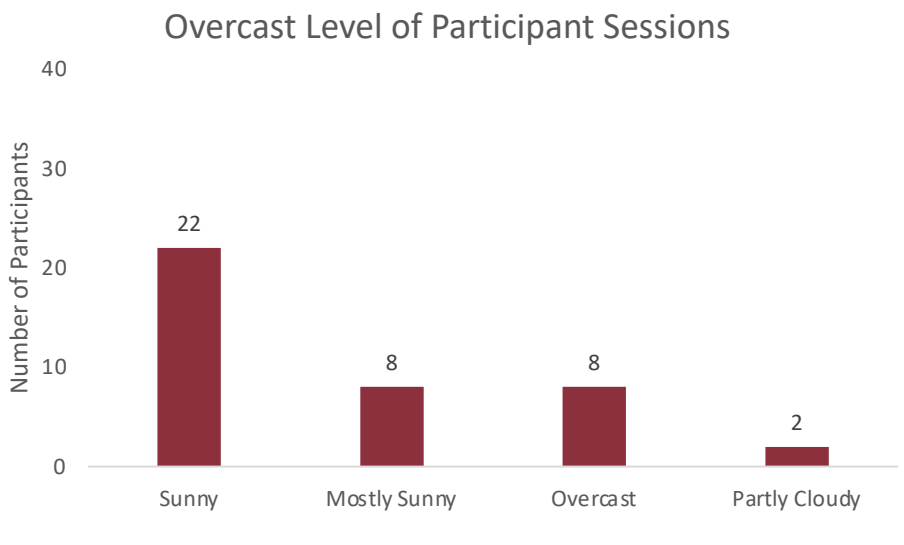






Participant Session Summary





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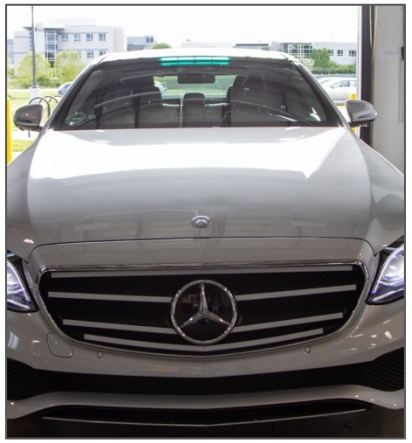
STUDY DESIGN

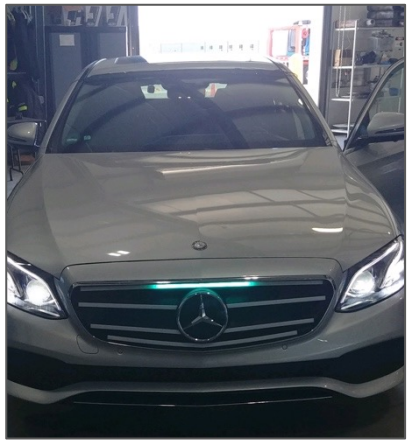
Group	Variable	Levels	Description
Vehicles	Light Bar Location	2	1) Grill 2) Windshield
Vehicles	Light Bar Color	2	1) White 2) Teal
Vehicles	Light Bar Pattern	3	1) Yield 2) Stop 3) Proceed
Scenario	Passenger	4	1) Naïve 2) Scenario 2 3) Scenario 3 4) Steve
Scenario	Pedestrian	4	1) Scenario 5 2) Scenario 6 3) Scenario 7 4) Scenario 8

White Windshield

White Grill



Teal Windshield



Teal Grill

STUDY DESIGN

Glances to HAV
The number of glances the participants make to the HAV throughout a single scenario trial.

Distance to HAV
The distance between the participant and the vehicle when they decide to cross the street or not to cross the street (i.e., when they step inside and outside the decision-making box).

Crossing Decision
Quantify how many times does the participant decides to cross the street across scenario and vehicle condition.

Learning Over Exposure
Quantify when the participant correctly interprets the patterns of the light bars. How many trials does it take for the participant to identify the vehicles' lights and the patterns correctly.

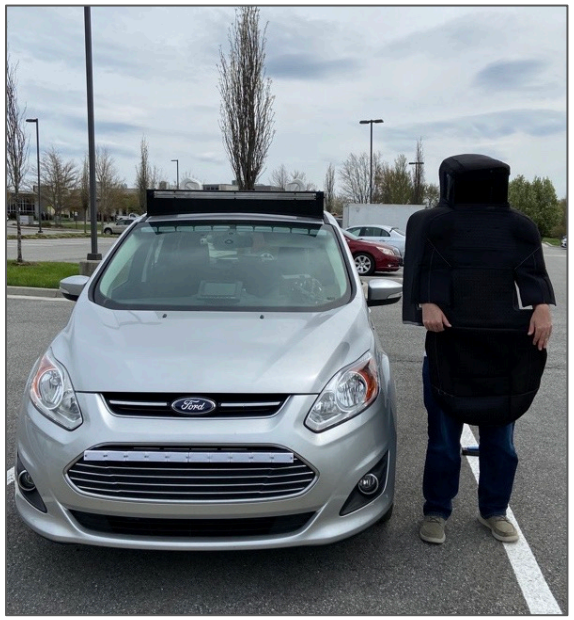
LOCATION: Surface Street

- Portable, reconfigurable buildings and other infrastructure elements
- Multiple actor (e.g., multiple vehicles, pedestrians, and cyclists) scenarios
- Reconfigurable roundabout
- Multiple merge areas
- Reconfigurable automation-compatible pavement markings
- Multilane layouts
- Signalized intersections with various geometries and numbers of lanes
- Multiple parking and passenger pick-up/drop-off areas

Aerial Photo of Surface Street

SEAT-SUIT & CONTROLS

- To simulate a fully self-driving experience without using an actual autonomous vehicle
- VTTI developed a way to conceal the driver with a “seat suit”
- Creates the illusion of a fully autonomous vehicle, which is necessary to test and evaluate real-world encounters and behaviors.
- Control boxes for light location, color, and patten



Seat-Suit A

Seat-Suit B

Pattern Control Box

Location and Color Control Box

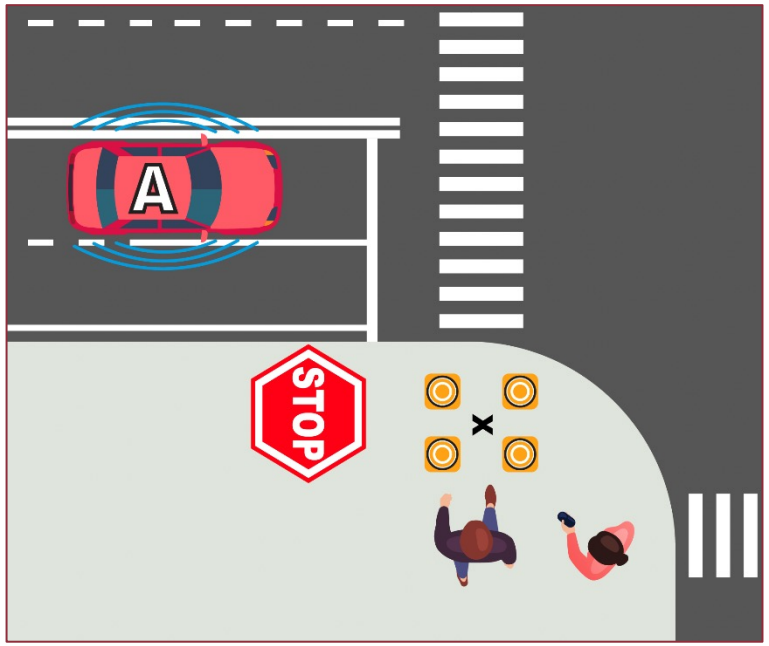
LIGHT PATTERNS TESTED

THREE PATTERNS:
(1) Drive: Solid
(2) Yielding: Out to In
(3) Ready: Blink

Same light pattern on both vehicles.

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



Scenario Overview

SCENARIO ORDER

All sessions will be completed in the same scenario orders. This is to limit the potential for risks if the complicated scenario order were to change.

PEDESTRIAN SCENARIOS

- Naïve participant at 4-way stop (Repeated 4 times)
- Vehicle Right Turn at 4-way stop (Repeated 2 times)
- Both Vehicles Proceed Straight (Repeated 2 times)
- Lane Change and Steve (Repeated 2 times)

PASSENGER SCENARIOS

- Vehicle Lane Change with Expert Pedestrian (Repeated 2 times)
- 4-way Stop and Vehicle Left Turn (Repeated 2 times)
- Construction Zone With Flagger (Repeated 2 times)
- Mid-block Lane Change (Repeated 2 times)

SCENARIO 1: Naïve participant at 4-way stop

APPROACH SPEED – 10 MPH

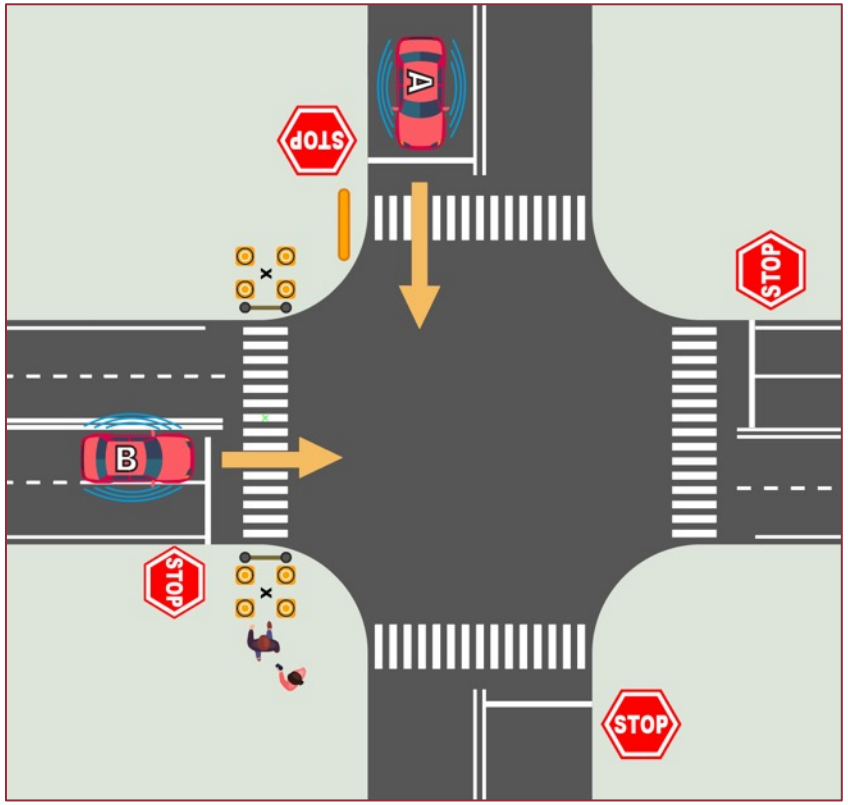
SCENARIO OVERVIEW

- 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 25 mph and then at 100-foot markings from the intersection the 'AV's' will not press the gas and decelerate to 10 mph.
- Vehicle B arrives first, and then A.
- Vehicle B will proceed first, then A.

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

RISK MITIGATION

- All vehicles are required to approach intersection at 10 MPH and come to a complete stop.
- Barricades will be placed in appropriate locations 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 2: Vehicle Right Turn at 4-way stop

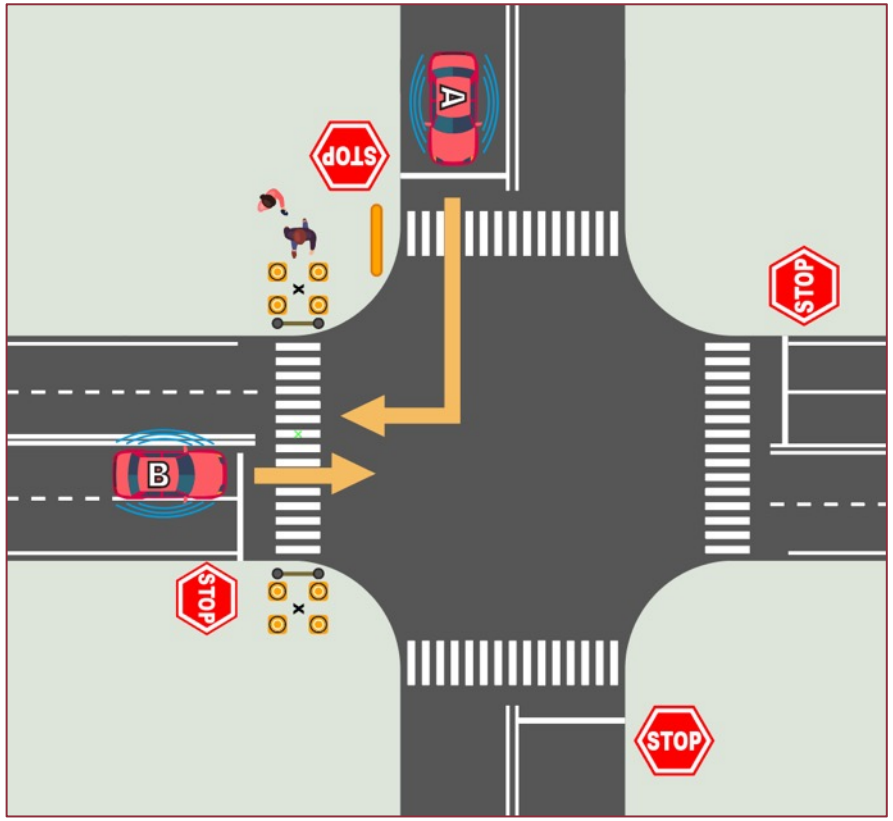
APPROACH SPEED – 10 MPH

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'.

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.



SCENARIO 3: Both Vehicles Proceed Straight

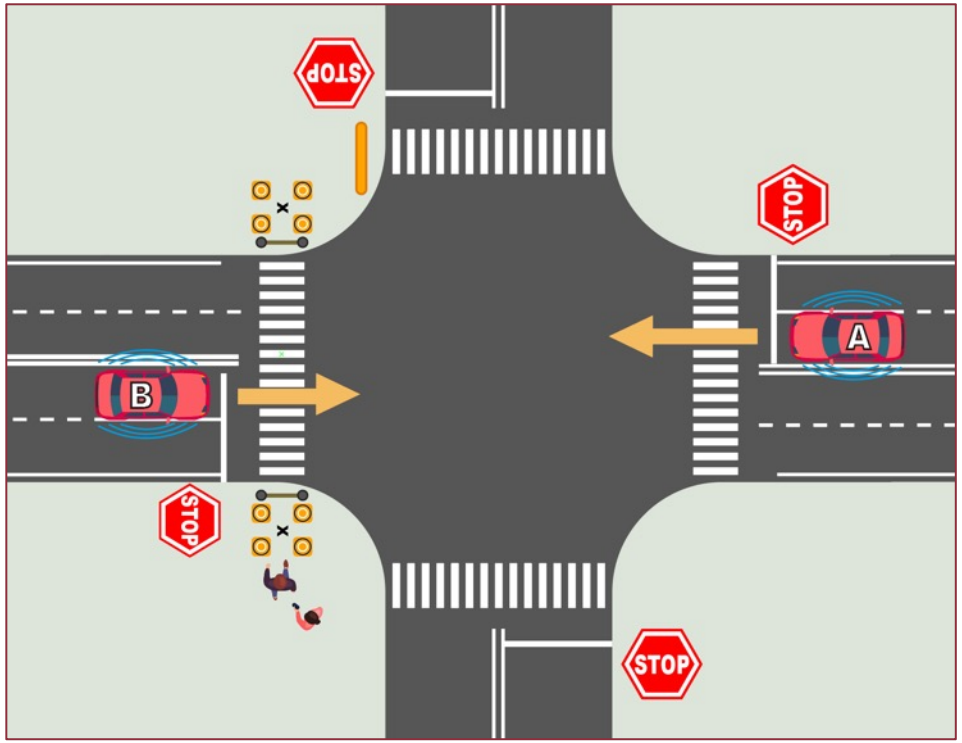
APPROACH SPEED – 10 MPH

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'.

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.
- Mercedes vehicle will have AEB.

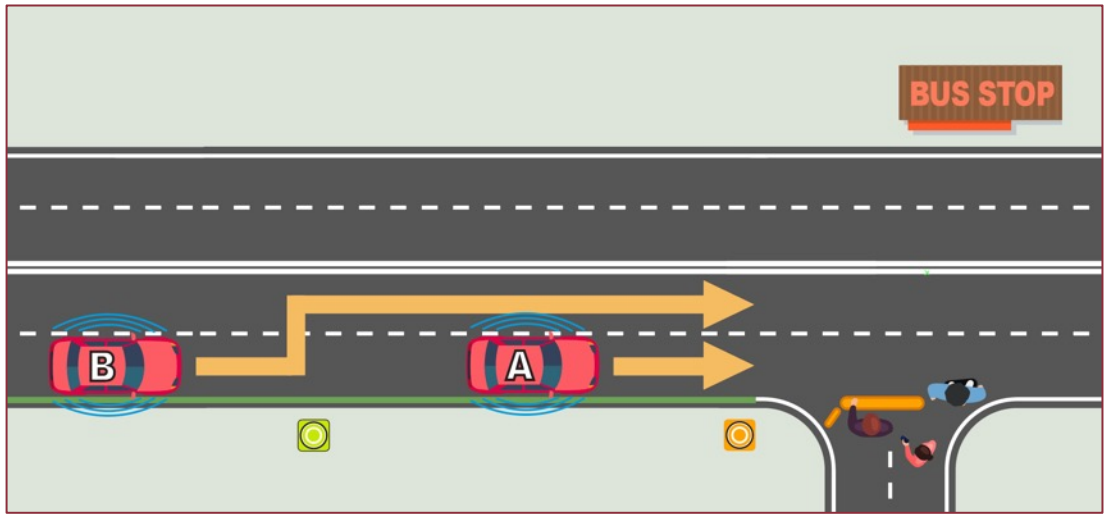


SCENARIO 4: Lane Change and Steve

SPEED – 35 MPH

SCENARIO OVERVIEW

- Participant will be in control of fake pedestrian (Steve).
- Participant will direct the fake pedestrian target to cross in front of the vehicles.
- A yellow/green cone will be on the right-hand side of the road to indicate where 'AV B' will need to complete the lane change.
- An orange cone will be on the right-hand side of the road to indicate where the 'AV A' will need to begin braking.
- Leading 'AV A' will stop and yield for the crossing fake pedestrian.
- The following 'AV B' will pull from behind the leading 'AV A' and the passenger vehicle into the next lane and yield to the researcher with a hard brake.
- After 'AV B' completed the lane change, then 'AV B' will hard brake (.7 g brake) in order to maintain distance.



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.
- Yellow cone indicate when 'AV B' will complete lane change at the same point across trials.
- Orange cone indicate when 'AV A' will begin to brake at the same point across trials.
- The participant and moderator will be at least one car lane width away from the scenario.
- Vehicle B will lane change without applying brakes and THEN brake at ~ .7g.
- Barricades will be place between the participant and any moving vehicles.

SCENARIO 5: Lane Change with Expert Pedestrian

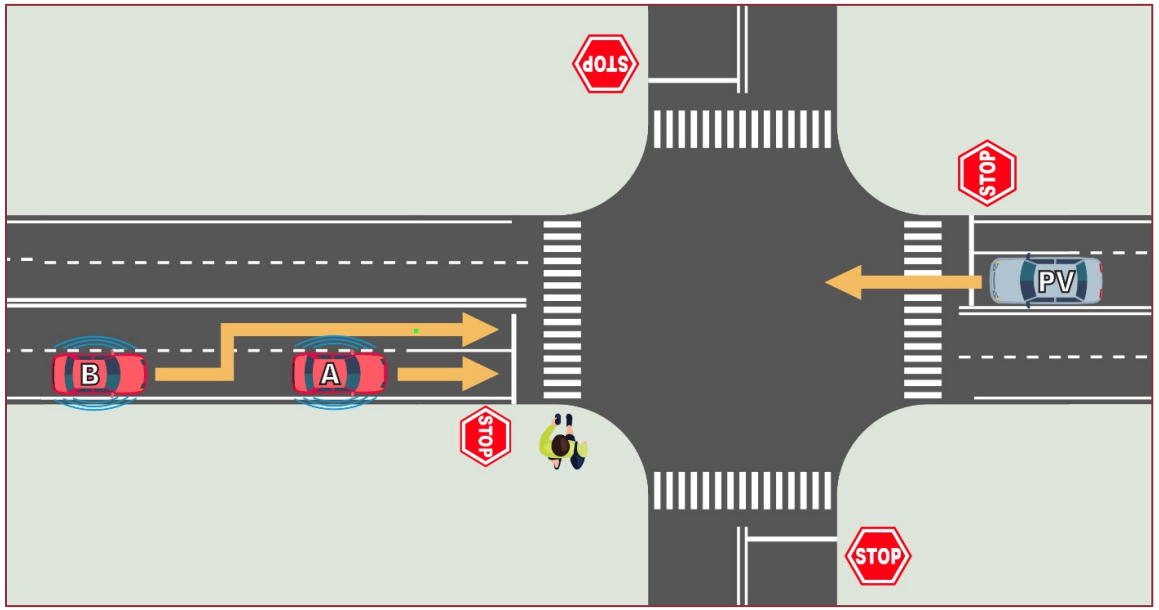
APPROACH SPEED – 10 MPH

SCENARIO OVERVIEW

- Participant will be acting as a passenger inside the test vehicle (PV).
- The 'expert pedestrian' is a trained researcher.
- The participant will sit in the passenger seat of PV and observe the scenario.
- 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.
- Leading 'AV A' will stop and yield for the crossing researcher.
- The following 'AV B' will pull from behind the leading 'AV A' and go into the next lane. The vehicle will come to a normal stop. The Vulnerable Road User (VRU) will never be in front of a vehicle that is moving.
- 'AV A' will proceed through the intersection, followed by 'AV B'.

RISK MITIGATION

- All vehicles are required to come to a complete stop for a period *of 5 sec.*
- 'Expert pedestrian' only enters the first lane after 'AV A' has completely stopped. 'AV B' is approaching, but pedestrian NEVER enters 'AV B''s lane of travel.
- The Mercedes vehicle ('AV B') is equipped with AEB.
- 'Expert pedestrian' does not enter roadway until 'AV A' is completely stopped.
- 'Expert pedestrian' NEVER goes further and never enters the lane of 'AV B'.



SCENARIO 6: 4-way Stop and Vehicle Left Turn

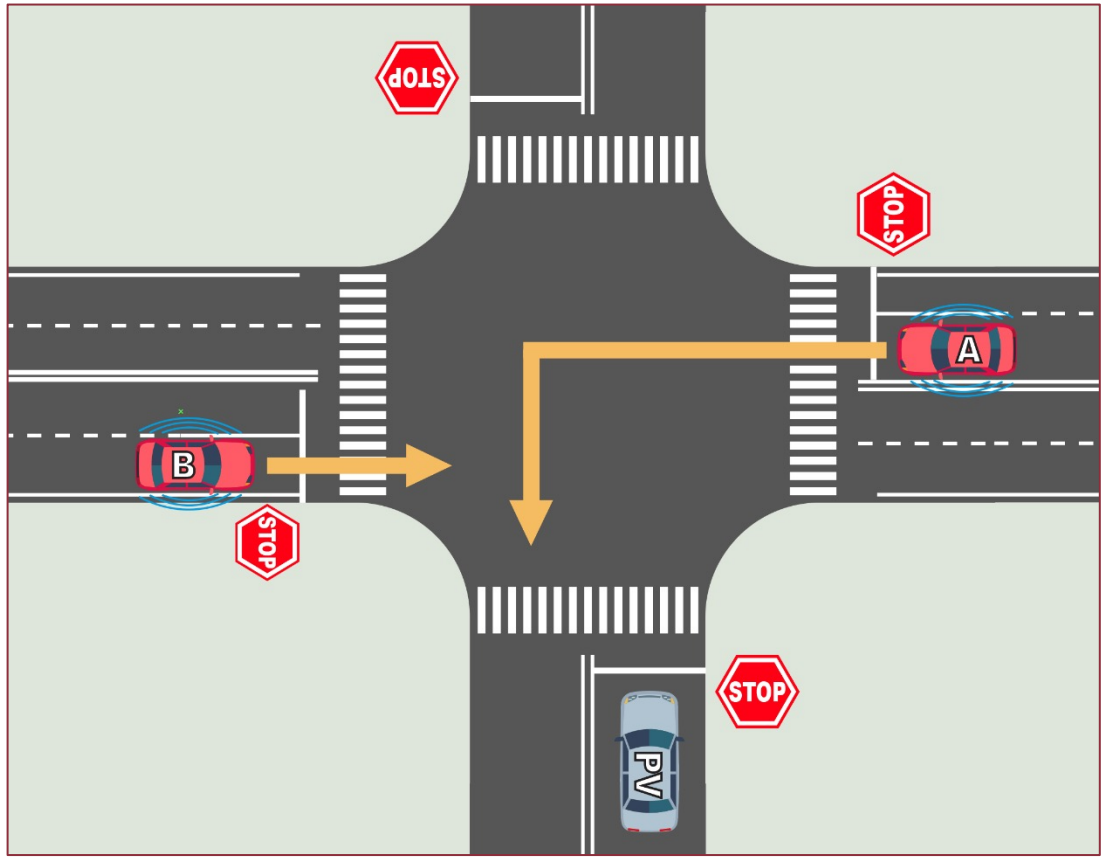
APPROACH SPEED – 10 MPH

SCENARIO OVERVIEW

- Participant will be acting as a passenger inside the test vehicle (PV) and observe the scenario.
- 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.
- The two 'AV's' (both A and B) will arrive at the same time and negotiate who will proceed into the intersection first.
- 'AV B' will go first, and then 'AV A'.

RISK MITIGATION

- All vehicles are required to come to a complete stop.
- The Mercedes vehicle ('AV B') is equipped with AEB.

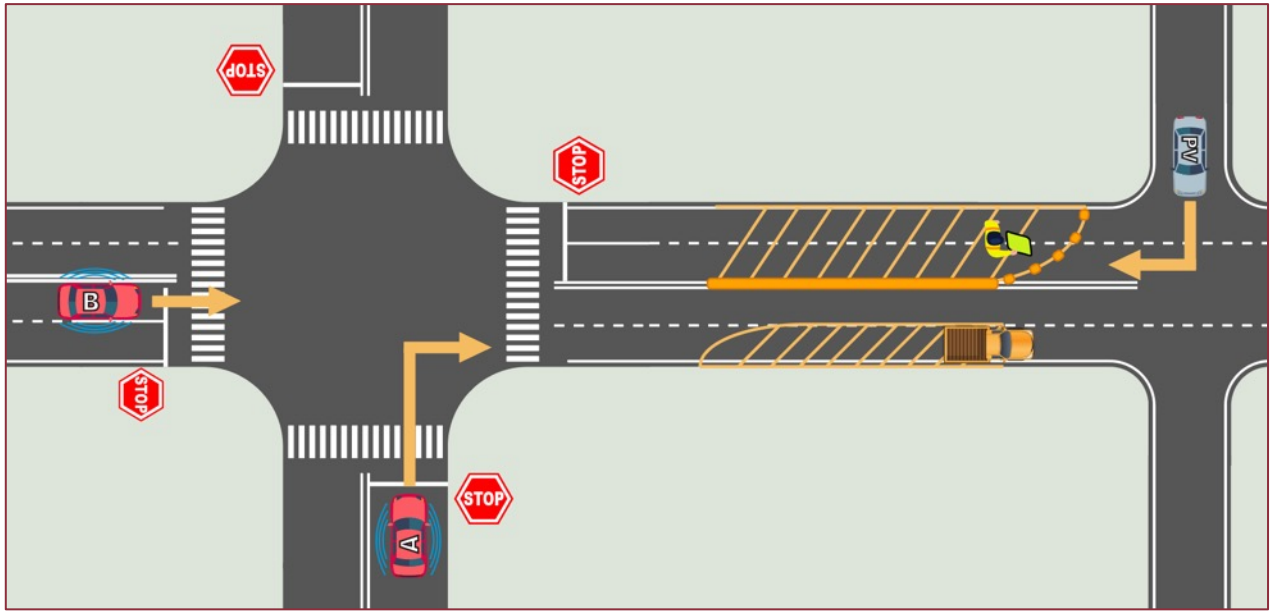


SCENARIO 7: Construction Zone With Flagger

APPROACH SPEED – 10 MPH

SCENARIO OVERVIEW

- Participant will sit in the test vehicle and observe the scenario.
- 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.
- The right turning 'AV A' will arrive at the stop sign first and turn into the closed lane.
- Then it will wait after the straight ongoing 'AV B' finishes the lane change, and then proceed with its own lane change.
- The test vehicle will proceed straight from the other side of the road as the 'AV's' approach the intersection and then park inside the lane, following the flag persons' instructions.



RISK MITIGATION

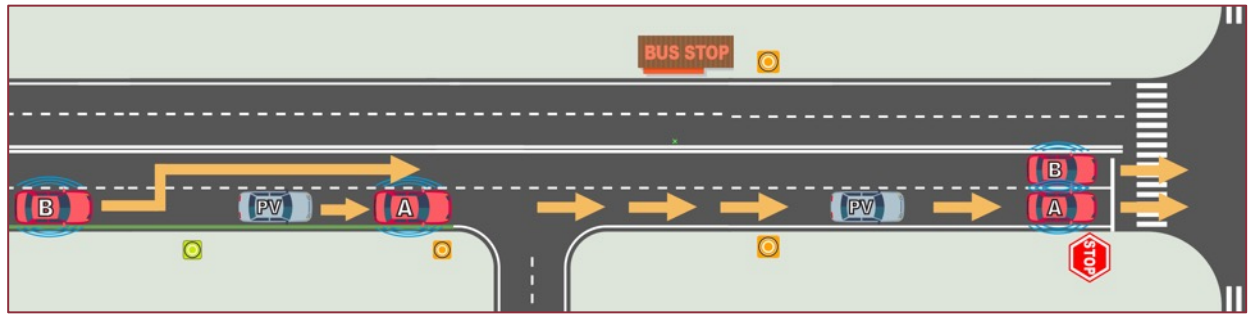
- All vehicles are required to come to a complete stop.
- The Mercedes vehicle ('AV B') is equipped with AEB.
- Flagger will be behind the barricades.
- 'AV A' will always yield to 'AV B'.

SCENARIO 8: Mid-block Lane Change

APPROACH SPEED – 10 MPH

SCENARIO OVERVIEW

- The participant will sit in the passenger seat of the car and observe the scenario.
- In the first segment, leading 'AV A' will stop and yield at near the street entrance after the fence (there will be no one there, and it will be a controlled stop).
- A yellow/green cone will be on the right-hand side of the road to indicate where 'AV B' will need to complete the lane change.
- An orange cone will be on the right-hand side of the road to indicate where the 'AV A' will need to begin braking.
- The following 'AV B' will pull from behind the leading 'AV A' and the passenger vehicle into the next lane and continue straight.
- Passenger vehicle will remain behind 'AV A'.
- 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' and 'AV B' will come to a stop at the stop sign, and then proceed straight.



RISK MITIGATION

- All vehicles are required to come to a complete stop.
- The Mercedes vehicle ('AV B') is equipped with AEB.
- Yellow cone indicate when 'AV B' will complete lane change at the same point across trials.
- Orange cone indicate when 'AV B' will begin to brake at the same point across trials.

Executive Summary

Executive Summary

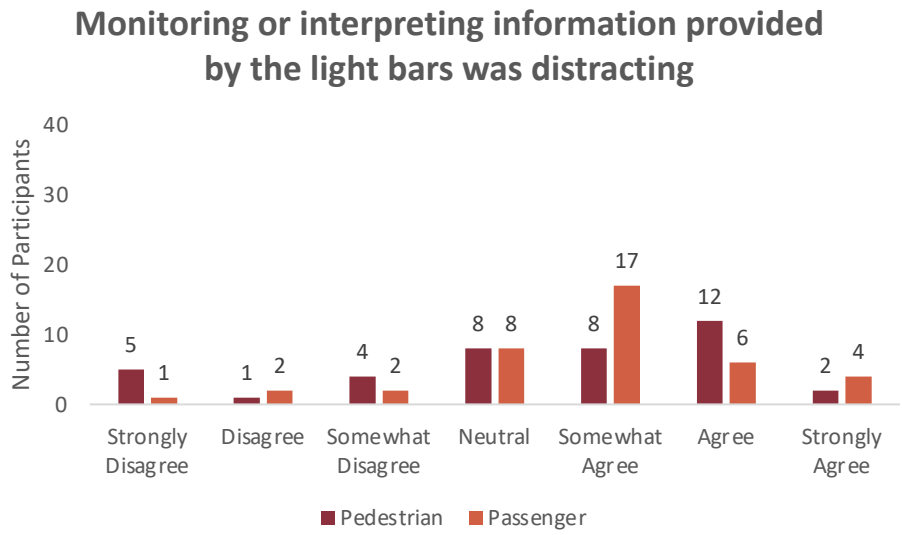
Overall, participants were overwhelmed making crossing decisions with multiple vehicles with light bars in their crossing vicinity.

Fighting for attention.
Participants experienced difficulty prioritizing their attention across multiple vehicles and the different light bars.

Complete patterns were missed.
'Yielding' and 'Driver' pattern were most recognized, whereas the 'Ready' pattern was missed. It was challenging to pay attention to two light bars in their crossing vicinity.

Crossing decision not impacted by condition.
Overall, the location impacted perceived system desirability, but there was no significant difference amongst conditions regarding crossing decisions.

Not necessary as a passenger.
As a passenger, participants did not find the light bars a necessary feature. Light bars added another complex level of information that needed to be deciphered, and they know where to look for more informative information (brake lights, turn signal).



Executive Summary

Overall, participants were overwhelmed making crossing decisions with multiple vehicles with light bars in their crossing vicinity.

Windshield location preferred.
Light bar location in the windshield was preferred over the grill placement due to ease of visibility.

Color preference was split.
Color preference was nearly split between teal and white, with a few more preferring Teal.

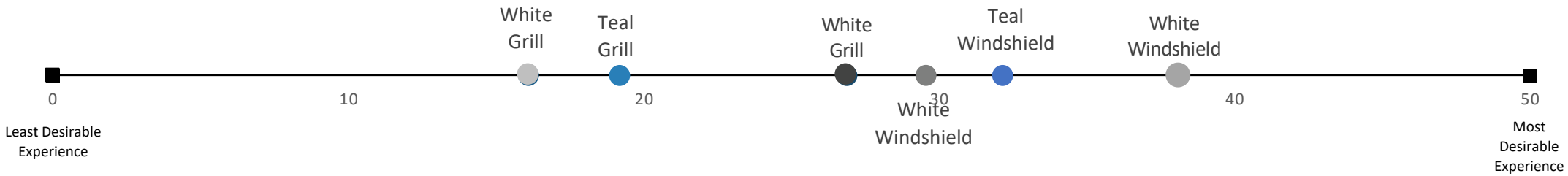
Preferred lightbars stood out, were thicker, and segmented.
Light bars that stood out from the vehicle were preferred as they were more noticeable.

Split on Emergency Vehicle.
Participants were nearly split on if they thought the light bars could confuse other vehicles on the roadway.

Desirability

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.



Desirability Qualitative Analysis

The location of the lights bar had the biggest impact on overall desirability.

Overall Findings

Overall, the windshield conditions were clustered higher on the desirability scale against the grill location. The higher placement allowed for easier visibility, and this location is where participants look for vehicle information as a pedestrian.

Additionally, for both location segments, the color order was the same. Participants preferred the thicker white light bar, followed by the Teal light bar, then the thinner white light bar. This preference was due to the ease of visibility of the light bar across exposures.

White Windshield, Thick

Participants preferred the white windshield location the most because the light bar was thicker and more prominent on the vehicle. Additionally, the location in the windshield was ideal because it was in the participants' line of sight.

Teal Windshield

Participants preferred the Teal windshield next due to the location. Participants preferred this location and even though this light bar was thinner the Teal color allowed for easier visibility.

White Windshield, Thin

The white windshield condition was the least preferred among the windshield options. This was because the light bar was too thin, which made it difficult to view. However, since the light bar was placed in the windshield it was still rated higher than other conditions.

White Grill, Thick

Compared to the other grill conditions, this light bar was thicker and the most visible. However, participants did not like the placement of the light bar because they do not look for vehicle information in the grill.

Teal Grill

Participants did not prefer this location because they do not look for vehicle information in the grill. However, the Teal light allowed for easier visibility compared to the following condition.

White Grill, Thin

Overall, participants did not prefer this condition due to the visibility of the color, location, and thickness. This light bar blended in with the vehicle making it difficult to see and placed too low on the vehicle.

Qualitative Analysis

Qualitative Analysis: Overall Findings

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated.

Through the qualitative analysis, several high-level categories patterned for the light bars; these are location, color, blend in, thickness, brightness, sun, and segmented lights.

Other general categories that patterned include competing for attention, existing lights, and general crossing.

The subsequent pages include a breakdown of each section. Followed by individual analysis of each condition tested.

See Appendix for detail on impact ratings for findings.

Qualitative Analysis: Impact Ratings

Detailed findings that were consistently repeated were assigned a positive or negative impact rating based on expected affect on user experience and frequency of occurrence. Not all findings qualify for an impact rating.

Impact ratings were assigned by the research team and based upon observations, subjective participant feedback, and quantitative data collected (e.g., performance data). These ratings are intended to provide a way of sorting issues by the impact they have on users, thereby guiding decision-making on design change implementation, as well as positive experiences that should not be changed.

NEGATIVE (ISSUE)

-5 Critical issue results in users unable to achieve goals.

-4 Issue is severe inhibitor, and in some cases, users are unable to achieve goals.

-3 Issue causes users to change their strategy to avoid problems causing additional effort.

-2 Issue causes irritation but users can still achieve goals.

-1 Issue is cosmetic or visual detail that is distracting but users can still achieve goals.

POSITIVE

1 Few users notice this low importance aspect that could be kept or changed with little negative impact.

2 Users content with this aspect, but it could be kept or changed with minimal negative impact.

3 Users generally positive toward this, and removal could have a negative impact.

4 Users pleased with this, and removal could have a negative impact.

5 Users extremely happy with this, and removal is likely to have a significant negative impact.

Location

Light bar location in the windshield was preferred over the grill placement due to easy of visibility.

Grill Location

Some participants preferred the grill over the windshield location because it was easier to see in this location.

-2 | Many participants did not prefer the grill location. Many of these participants said the grill location was too low. Their eyes do not look to the grill usually for information.

-2 | Additionally, participants were not looking at the grill because they usually look at the windshield because they look at the windshield more to find the driver.

-3 | The light bar looked like decoration in this location and could not differentiate the light bar from an accent light. Participants stated the surrounding area had too much happening already. Specifically, the surrounding chrome and headlights made it hard to see.

Windshield Location

3 | Many participants preferred the windshield location over the grill location because it was easier to see. The windshield location was more visible on top of the vehicle, and no other distracting lights were grabbing their attention.

Less than half of the participants did not prefer the windshield location. Some stated the windshield location was more difficult to see or was too similar to police lights.

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Color

Overall, the color preference was nearly split between teal and white, with a few more preferring Teal.

Teal Color

2 | A little more than half of the participants preferred the teal color. The teal color was easy to see because teal was contrasted from the vehicle and stood out from the headlights.

-1 | However, less than half of the participants did not prefer teal. These participants thought, in general, the teal was difficult to see.

Participants continually stated that they viewed the teal color as green.

White Color

1 | Some participants preferred the color white because it was easier for them to see white versus teal.

-2 | However, a little more than half of the participants did not prefer the white color. Most of these participants said the white color was less visible because it did not stand out and was similar to the headlight color.

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Blend In

Light bars that stood out from the vehicle were preferred as they were more noticeable.

-4 | Participants did not prefer light bars that blended into the vehicle because they were difficult to discern from the vehicle. Based on different light bar conditions, participants did not prefer light bars that blended in with the grill, headlights, or with the roofline of the vehicle.

4 | The light bars that stood out from the vehicle were preferred by participants. These light bars were more visible because they were prominent from the vehicle. These prominent light bars also grabbed participants attention more easily.

It is important to note that a few participants stated that they would want the lights to stand out from the vehicle when these light bars are first introduced into society. Then over time, once they are learned by pedestrians and drivers, they can become smaller, and more integrated into the vehicles.

However, a few participants preferred that the lights blended in with the vehicle because it was more aesthetically pleasing.

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Thickness, Brightness, Segmented Lights, and Sun

Several factors negatively impacted participants visibility of the lights.

Thickness

Thicker lights had improved visibility for participants. Nearly half did not prefer the thin light bars, because it was too small, and did not stand out.

These participants wanted bigger, thicker lights, especially when this was their first-time learning what the lights mean.

Brightness

Overall, participants wanted the thinner white and Teal light bars to be brighter because they were difficult to see.

A handful of participants thought the brightness level was good, but these were only regarding the large white light bar.

Segmented Lights

A few participants preferred that the individual lights in the light bar were segmented (i.e., broken into individual lights) because it was easier to see.

Sun

The sun's brightness influenced the visibility of the lights. Some participants stated the brightness level of the sun made it difficult to see.

The angle of different testing scenarios influenced the impact of the sun. Specifically, scenario 5 and scenario 6.

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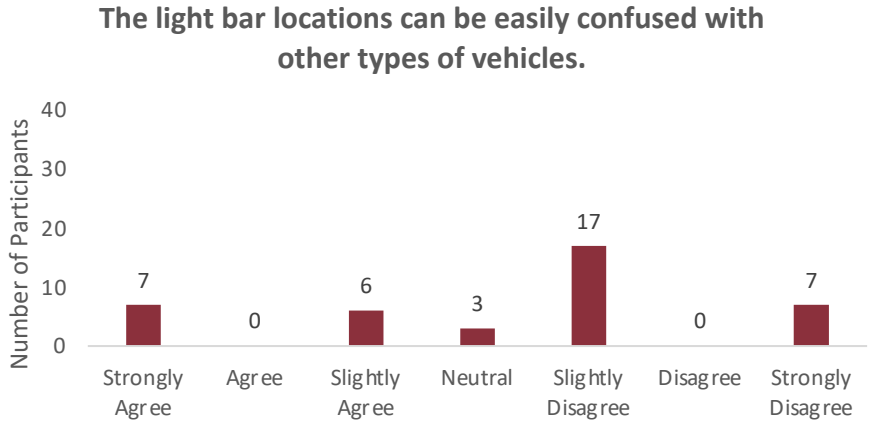
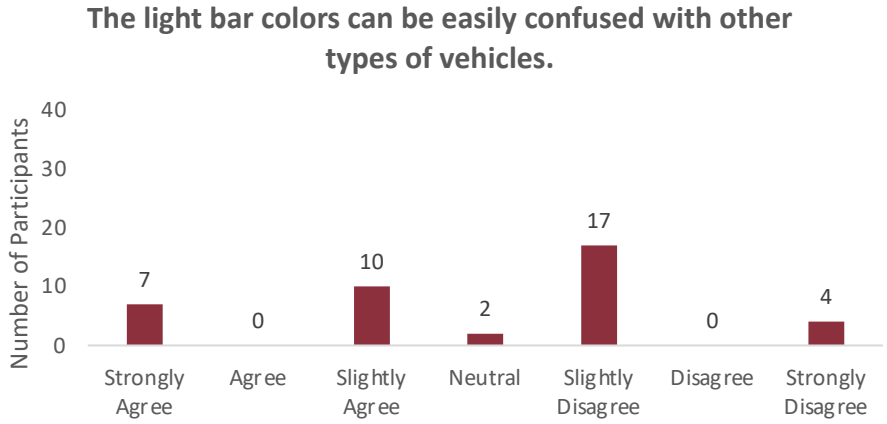
Emergency Vehicle

Participants were nearly split on if they thought the light bars could confuse other vehicles on the roadway.

A little over half of the participants did not think the light bars could be confused with other vehicles on the roadway (i.e., emergency vehicles, construction vehicles).

However, nearly half thought the light bars could be confused with other vehicles (i.e., emergency vehicles, construction vehicles, accent light on vehicles). These participants stated that either color (white or teal) and either location (windshield or grill) could be confused. Some noted that the "green" color would be better than the white because "green" is not used on regular and undercover police vehicles.





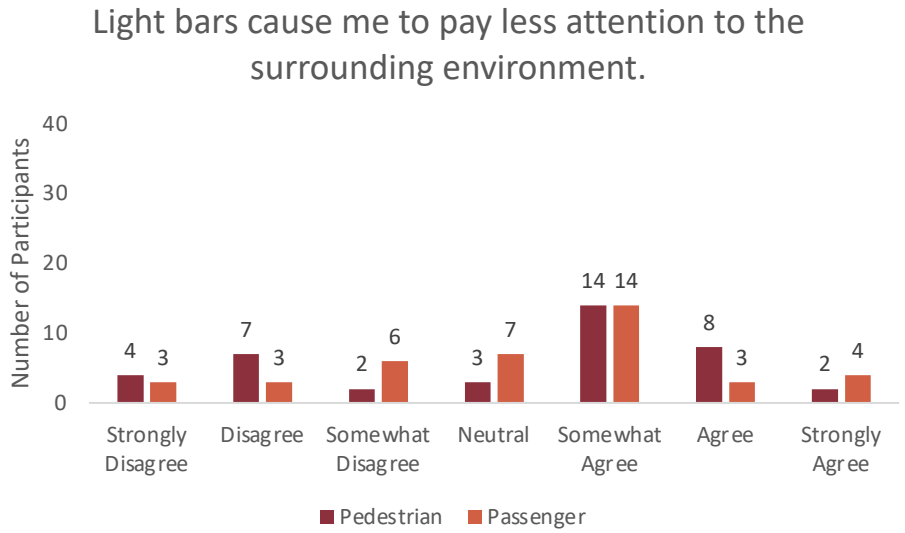
Overall Findings

Participants experienced difficulty prioritizing their attention across multiple vehicles, and across the different forms of lights on a vehicle.

Vehicles Competing for Attention

It was difficult for participants to focus on a vehicle's light bars when multiple vehicles were fighting for their attention. Participants would often choose one vehicle that was in their immediate path and focus on that vehicle. Then, they would change their glance to the other vehicle a few times to understand its future action. However, when they looked back and forth, they often missed patterns portrayed from the vehicle.

Participants expressed concern when both vehicles were crossing their intended path, and they had to interpret two light bars. The light bar patterns were often not synchronized (because they were completing different movements), and the various viewing sequences were confused.



Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Overall Findings

Existing vehicle lights conflict with light bars.

Existing Vehicle Lights

Participants thought the light bars could be easily confused with existing surroundings lights on the vehicle. As a result, some thought the light bars provided conflicting information (e.g., “green” lights on the rear combined with red brake lights, or white lights with reverse lights).

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Passenger Scenario Feedback

As a passenger, participants did not find the light bars a necessary feature.

Necessity
When participants were a passenger, they did not think the light bars were necessary. Participants stated the critical information for decision making is the vehicle dynamics and existing lights (brake lights, turn signals, reverse lights, headlights).

The light bars added another complex level of information that needed to be deciphered. In driving scenarios, there is not enough time to understand new pieces of information. However, they could see the necessity as a pedestrian.

Angle of HAV
The angle participants were viewing the scenario cause difficulty viewing the light bars. When the participants were perpendicular to the HAV, the lightbars were nearly impossible to view until after the vehicle had turned, completing its maneuver. A few participants stated the light bar should be a little longer to wrap around the vehicle's roof, so it was viewable from different angles.

Rear Light Bar
Participants were only able to see the solid light on the back of the Mercedes. The back solid light bar did not align with participants' expectations because they thought it would change similarly to the front. The rear light bar provided conflicting information from the rear brake lights and reverse lights, and they thought this information would confuse other road users.

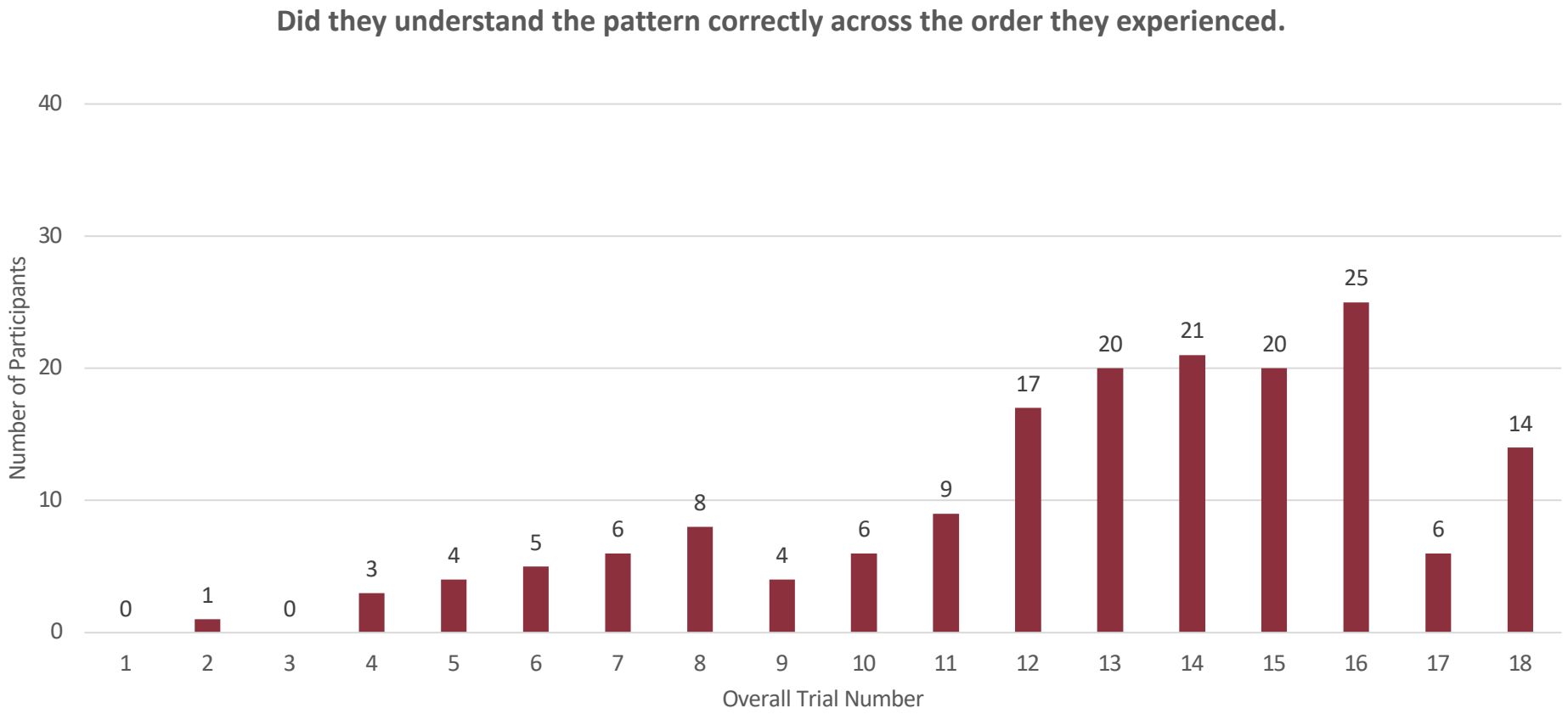
Following Vehicle
Most participants did not notice the light bars in the following vehicle behind. However, a few people saw the lights by looking in the side-view mirror.

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Pattern

Did they notice the patterns?

Did they correctly identify the intention of the external lights on their own?



Pattern

‘Yielding’ and ‘Driver’ pattern were most recognized over the ‘Ready’ pattern.

All participants experienced all three light patterns across all scenario and trials. Participants were never provided any information on the patterns. Participants were noted as successfully understanding the patterns when they can discern all three patterns and their specific purpose.

‘Yielding’ and ‘Driver’ patterns were the first two patterns for participants to interpret. Some participants *only* noticed the yield and drive pattern (15/40, 38%) across the entire study.

It took participants more than 12 exposures to the light bars to begin to understand what the pattern meant.

After 16 exposures, the largest percentage of participants (25/40, 63%) understood all three patterns.

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Pattern

It was difficult pay attention to two light bars in their crossing vicinity.

The ‘Ready’ pattern was the most difficult and last pattern participants to understand. The pattern length was too short for participants to catch.

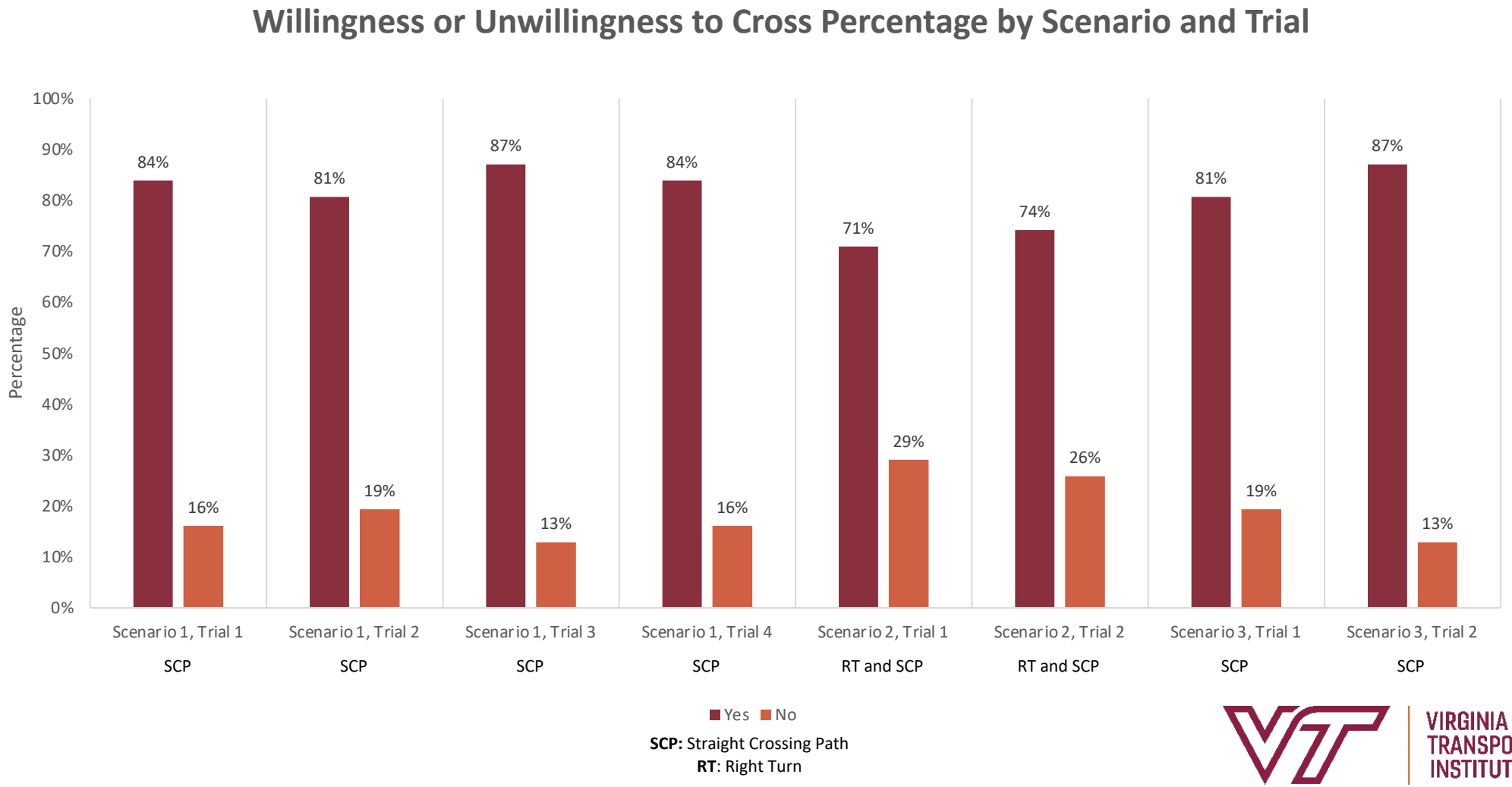
Participants stated that it was difficult to watch and interpret the light patterns for two vehicles in their environment. Often, they had to prioritize their focus on the vehicle they felt had the most risk to their crossing decision.

They would also miss the light patterns on the vehicles because they would turn their head back and forth to look at the other vehicles. During this movement, they missed the short ‘Ready’ pattern change.

Some counts are based on participants naturally sharing their opinion; it should not be presumed that the remaining participants said the opposite unless otherwise indicated. See Appendix for detail on impact ratings for findings.

Crossing Data by Scenario

Crossing Decision: Scenario 1-3



SCP: Straight Crossing Path
RT: Right Turn

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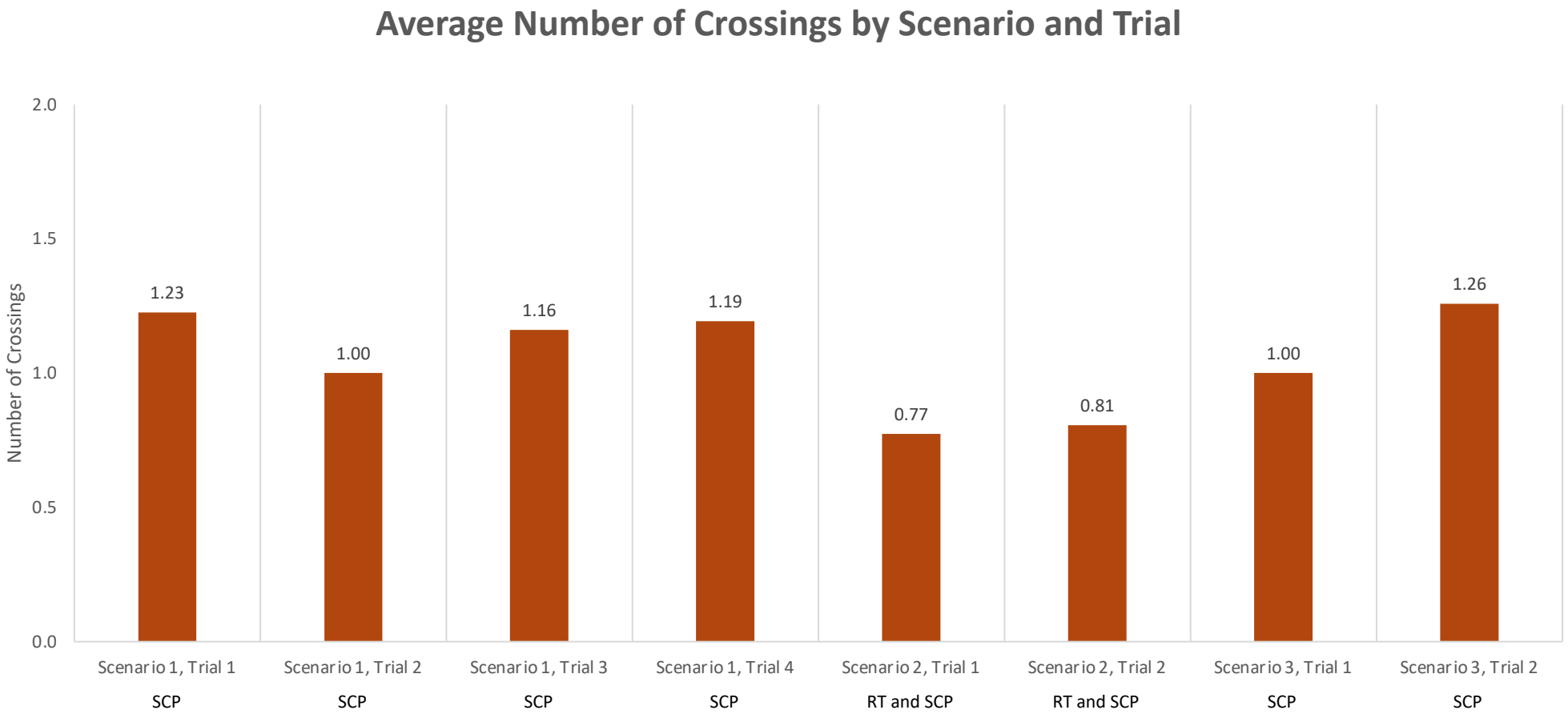
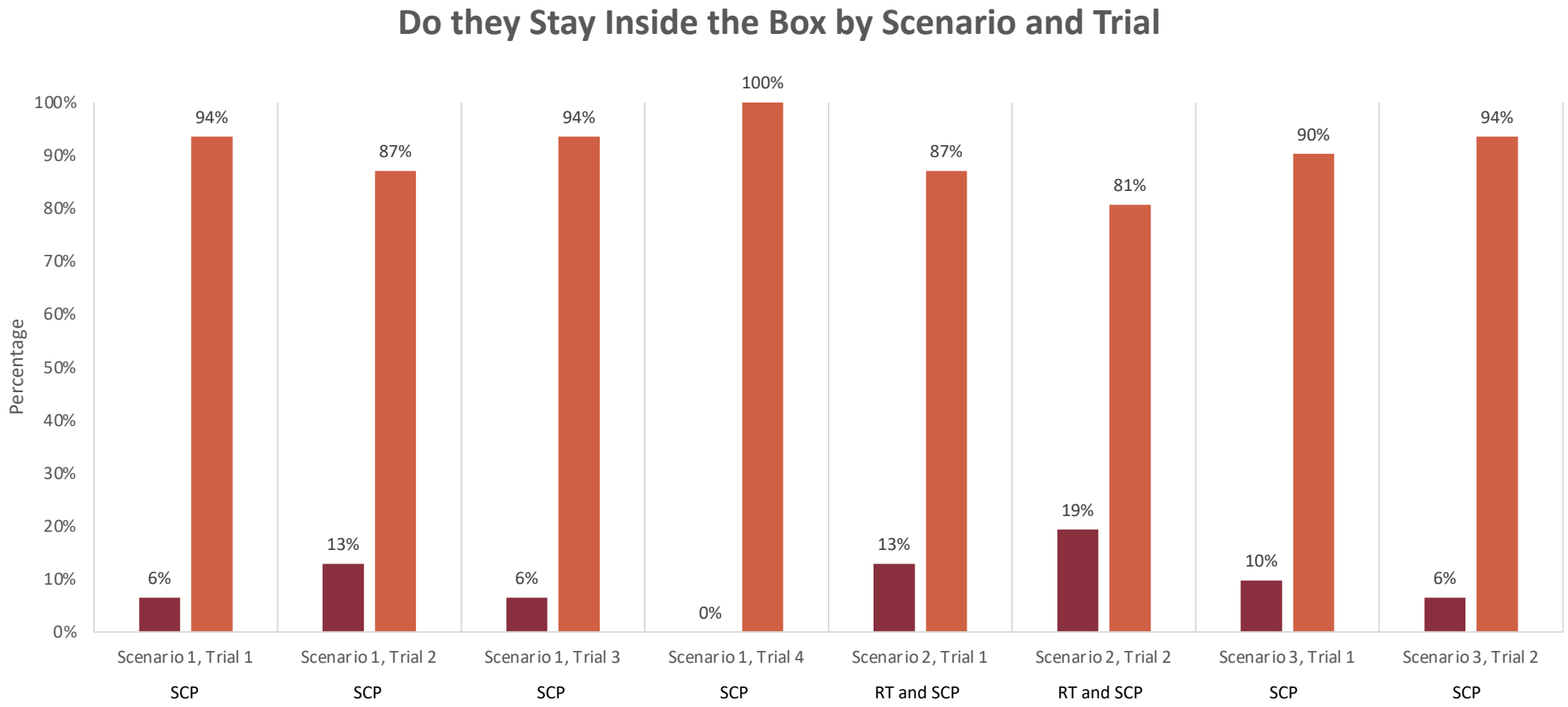
Crossing Decision: Scenario 1-3



SCP: Straight Crossing Path
RT: Right Turn

Crossing Decision: Scenario 1-3



SCP: Straight Crossing Path
RT: Right Turn

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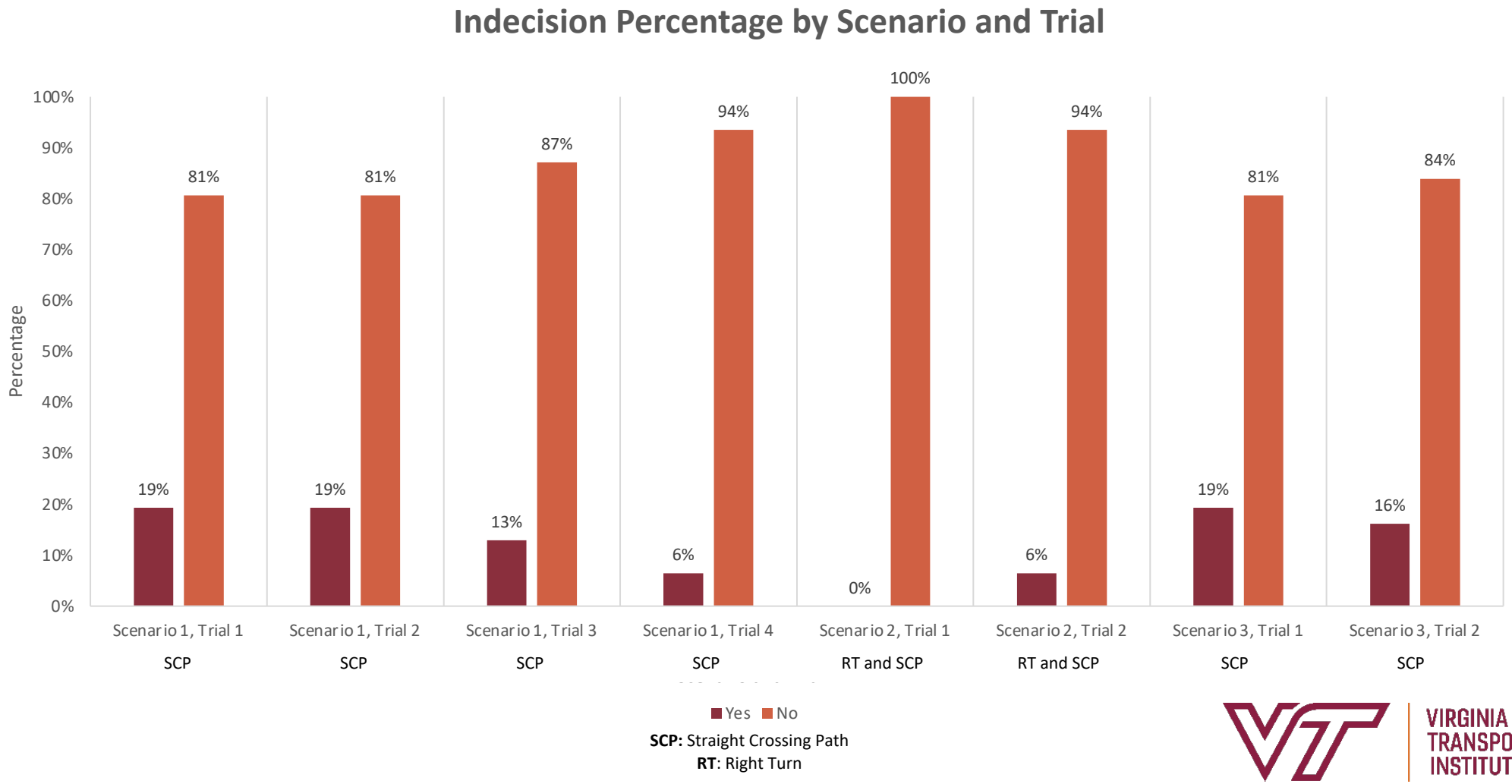
Crossing Decision: Scenario 1-3



SCP: Straight Crossing Path
RT: Right Turn

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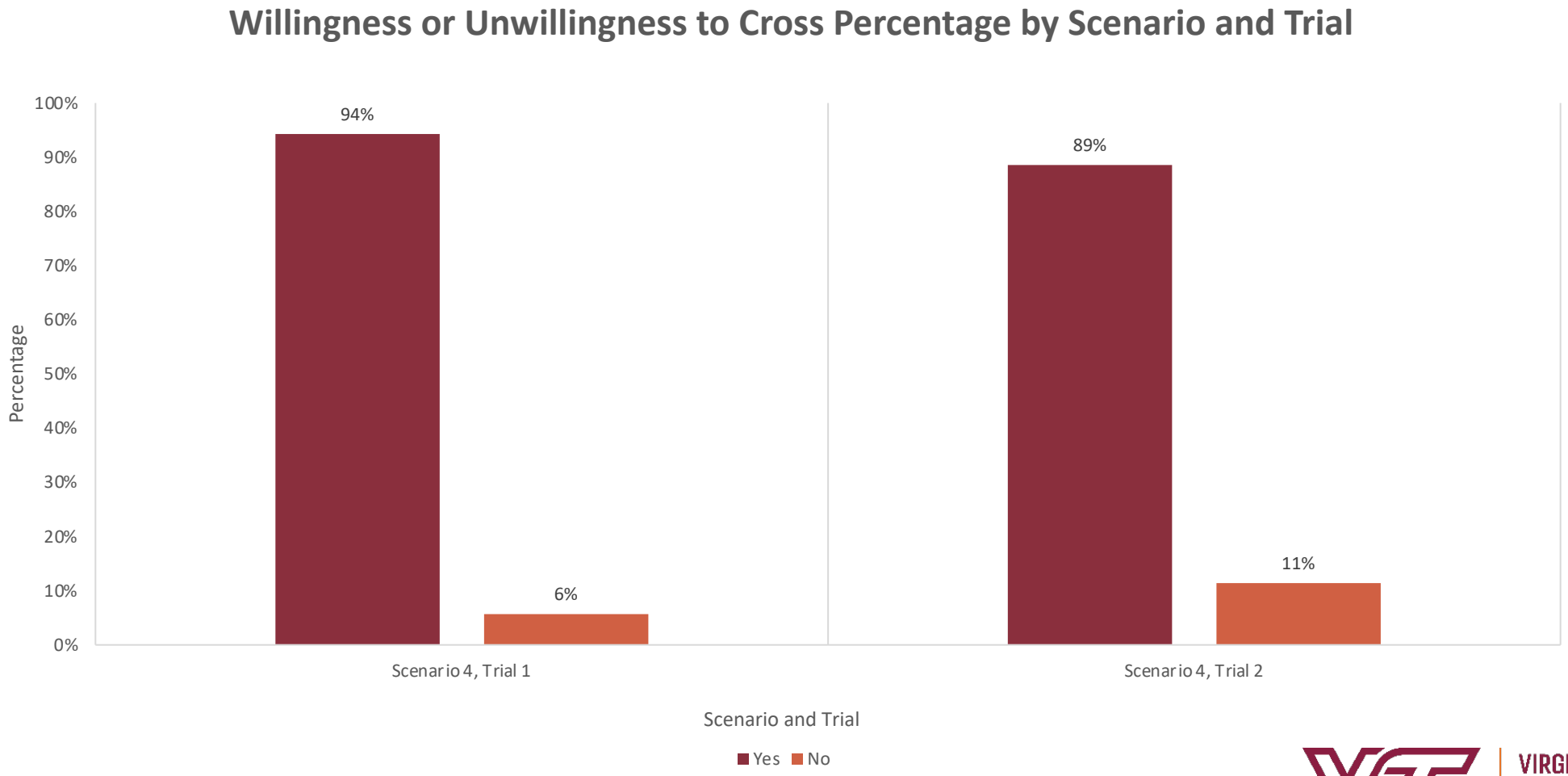
Crossing Decision: Scenario 4



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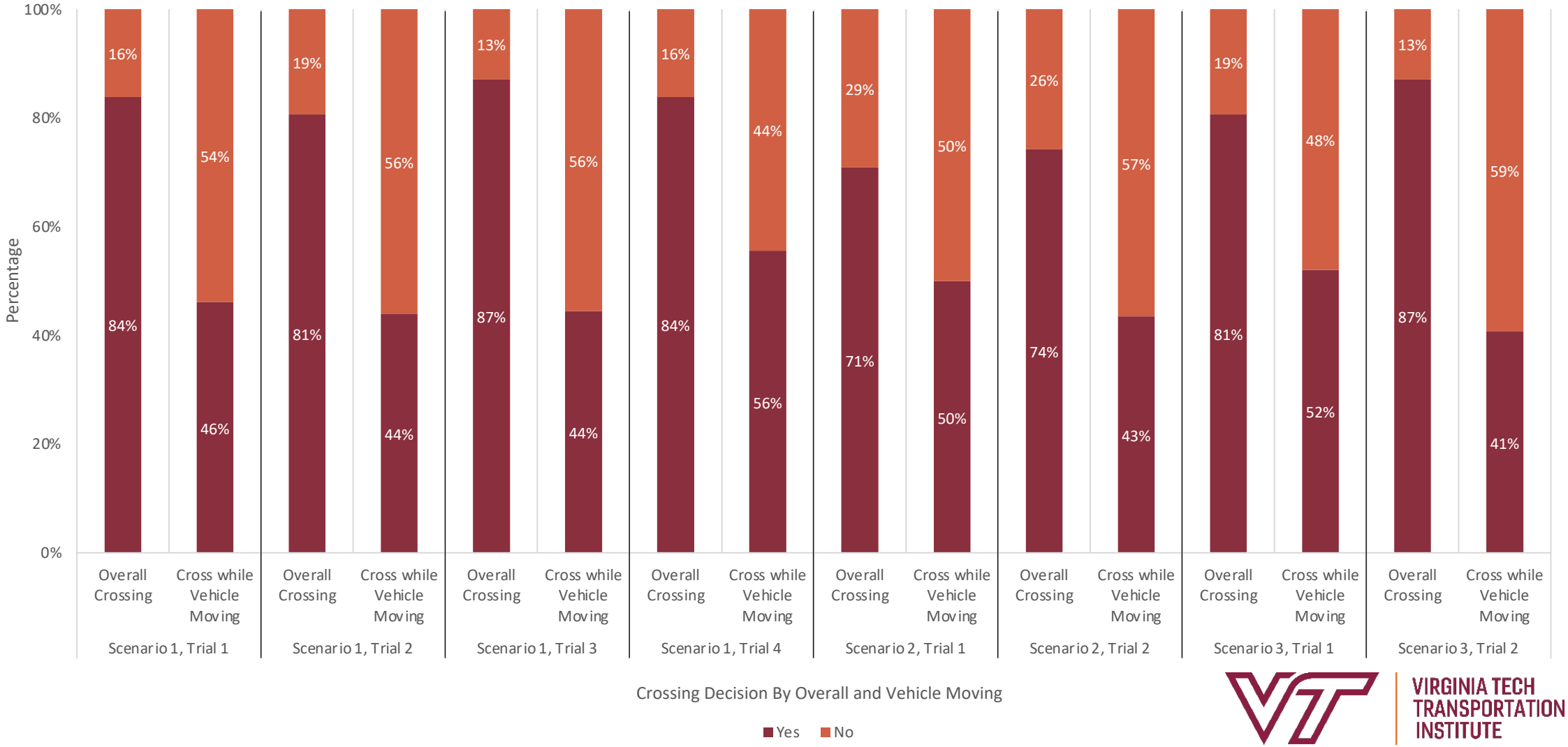
Crossing Decision by Vehicle Movement

Crossing Decision: Overall and Vehicle Moving (OPTION 1)



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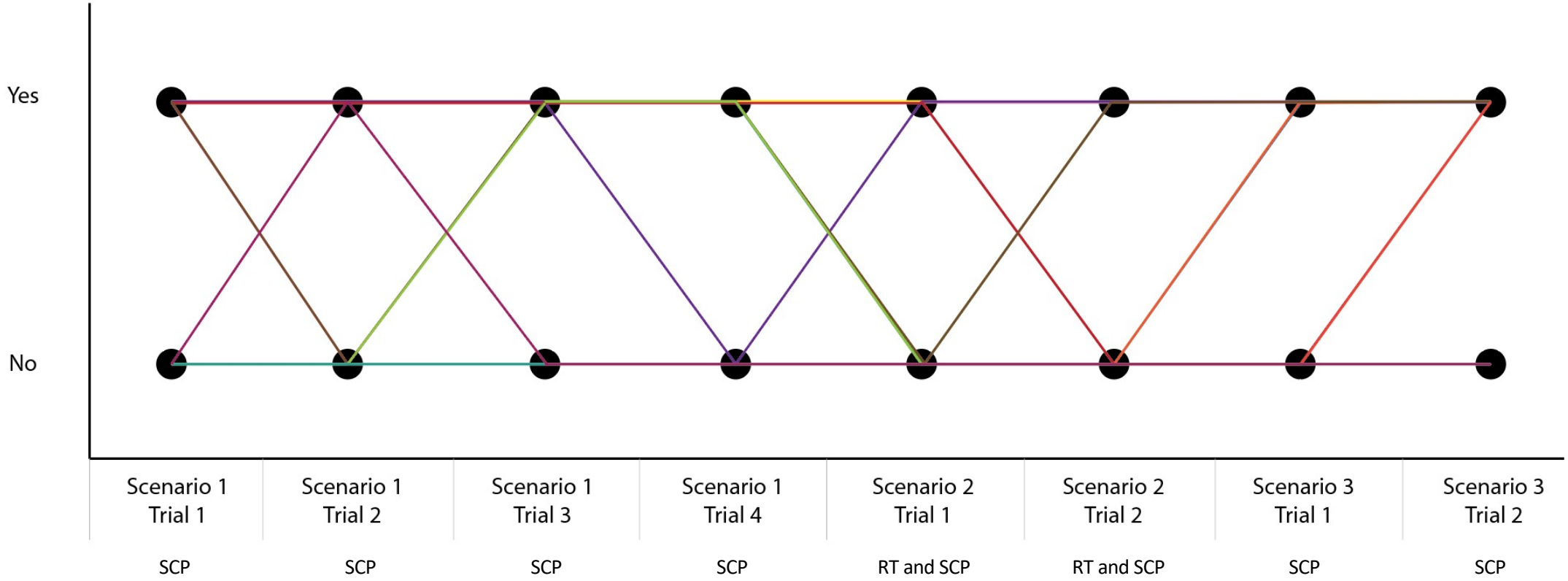
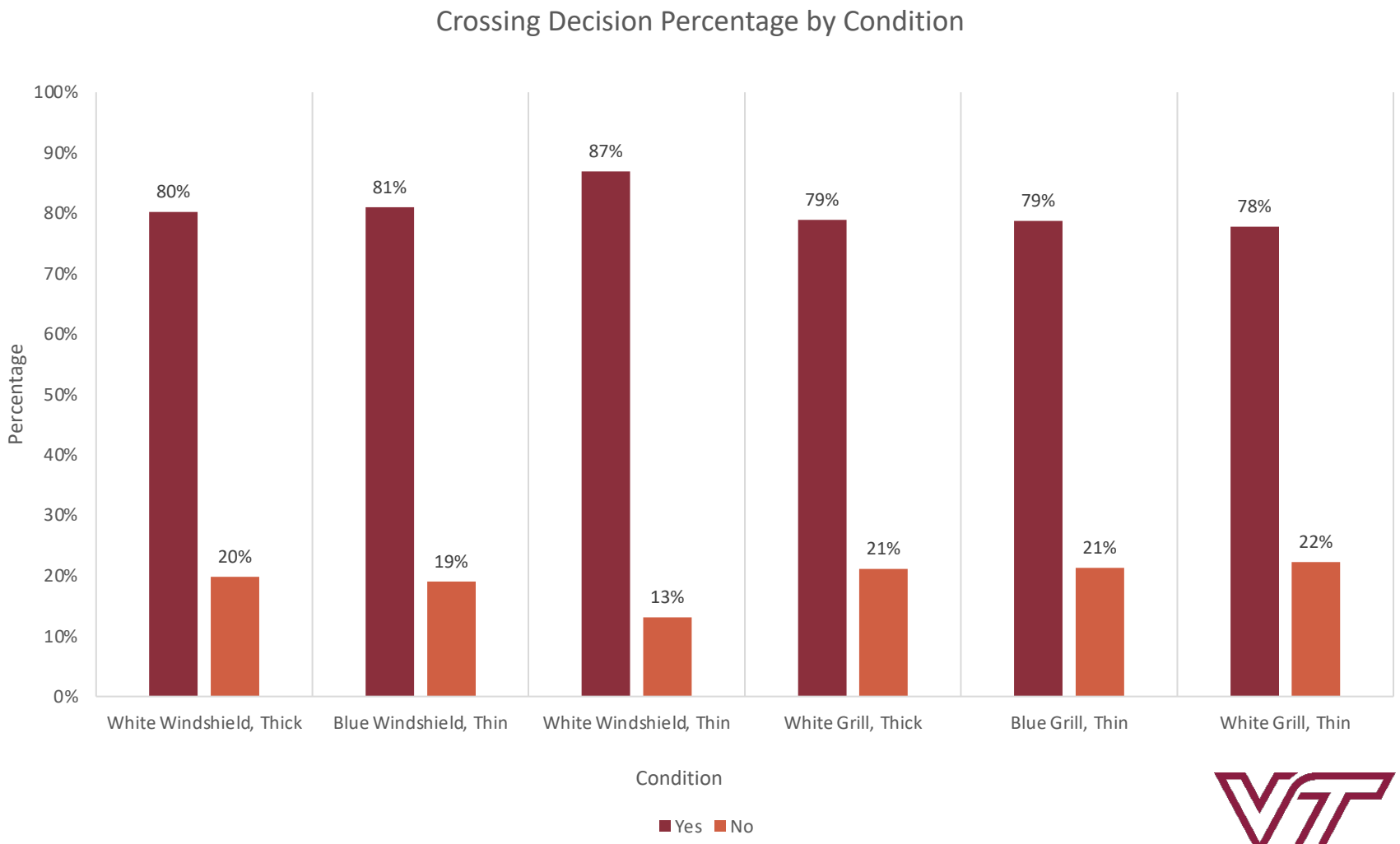
Crossing Decision: Would not cross for a period (OVERVIEW)



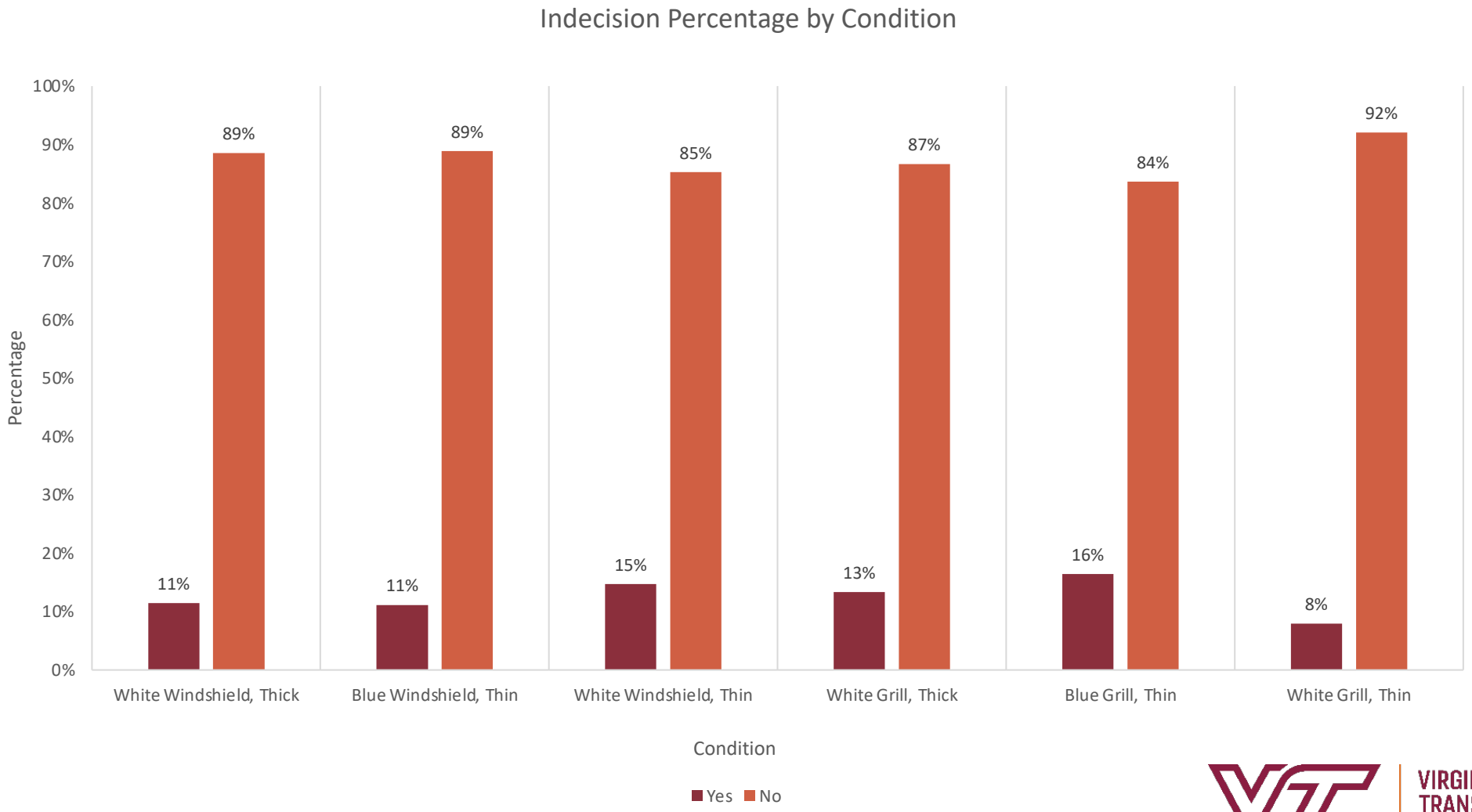
SCP: Straight Crossing Path
RT: Right Turn

Crossing Data by Condition

Crossing Decision: Overall decision by condition



Crossing Decision: Overall indecision by condition



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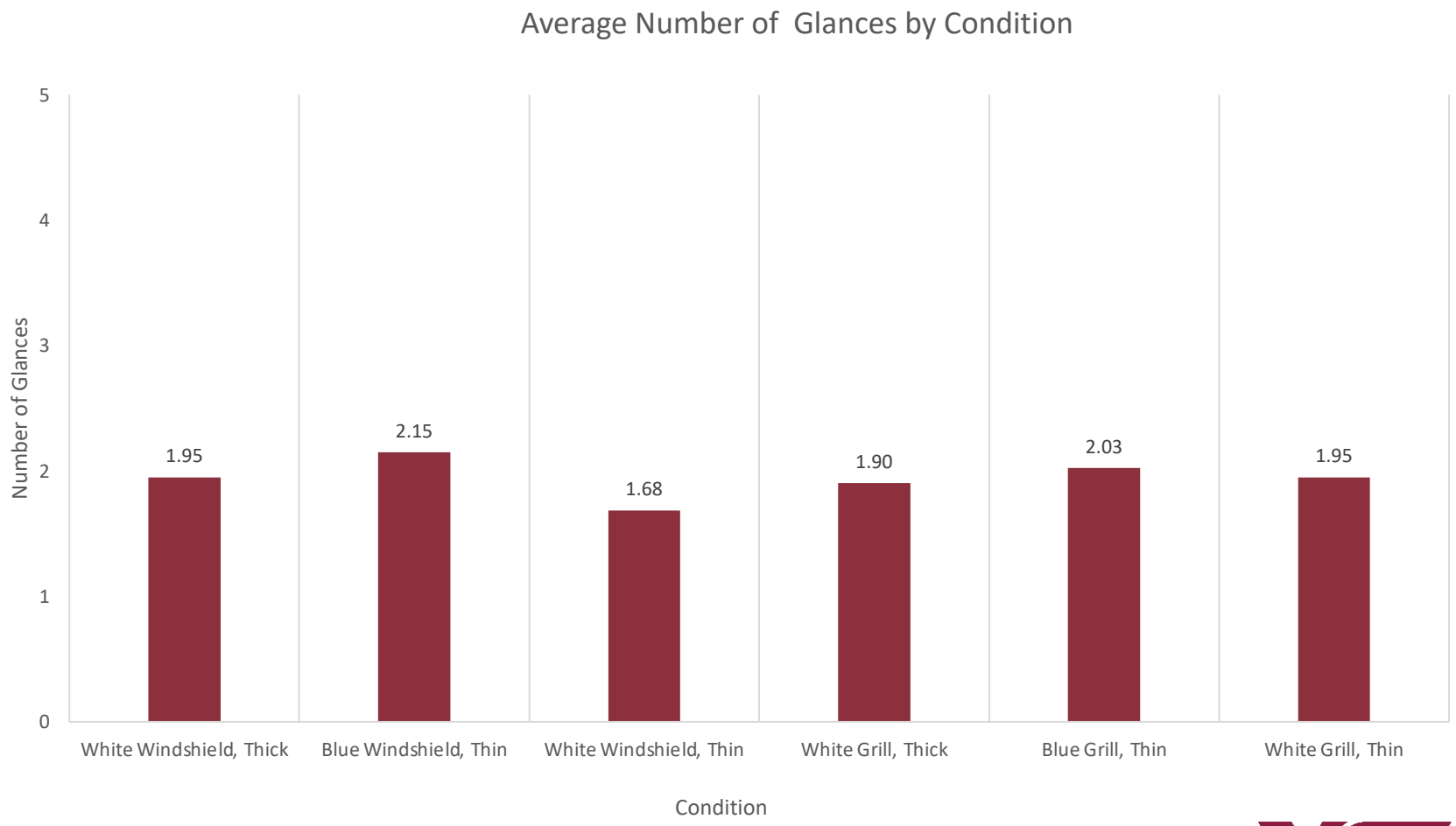
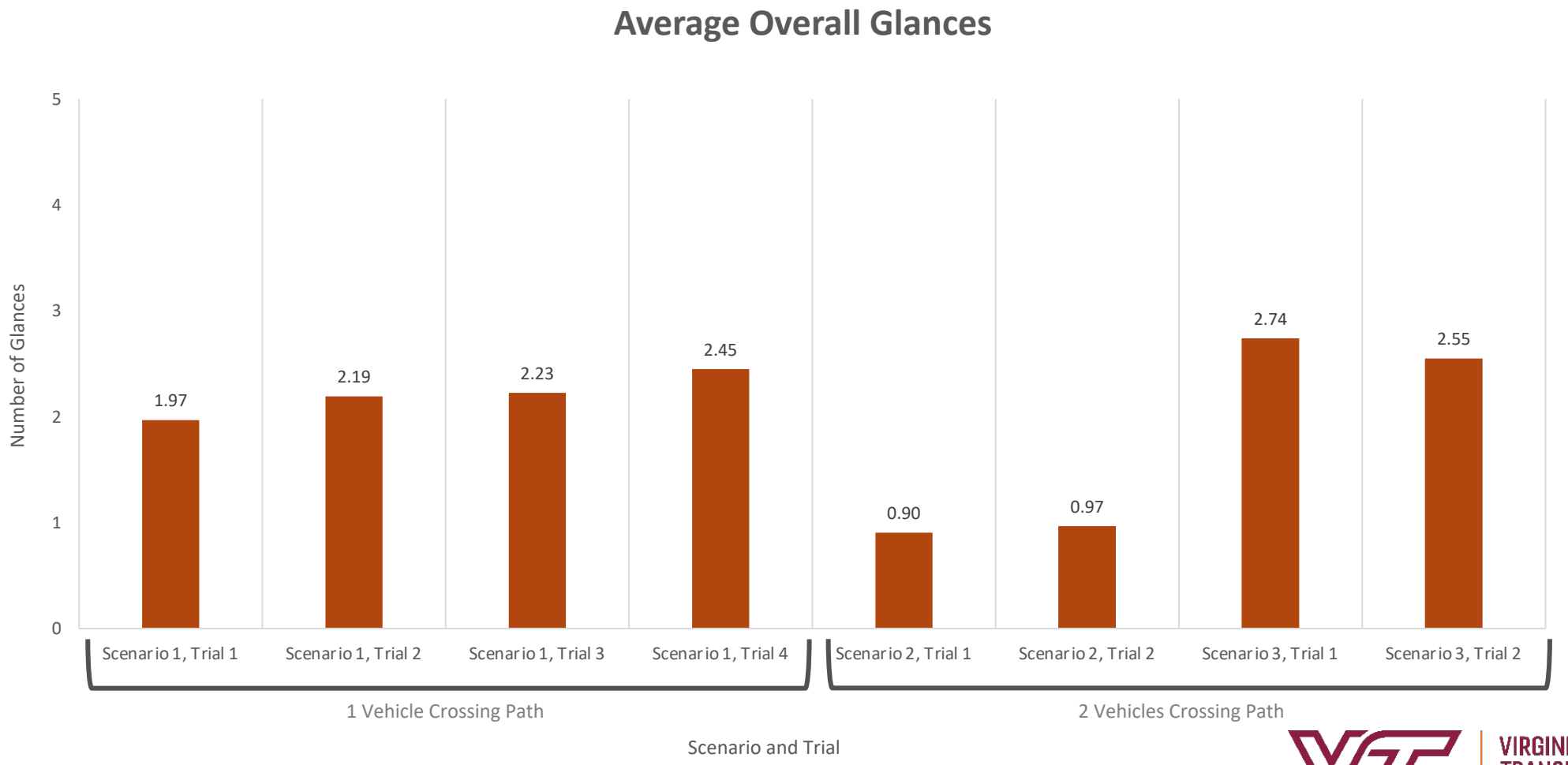
Crossing Decision: Overall eye glance by condition

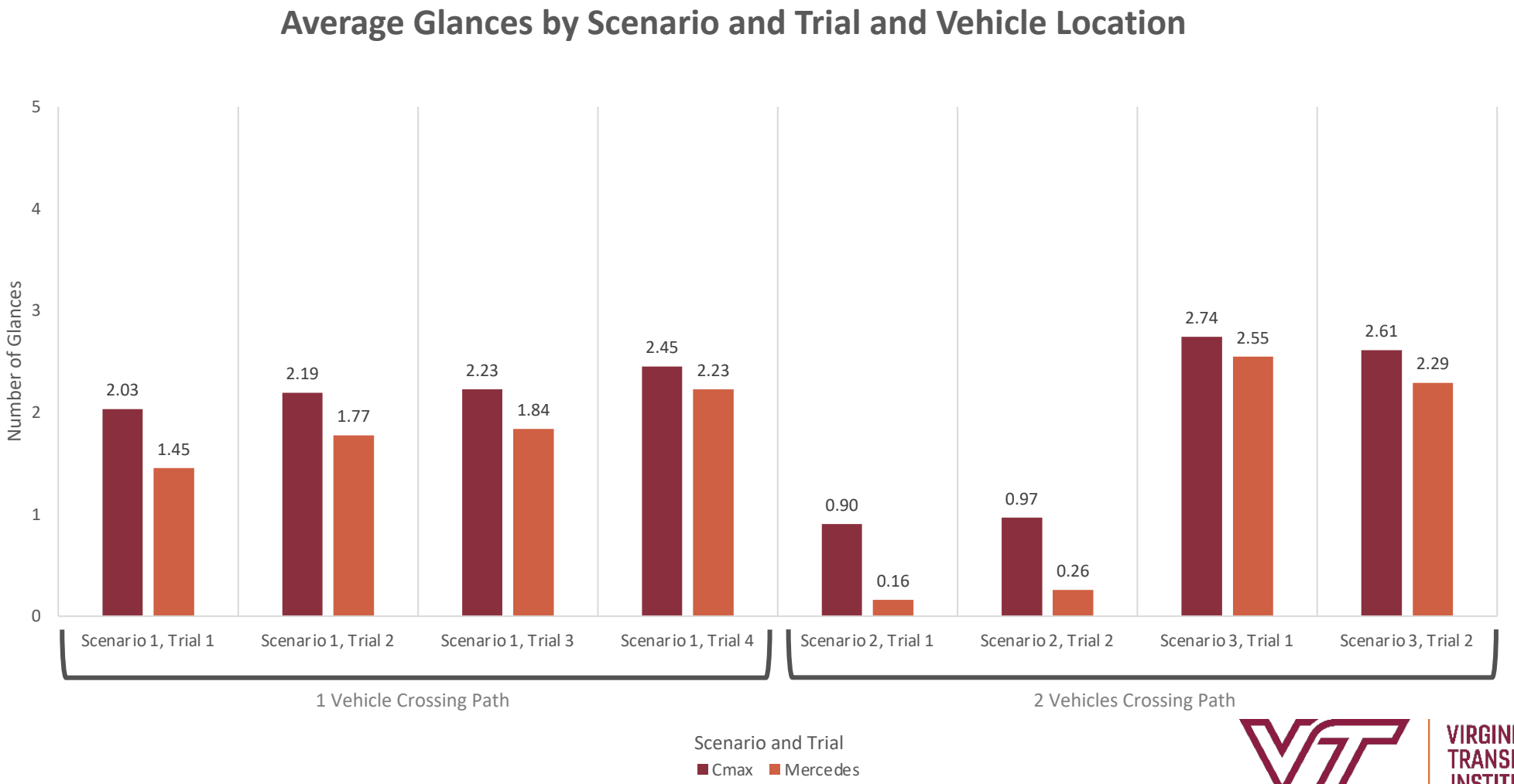


Glance Data

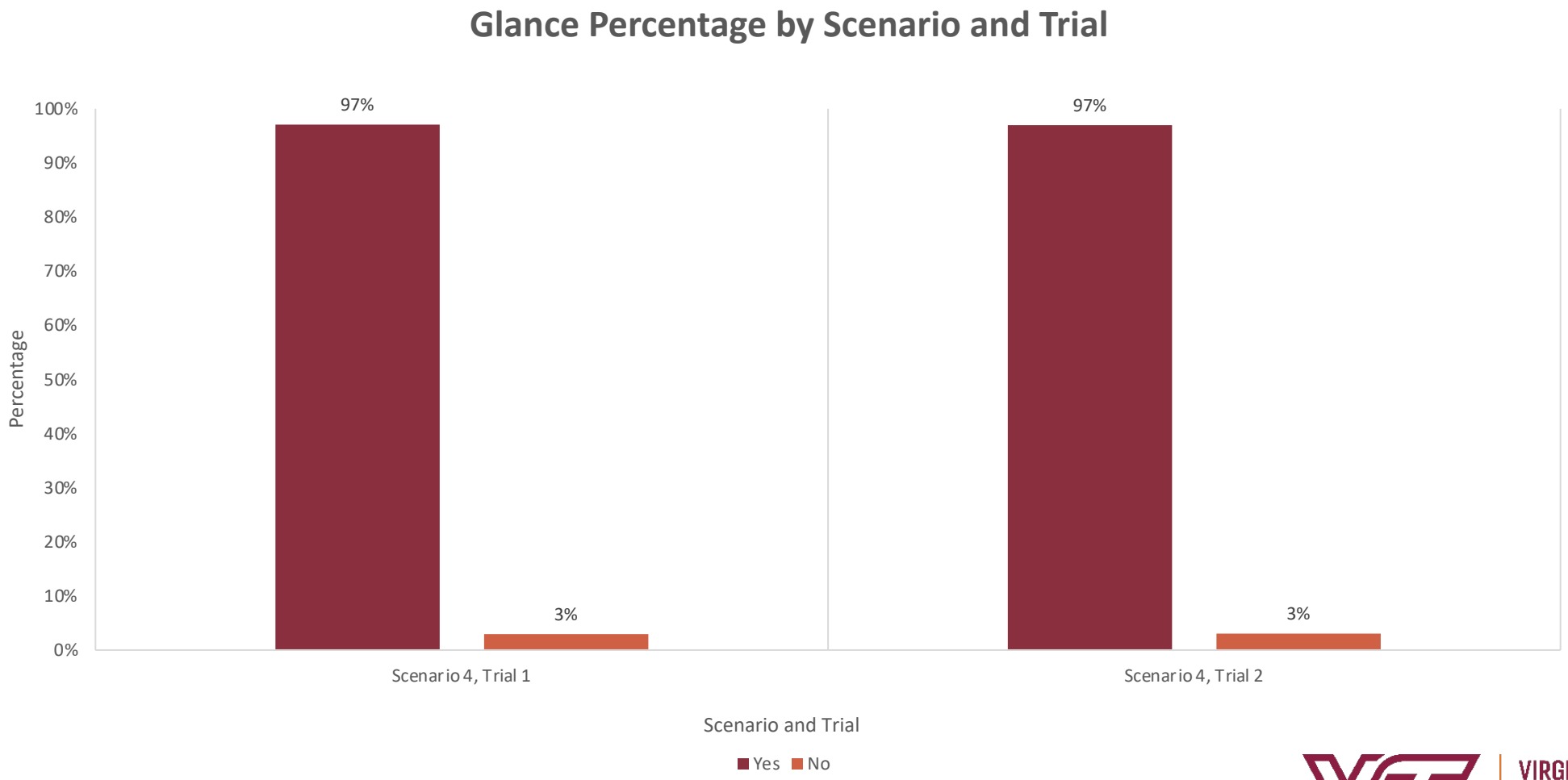
Glances: Scenarios 1 to 3



Glances: Scenario 1 to 3



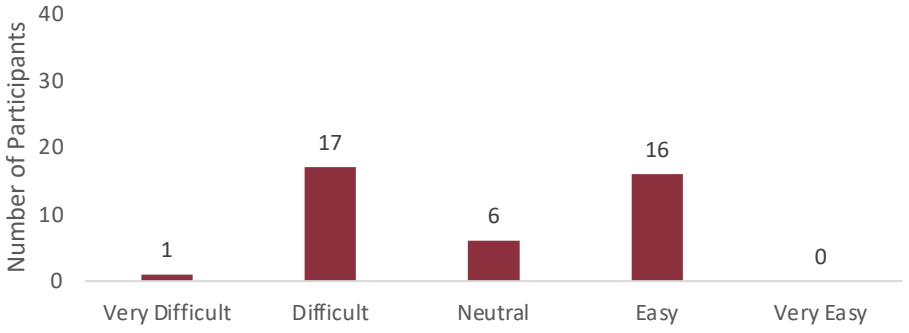
Glances: Scenario 4



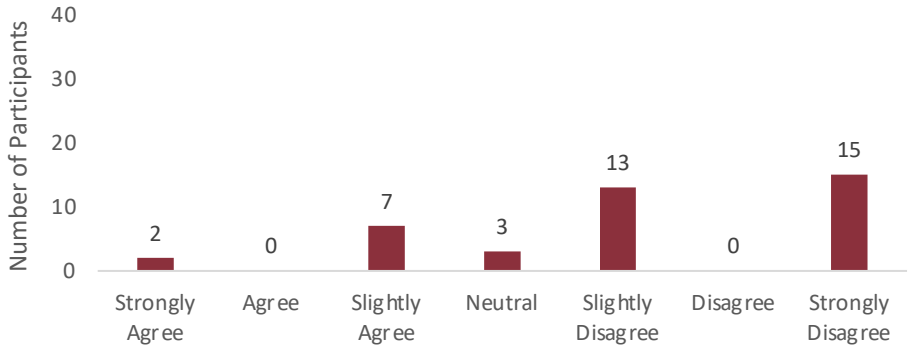
End of Session Questionnaire

End of Session Questions

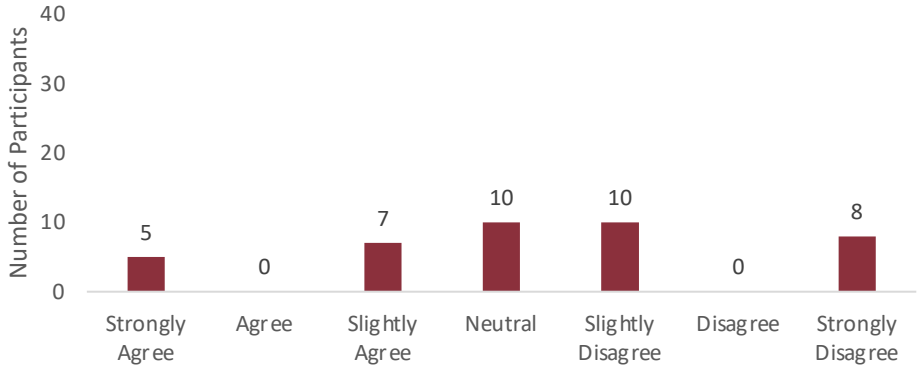
How would you rate your ability to monitor the road while interacting with the automated vehicles in your environment?



I found it easier to interpret the light bars when the vehicle were not moving.



My decision to cross the street would have changed if there were no external lights on the vehicles.



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Potential Next Study

We propose a second study that would mimic the same foundational methods from the Allusion Project.

Changes based on our learnings:

- Adding a true baseline (adding two human-operated vehicles)
- Editing the scenarios
- Narrowed testing conditions
- Dependent measurement collected from passenger scenarios

Thank you.

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