AV EXTERNAL COMMUNICATIONS
AUG 2, 2018

- Lights enhance comfort with AVs
- Signals easily learned
OVERVIEW

• Goals
  • Do light bar signals enable more ‘trust/acceptance’ of AVs?
  • Can these signals be learned?
  • Can previous VR study results hold with more complex scenarios?

• Sample videos of scenarios tested
• Experimental design
• Study protocol
• Results
• Discussion
EXPERIMENTAL DESIGN

Independent Variables
• Vehicle intent message / signal
  • Driving
  • About to go
  • Yielding
• Structured traffic scenario
  • AV lead car at stop light
  • AV 3rd at stop light
  • AV 1st and 3rd at stop light
  • Parking
  • Turning
• Additional busy scenarios
  • Pedestrian at busy intersection
  • Passenger within vehicle traveling forward

Control Variables
• Order
  • Structured scenarios counterbalanced
  • Additional busy scenes presented after structured scenarios

Dependent Measures
• Trust
  • Trust survey
  • Given pre- and post- study
  • Included questions regarding lights in post-study survey
• Light bar saliency
  • Participants noticing without prompting
• Signal learnability
  • Interpretation
    • Correct
    • Somewhat correct
    • Do not know
    • Incorrect
  • After X exposures, people learn what the signals mean

Trust Survey Questions:
1. I feel safe around automated vehicles.
2. I understand how automated vehicles work.
3. I think automated vehicles are reliable.
4. I trust automated vehicles.
5. The lights on the car help me understand what the vehicle will do.
6. Understanding what the vehicle will do is comforting

Trust Survey Scoring:

Learnability Scoring:
wrong -1
no answer / don't know 0
somewhat correct 1
correct 2
PARTICIPANTS

- Recruited non-manager, Ford employees in RIC
- 31 respondents
- 26 participated in study
PROTOCOL

• **Trust “pre-survey”**
  • Get a sense of how safe/comfortable participants feel with AVs on the road.

• **Scenarios within VR environment – learnability questions / scores**
  • Five counterbalanced “simple scenarios”
    • After every structured scenario, participants described the situation in their own words.
      • Recorded when they commented on the lights and the accuracy of these comments.
    • If the participant had not mentioned the lights and what they mean after all presentations, they were shown the 3 light patterns and asked to explain what they mean.
      • Only one participant required this.
  • Two busy scenes, one as a pedestrian then one as a passenger in a vehicle, two minutes each
    • Participants were asked what each signal meant and comments were scored.

• **Trust “post-survey”**
  • Same as “pre-survey”
  • Two additional questions regarding lights
    • “The lights on the car helped me understand what the vehicle will do”
    • “Understanding what the vehicle will do is comforting”
RESULTS AND ANALYSIS - SUMMARY

• Trust
  • [positive impact]

• Learnability
  • [for any given signal, after 2 exposures]
  • [for all signals, 5-10 exposures]

• Notice light bar
  • [2.9 exposures]

• Signal
  • [Yielding and About to Go learned first, Driving next]

• Scenario
  • [AV lead car most easily learned, other scenarios equal]

• Busy scenario carryover learning
  • [understanding maintains]
TRUST RESULTS AND ANALYSIS

1. I feel safe around automated vehicles.  4.04  4.31  0.27
2. I understand how automated vehicles work.  4.31  4.3  0.00
3. I think automated vehicles are reliable.  4.12  4.27  0.15
4. I trust automated vehicles.  3.92  4.15  0.23
5. The lights on the car help me understand what the vehicle will do.  4.81  
6. Understanding what the vehicle will do is comforting.  5.42

- The lights help people know what the vehicle will do and that is comforting to them
- Likely increase with education

Trust Survey Scoring:
1 Strongly Disagree
2 Somewhat Disagree
3 Slightly Disagree
4 Slightly Agree
5 Somewhat Agree
6 Strongly Agree

Impact of Lights on Trust / Acceptance

- The lights on the car help me understand what the vehicle will do.
- Understanding what the vehicle will do is comforting.
LEARNABILITY RESULTS AND ANALYSIS– SIMPLE SCENARIOS

• Light bar noticeability
  • Average of 2.9 exposures

• Signal
  • “Yielding” and “about to go” were comprehended faster than “driving” (p < .05)
  • “About to go” and “yielding” were comprehended equally (p = .58)

• Scenario
  • Simplest scenario [AV the lead car at a stop] was understood more easily than all others
    • People understood other scenarios equally
  • Learning translates from simple scenario to busy scenes
    • 76.9% [20/26 participants] noted their understanding stays the same after seeing all scenarios

• Exposures to learn
  • Comprehension of any given signal after 2 exposures.
    • Similar finding in previous VR studies
  • 85% of participants took 9-10 exposures to comprehend all three signals.
    • 75% took 7 exposures, 50% took 5 exposures, 25% took 2-3 exposures
    • Different finding than previous VR studies
      • Could be a function of scenario complexity, counterbalanced order of scenes, number of participants, etc.

* Post-hoc Tukey tests on ordinal logistic regression models
LEARNABILITY RESULTS AND ANALYSIS – BUSY SCENES

- Majority of people understood.
- For the simplest scenario, scores were similar.
  - Some participants may have had this scenario early on in the study.
  - More people were unsure [compared to busy scenes] but few incorrectly interpreted.
  - Could indicate learning curve from simple scenario to busy scene.

<table>
<thead>
<tr>
<th>Contingency Table Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busy Ped</td>
</tr>
<tr>
<td>Driving</td>
</tr>
<tr>
<td>Yielding</td>
</tr>
<tr>
<td>A-I-G</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

| Busy Pass | 1 | 0 | 1 | 2 |
| Drive     | 2 | 9% | 4 | 16% | 1 | 4% | 18 | 72% |
| Yielding  | 3 | 12% | 2 | 8% | 2 | 8% | 18 | 72% |
| A-I-G     | 1 | 4% | 1 | 4% | 1 | 4% | 23 | 92% |
| Total     | 25 | 25 | 25 | 25 |

| Scenario W | 1 | 0 | 1 | 2 |
| Drive      | 0 | 0% | 0 | 0% | 0 | 0% | 17 | 66% |
| Yielding   | 1 | 5% | 0 | 0% | 2 | 10% | 18 | 66% |
| A-I-G      | 0 | 0% | 1 | 10% | 0 | 0% | 17 | 66% |
| Total      | 22 | 22 | 22 | 22 |

* Totals may vary due to some participants noting different signals.
** Participants saw 'busy ped' and 'busy pass' scene in some order, at end.
*** Participants saw 'scenario W' in a counterbalanced order.