Breakout Session # 2.2

Summary of Key Findings and Lessons Learned

- Our expert panel: Alex Epstein, Emily Frascaroli, Nidhi Kalra, Bernard Soriano
- Driver education will become more important, and more of a gap
- Customer acceptance is still an open question. How safe do AVs need to be for them?
- People are creative and will find ways to misuse any automated driving system
- People aren't necessarily good judges of relative risk
- It seems likely that 94% driver error is hiding some vehicle and environmental issues

Breakout Session # 2.2

Recommended Action Items

- New education methods need to be adopted. “OK Ford, how do I … ?”
- Need to close the gap between reality and marketing
- OEMs are learning from aviation. We should continue to learn those lessons from the similarities
- Must help drivers be aware of the system limitations
- There are still important research needs
  - Should manual override always be available?
  - How big a risk is skill degradation? How to mitigate?
  - …
- We hope to develop new research needs statements from the groups contributions

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Needs of Pedestrians Interacting with Automated Vehicles

Ruth Madigan

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Acknowledgements

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Lausanne: Anne Koymans Mellano, Philippe Vollichard

Trikala: Evangelia Portouli, Giannis Karaseitanidis, Xristina Karaberi,

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ITS

No ‘Drivers’ in the Vehicle

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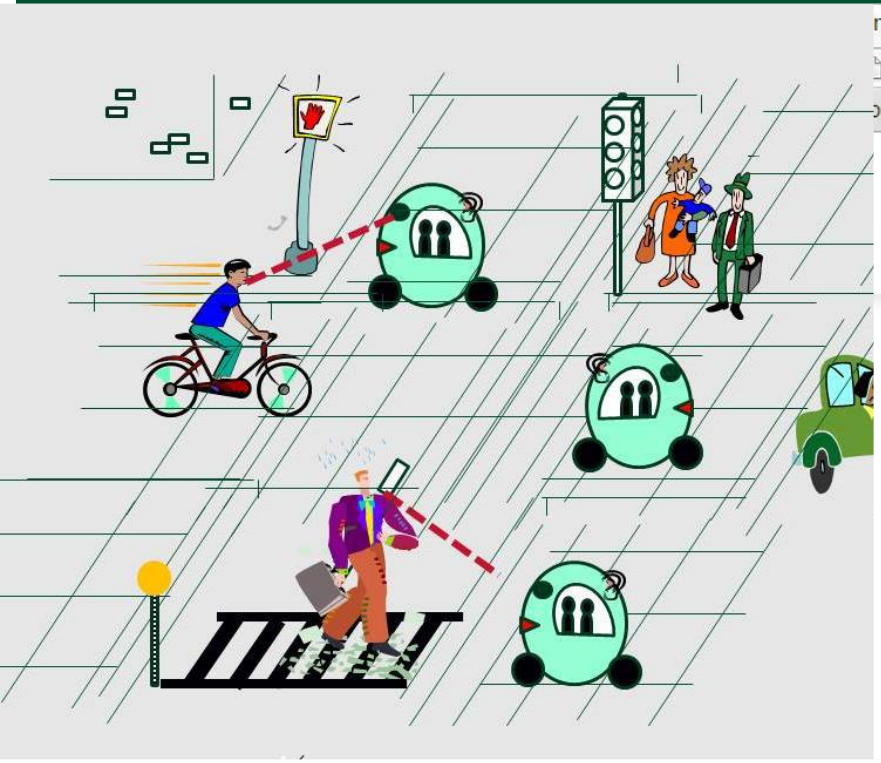

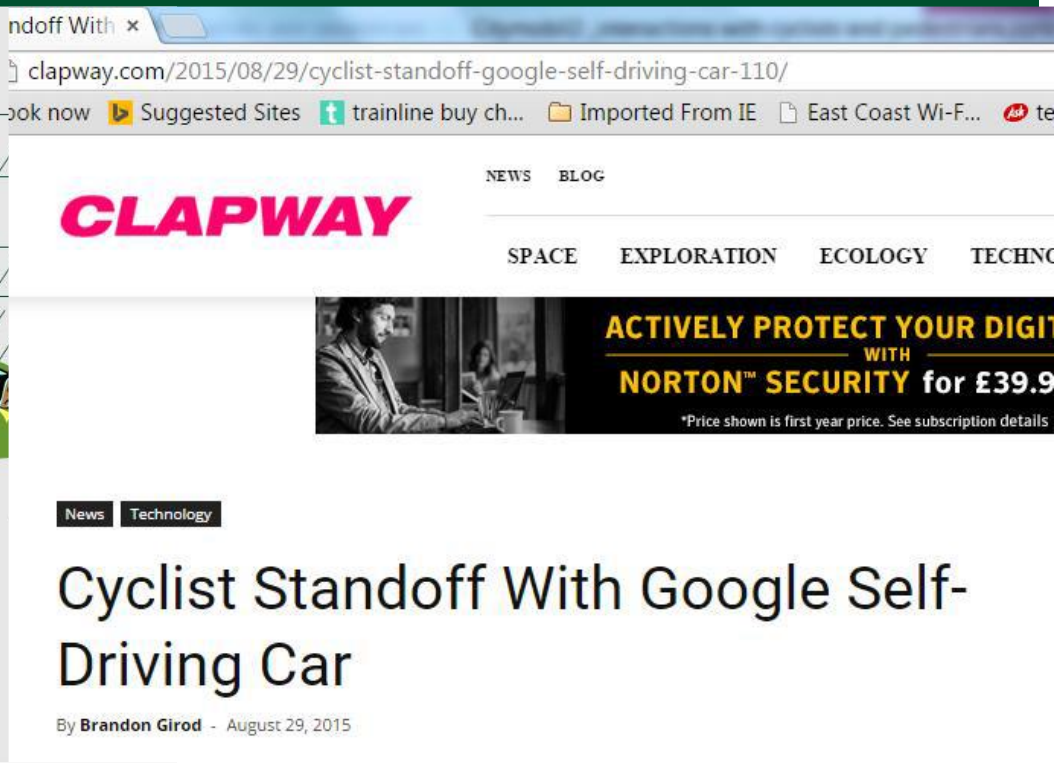

- No more eye-contact
- No more gestures
- Not about obstacle avoidance/detection, but about COMMUNICATION & <u>mutual</u> intention recognition

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Automated/Autonomous/ Driverless/Self-driving

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Human Machine Interface

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Nissan

Mercedes

Door opening indicator | Forward indicator | Reverse indicator

Mitsubishi

ITS

Google Patents

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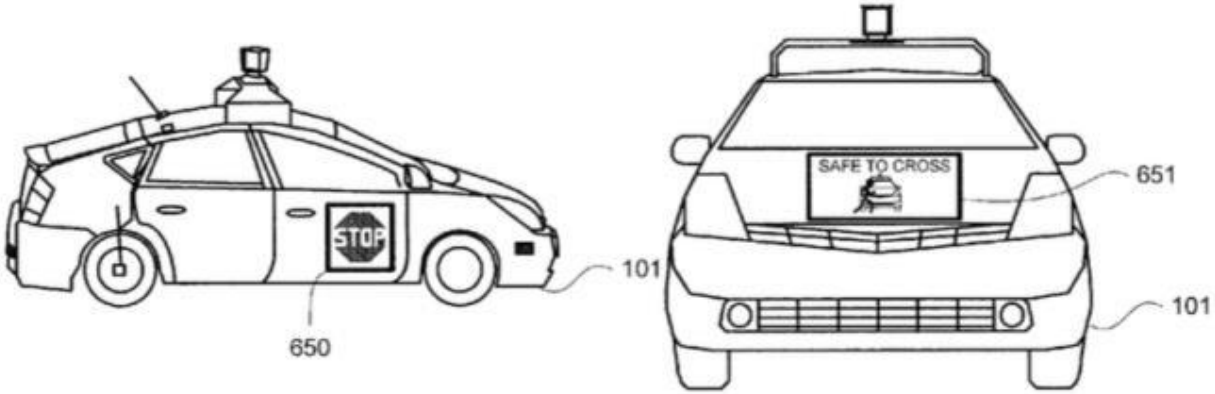

Urmson et al., 2015

FIGURE 6C

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Clamann, Albert, & Cummings, 2016

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Lagström & Lundgren, 2016
Habibovic et al., 2016

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Rothenbücher et al., 2016

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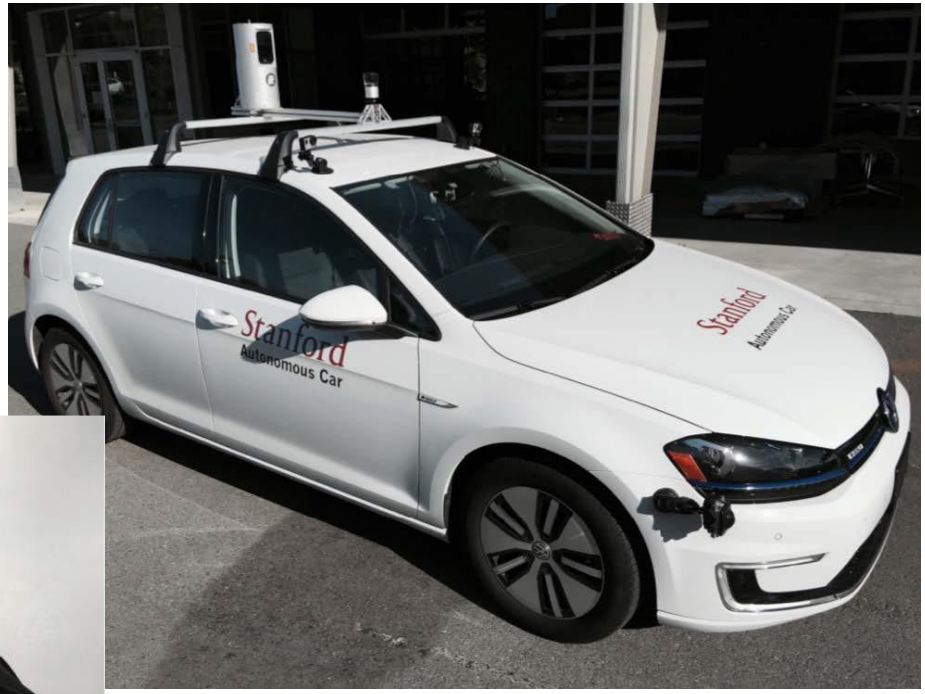

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- Large-scale demonstration of Automated Road Transport Systems (ARTS) in a number of cities across Europe
- Public transport
- No driver/operator
- Low speed (up to 45 km/h)
- Simultaneous Localisation and Mapping (SLAM)
- Shared space
- First mile/last mile solution to complement other public transport options

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Demo Vehicles

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Interviews, Focus Groups, on-site surveys & video analysis

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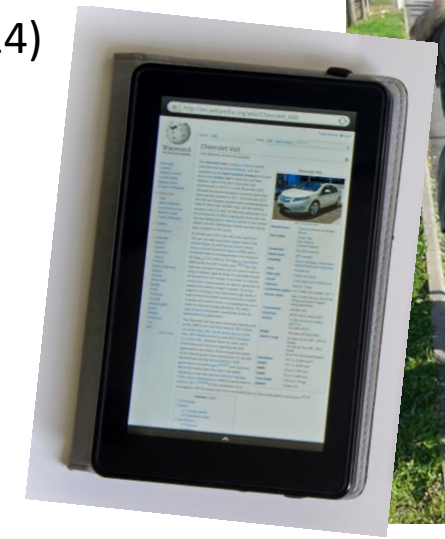
(N = 24)



(N = 349)
La Rochelle = 204
Lausanne = 145

(N = 20)

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Questionnaire Study

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- 42 questions
  - 8-10 minute completion time
- Demographics & travel patterns
- Interaction & communication requirements
- Unified Theory of Acceptance and Use of Technology (Madigan et al., 2016)

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Trial Locations

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La Rochelle, France:

- November 2014 to April 2015
- Route 1.7km including 7 station stops
- Mainly operating in shared space
- 204 participants

Lausanne, Switzerland

- April to August 2015
- Route 1.6km including 6 station stops
- 145 participants
- Mainly operating on EPFL campus

Trikala, Greece

- September 2015 to February 2016
- Route 2.5km including 8 station stops
- 315 participants
- Mainly operating in dedicated lane

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Population Characteristics

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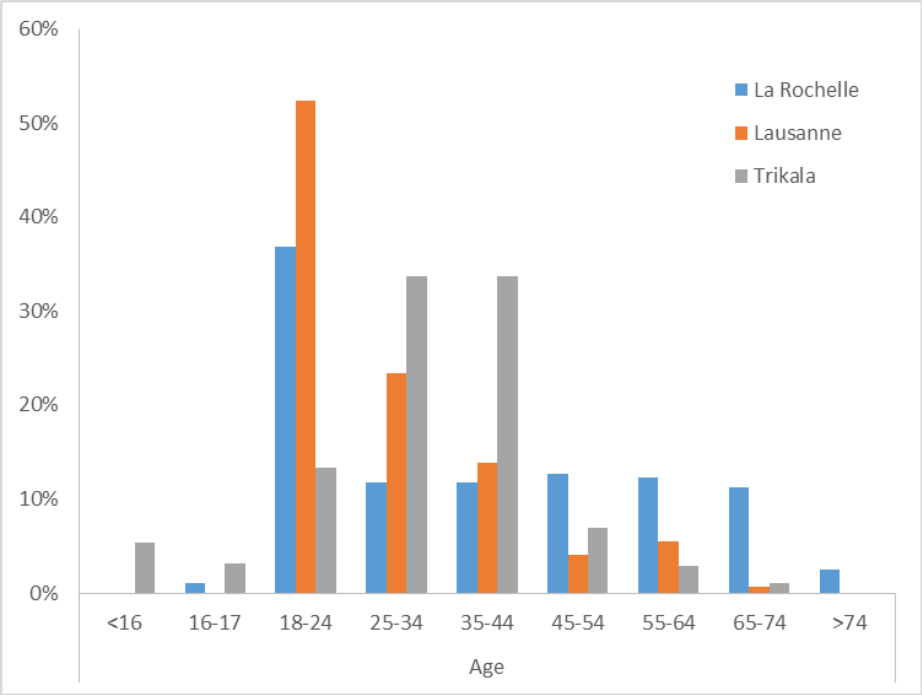

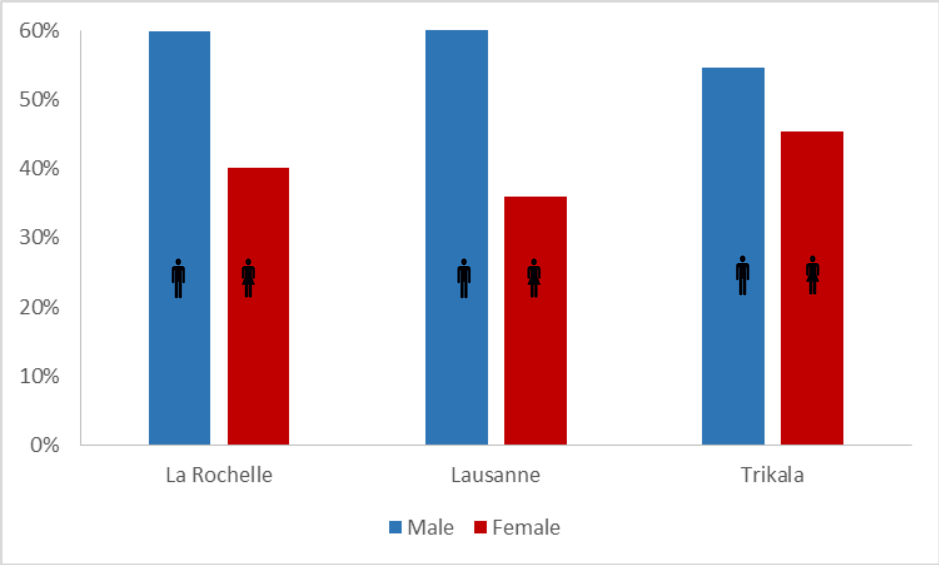

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Key Questions

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- How do cyclists and pedestrians feel (safety/priority) about the ARTS?

- What information do cyclists & pedestrians require from the ARTS?

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Safety and Priority?

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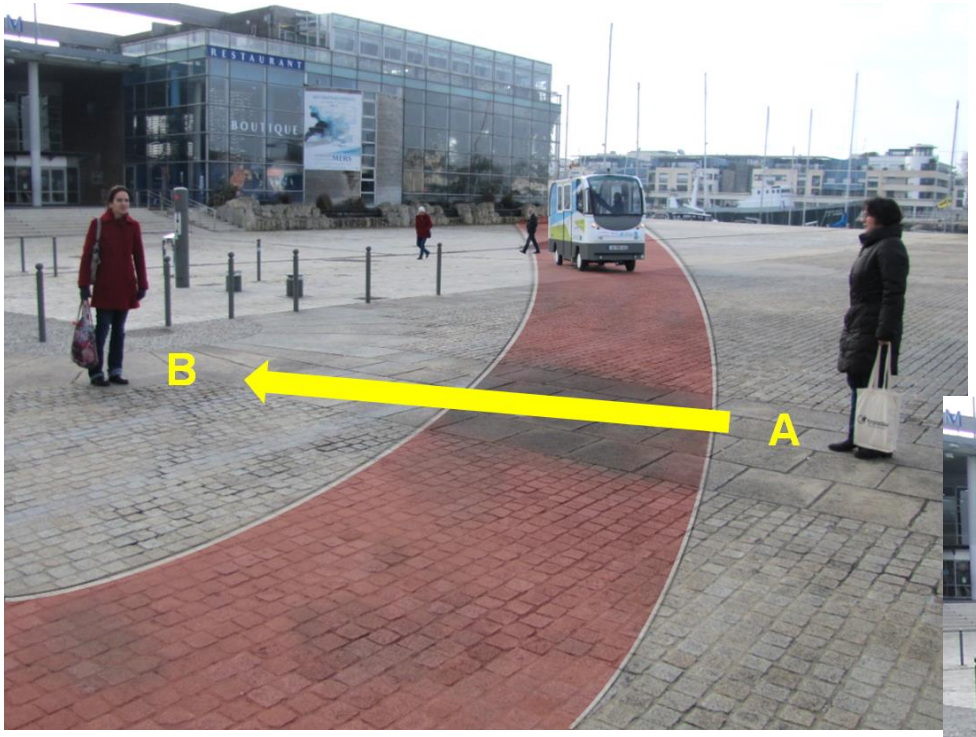

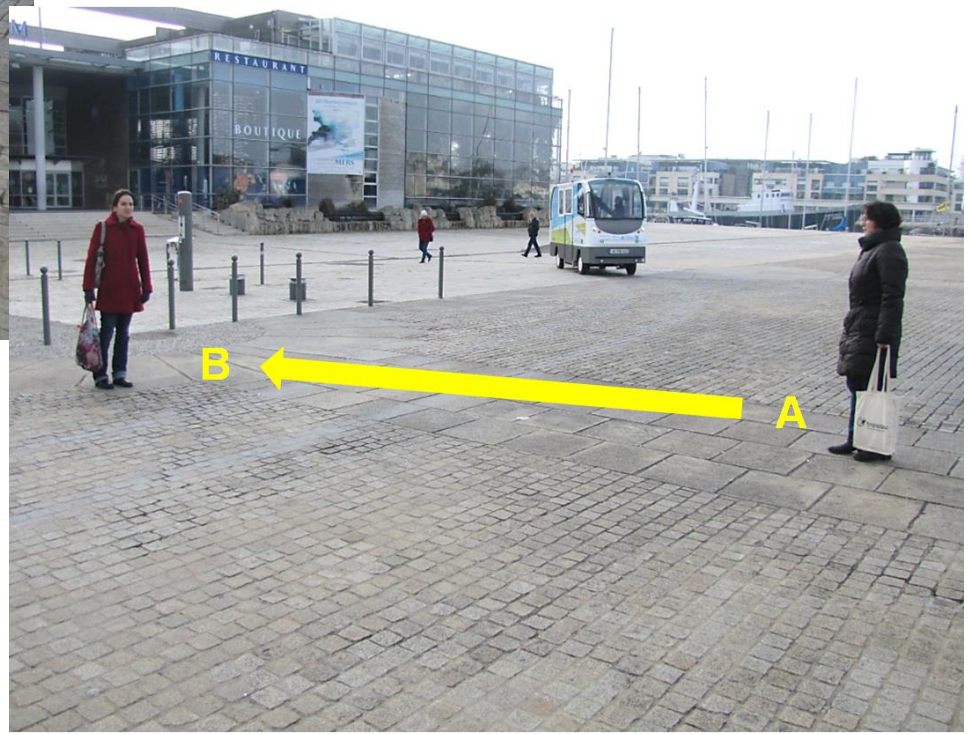

Images from La Rochelle

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Do you feel more safe?

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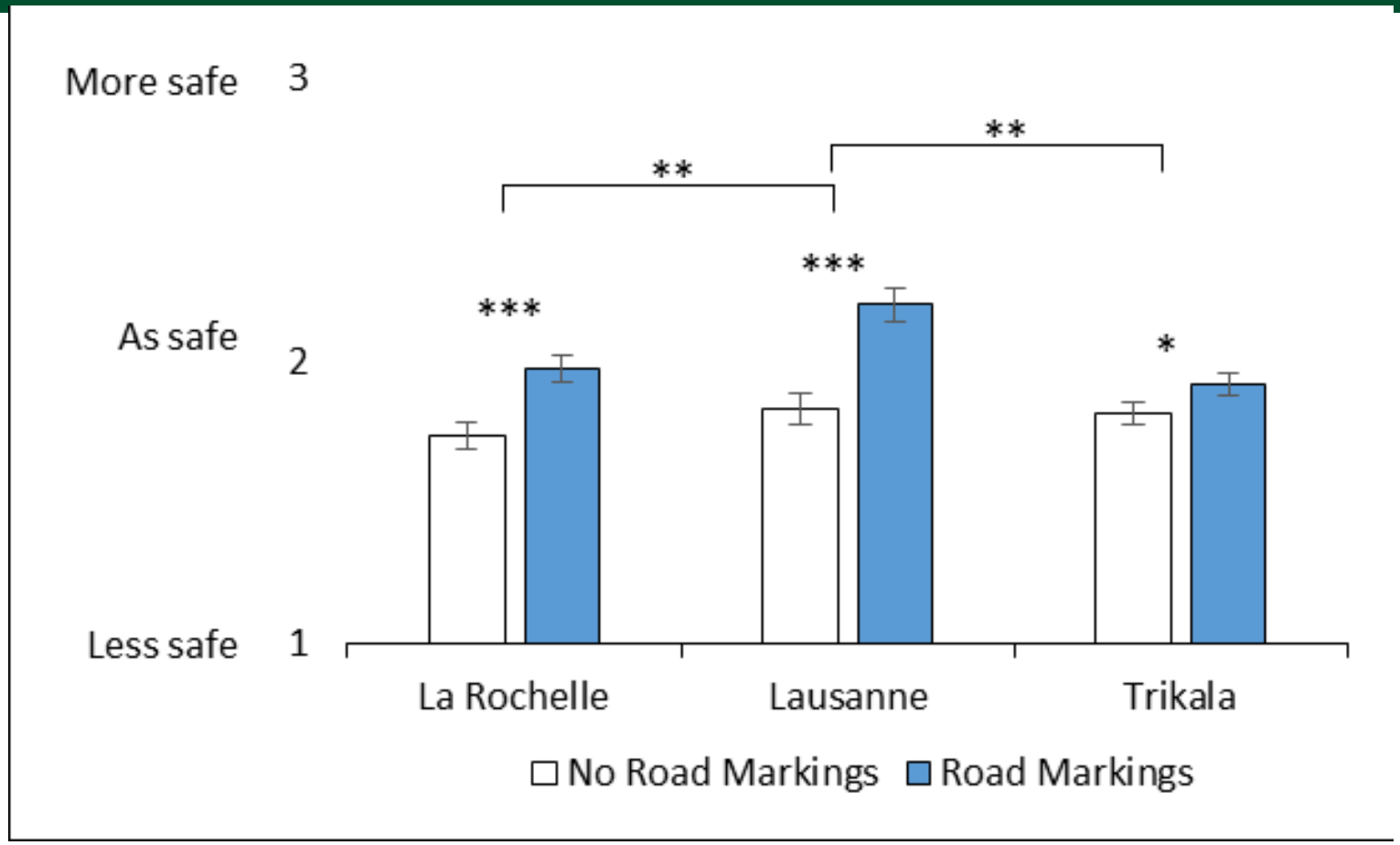

- Road Marking ($F(1,659) = 5.26$, $p<0.05$, $\eta p^2 = 0.08$
- Location ($F(2,659) = 2.493$, $p<0.05$, $\eta p^2 = 0.01$)
- Road Markings & Location ($F(2,659) = 6.27$, $p<0.01$, $\eta p^2 = 0.02$)

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Who has priority?

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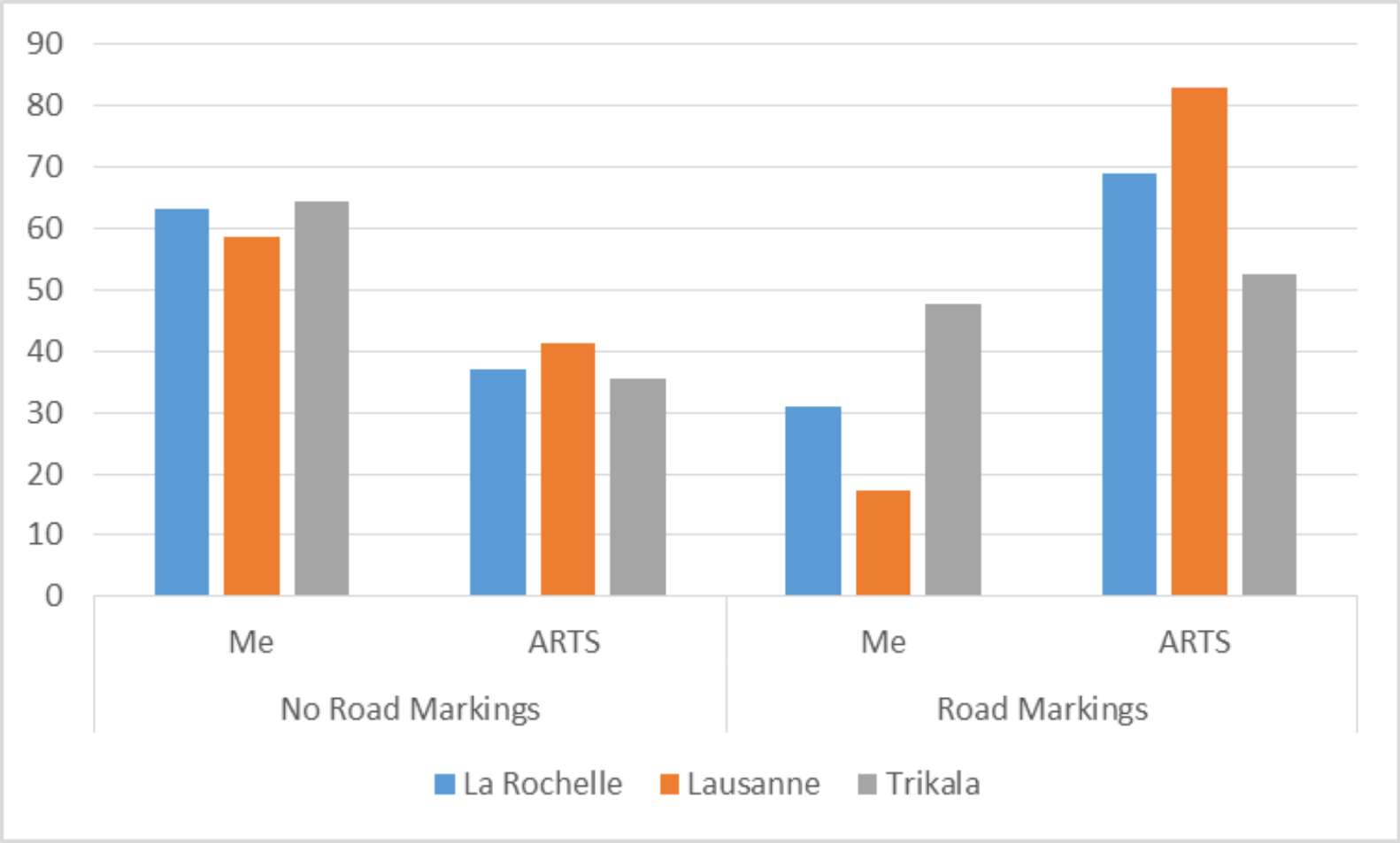

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What information?

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ARTS Behaviour (5 point likert scale)

- Whether it is stopping?
- Whether it is turning?
- How fast is it going?
- Whether it is going to start moving?
- Whether it has detected me?

Overall Results

- Most important: **has it detected me?**
- Least important: speed of travel
- No effects of Road Markings

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How would you like to receive this information?

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- Visual (lights)
- Visual (words)
- Auditory (tones/signals)
- Auditory (words)

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La Rochelle

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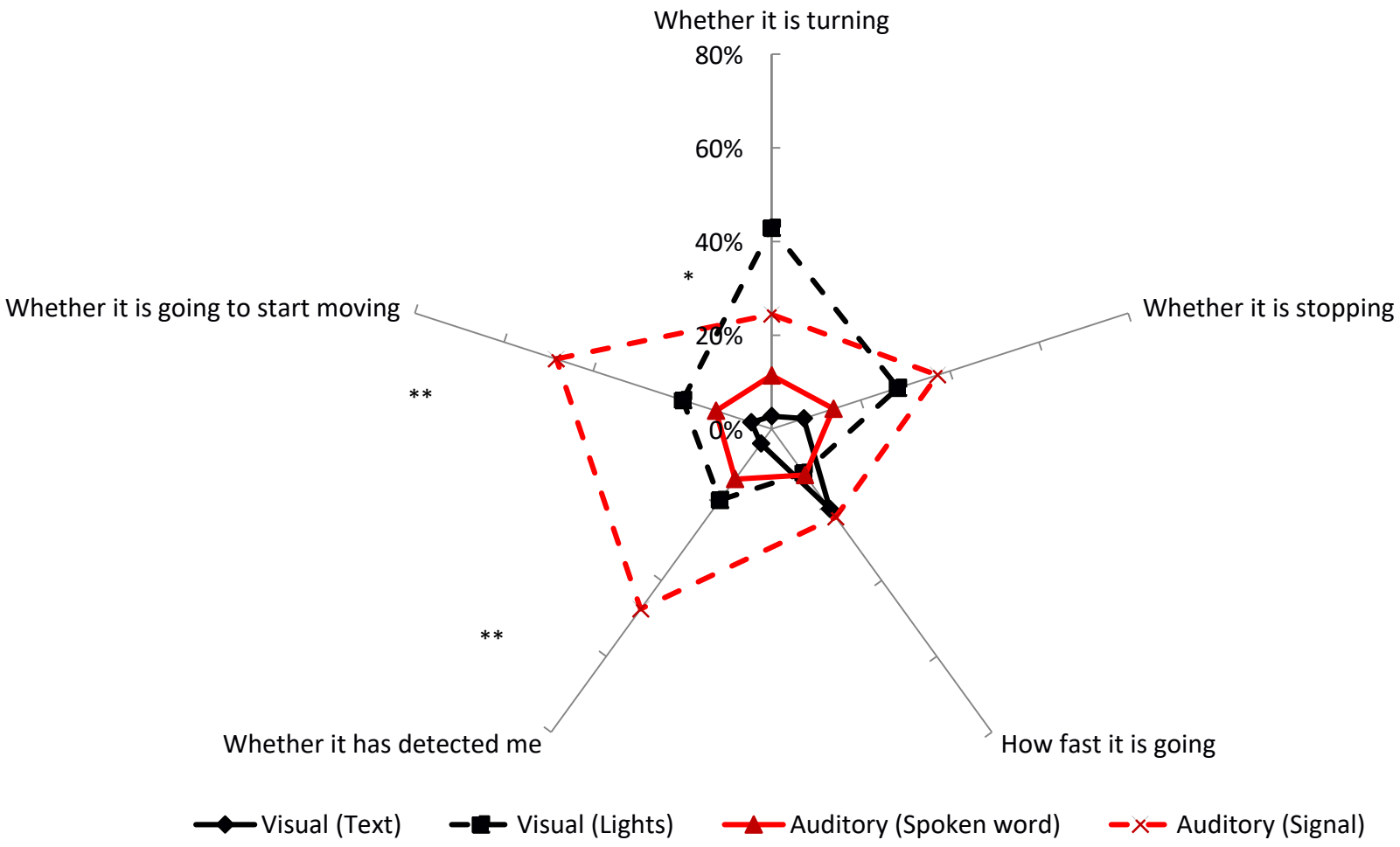

ITS

Lausanne

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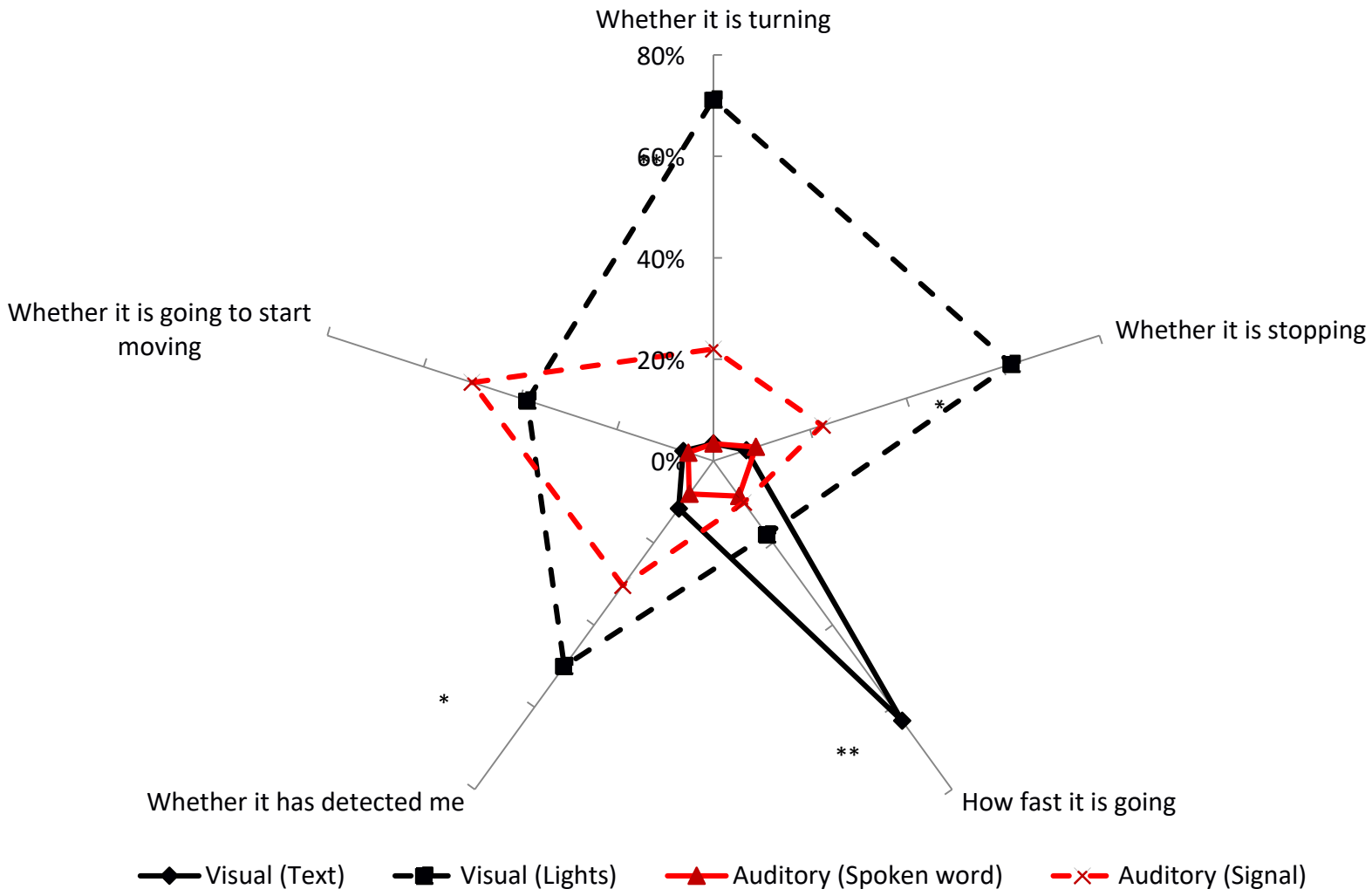

Trikala

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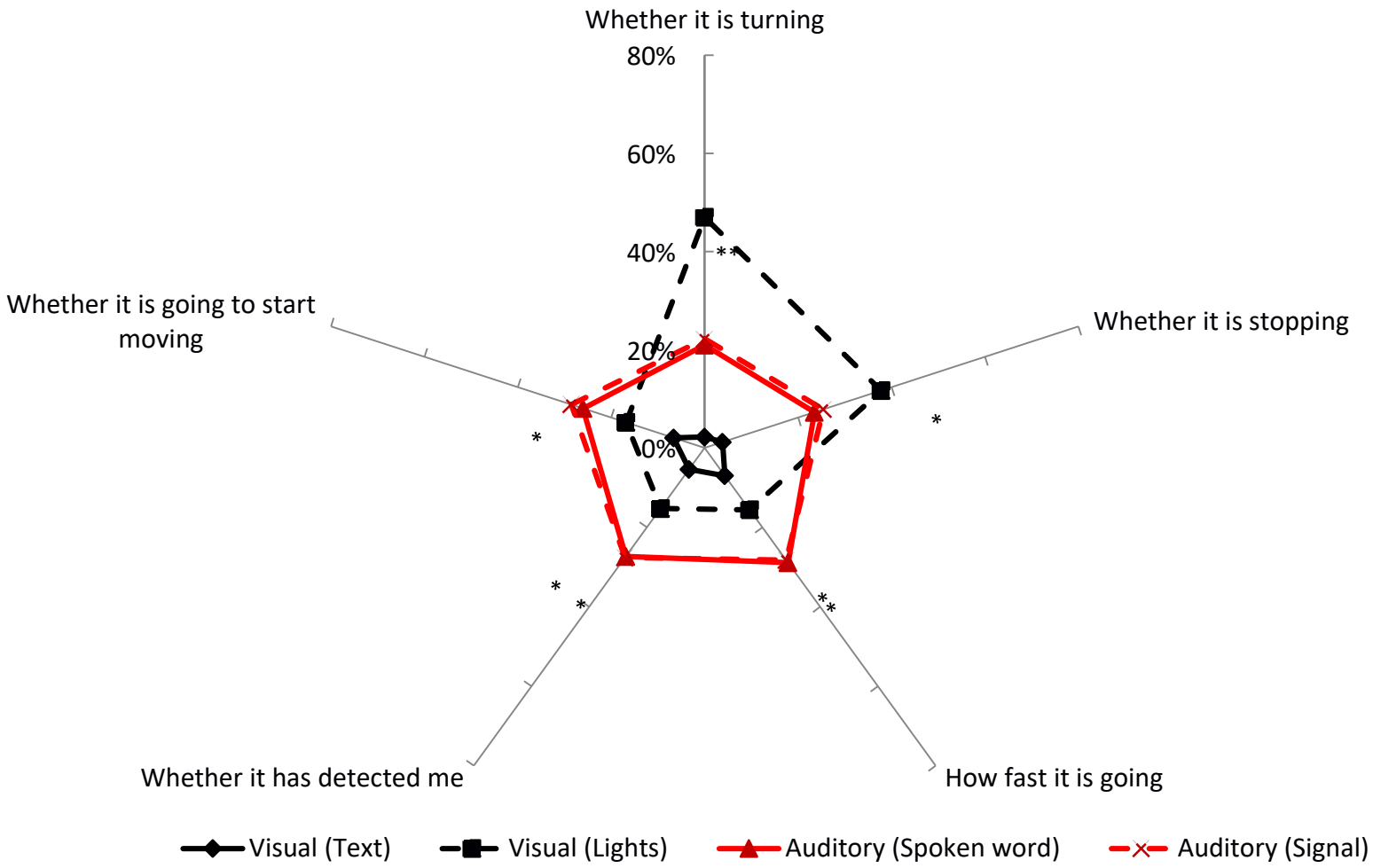

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Focus Group: La Rochelle

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Priority

- **Direction of travel** not obvious
- Not sure who had priority
- Would prefer **demarcations**
- Not sure if the vehicle can **identify hazards**?
- Suggested use of horns and lights for **detection and communication**

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Other Focus Group comments

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- **Visibility**: Colour maybe too discrete, brighter colour to make it easy to see. In La Rochelle yellow would be more suitable to fit in with other public transport modes

- **Sound**: Lack of engine noise a problem for its localisation, especially for the visually impaired

- **Speed:** Too slow, but probably ok in shared space

- Better for **tourists** than commuters

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Summary & Conclusions

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- As the deployment of automated vehicles become commonplace, the views of other road users should be sought
- In particular, understanding how VRUs (and other vehicles) interact and communicate with a ‘driverless’ vehicle is important
- This study shows that VRUs definitely want some information and (at the moment) prefer the ARTS to be in a dedicated space.
- They assume they have priority in a shared space

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Issues to consider…

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- Ability to see/hear/understand messages & stimuli
- Global understanding (international standards) of messages used
- Two-way communication vs. uni-directional
- Role/responsibility of the ‘driver’

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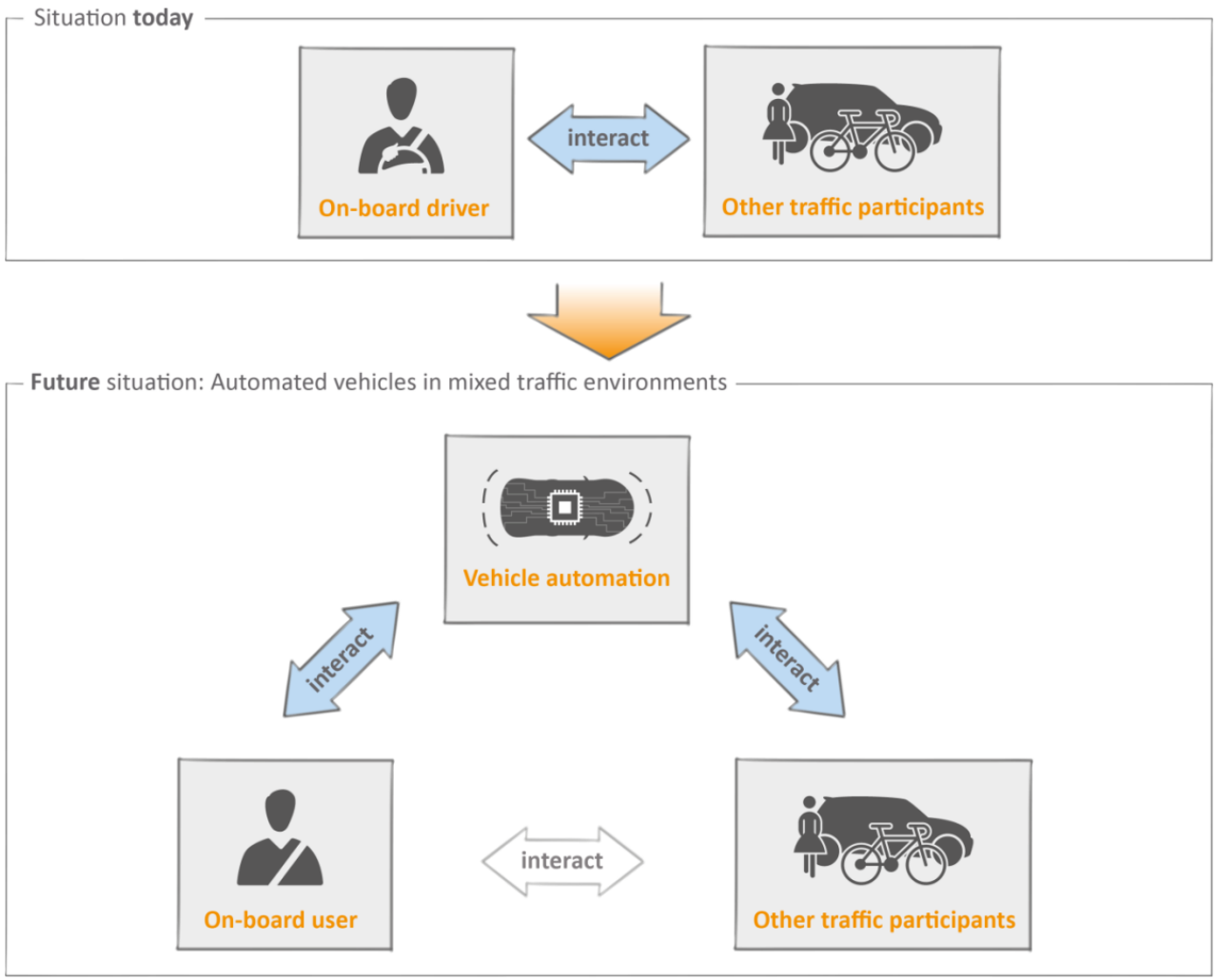
Next Steps…….

interACT

Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

This project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723395.


Situation today
On-board driver
interact
Other traffic participants
Future situation: Automated vehicles in mixed traffic environments
Vehicle automation
interact
interact
On-board user
interact
Other traffic participants

Questions?

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Effects of Non-verbal communication cues on decisions and confidence of drivers at an uncontrolled intersection

Satoshi Kitazaki, Ph.D.
Director, Automotive Human Factors Research Center
National Institute of Advanced Industrial Science and Technology

This research was funded in part by grant # 1R49CE002108-01 of the National Center for Injury Prevention and Control/CDC and conducted at Department of Neurology, University of Iowa.

Background

- The traffic regulations are sometimes uncertain in situations such as uncontrolled intersections, transition of traffic signals, merging/changing lane, and multi-lane roundabouts.

- Drivers exchange their intentions with other drivers in those situations to arrive at safe and efficient joint actions using various formal and informal non-verbal communication cues that include signals sent by the devices (blinker, brake lights etc.), vehicle behaviors (position, speed, acceleration/deceleration etc.), and driver's behaviors (eye contact, hand gestures etc.)

- What about automated vehicles (Level 3+) in mixed traffic?
- Automated vehicles are also expected to communicate with other road users.

- First, it is important to understand how current drivers non-verbally communicate with other road users.

Objective and research questions

Objective

To understand effects of non-verbal communication cues on drivers' decisions and confidence.

Specific research questions

When and how do vehicle behaviors and hand gestures influence drivers' yielding decisions and confidence at an uncontrolled intersection?

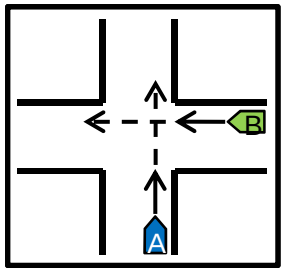
Some expectations and recommendations for automated vehicles will be discussed.

Methods

1. Scenarios

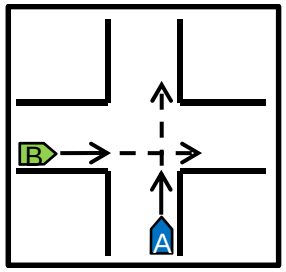
One-on-one interviews were conducted to measure subjective responses to stimuli. The study used straight-cross-path and left-turn scenarios around an uncontrolled intersection where priority rules were officially in force but sometimes uncertain.

SC



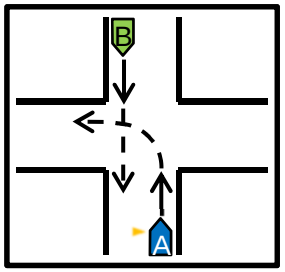
Straight-Cross-Path

SCP



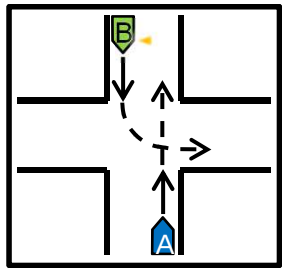
Straight-Cross-Path with Priority

LT



Left-Turn

LTP



Left-Turn with Priority

- Crossing two roads had the same width and there was no major road.
- Two cars were approaching the intersection and expected to reach the intersection at the same time.
- Car-A was assumed to be driven by the subject.
- Car-B sent various communication cues to the subject.
- The subject officially had priorities to go in SCP and LTP.

Methods

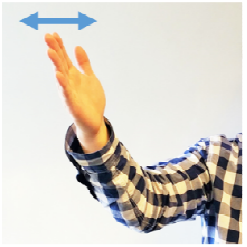
2. Communication cues

The communication cues were various combinations of vehicle behaviors and hand gestures.

Experimental conditions: combinations of vehicle behaviors and hand gestures

		Hand gestures		
		No hand gesture	Stop hand gesture	Go hand gesture
Vehicle behaviors	Constant speed	X (Baseline)		
	Speeding up	X	X	
	Slowing down	X		X

Stop hand used in all scenarios



Go hand gesture used in SC and SCP

Go hand gesture used in LT and LTP

Methods

3. Rating scales

- Yielding frequency (*YF*)

  Frequency of yielding in similar situations in subject's driving experience

Never	*Rarely*	*Occasionally*	*Frequently*	*Always*
(1)	(2)	(3)	(4)	(5)

- Confidence level (*CL*)

  Confidence about the inferred intention of the Car-B driver.

Not confident at all				*Perfectly confident*
(1)	(2)	(3)	(4)	(5)

Methods

4. Subjects

- A total of 65 subjects with the age of 30 and older (mean age of 57 years) were recruited from the general population of Iowa City.
- The gender was balanced.
- Each subject participated in the experiment either with the scenarios SC and SCP or with the scenarios LT and LTP (N.B. 32 subjects for SC and SCP, and 33 subjects for LT and LTP).
- The order of the two scenarios and the order of the cue conditions within each scenario were counterbalanced to avoid the order effect.

Experimental conditions and the number of subjects

		Scenarios			
		Straight-Cross-Pass	Straight- Cross-Pass with Priority	Left-Turn	Left-Turn with Priority
Cue conditions	Constant speed Speeding up Slowing down Speeding up + Stop Hand gesture Slowing down + Go Hand gesture	32 subjects		33 subjects	

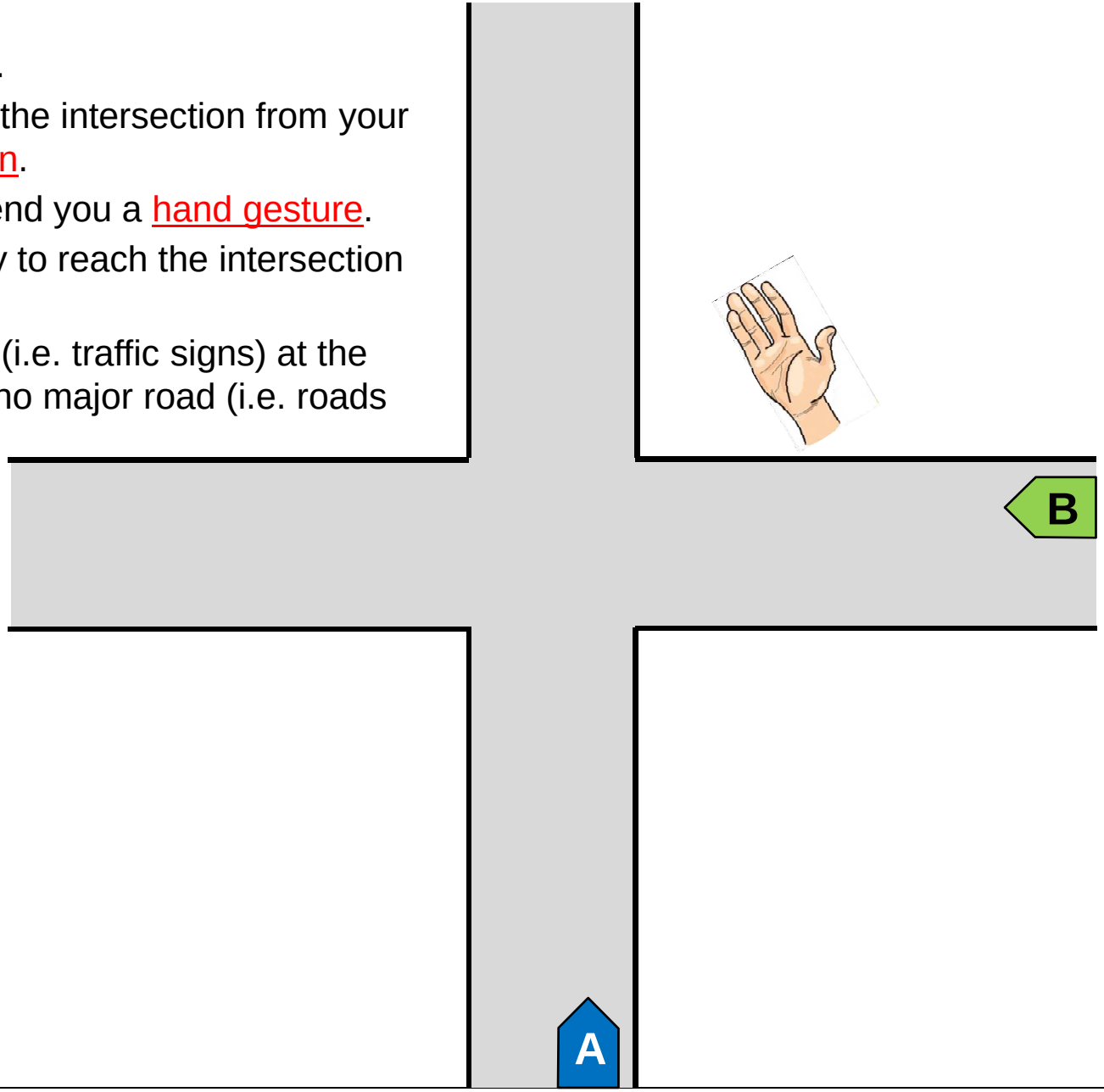
Methods

5. Experimental procedure

1. The experimenter showed the video of the intersection for calibration of subject's image of the intersection (only once at the beginning of the experiment)
2. The experimenter verbally explained each scenario and each cue condition to the subject. The priority rule was NOT explained to the subject.
3. For hand gestures, the experimenter demonstrated one of the two hand gestures.
4. A schematic computer animation showing the plan view of the intersection and the two moving cars was presented to the subject.
5. The animation was terminated before the two cars reached the intersection to avoid showing additional cues.
6. The subject rated Yielding frequency and Confidence level.

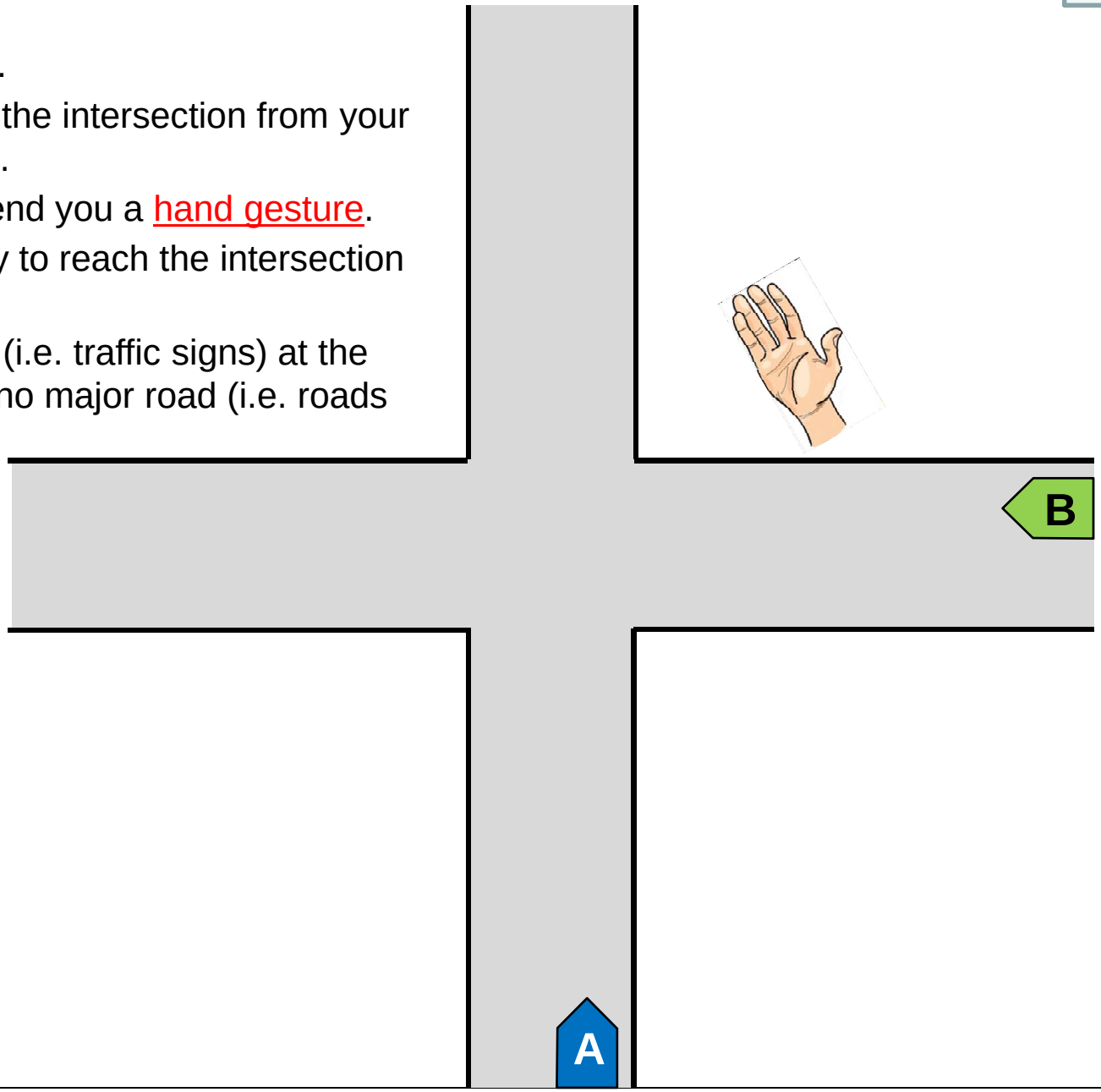
Situation 1.2.3

- You are driving Car-A.
- Car-B is approaching the intersection from your right and slowing down.
- The driver of Car-B send you a hand gesture.
- The two cars are likely to reach the intersection at the same time.
- There are no controls (i.e. traffic signs) at the intersection. There is no major road (i.e. roads are equivalent).



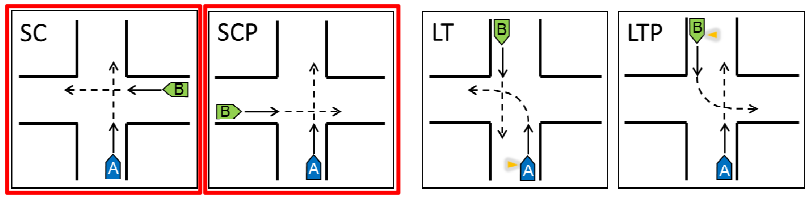
Situation 1.3.3

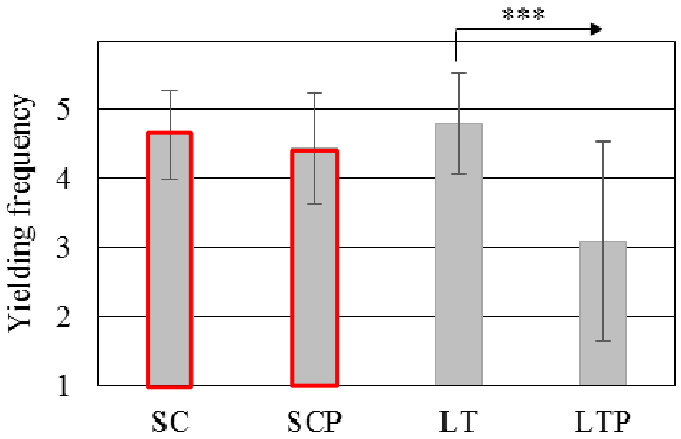
- You are driving Car-A.
- Car-B is approaching the intersection from your right and speeding up.
- The driver of Car-B send you a hand gesture.
- The two cars are likely to reach the intersection at the same time.
- There are no controls (i.e. traffic signs) at the intersection. There is no major road (i.e. roads are equivalent).

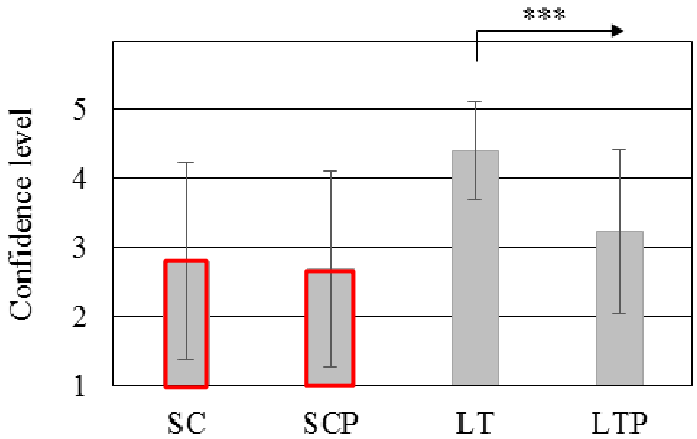


Results

1. Effects of priority rules







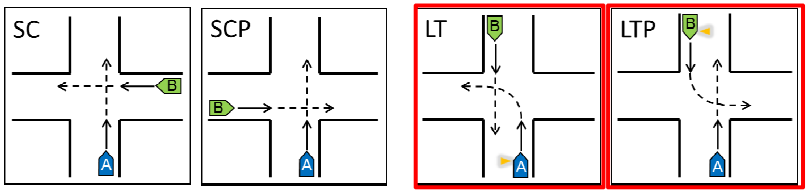
Mean±SD of *YF*s and *CL*s with constant speed. Statistical differences were calculated between SC and SCP, and between LT and LTP; *** $p \leq 0.01$, ** $0.01 < p \leq 0.025$, * $0.025 < p \leq 0.05$.

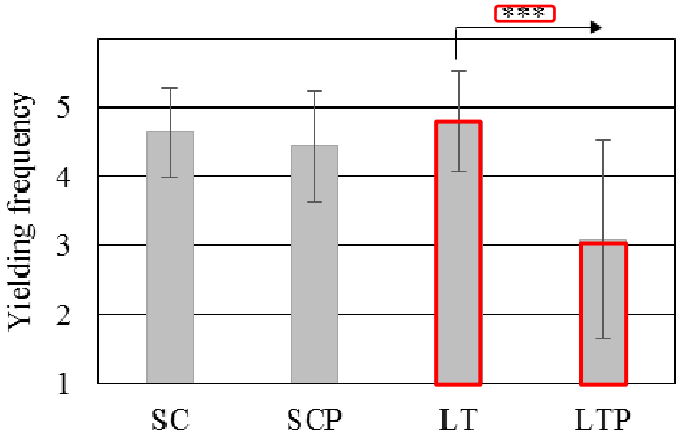
- 87% of the subjects knew the right-car-priority-rule and 99% of the subjects knew the straight-car-priority-rule.

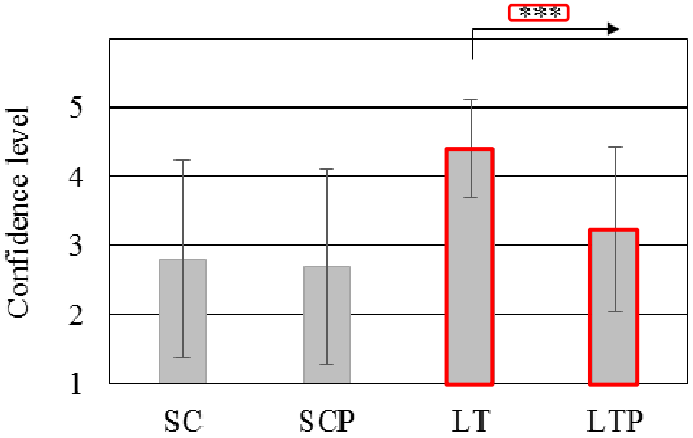
	Scenario SC	Scenario SCP	Scenario LT	Scenario LTP
Effects of priority rules	The effect was insignificant, resulting in high YFs and low CLs.		The subjects were likely to yield with high confidence.	The subjects were less likely to yield with lower confidence.

Results

1. Effects of priority rules







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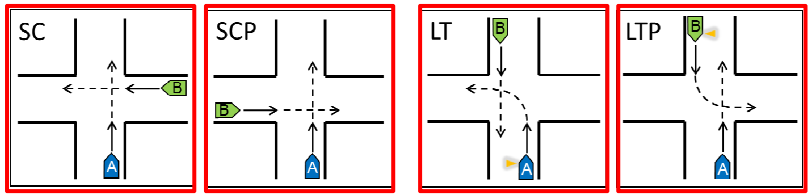
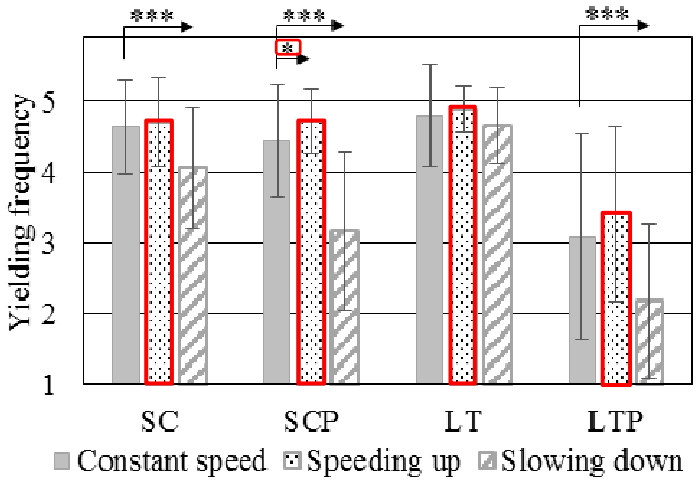
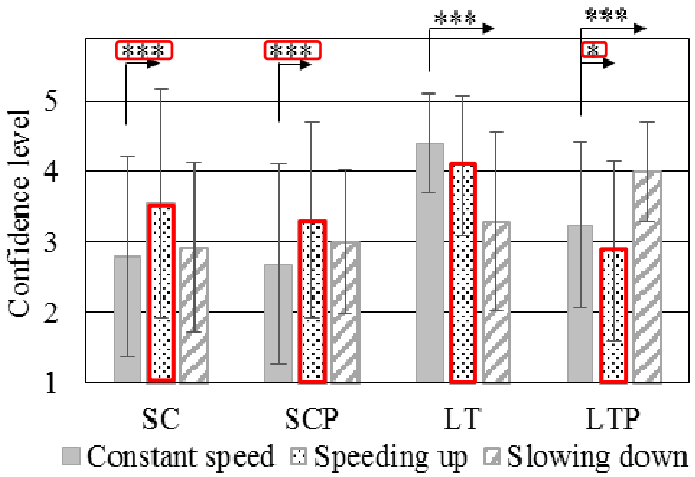
Effects of priority rules	The effect was insignificant, resulting in high YFs and low CLs.		The subjects were likely to yield with high confidence.	The subjects were less likely to yield with lower confidence.

Results

2. Effects of vehicle behaviors







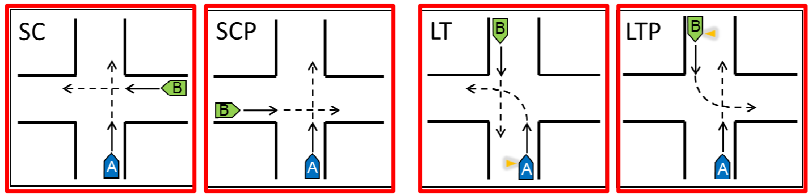
Mean±SD of *YF*s and *CL*s with constant speed, speeding up and slowing down. Statistical differences were calculated from the constant speed; *** $p \leq 0.01$, ** $0.01 < p \leq 0.025$, * $0.025 < p \leq 0.05$.

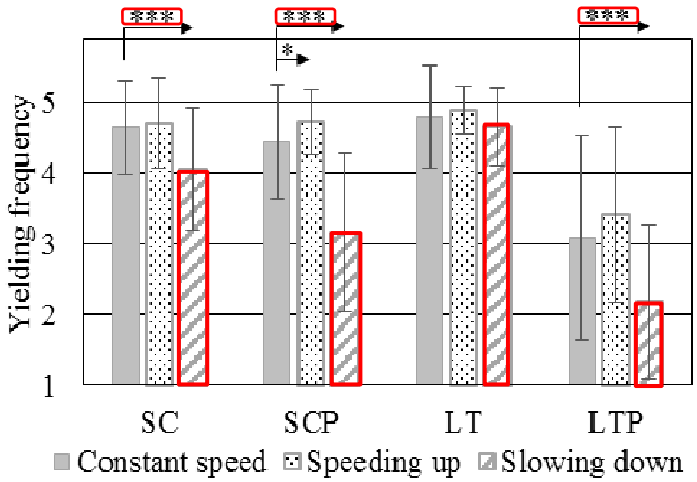
Summarized results. ■ indicates a condition where the cues conflict with the effective priority rule.

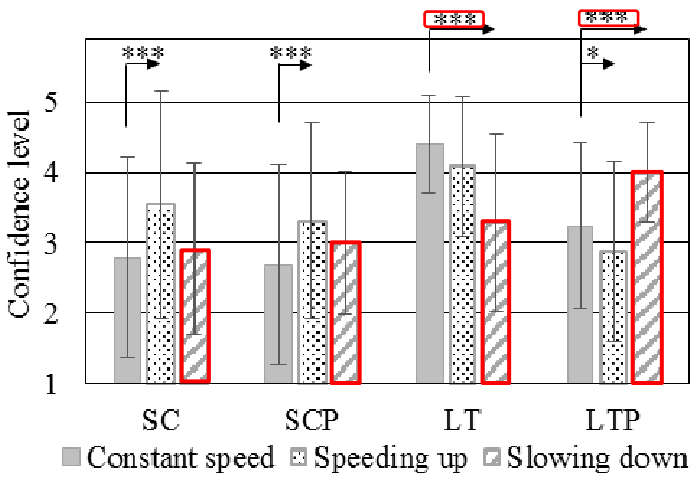
		Scenario SC	Scenario SCP	Scenario LT	Scenario LTP
Effects of vehicle behaviors	Speeding up	- CL increased.	YF increased. CL increased.	- -	- CL decreased.
	Slowing down	YF decreased. -	YF decreased. -	- CL decreased.	YF decreased. CL increased.

Results

2. Effects of vehicle behaviors







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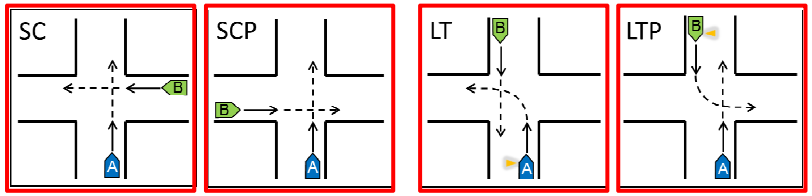
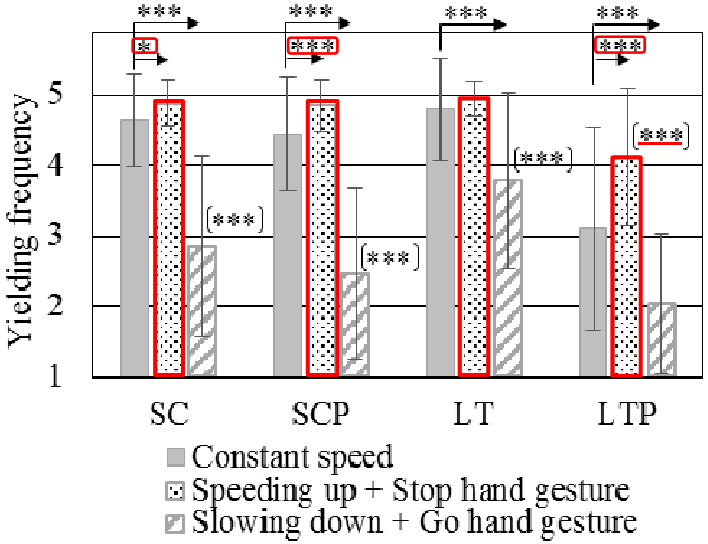
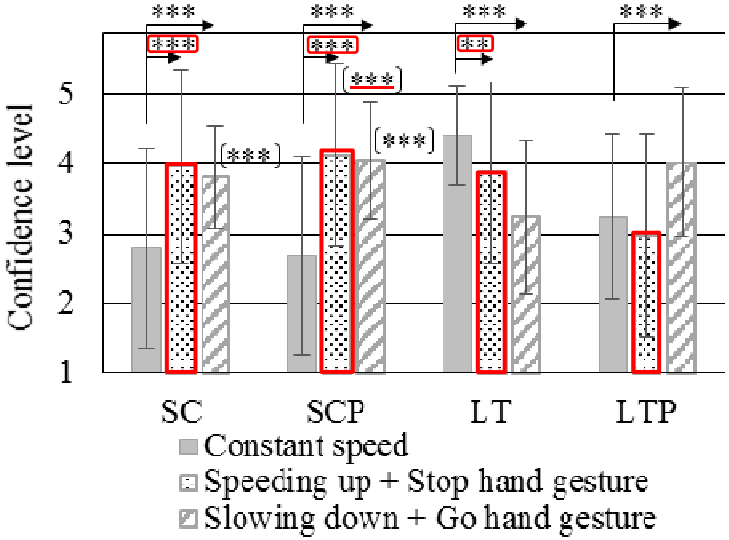
Effects of vehicle behaviors	Speeding up	- CL increased.	YF increased. CL increased.	- -	- CL decreased.
	Slowing down	YF decreased. -	YF decreased. -	- CL decreased.	YF decreased. CL increased.

Results

3. Effects of hand gestures combined with vehicle behaviors







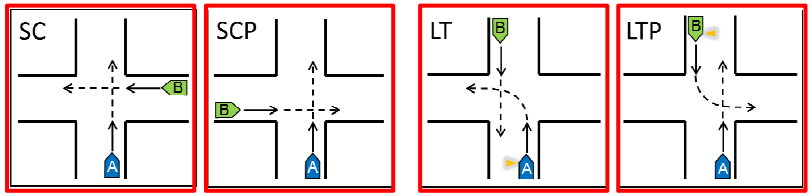
Statistical differences were calculated from the constant speed and also for additional effects of the hand gestures (indicated in parentheses); *** $p \leq 0.01$, ** $0.01 < p \leq 0.025$, * $0.025 < p \leq 0.05$.

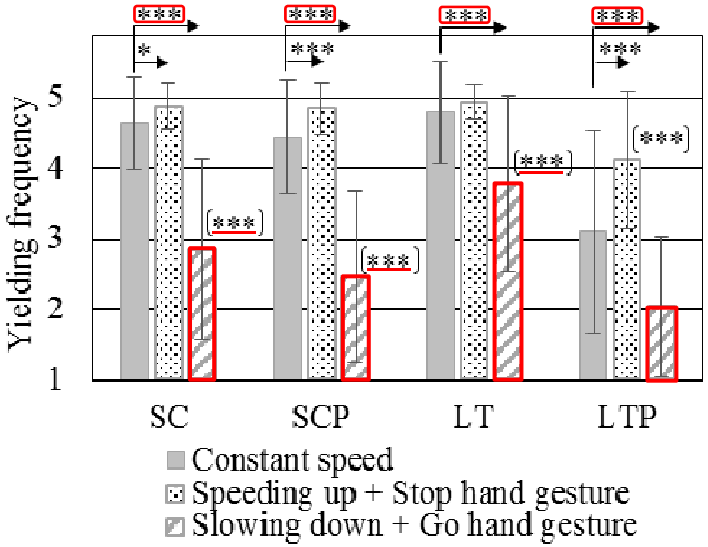
Summarized results. ■ indicates a condition where the cues conflict with the effective priority rule. # indicates a significant additional effect of the hand gesture.

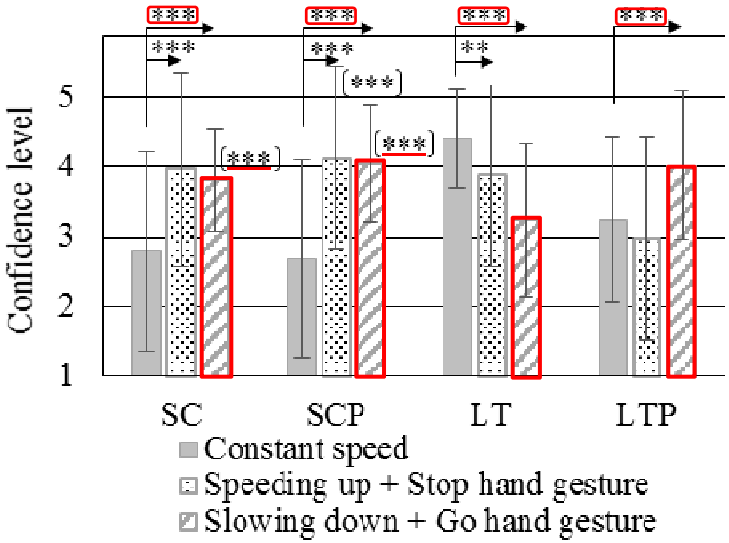
		Scenario SC	Scenario SCP	Scenario LT	Scenario LTP
Effects of combinations	Stop hand gesture + speeding up	YF increased. CL increased.	YF increased. CL increased.#	- CL decreased.	YF increased.# -
	Go hand gesture + slowing down	YF decreased.# CL increased.#	YF decreased.# CL increased.#	YF decreased.# CL decreased.	YF decreased. CL increased.

Results

3. Effects of hand gestures combined with vehicle behaviors







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Summarized results. ■ indicates a condition where the cues conflict with the effective priority rule. # indicates a significant additional effect of the hand gesture.

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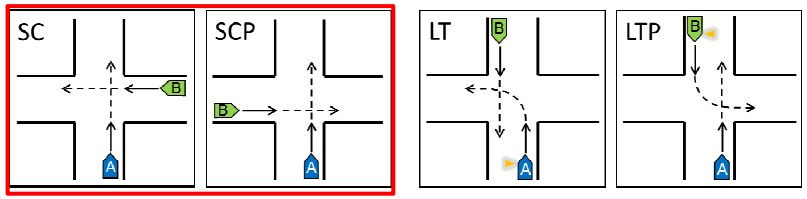
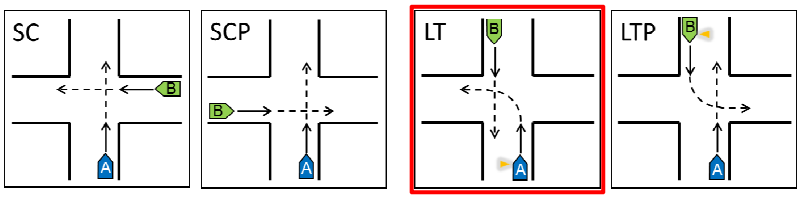
Effects of combinations	Stop hand gesture + speeding up	YF increased. CL increased.	YF increased. CL increased.#	- CL decreased.	YF increased.# -
	Go hand gesture + slowing down	YF decreased.# CL increased.#	YF decreased.# CL increased.#	YF decreased.# CL decreased.	YF decreased. CL increased.

Discussion

- Overall, the hand gestures combined with vehicle behaviors showed larger effects than vehicle behaviors alone in the scenarios SC and SCP where the priority rule was ineffective. The combinations modulated subjects' decisions to yield or go and also gave more confidence to the subjects regardless of the priority side. The vehicle behaviors alone were not sufficient cues to consolidate subjects' decisions and confidence.

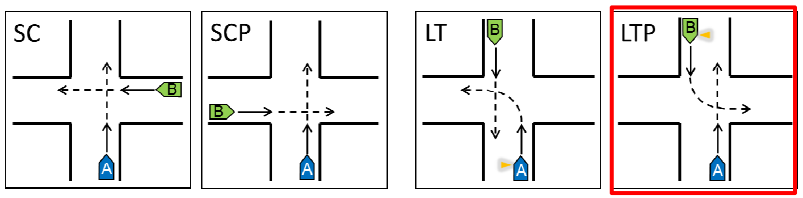


- In the scenario LT, the subjects were confident to yield based on the priority given to the other vehicle, and no additional benefits of Speeding up and Stop hand gesture were found to consolidate subjects' decision to yield and confidence.



Discussion

- In the scenario LTP, Slowing down gave the subjects more confidence to go, and no additional benefits of Go hand gesture were found to consolidate subjects' decision to go and confidence.
- The hand gestures showed significant effects to change *YF*s to accept the cues against the effective priority rule in the scenarios LT and LTP, where the vehicle behaviors alone did not affect *YF*s.
- The increment of *YF* against the priority rule by Stop hand gesture in LTP is considered to be a potentially positive effect to improve safety when the other vehicle do not follow the straight-car-priority-rule.
- The decrement of *YF* against the effective priority rule by Go hand gesture in the scenario LT is considered to be a potentially positive effect to improve efficiency when the other vehicle offers the right of way against the priority rule. The subjects showed low CL in this condition which implied that they were cautious in accepting the offer.



Discussion

Limitation of generalization of the results and remaining factors for future studies

- In practice, drivers need to make decisions within limited time. Such time pressure may influence drivers' decisions, especially for older drivers with slower cognitive processing.
- This study excluded the effects of visual perception of the cues. In practice, drivers need to perceive the cues in distance and the thresholds of visual perception may affect the effectiveness of the cues.
- The communication cues studied were limited and more cues currently used by drivers need to be explored. For example, drivers use longer distance to an intersection with slower constant speed than necessary to stop as a cue for yielding.
- The effects of the priority rules and the effects of the communication cues may vary depending on the traffic culture.

Discussion: implications for AV external communication

- Automated vehicles are expected to understand cues sent by the other driver to show intention to go such as speeding up (N.B. Stop HG is not a commonly used cue by drivers), and yield to avoid a crash regardless of the priority side.
- Automated vehicles are expected to understand cues sent by the other driver to show intention to yield such as slowing down and Go hand gesture. The automated vehicle can accept the offer and go for traffic efficiency as long as the cues are interpreted with sufficient accuracy.
- When yielding, the automated vehicle is expected to send a signal such as a combination of slowing down and a cue equivalent to Go hand gesture to let the other driver go with confidence.
- When going, the automated vehicle is expected to send a signal such as a combination of speeding up and a cue equivalent to Stop hand gesture to consolidate the other driver's decision to yield with confidence.
- For enhancement of general traffic safety and efficiency, it is recommended to design behaviors of automated vehicles as communication cues on top of kinematic requirements.
- It may be effective to implement automated vehicles with new signals as communication cues with minimized uncertainty, equivalent to or more effective than the hand gestures used in this study.

Conclusions

- The vehicle behaviors and the hand gestures affected subjects' yielding decisions and confidence in all the scenarios studied.
- Those communication cues also interacted with the priority rule in the left turn scenarios.
- The hand gestures were especially effective, when combined with vehicle behaviors, to consolidate subjects' decisions to yield or go with confidence when the priority rule was ineffective (i.e. in the straight-cross-path scenarios).
- The hand gestures were also effective to change the yielding frequency to accept the cues conflicting with the effective priority rule (i.e. in the left-turn scenarios).
- Some expectations and recommendations for automated vehicles were discussed.

ISO TC 22 / SC 39 WORKSHOP ON AV EXTERNAL COMMUNICATIONS

JOHN SHUTKO

OUTLINE

- **Workshop recap**
- **Current status of ISO task force**
- **Task force next steps**

ISO MEETING

- **ISO TC 22 / SC 39 workshop on AV exterior communications**
- **49 participants**
- **8 countries**
- **11 OEMs**

ISO WORKSHOP AGENDA

Discussion of potential problem: **2.5 hrs.**

9:15 – 9:45	Title: **Effects of Non-verbal communication cues on decisions and confidence of drivers at an uncontrolled intersection** Presenter: Satoshi Kitazaki, Ph.D., Director, Automotive Human Factors Research Center, National Institute of Advanced Industrial Science and Technology, Japan
9:45 – 10:15	Title: **Preliminary Study for designing Communication HMI between Automated Vehicle and Surrounding Road Users** Presenter: Tatsuru Daimon, Dr. Eng., Professor, Keio University, Japan
10:15 – 10:45	Title: **What information do pedestrians and cyclists need from automated vehicles in a mixed urban environment? Results from the citymobil2 project** Presenter: Professor Natasha Merat, Ph.D., University of Leeds
10:45 – 11:15	Title: **What we can learn from the empirical analysis of the interactions of multiple road users in semi-ambiguous situations for the future of autonomous vehicles** Presenters: Tomohiro Yamamura, Nissan, Japan and Melissa Cefkin, PhD, Nissan Research Center Silicon Valley
11:15 – 11:30	Title: **Considerations and criteria for AV external communications** Presenter: Asaf Degani, Ph.D., General Motors, Israel
11:30 – 11:45	Tentative Title: **Identification for AV: What do other road users need to know?** Presenter: Marieke Martens, Ph.D., TNO

ISO WORKSHOP AGENDA

Potential solutions: **2.5 hours**

13:00 – 13:30	Title: **HMI for External Communications** Presenter: Lennart Bendewald, Volkswagen Group Research
13:30 – 14:00	Tentative Title: **An academic view on the field of external communication** Presenter: Klaus Bengler, Ph.D., Professor, Technical University Munich
14:00 – 14:30	Title: **Possible solutions for communicating AV state and intent** Presenters: Tomohiro Yamamura, Nissan, Japan and Melissa Cefkin, PhD, Nissan Research Center Silicon Valley
14:30 – 15:00	Title: **Automated vehicles in mixed traffic – How to ensure safe & pleasant interactions**? Presenter: Azra Habibovic, Ph.D., RISE Viktoria
15:00 – 15:30	Title: **Results from VR studies and future plans** Presenter: John Shutko, Ford

ISO WORKSHOP AGENDA

Discussion of international regulations and how to influence: **1.25 hrs.**

15:30– 16:00 Title: **NHTSA Perspective**
Presenter: Chris Monk, Ph.D., NHTSA

~~*16:00 – 16:30 Title: TBD – EU perspective on regulations*~~
~~*Presenter: TBD*~~

16:00 – 16:15 Title: **Potential standard framework**
Presenter: John Shutko, Ford

WORKSHOP RECAP

- **Current methods of vehicle to pedestrian communications tend to work well**
  - Vehicle motion / body motion
  - Hand gestures
  - Eye contact
- **Context impacts pedestrian behavior**
- **Any additional indications need to be:**
  - Perceptible
  - Interpretable
  - *Learnable*
- **Vehicle intent/ state should be communicated, if anything**
- **AV communications may have positive impact on societal acceptance**

WORKSHOP RECAP

- **Agreed to develop a technical report early next year; 2018**
- **Clarify standards creation responsibility**

CURRENT STATUS

- **Task Force editing committee established**
  - 9 members
  - 6 countries
- **3 meetings thus far**
  - Weekly
  - 1 hour
- **Agreed on the title, purpose, scope and an outline**
  - Items needed for Form 4
- **2 month NWIP**
  - July

TITLE

Road Vehicles – Ergonomic aspects of external visual communication from automated vehicles to other road users

PURPOSE

The purpose of this document is to provide a common strategy for developers of automated vehicle (AV) visual external communication systems. As AV systems enter the market, road users need to understand how to safely interact with these vehicles. This is particularly important when complex situations occur such as uncertainty of right-of-way involving road users of all types (e.g. AVs, pedestrians, bicyclists, drivers, passengers). The implementation of supplemental visual signaling on AVs may help other road users more easily navigate these complex scenarios. Consistency across the automotive industry is needed to minimize road user confusion among AVs and establish societal trust.

SCOPE

This document proposes a strategy of external visual communication systems for highly automated vehicles, focused on how these systems communicate with other road users. The main objective of this document is to propose how AVs could communicate with other road users via an external communication system. It discusses the interaction between humans and AVs within roadway environments, including public roads, sidewalks, pedestrian crossings, intersections, etc. Recommendations for the type of external visual communication messaging are presented along with the supporting methodological rationale. It is recommended that if AVs have external visual communication systems that the communication should be common across industry. Learnability of these systems is a main focus, limiting the number of signals and ensuring they are distinct and salient, with the aim of the implementation providing a positive impact on societal acceptance.

The document does not address functionality elements of the AV external visual communication itself. This serves to propose how the system communicates to human users such that it can be learned and understood by society at large.

OUTLINE

- **Traditional vehicle-pedestrian interactions**
  - Literature summary
- **Potential AV communication & analysis**
  - Acknowledgement
  - Recommendations
  - Intent
- **Recommendation for communication**
- **Learnability**
  - History with other transportation signaling
  - Co-exist with current signals
  - Quickly understand
- **Societal acceptance**

NEXT STEPS

- **Issue NWIP**
  - 2 month ballot
- **Develop a draft for fall meeting**
  - November
- **Issue CD ballot after fall meeting**

END