

- ✓ Lights enhance comfort with AVs
- ✓ Signals easily learned

AV EXTERNAL COMMUNICATIONS

AUG 2, 2018

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:

- 1 Strongly Disagree
- 2 Somewhat Disagree
- 3 Slightly Disagree
- 4 Slightly Agree
- 5 Somewhat Agree
- 6 Strongly Agree



Learnability Scoring

wrong	-1
no answer / don't kn	0
somewhat correct	1
correct	2



PARTICIPANTS

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

External_HMI_VR_recruiting_survey

Finish Cancel

Gender

Male

Female

Age

< 30

30 - 39

40 - 49

50 - 60

> 60

Do you work within any Automated Vehicle (AV) projects?

Yes

No

If yes, please describe this work.

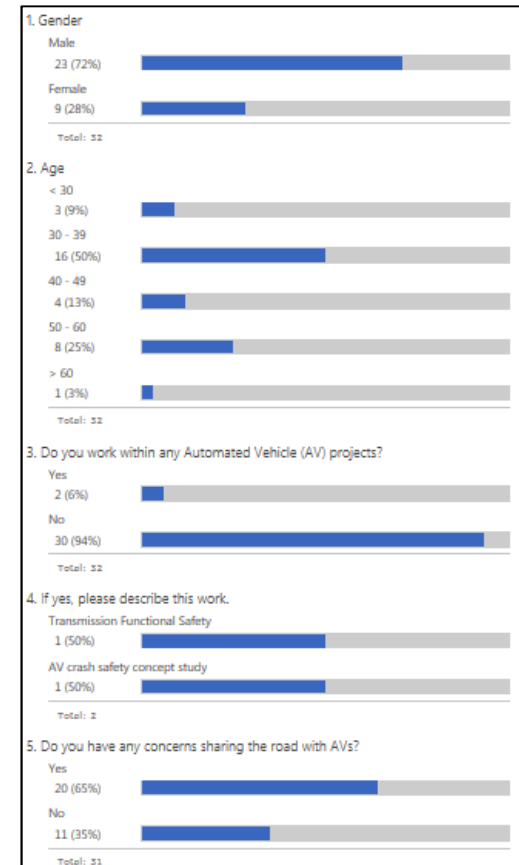
Do you have any concerns sharing the road with AVs?

Yes

No

If yes, please describe these concerns.

Finish Cancel



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]

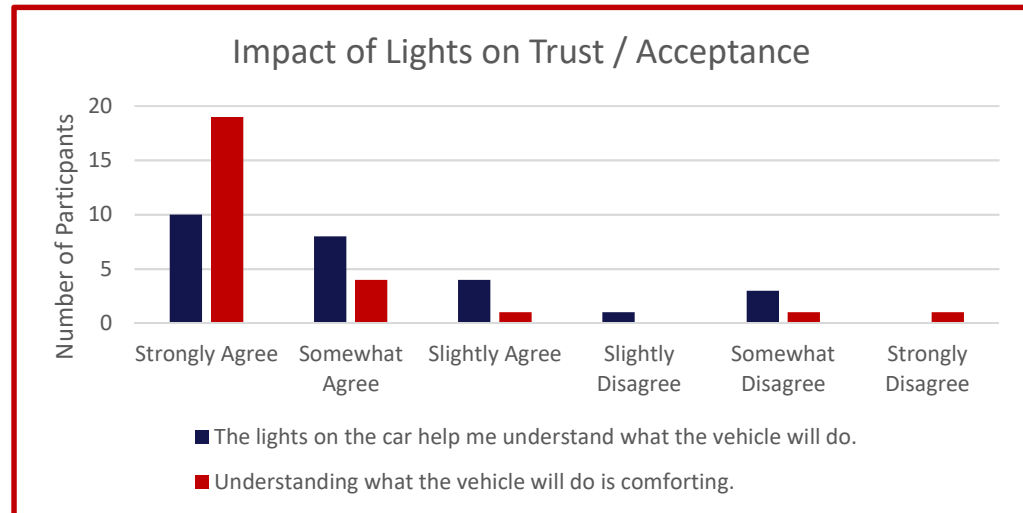
TRUST RESULTS AND ANALYSIS

	pre-study survey average	post-study survey average	change in score
1. I feel safe around automated vehicles.	4.04	4.31	0.27
2. I understand how automated vehicles work.	4.31	4.31	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. <i>The lights on the car help me understand what the vehicle will do.</i>		4.81	Not much change
6. <i>Understanding what the vehicle will do is comforting.</i>		5.42	

Trust Survey Scoring:

- 1 Strongly Disagree
- 2 Somewhat Disagree
- 3 Slightly Disagree
- 4 Slightly Agree
- 5 Somewhat Agree
- 6 Strongly Agree

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



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.

wrong	-1
no answer / don't kn	0
somewhat correct	1
correct	2

[W]	AV 1 st /lead car at stop light
[E]	AV 3 rd at stop light
[T]	AV 1 st /lead car and 3 rd at stop light
[Q]	Parking
[R]	Turning

** Post-hoc Tukey tests on ordinal logistic regression models*

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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.

Learnability Scoring	
wrong	-1
no answer / don't kn	0
somewhat correct	1
correct	2

Contingency Table Analysis										
Busy Ped		-1		0		1		2		Total
	Driving	3	12%	2	8%	1	4%	19	76%	25
	Yielding	1	4%	3	12%	1	4%	20	80%	25
	A-t-G	1	4%	1	4%	1	4%	22	88%	25
Busy Pass		-1		0		1		2		Total
	Driving	2	8%	4	16%	1	4%	18	72%	25
	Yielding	3	12%	2	8%	2	8%	18	72%	25
	A-t-G	1	4%	1	4%	0	0%	23	92%	25
Scenario W		-1		0		1		2		Total
	Driving	0	0%	5	23%	0	0%	17	77%	22
	Yielding	1	5%	0	0%	2	10%	18	86%	21
	A-t-G	0	0%	5	23%	0	0%	17	77%	22

* Totals are different due to some participants not noticing signal
 ** Participants saw 'busy ped' and 'busy pass' scene in same order, at end
 *** Participants saw 'scenario w' in a counterbalanced order