How can we help autonomous vehicles to communicate with human drivers ?

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INTRODUCTION

Mixed environment, induces communication problems between **autonomous vehicles** and other road users (Kalda, et al., 2022):

- vulnerable users' (pedestrians, etc.) solution = a message posted on an external human machine interface (HMI)(Fig, 1). (Dey et al., 2020)
- car drivers : no solution explored.

Humans base their decision to cross the road on the (Fig, 2):

- Spatial lag (SL) = "the distance of the first conflicting vehicle (A) from the conflict point (CP) when a subject vehicle (B) reaches the stop line". (Patil et al., 2014)
- speed of the conflicting vehicle (A). (Quante, et al., 2021)

Sahaï et al., (2021) showed that posting the speed of the conflicting car, helps pedestrian to make a safer decision to cross the road.

Would this message also help drivers to communicate with autonomous vehicles?

H1 = Speed message will have no effect on the drivers' mental workload while turning left.

H2 =Speed message will influence the drivers' behavior while making a left-turn.

H3 = The incoming vehicle's approach distance will affect drivers' behavior while turning left.

Five levels of vehicle's automation are defined by the driver implication on the driving task, by the SAE 2014. Higher is the level, less the driver is implicated.

Figure 1: Semcon Smiling Car Concept of the HMI. (Semcon, 2016)

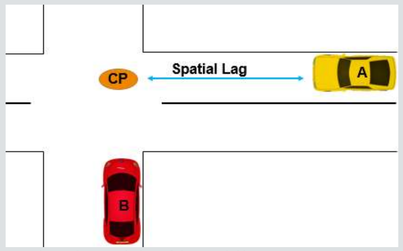

Figure 2: Description of the spatial lag.

METHODES

Participants (N = 61)

Table 1: Experimental design with participants distribution

Independent Variables	No HMI	With HMI (speed screen)
Proximal Approach Distance (PAD) 10 seconds from the intersection	n = 15 Mean age: 24.45 years SD of age: 2.9 years	n = 15 Mean age: 24.53 years SD of age: 2.75 years
Distal Approach Distance (DAD) 18 seconds from the intersection	n = 16 Mean age: 24.71years SD of age: 2.15 years	n = 15 Mean age: 27 years SD of age: 3.65 years

Two conditions of Spatial Lag.

Figure 3: Picture of the condition with HMI,

Experiment Procedure

Practice session on the driving simulator + Eye Tracking Calibration

Instructions:
- Drive like you usually do
- Respect the speed limits
- For the direction, follow the arrows.

Scenario 1:
- 9 intersections
- 4 left turns

=~ 12 minutes

5 minutes break

Scenario 2:
- 8 intersections
- 2 left turns

=~ 9 minutes

NASA TLX + HMI questionary

Data Collection

Table 2: Measures effected for each dependent variable.

Materials / Dependent Variables	NASA TLX	Self reported HMI questionary	Driving Simulator	Eye Tracking Glasses
Mental Workload	Score to the 6 items Global Score			Diameter of the pupil
Driver Behavior			Acceleration Breaking	Number of fixations Time of fixations
HMI verification		Perception item Comprehension item Use item		Number of fixations Time of fixations

RESULTS

Interaction effect of the Spatial Lag and the speed information displayed on the force applied to the break pedal: (F(1,57) = 4.99, MSE = 113.2, p=.029, eta2 = 0.07).

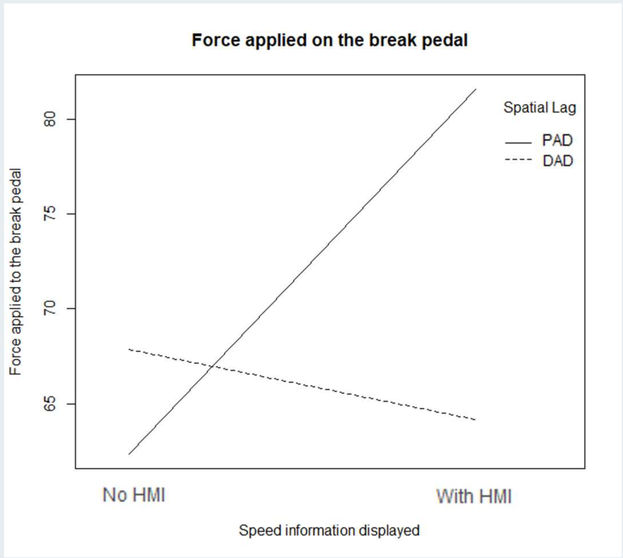

Figure 4: Graph of the mean force applied on the break pedal, under different Spatial Lag and HMI conditions.

Main effect of the Spatial Lag on the force applied to the accelerator pedal: (F(1,57) = 6.25, MSE = 0.003, p = .02, eta2 = 0.009)

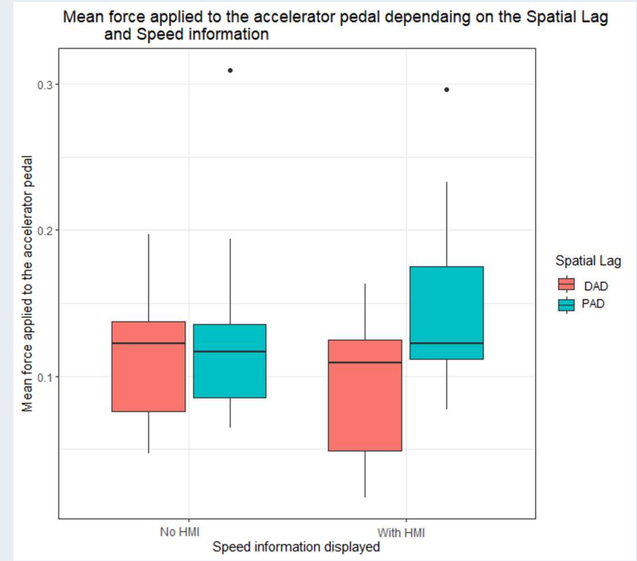

Figure 5: Representation of the mean force applied to the accelerator pedal under different Spatial Lag and HMI conditions.

No statistically significant effect from the speed screen was found on the mental workload:
- diameter of the pupil : F (1,34) = 2, MSE = 0.32, ns, eta2 = 0.05)
- NASA TLX: F (1,57) = 1,07; MSE = 552; ns ; eta2 = 0.02)

DISCUSSION - CONCLUSION

- ☑ Hypothesis 1: Speed information displayed on the HMI doesn't affect the mental workload.
- ☑ Hypothesis 2: Speed information posted on the conflicting car, contribute to modify how the driver plan his left turn maneuver.
- ☑ Hypothesis 3: The incoming vehicle's approach distance is the main factor influencing drivers' decision at an unsignalized left turn intersection

Speed of the incoming conflicting car = helpful information to make safer decision when interacting with autonomous vehicles.
improve communication in a mixed environment for vulnerable road users and drivers.

Posting the autonomous vehicle' speed, seems to be a great idea to help drivers understand autonomous vehicles' behavior.

To improve the Experimental design: analyze the effect of the speed information on the mental workload for different age groups.

REFERENCES

Dey, D., Matviienko, A., Berger, M., Pfleging, B., Martens, M., & Terken, J. (2021). Communicating the intention of an automated vehicle to pedestrians : The contributions of eHMI and vehicle behavior. *it-Information Technology*, *63*(2), 123-141.

Driving, A. (2014). Levels of driving automation are defined in new SAE international standard J3016 : 2014. *SAE International: Warrendale, PA, USA*, *1*.

Kalda, K., Pizzagalli, S.-L., Soe, R.-M., Sell, R., & Bellone, M. (2022). Language of Driving for Autonomous Vehicles. *Applied Sciences*, *12*(11), 5406. https://doi.org/10.3390/app12115406

Patil, G. R., & Pawar, D. S. (2014). Temporal and spatial gap acceptance for minor road at uncontrolled intersections in India. *Transportation Research Record*, *2461*(1), 129-136.

Quante, L., Theisen, M., Junghans, M., & Schießl, C. (2021, octobre 29). *Turning Left at Urban Intersections : Turning Patterns and Gap Acceptance*. 33th ICTCT Conference, Berlin, Deutschland. https://elib.dlr.de/147627/

Sahaï, A., Labeye, E., Caroux, L., & Lemercier, C. (2021). Enhancing child, young and older adult pedestrians' crossing decision presenting vehicle's state information through an external vehicle display. *12th International Conference on Applied Human Factors and Ergonomics-AHFE 2021*.

Semcon. (2016) Who Sees You When the Car Drives Itself? https://semcon.com/smilingcar(accessed on 2 December 2019).