External HMI of communication and autonomous vehicles: a pedestrian's study

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SUMMARY

THE PROJECT « PARIS SACLAY AUTONOMOUS LAB » (EVAPS)

Objective: develop Disruptive Intelligent Mobility services to cover peri-urban circuits:

- On Paris-Saclay territory

- With autonomous driving (= without driver)

- On private site and dedicated lanes

- With two types of electrical vehicles (car and shuttle)

- With the last kilometer included

FUNDING INSTITUTIONS & PARTNERS

CHALLENGES

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Pedestrians and the eHMI

- Around the AV, there is not only the driver but also a lot of people ;

- A lot of researches on drivers, less on pedestrians ;

- With the AV, a human is not necessarily in the vehicle so there is no more non-verbal communication between the driver and the pedestrians ;

    → **Question**: *Is an eHMI necessary to communicate the vehicle intention to the pedestrians?*

- VEDECOM is involved in the ISO group for this question.

THEORITICAL ELEMENTS

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- Current research seems to show the importance of an eHMI (e.g., de Clercq et al., 2019; Lagström & Lundgren, 2015; Mahadevan et al., 2018b, 2018a; Matthews et al., 2017; Schieben et al., 2019)

- Many eHMIs exist and are tested
  - Display (Ackermann et al., 2019; Clamann et al., 2017; de Clercq et al., 2019)
  - Band of LEDs (Ackermann et al., 2019; Faas & Baumann, 2020; Gruenefeld et al., 2019; Lagström & Lundgren, 2015)
  - Eyes (Chang et al., 2017; de Miguel et al., 2019; Mahadevan et al., 2018b, 2018a)
  - Hands (Mahadevan et al., 2018b, 2018a)

PRINTED HAND
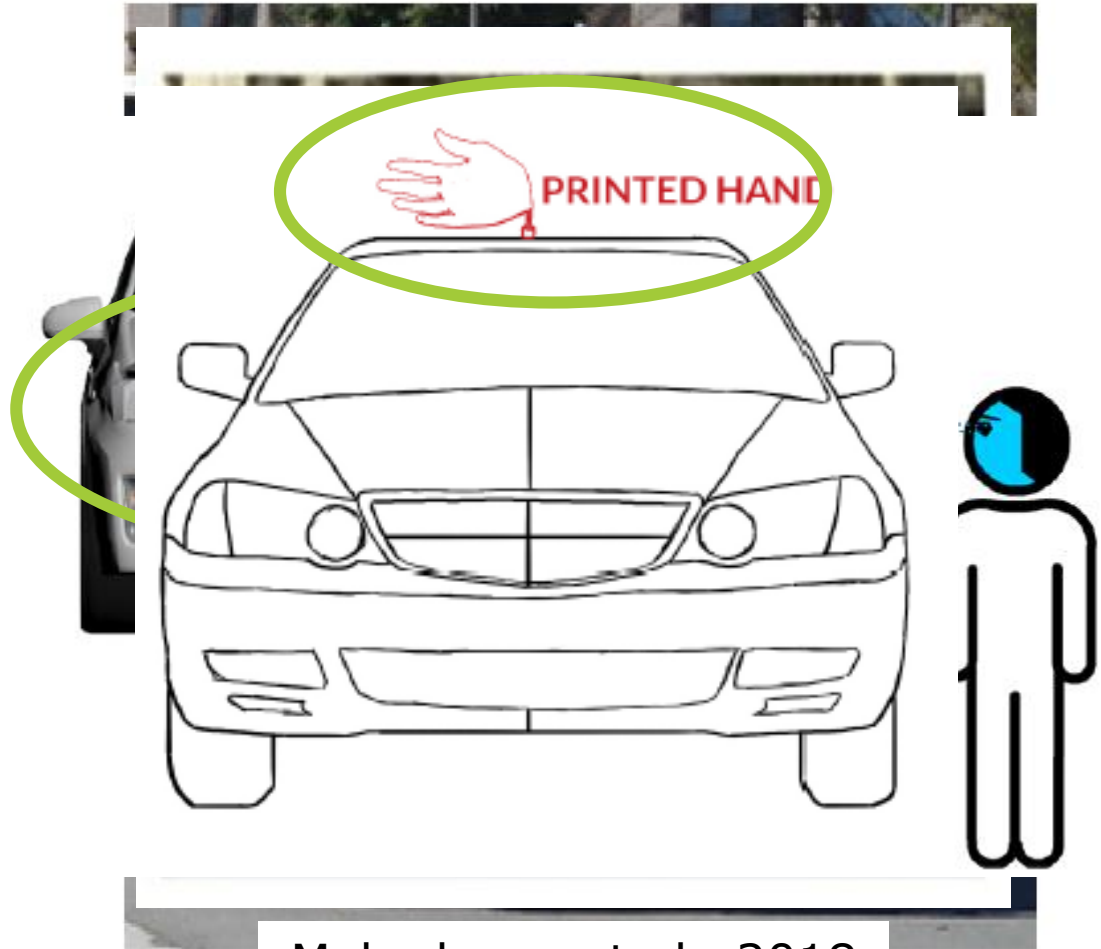
Mahadevan et al., 2018

- Pedestrians do not necessarily perceive eHMIs (Chang et al., 2017)

- Pedestrians consider the distance between them and vehicles and their speed when crossing (Clamann et al., 2017; Dey et al., 2017, 2019)

- Pedestrians correctly manage their interactions with the AV without eHMI (Rothenbücher et al., 2016)

- Without an eHMI, only 13% of pedestrians cross in front of an AV before it was completely stopped, compared to 38% for an AV with an eHMI (Lagström & Lundgren, 2015; Lee et al., 2019)

- Presence of a pedestrian crossing have an impact on pedestrian's behaviour (e.g., Clamann et al., 2017; Jayaraman et al., 2018)

HYPOTHESIS

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H1: Pedestrians would cross the street more often in front of a vehicle with an eHMI than a vehicle without eHMI... (e.g., de Clercq et al., 2019; Schieben et al., 2019)

H2: ... especially when there is no pedestrian crossing (e.g., Clamann et al., 2017; Jayaraman et al., 2018).

H3: No objective difference would be observed between eHMIs.

H4: The subjective data should highlight a preference for one system rather than the two others (e.g., Ackermann et al., 2019).

STUDY

- **Participants**
- **49 participants** (24 men and 25 women, Mean age = 41.02 years old, $SD = 12.3$)

- **Material**
- **Many questionnaires**
  - The street-crossing assessment questionnaire
  - Acceptance scale (Van Der Laan, Heino, & De Waard, 1997)
  - Presence questionnaire (Witmer & Singer, 1998)
  - Preference
- **Learning stage of the eHMI**
- **Virtual environment**
  - Urban environment
  - 5 buildings
  - 5 crossings

A top view of virtual environment

TWO INDEPENDENT VARIABLES

- **Road infrastructure**

- **Vehicle**

ROAD INFRASTRUCTURE

A pedestrian crossing with pedestrian traffic light

A pedestrian crossing without pedestrian traffic light

No pedestrian crossing

VEHICLES

Conventional =
with a driver

Autonomous
vehicle

LED light strips

Autonomous
vehicle with eHMI

Pictograms

Threads of diodes

THE EXTERNAL HMI

4 messages :

- **The vehicle circulates**

- **The vehicle brakes**

- **The vehicle is stopped**

- **The vehicle starts**

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What is the pedestrian's behaviour when he has to cross ?

EXAMPLES

One configuration :

➢ The autonomous vehicle without eHMI and no pedestrian crossing

➢ *All vehicle stop when they detect a pedestrian even if there is no pedestrian crossing*

Does the pedestrian pass or not?

Day of study

1 week before study

3 times
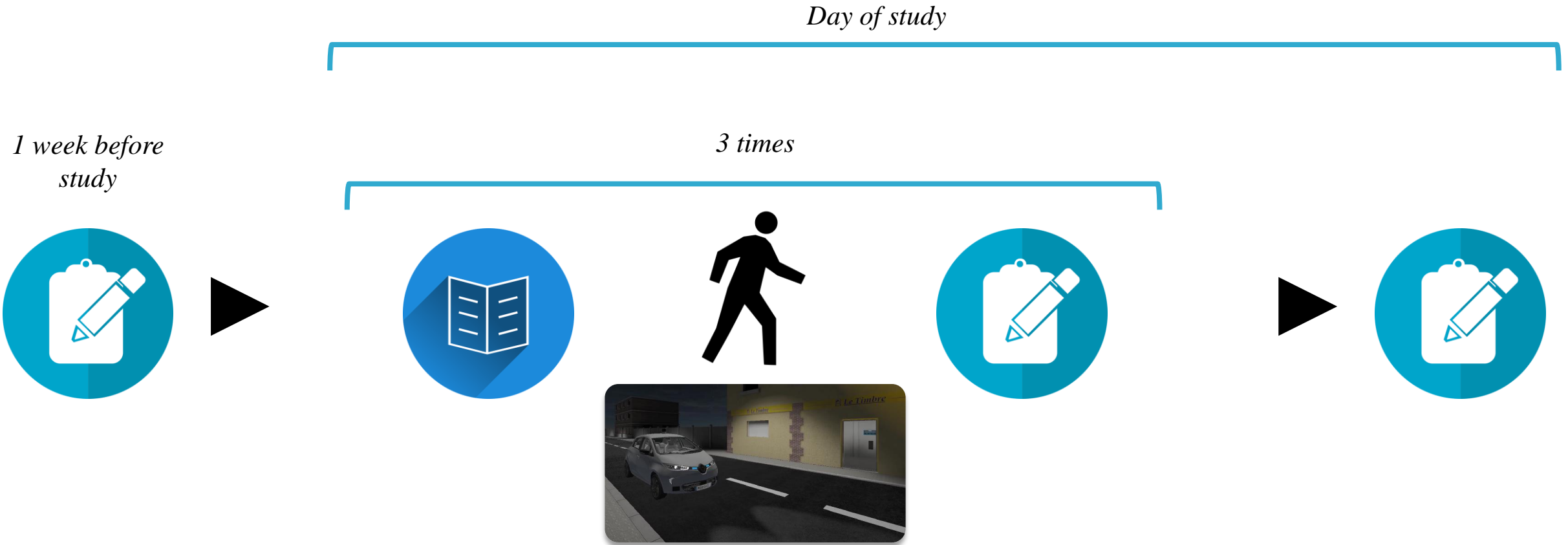
RESULTS

- The crossing behaviour
- The subjective measures

The crossing behaviour

GO OR NO GO ?
Vehicle

	No go	Go
Thread of diodes	1%	99%
LED light strips	1%	99%
Pictograms	2%	98%
Autonomous vehicle without eHMI	8%	92%
Conventional vehicle	5%	95%

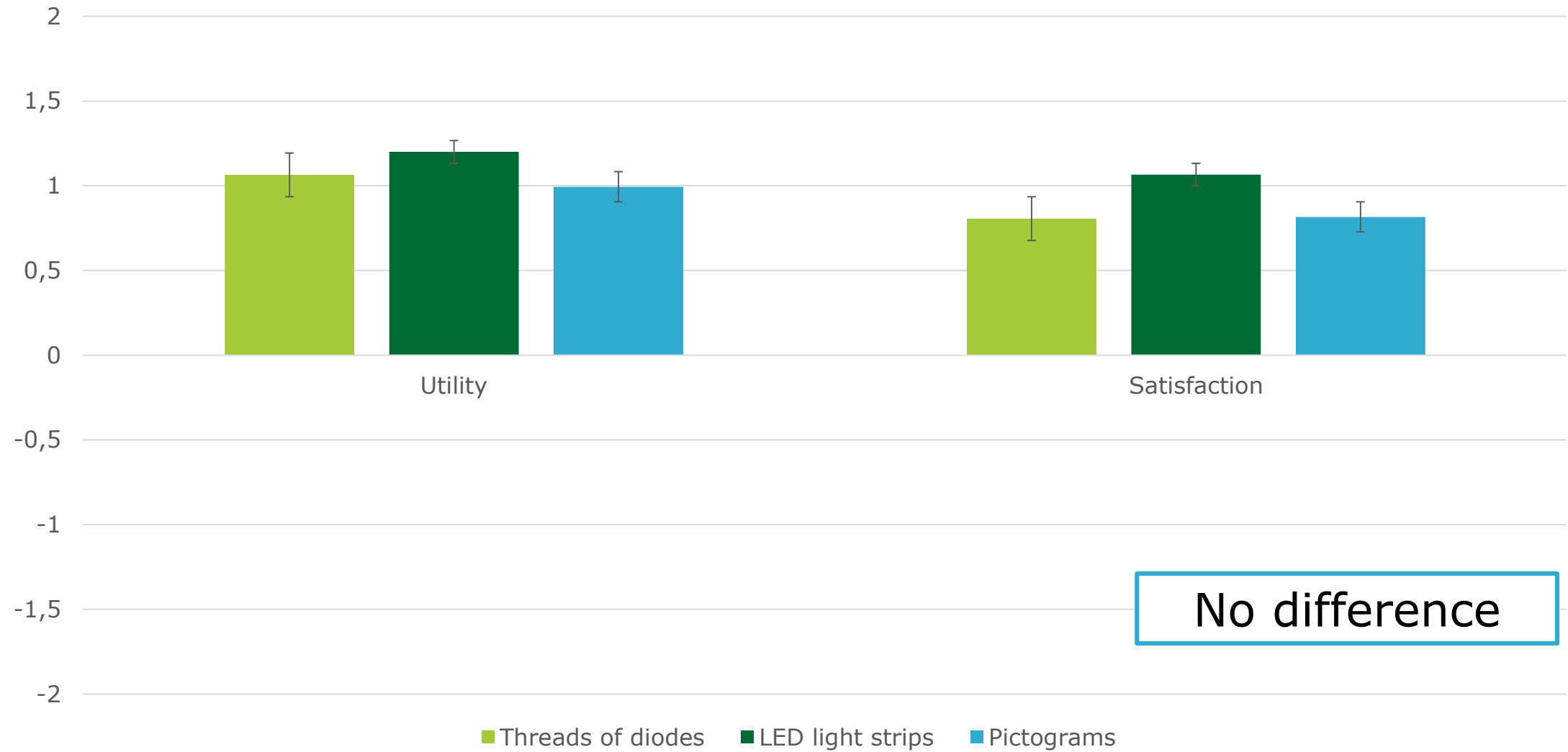**Significant difference between vehicle with eHMI and vehicle without eHMI**

	No go	Go
Without pedestrian crossing	8%	92%
With pedestrian crossing	2%	98%
With pedestrian crossing and lights	0%	100%

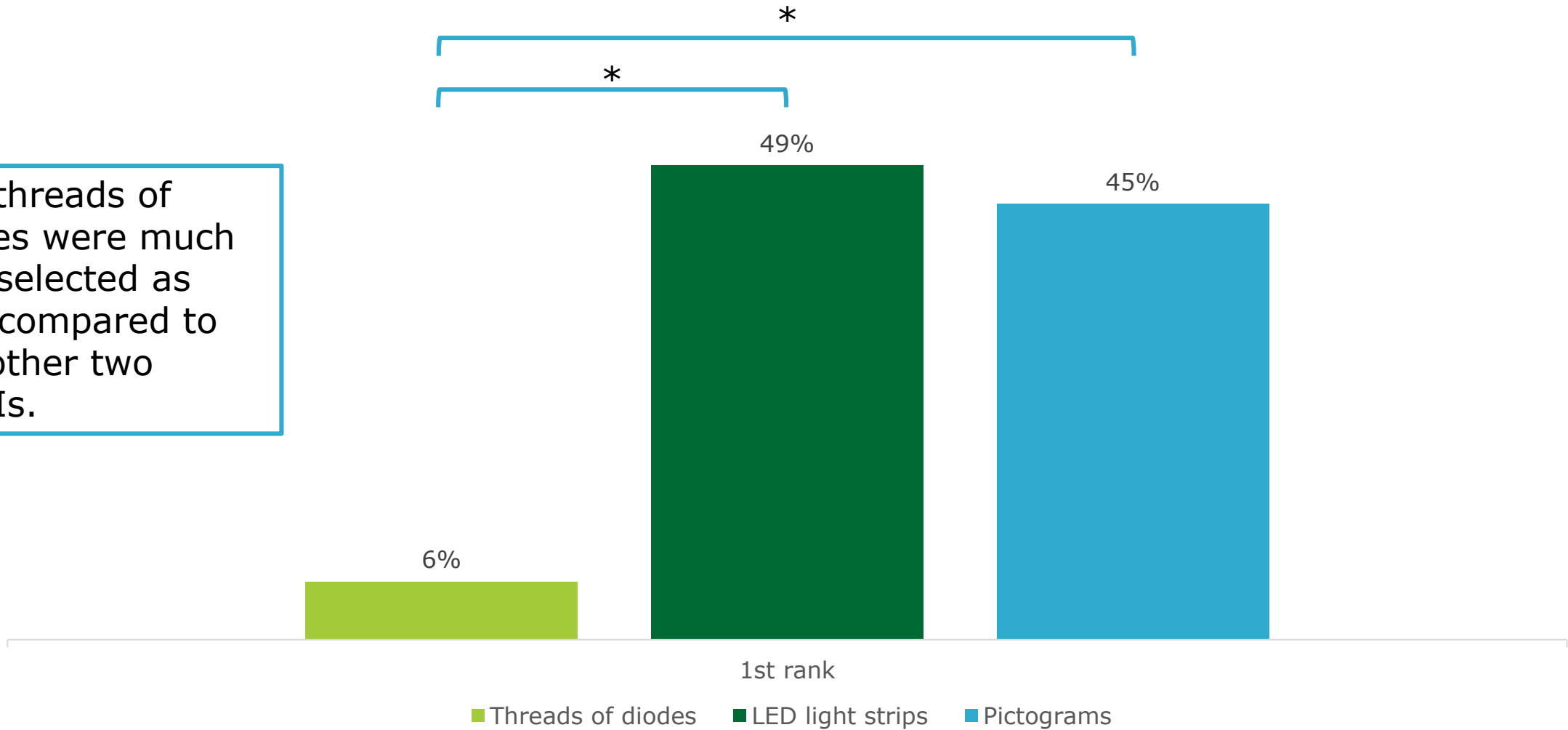**Significant difference between no protected crossing and protected crossing**

And the combination of the two variables ?

GO OR NOT GO ?

Vehicle	Road Structure	No go	Go
Without eHMI	No pedestrian crossing	14%	86%
	With pedestrian crossing	2%	98%
With eHMI	No pedestrian crossing	4%	96%
	With pedestrian crossing	0%	100%

The subjective measures

eHMIS' UTILITY AND SATISFACTION

No difference

Legend: ■ Threads of diodes ■ LED light strips ■ Pictograms

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PREFERENCE – MESSAGE BY MESSAGE

The vehicle circulates	The vehicle brakes	The vehicle is stopped	The vehicle starts
1st rank			
3rd rank			

The vehicle circulates	The vehicle brakes	The vehicle is stopped	The vehicle starts
1st rank			
LED light strips	LED light strips	LED light strips	LED light strips
Pictograms	Pictograms		
3rd rank			

PREFERENCE – MESSAGE BY MESSAGE

The vehicle circulates	The vehicle brakes	The vehicle is stopped	The vehicle starts
1st rank			
LED light strips	LED light strips	LED light strips	LED light strips
Pictograms	Pictograms		
3rd rank			
Threads of diodes	Threads of diodes	Threads of diodes	Threads of diodes
	Pictograms		Pictograms

Why these choices?

1st rank	3rd rank

1st rank	3rd rank
The visibility	
The ease of understanding	

1st rank	3rd rank
The visibility	The lack of visibility
The ease of understanding	The complexity of messages

CONCLUSION

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Hypothesis	Results

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H1: Pedestrians would cross the street more often in front of a vehicle with an eHMI than a vehicle without eHMI...	✔

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H3: No objective difference would be observed between eHMIs.	✔
H4: The subjective data should highlight a preference for one system rather than the two others.	✔

- The presence of eHMI seems important especially when there is no protected crossing

- No behaviour difference appears between the 3 eHMIs

- The participants do not like the threads of diodes eHMI (complexity and lack of visibility), they prefer pictograms and LED light strips (visibility and ease of understanding)

→ What's next?

    Develop a prototype of eHMI and test it on the road

Thank you for your attention

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