Comparison of VRU Perception of the Driving Behaviour of Automated and Manually Driven Vehicles

Master's Thesis of Marie Vollmer

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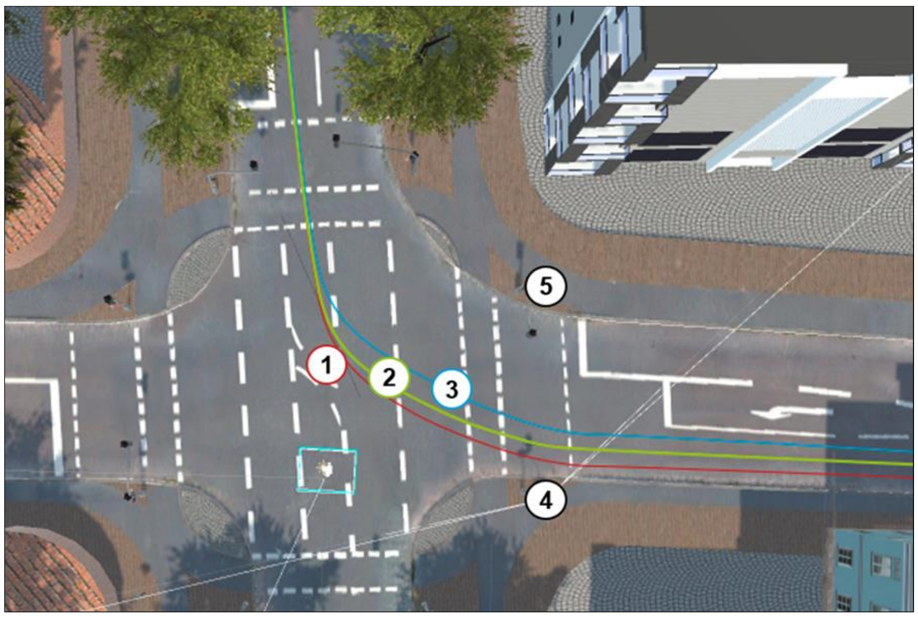

Fig. 1 Top view of the virtual intersection with the different vehicle trajectories (1) stopping position of the test car in the defensive condition (2) stopping position of the test car in the neutral condition (3) stopping position of the test car in the aggressive condition (4) starting position of the participant (5) position of the participant after crossing the road

Automated vehicles (AVs) are on the verge of entering our everyday lives with the first level 3 cars being in production to hit the German market this year. For the successful introduction of AV technology, public acceptance is essential which in turn is dependent on the amount of trust the population is willing to place in AVs. To maximize trust in AVs, the communication between AVs and vulnerable road users (VRUs) should be optimized to minimize uncertainty. Since implicit communication is the primary source for communication in current traffic, the design of motion cues into the AV driving dynamics deserves an elevated focus and inspired the main objective of this thesis. The main research question inquires whether VRUs perceive and interpret AV driving behaviour the same way they perceive the driving behaviour of manually driven vehicles (MDVs) in respect to the sensed aggressiveness and the resulting trust in the driver or the AV.

To answer this question and test three corresponding hypotheses a study design is proposed and tested in a virtual reality (VR) Proof-of-Concept study. For this an urban intersection of which the layout and traffic infrastructure mirrored the one from the real life intersection of the Milbertshofenerstraße and Knorrstraße in Munich was programmed in Unity. During the experiment participants repeatedly crossed the road before an approaching vehicle (Fig. 1).

The 2 x 2 x 3 within subjects design included the factors *state of automation* (automated, manual)*, traffic light presence* (with, without) and *aggressiveness* (defensive, neutral, aggressive; see Tab. 1). Recorded were the participants' subjective trust ratings, their assessment of the aggressiveness of the driving behaviour, answers from a semi structured interview as well as videos of the participants and their perspective of the virtual environment.

Aggressiveness level	Distance of deceleration/ acceleration onset	Initial Speed	Stopping distance	Lateral road position
Defensive	50 m	30 km/h	15 m	right
Neutral	30 m	60 km/h	10 m	middle
aggressive	70 m 50 m 30 m	60km/h 30 km/h 60 km/h	8 m	left

Tab 1. The speed profiles for the different levels of aggressiveness

Hypothesis 1 states that displaying the same driving behaviour automated and manually driven vehicles evoke the same level of trust in participants.

Equivalence Paired Samples T-Test				
	Statistic	t	df	p
Trust with driver - Trust without driver	T-Test	0.513	74.000	0.610
	Upper bound	-1.289	74.000	0.101
	Lower bound	2.314	74.000	0.012

Tab 2. The results of the Two One Sided Tests comparing the trust means for the conditions with and without the driver

The equivalence test for the trust scores for the automated and manually driven vehicles was not significant (Tab. 2). Based on the small sample of this study H1 was therefore rejected. Hypothesis 2 says that the presence of the driver influences how the participants interpret driving behaviour. A qualitative analysis of the answers from the semi-structured interviews revealed that the hypothesis is supported by the data. For MDVs, participants tended to view different driving behaviours as intentional whereas for AVs, interpretations centred around the sensors recognising the participants too early or too late. Hypothesis 3 stated that the presence of traffic lights reduces the negative influence of aggressive driving on trust. A linear mixed model with assessed aggressiveness and traffic light presence as fixed factors and the participant as a random factor did not find a significant effect for the interaction *(*$F(1, 51.69) = 0.36$, $p = 0.553$*).* Therefore H3 was rejected as well.

The research design was found to be rather effective. With a few modifications, it can be applied in VR and real-life studies in the MCube and TEMPUS projects to extend and confirm the results of this study with a larger sample.