Impact of Highly Automated Vehicle (HAV) External Communication on Vulnerable Road User (VRU) Understanding of Vehicle Intention

VIRGINIA TECH

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Motivation

With the introduction of different levels of highly automated vehicles (HAVs) onto our roadways, it is essential to understand the interaction and relationships among surrounding vehicles and vulnerable road users (VRUs). Specifically, we need to understand communication between drivers, VRUs, and HAVs.

(1) Understand VRU decision-making when **multiple HAVs** are operating within their environment.
(2) Observe VRUs make real-time crossing decisions on a **controlled test track with live vehicles**.
(3) Assess VRUs' interpretations of external communication from the **perspectives of pedestrian and passenger**.

Objectives

This research examined how an L4+ HAV can best communicate with other drivers and VRUs about its intentions.

External Communication Impact

- Does head-pose and decision-making behavior change once a participant understands the external communication displays?
- How many exposures to a vehicle's external communication does it take for participants to understand the meaning of the displays?
- How many exposures to the light bar patterns does it take until participants correctly interpret the meaning of all three intentions?

Study Design

A within-subject design was used, and each participant viewed eight different testing scenarios that were repeated for multiple trials. The scenarios included various dynamic traffic scenarios on the closed test track. All participants experienced all three light patterns across all scenarios and trials.

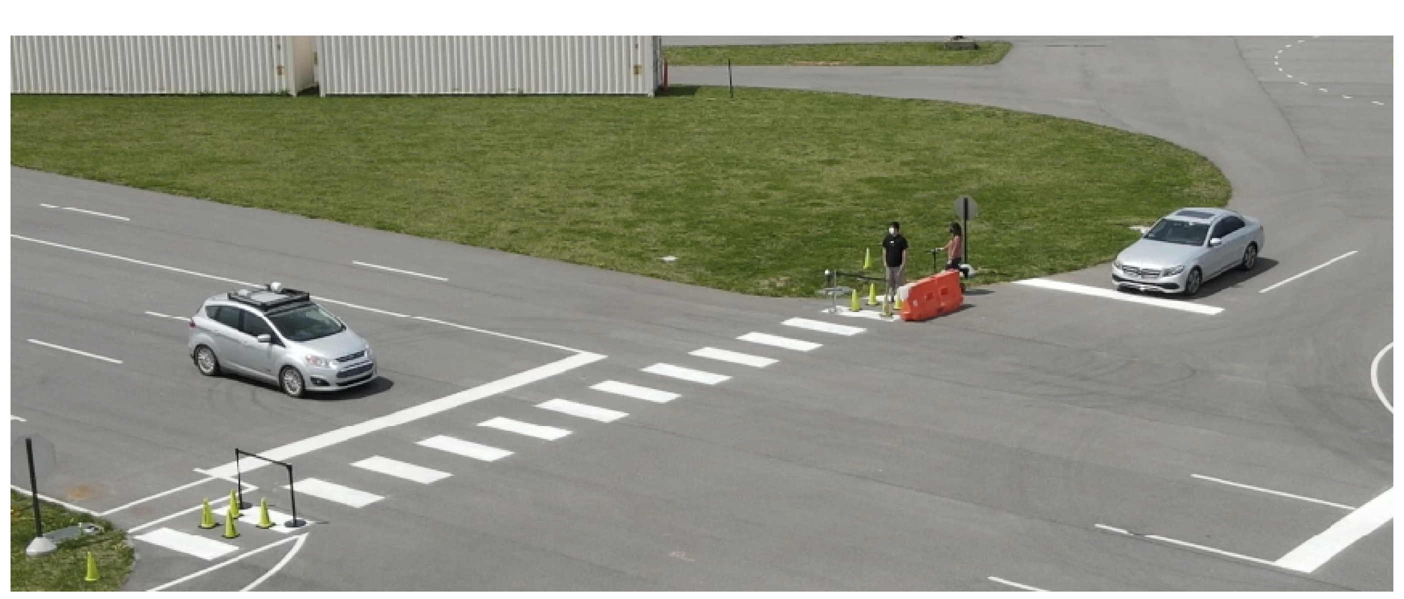

Figure 1. Overview of study design.

Tested Interface

There were two emulated L4+ HAVs used in this study. The light bars' location (windshield and grill) and color (white and teal) were changed between scenarios, so all participants experienced both locations and all color combinations.

Figure 2. Overview of interface location and color.

Method

Forty participants observed external communication displays on two vehicles that emulated L4+ AVs.

Table 1. Overview of tested variables.

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) Scenario 4
Scenario	Pedestrian	4	1) Scenario 5 2) Scenario 6 3) Scenario 7 4) Scenario 8

Every participant viewed eight different testing scenarios that were repeated for multiple trials. The eight scenarios were split between pedestrian and passenger perspectives. When participants were experiencing the pedestrian scenarios, they would make crossing decisions and complete rankings on their understanding of the displays. When participants were experiencing the passenger scenarios, they would observe the scenario and complete ratings on their understanding.

Results

After each exposure to the light bars, participants' knowledge of the light bar patterns and correct interpretation of the patterns was coded. The percentage of participants noticing the light bars were statistically significantly different at different exposures.

Cochran's Q test was run to determine if the percentage of participants noticing the light bars was different at the different time points. The percentage of participants noticing the light bars was statistically significantly different at the different time points, $\chi2(17) = 174.629$, $p < .001$. Exposures 1, 9, 17, and 18 had statistically significant pairwise comparisons.

Results

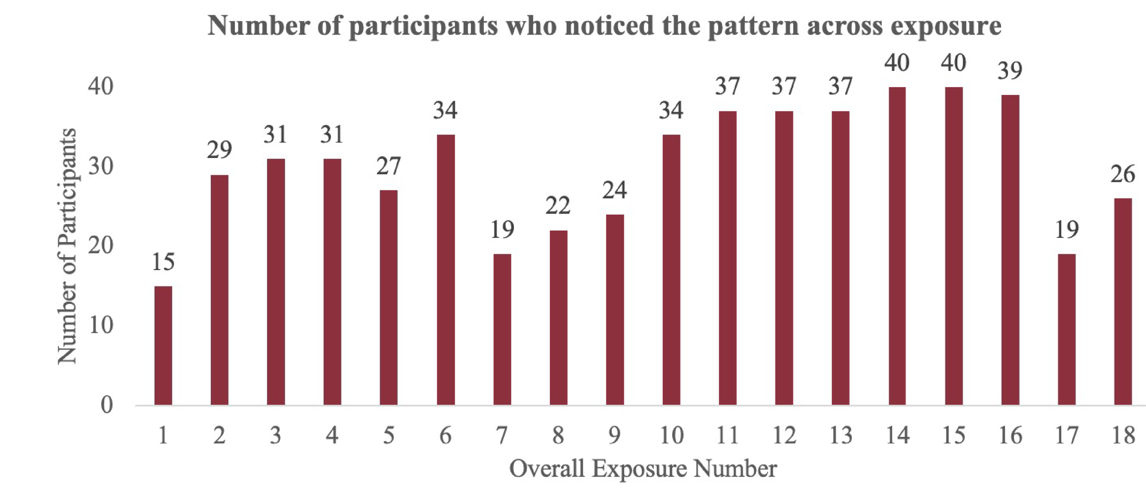

Figure 3. Participants who noticed the light bars over exposure.

Cochran's Q test was run to determine if the percentage of participants understanding the patterns was different across the number of exposures (Figure 4). The percentage of learning was statistically significantly different over number of exposures, $\chi2(17) = 79.928$, $p < .001$. Pairwise comparisons were completed using Dunn's procedure with a Bonferroni correction for multiple comparisons, resulting in 16 significantly different comparisons.

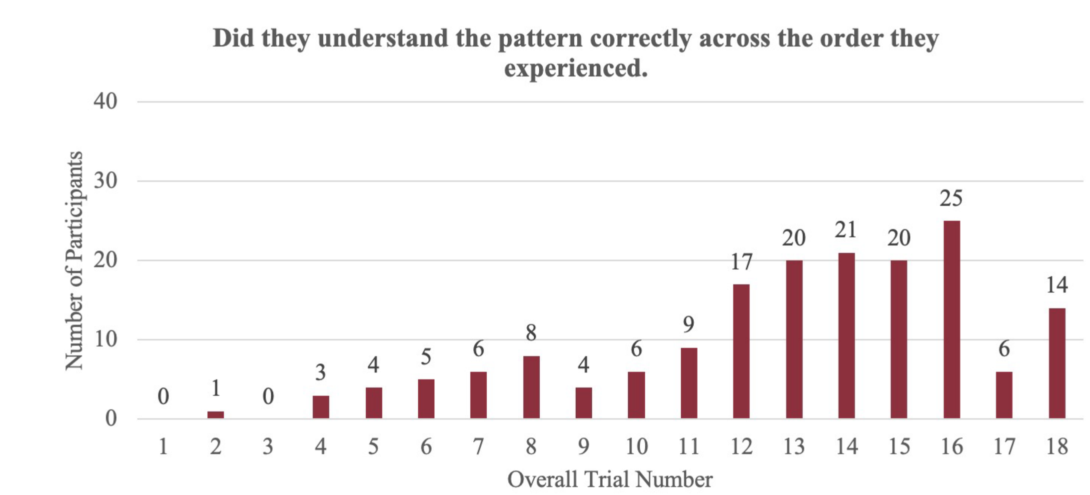

Figure 4. Number of exposures until correct interpretation of patterns.

Conclusion

(1) Participants stated that it was **difficult to watch and interpret the light patterns for two vehicles** in their environment.

(2) Often, they had to **prioritize their focus** on the vehicle they felt had the most risk to their crossing decision.

(3) 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.

Previous studies conducted on external communication displays on HAVs were conducted with one HAV. We found with two HAVs that there was confusion in where to look and difficulty understanding the intention of the display because they were forced to split their attention between two HAVs (they would turn their head back and forth to look at the other vehicles).

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