I Also Care in Manual Driving - Influence of Type, Position and Quantity of Oncoming Vehicles on Manual Driving Behaviour on Straights on Rural Roads

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Abstract. There is not yet sufficient knowledge on how people want to be driven in a highly automated vehicle. Many studies suggest that automated vehicles should drive like a human driver, e.g. moving to the right edge of the lane when meeting oncoming traffic. To generate naturally looking trajectory behaviour, more detailed studies on manual driving are necessary. The authors report on a driving simulator study investigating twelve different oncoming traffic scenarios. 46 subjects experienced scenarios with variations in type of vehicle (trucks, cars), quantity (one, two) and position (with/without lateral offset) – each on a lane 3.00 m or on 2.75 m wide respectively. Results show that subjects react to oncoming traffic by veering to the right edge of the lane. We also found that quantity, type, and position of oncoming vehicles influence manual driving behaviour. Trucks and vehicles with lateral offset to the road centre lead to greater reactions and hence to more lateral distance between the ego and the oncoming vehicle. From this study on manual driving, we recommend an adaptive autonomous driving style which adjusts its trajectory behaviour on type and position of oncoming vehicles. Thus, our results help to design an accepted and trusted trajectory behaviour for highly automated vehicles.

Keywords: Automated driving · Manual driving · Trajectory behaviour · Rural roads · Straights

1 State of Knowledge

Sensory and algorithmic developments enable an increasing implementation of automation in the automotive sector. Ergonomic studies on highly automated driving are essential aspects for later acceptance and use of highly automated vehicles [1, 2]. In addition to studies on driving task transfer or out-of-the-loop issues, there is not yet sufficient knowledge on how people want to be driven in a highly automated vehicle [3, 4].

First insights show that preferences regarding the perception and rating of driving styles are widely spread. Many prefer their own or a very similar driving style and reject

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other driving styles that include e.g. very high acceleration and deceleration rates or small longitudinal and lateral distances to other road users [5–7]. Studies show that swift, anticipatory, safe and seemingly natural driving styles are prioritized [7–9]. In literature, trajectory behaviour as one part of the driving style is mostly implemented as a lane-centric position of the vehicle in the lane. From a technical point of view this is a justifiable and logical conclusion, but drivers show quite different preferences, especially in curves and in case of oncoming traffic [10, 11].

In manual driving situations without oncoming traffic, participants drive close to the centre of the lane on straights [12, 13]. In curves, participants show a different driving behaviour and move closer to the road centre in left turns and closer to the roadside in right turns [14]. Several studies report a tendency to cut the curve by hitting the apex, especially for left turns [15–17]. When meeting oncoming traffic in manual driving, participants increase their lateral safety distance by moving to the right edge of the lane, both on straights [12, 13, 18] as well as in left and right curves [11, 12]. When meeting heavy traffic, participants' reactions are even greater [12, 13, 17, 19–21]. With the appearance of oncoming traffic in left curves, two manual driving strategies overlay: to hit the apex and to avoid short lateral distances to the oncoming traffic.

In summary, the implementation of this natural driving behaviour into an automated driving style includes high potential to improve the driving experience in an automated car. Previous studies [14, 22–25] show that reactive trajectory behaviour in highly automated driving leads to significantly higher acceptance, trust and subjectively experienced driving performance on straights and in curves. In order to implement adaptive trajectories that modify trajectory behaviour on different lane widths and adjust their behaviour on type and position of oncoming vehicles, it seems most relevant to investigate manual trajectory behaviour in more detail.

The aim of this study is to gain more knowledge on manual driving to implement better reactive trajectories that include less negative side effects and lead to a better driving experience. The results of the study will help to design an accepted and trustfully trajectory behaviour for highly automated vehicles.

2 Method and Variables

Fig. 1. Driving simulator with instructor centre (left) and an exemplary subject (right)

A fixed-based driving simulator (Fig. 1) was used to conduct a mixed-design experiment. Forty-six participants experienced twelve different oncoming traffic scenarios that varied in type (trucks and cars), quantity (one or two in a row) position (cars in the middle of the oncoming lane and cars with lateral offset to the road centre) in balanced order to minimize sequence and habituation effects – see Fig. 2 – either on a 3.00 m or on a 2.75 m lane width in manual driving.

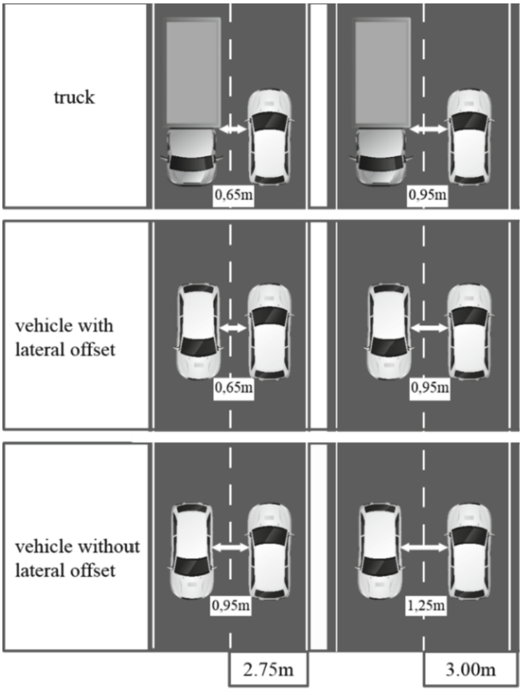

Fig. 2. Variations of oncoming traffic and theoretical lateral distances to the oncoming traffic from a central ego vehicle position

The speed of the oncoming traffic was set at 80 km/h. Participants were instructed to drive 100 km/h, but should feel free to reduce speed. Higher speeds of the ego vehicle were excluded by an activated limiter function at 100 km/h within the driving simulation. Driving data, e.g. velocity or lateral position, was recorded throughout the whole experiment. All subjects were at least 25 years old and had a minimum driving experience of 2.000 km last year and 10.000 km over the last five years (see Table 1 for details).

Table 1. Subjects characteristics

	Number	Age		Driver's license holding [years]		Mileage last five years [km]	
		M	SD	M	SD	M	SD
female	13	35.2	6.9	17.3	6.9	60,300	57,000
male	33	33.9	7.7	15.7	7.8	98,300	69,900
total	46	34.3	7.4	16.2	7.5	87,500	68,100

3 Results

Script-based data monitoring discovered zero invalid data recording cases, which needed to be excluded for further analysis. Each encounter with oncoming traffic was divided into 10 equal parts of 40 m, which results in 400 m of driving data – 250 m before and 150 m after meeting the oncoming traffic. Driving data were averaged for each section (S). The analysis focused on the lateral behaviour of the ego vehicle in each section in dependence of oncoming traffic and lane width. Lateral distance as main dependent variable was measured form the centre of the ego vehicle to the roadside (Fig. 3).

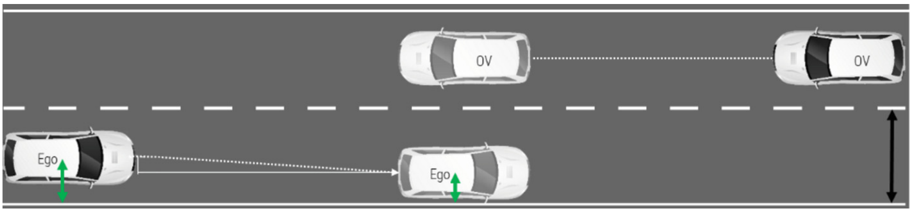

Fig. 3. Measures in oncoming traffic scenario. OV = Oncoming vehicle, Ego = Ego vehicle, black double arrow = lane width, green double arrow = lateral distance measured as distance between centre of the ego vehicle and the roadside

Figure 4 and 5 show mean values of lateral distances to the roadside for each section for lane widths 2.75 m and 3.00 m. Dashed lines represent a theoretical central ego vehicle position.

In the absence of oncoming traffic, participants tended to favour a slightly off-centred position of the ego vehicle by about 0.25 m. When approaching oncoming traffic at the end of Sect. 6, similar driving behaviour can be observed on both lane widths. Starting earliest at section two, a relocation of the trajectory in reaction to the oncoming traffic is executed. At Sect. 8 respectively Sect. 9, the initial position of the ego vehicle is regained. Participants reduce their lateral distance to the roadside and simultaneously increase their lateral distance to oncoming traffic by 0.10 to 0.15 m, depending on the width of the lane and the type, position and number of oncoming vehicles. Participants show greater reactions to cars with lateral offset and trucks compared to cars in the middle of the lane, especially on a lane width of 2.75 m. In addition, two oncoming vehicles cause a larger and longer relocation of the ego vehicle's trajectory compared to one oncoming vehicle. In summary, the trajectory behavior on the narrower lane are slightly less harmonious due to the generally higher stress on lane keeping.

Mean values of lateral distance to the roadside were compared performing ANOVAs with repeated measurements including lane width, section and oncoming traffic. The factors oncoming traffic ($F(3.80, 155.72) = 8.64$, $p < .001$, $\eta p^2 = .17$) and section ($F(2.13, 87.50) = 30.22$, $p < .001$, $\eta p^2 = .42$) were identified as significant main effects. Lane width also led to significantly different lateral distances ($F(1, 44) = 12.79$, $p < .001$, $\eta p^2 = .24$).

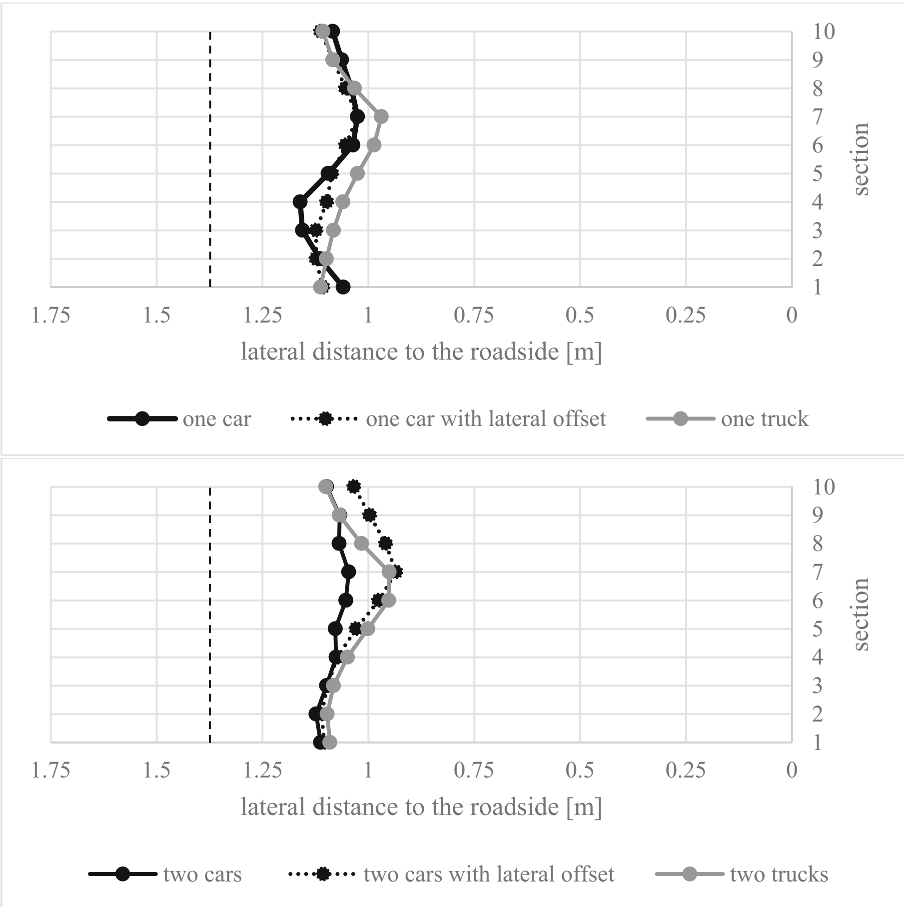

Fig. 4. Mean values of lateral distance to the roadside for each section for lane width 2.75 m, dashed line represents a theoretical central ego vehicle position

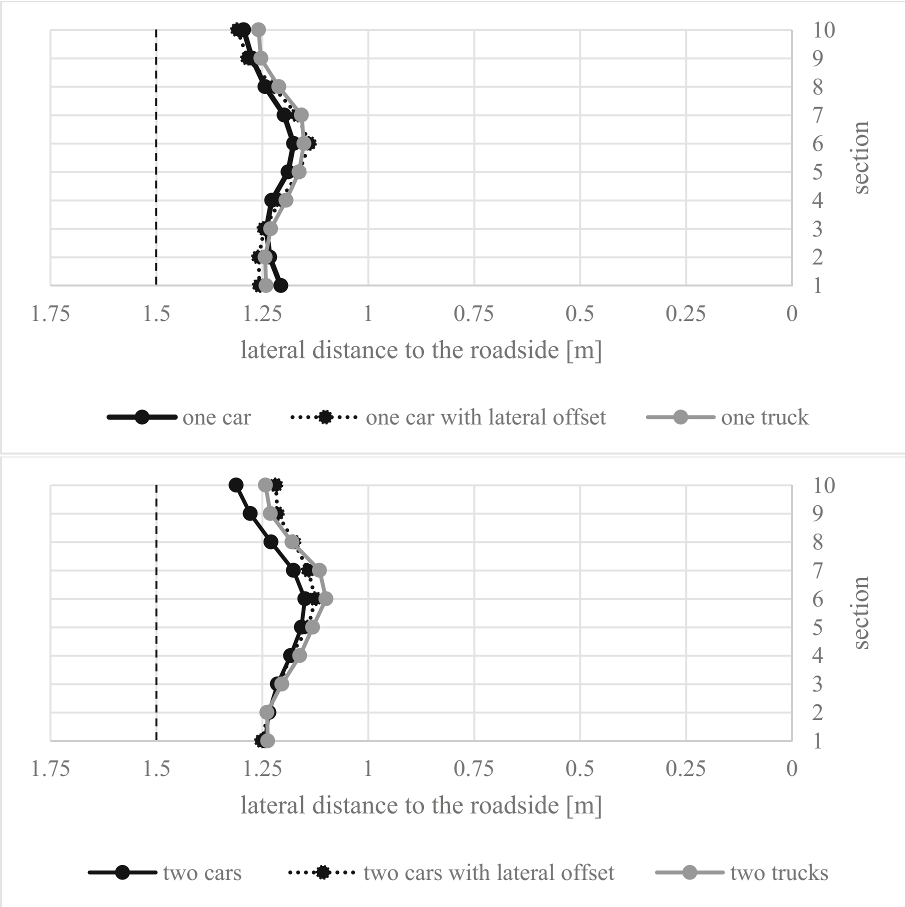

Fig. 5. Mean values of lateral distance to the roadside for each section for lane width 3.00 m, dashed line represents a theoretical central ego vehicle position

4 Conclusion and Outlook

The aim of this study was to gain more knowledge on manual driving to implement better reactive trajectories that include less negative side effects, e.g. passing oncoming traffic with too small distances to the OV or to the roadside, and that lead to a better driving experience. The use of manual drivers' trajectories as basis for implementing highly automated driving trajectories shows high potential to increase perceived safety on straights and curves [22–25].

Results of the study show that without oncoming traffic, participants tended to favour a slightly off-centred position of the ego vehicle by about 0.25 m. When considering the oncoming traffic situations, a distinction can be made with regard to the type of oncoming traffic. On both lane widths, differences in lateral position are found comparing none oncoming traffic, oncoming cars, oncoming cars with lateral offset and oncoming trucks.

When meeting oncoming vehicles, the lateral safety distance should be increased by moving about 0.10 m to 0.15 m to the roadside based on the trajectory without oncoming traffic. The results show less trajectory reactions than shown by studies in curves [15, 17].

These results amplify the need of adaptive trajectories for highly automated vehicles to generate a positive driving experience and, therefore, higher acceptance rates of highly automated vehicles [9, 26]. In all use cases, a safe driving performance has to be guaranteed. Finally, the limitations of studies in fixed-based driving simulators depict the transfer of the results to real world driving situations. Specific use cases can be researched and various parameters (e.g. speed, lateral distance, angle of the brake pedal) can be recorded in driving simulator studies [27]. Of course, no movement forces are perceptible, but the visual impression has a great influence on the perception of oncoming traffic situations and perceived lateral distances. The study focused on straights on rural roads with minimal longitudinal and lateral accelerations, so that the absence of movement forces is not that important. Nevertheless, it is very much recommended to conduct a similar study in a real-world driving environment. The results also cover only a small part of existing use cases. Other factors, such as straights with additional horizontal course or the influence of additional traffic on the ego vehicle's lane, are further topics to be investigated.

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