

Evaluation of AV External Communication in the Wild

Summary Presentation



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General Research Question:
Does the introduction of AV external visual communication candidates influence the outcomes of encounters with other road users?

Overview of Recent Field Study – Arlington, VA

- Public study, potential contribution to ISO/SAE standards
- Ford Transit Connect instrumented for data collection
- Data collected in urban environment, northern capitol region, Arlington, VA
- Concealed driver using a seat suit = seemingly driverless vehicle
- Over 2,350 miles (167 hours) of data collected
- Field study evaluating without visual external communication (Baseline encounters) and with visual external communication (Intervention encounters)
- Variety of roadway scenarios were targeted
- Several thousand encounters with a variety of road users
- Primary dependent variable of interest, “Change in Other Road User Behavior” for those who notice the vehicle

360 deg View Using Six Cameras



Three Signals Evaluated:

- Driving
- Yielding
- About-to-Drive



AV External Communication Signals

- **Driving (Signal State):** Obeying traffic rules/regulations, including stop/go traffic
 - Jaywalker crosses path of AV, AV will slow and avoid striking pedestrian, but signal still indicating intent to drive.
- **Yielding (Signal State):** Identified something to yield to, intent to yield, actively decelerating, including coming to a stop
 - Only if AV is lead vehicle (e.g. first approaching a red light at intersection, pulling over to side of road to pick up pedestrian)
- **About-to-Drive (Signal Transition):** Only if stopped
 - This signal is only and always activated after “Yielding” signal and AV has come to a complete stop (e.g. signal changes from red to green and AV is about to move forward).

Independent Variables (sample)

- Signal Condition
 - Baseline
 - Intervention (sequence of Yield, About-to-Drive, Drive)
- Scenario Types
 - Study Vehicle Moving Straight through Intersections
 - Study Vehicle Turning Across Traffic
 - Study Vehicle Turning With Traffic
 - Study Vehicle near High Density of Vulnerable Road Users (Groups)
 - Study Vehicle in Parking Situations (on roadway, parking lots)
 - Study Vehicle Mock Pick-ups and Drop-offs at Airport
- Intersection Type
 - Signalized
 - Signage (signs present only)
- Environment
 - Daytime & Nighttime
 - Clear & Rain



Dependent Variables (sample)

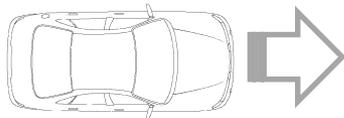
- Other Road User
 - Intended path
 - Right-of-way
 - Secondary activities
 - First road user glance to study vehicle
 - First change in behavior by other road user
 - Second change in behavior by other road user
 - Third change in behavior by other road user
 - Change in behavior by other road user after study vehicle has passed by
 - Emotions observe3d
- Study Vehicle
 - Location
 - Travel direction
 - Speed
- Environment
 - Pedestrian signal
 - Factors affecting path
- Signal Type

Collection Meta-data

- Intersections w/ Valid Encounters
 - 67% signal controlled; 33% signage only
- Lighting
 - Predominantly daytime; portion of nighttime but low visibility
- Weather
 - Sunny/partly cloudy = 86.5%; Rain/fog/mist = 9.8%, Overcast = 3.7%
- Lighting Signal Sequence Activations
 - >1,800
- Age
 - Predominantly middle-aged (~94%)
- Gender
 - Male = 57.8%; Female = 42.2%

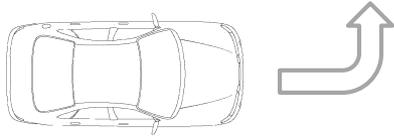
Scenarios

Study vehicle moving straight



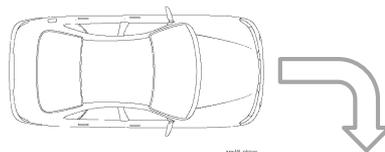
Sufficient sample of encounters w/ road user glance **+**

Study vehicle turning across



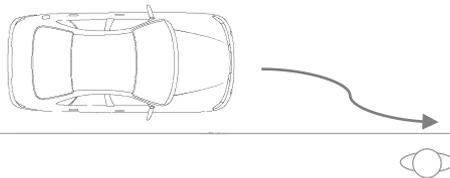
Sufficient sample of encounters w/ road user glance **+**

Study vehicle Turning with



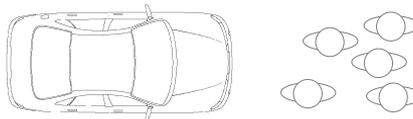
Sufficient sample of encounters w/ road user glance **+**

Study Vehicle Pickup/Drop-off



Insufficient sample **-**

Study Vehicle near High Density VRUs



Insufficient sample **-**

Research Questions

- A. Do external visual communication signals make the AV more noticeable?
- B. Do other road users change their behavior in presence of the signals?
- C. What types of other-road-user behaviors are observed in reaction to the signals?
- D. What types of emotions are observed by other road users in reaction to the signals?

RQA

Do external visual communication signals make the AV more noticeable?



Summary

In total, 19.48% of pedestrians glanced at study vehicle

- Baseline – 20.89% (33/158)
- Intervention – 18.53% (43/232)

- Pedestrians were not more likely to glance at the vehicle WITH lighting as compared to NO lighting.

RQB

Do other road users change their behavior in presence of the signals?

Summary

- Pedestrians were not significantly more or less likely, given that they glanced at the vehicle, to change their behavior WITH lighting compared to NO lighting.
- Additionally, this result did not depend upon the type of intersection (signed or signalized) nor on the type of maneuver the vehicle made (going straight, turning left or turning right).

Summary

- Jaywalkers gap acceptance was not significantly different with lighting compared to no lighting.
- Jaywalkers TTC was not significantly different.
 - (t value = $-.44$, p value = $.6647$)

Summary

- Right-of-way conflicts with other vehicles was not significantly more or less likely with lighting compared to no lighting.

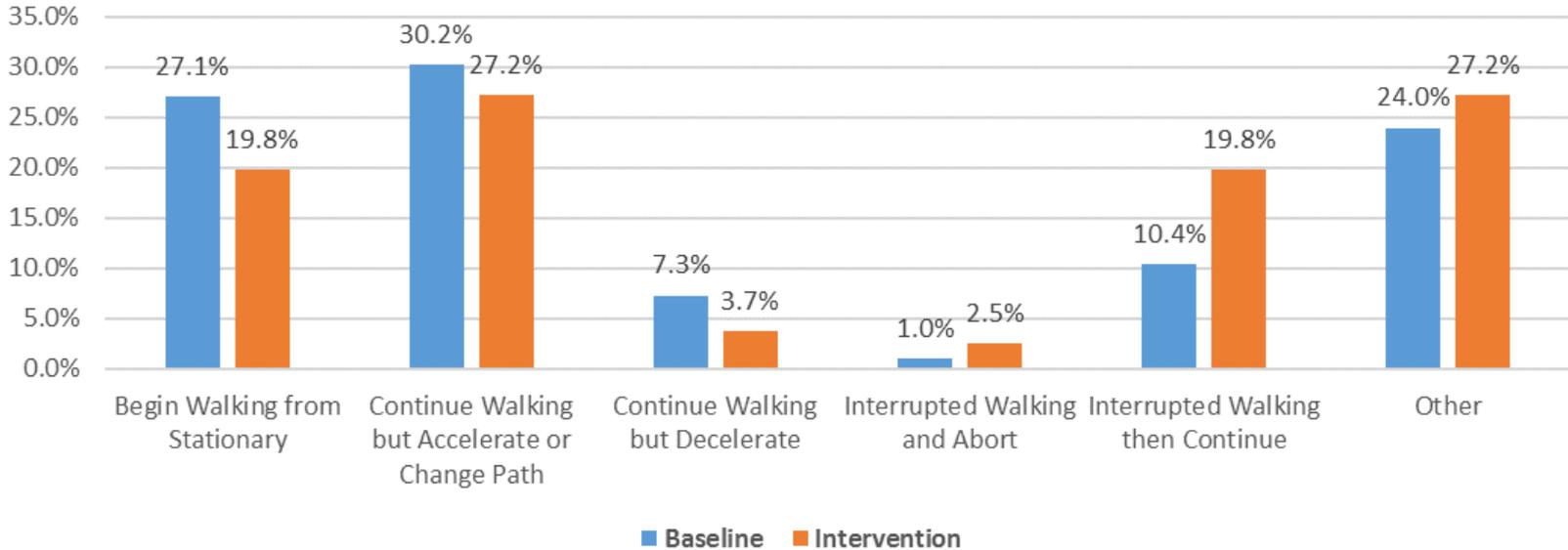
RQC

What types of other-road-user behaviors are observed in reaction to the signals?

Pedestrians - RQC: Behavior Type?

177 encounters w/ pedestrians that glanced at study vehicle AND changed initial behavior

Types of Behavior Changes After Glance



RQC Summary

- There was no statistically significant evidence that pedestrians changed their behavior, and this did not change significantly depending on the intersection type or maneuver type.
- With higher samples (more encounters), possible to see increased likelihood of “Interruption” w/ intervention, and “Begin Walking” w/ baseline?

Summary

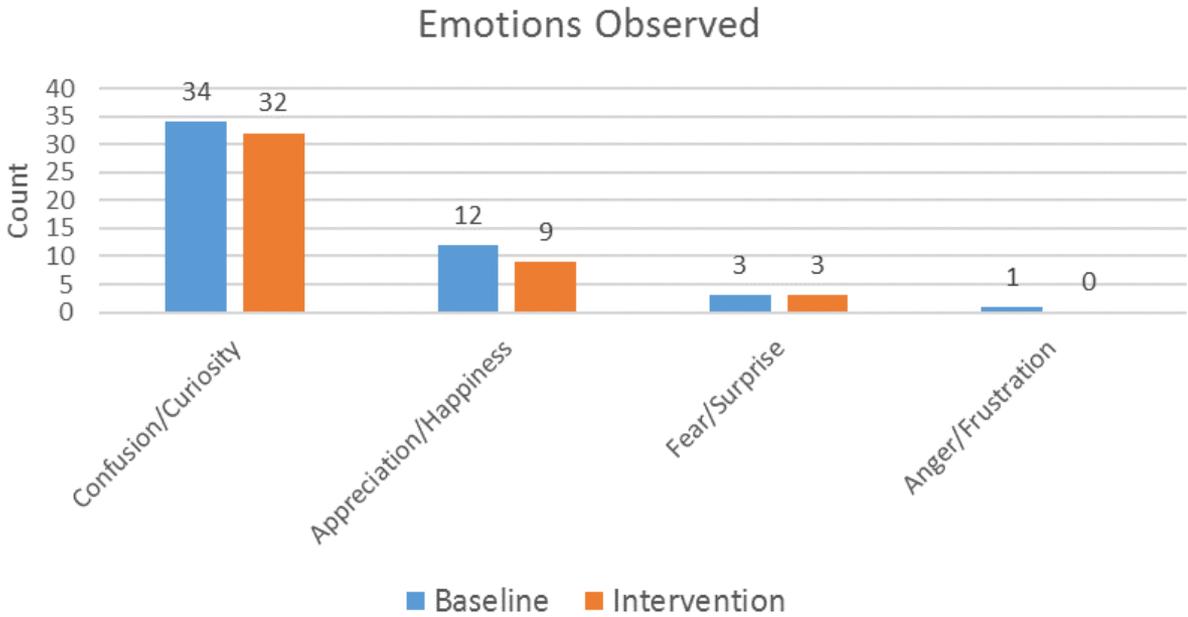
- Other drivers were not more likely to cede right of way or take away right of way regardless of intervention status

RQD

What types of emotions are observed by other road users in reaction to the signals?

Pedestrians - RQD: Emotions Observed?

Of the 377 encounters with pedestrians that underwent full video reduction, 82 were observed to express one or more emotions



RQD Summary

- There was no apparent difference in pedestrian emotions observed between conditions

Intercept Survey Results

- 9 respondents
- Mean Age: 31 (standard deviation ~13)
- 7 Male, 2 Female
- All respondents reported seeing an unusual vehicle pass by, and none reported seeing it prior to the day of their response
 - All given six forced choice/rating questions, and three open-ended questions.

Selection of Positive Survey Comments

- “It was new and exciting.”
- “This is awesome, keep up the good work.”
- “Made me stop and think about the future of self-driving cars”
- “ It peaked my interest”
- “It made me very intrigued, so definitely a positive change”

Selection of Neutral Survey Comments

- “Just saw it once. Once we noticed no one was driving it, it was very hard not to watch it.”
- “After a while I would no longer stop to observe.”
- “First time that I saw it. It looked like it had a motion sensor with a GPS on the front.”
- “I stopped and looked”
- “It made me stop for a second to observe. Other than that my behavior was not affected”
- “ Just made me wonder why nobody was in there”

Selection of Survey Comments Indicating Confusion

- “I didn’t understand why there was no driver ”
- “ I had questions ”
- “Made me ask questions ”

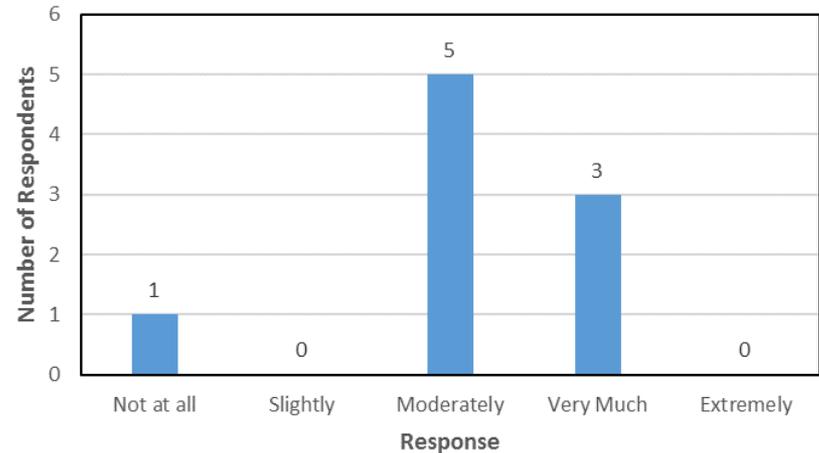
Intercept Survey Results, cont.

Q1: Did you see a lighted signal on the front windshield? What was it doing, and what did you interpret it to mean?

- 44% of respondents noticed the external signal on the windshield
- Comments regarding signal behavior, and interpretation:
 - “Sort of sensing”
 - “Processing similar to a spinning wheel”
 - “I don’t know”
 - "Red light in the front at the crosswalk the vehicle stopped and chirped."

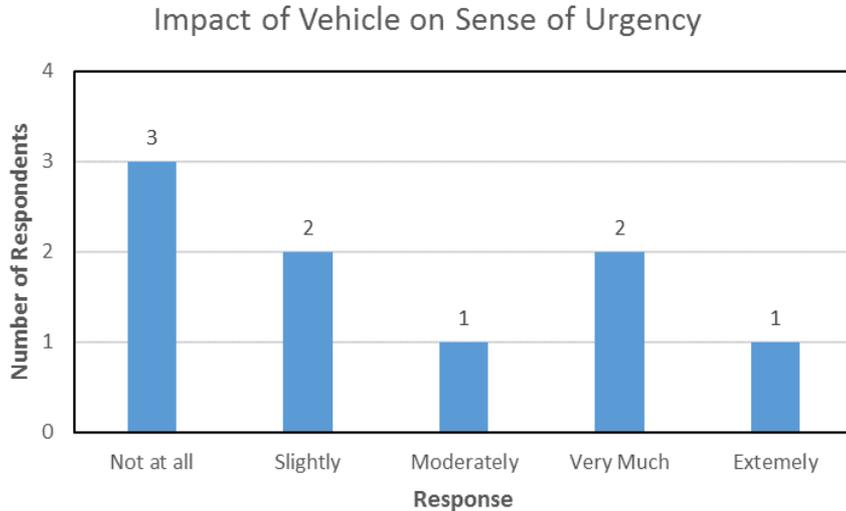
Q2: How much was your behavior affected by the vehicle?

Effect of Vehicle on Behavior

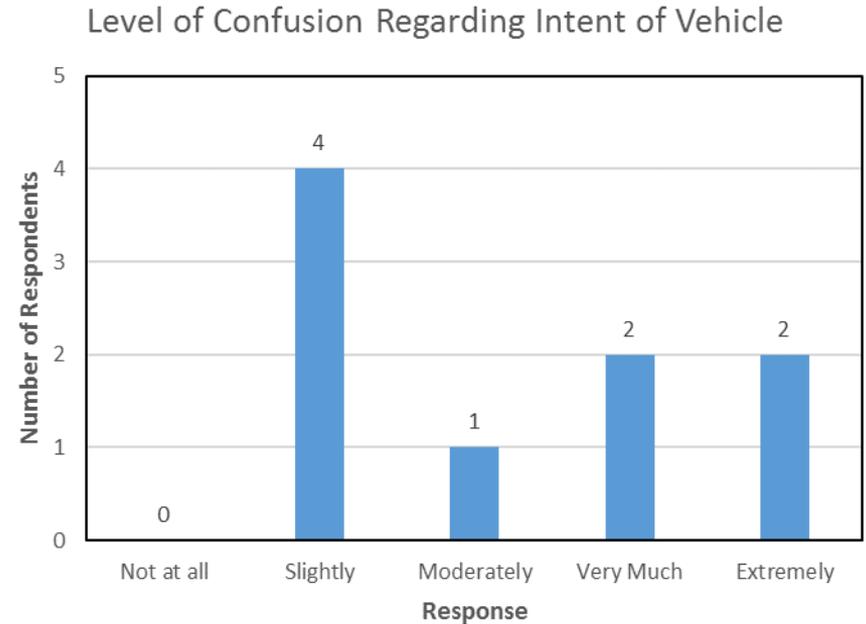


Intercept Survey Results, cont.

Q4: How was your sense of urgency affected by the vehicle?

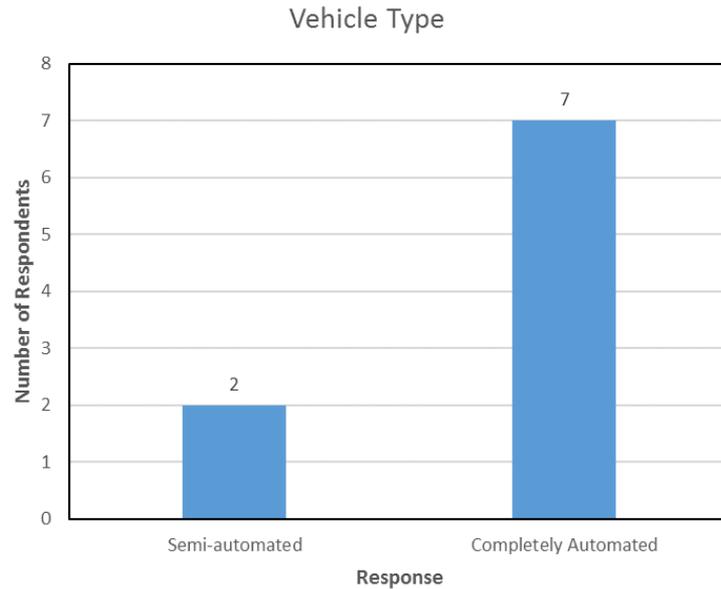


Q5: Were you confused about the intent of the vehicle (what its next move was going to be)?



Intercept Survey Results, cont.

Q6: What type of vehicle do you think it was?



Study Results

- Only ~19% of road users encountered noticed the vehicle (looked up) in baseline and in intervention
- Intersections w/ Valid Encounters
 - 67% signal controlled; 33% signage only
- Collected in various weather conditions
 - Sunny/partly cloudy = 86.5%; Rain/fog/mist = 9.8%, Overcast = 3.7%
- Pedestrian encounters across gender
 - Male = 57.8%; Female = 42.2%
- Based on data collected in Arlington, VA:
 - The presence of the signals did not make the AV more noticeable
 - Overall, other road users did not change their behavior in the presence of the signals (no concerning behaviors)
 - No different emotions were observed in the presence of the signals
 - Surveys indicate people in favor of AV external communication in some form

Remaining Questions

- **Will behavior change over time when in a more AV-immersive environment?**
 - Increase chance of multiple encounters with pedestrians (not just first exposure data)
- **Regardless of behavior change, does the presence of visual external communication help to improve road user trust and acceptance of AVs in their environment?**
 - If so, there will be tremendous value of such lighting above safety alone



Questions?

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