Social contagion when driving among automated vehicles – a driving simulator study

WP6

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Work package 6

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Project details:	
Project start date: **Duration:** **Project name:**	01/12/2018 36 months LEVITATE – Societal Level Impacts of Connected and Automated Vehicles
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1 Introduction

This document describes the driving simulator study performed within the LEVITATE project.
This working paper describes the different steps of the driving simulator study on behavioural adaptation of human drivers when around automated vehicles.

1.1 Levitate

LEVITATE (Societal level impacts of connected and automated vehicles) is a Horizon 2020 project that aims to forecast impacts of developments related to Cooperative, Connected and Automated Mobility (CCAM). By combining multiple methods impacts can be estimated by comparing different scenarios. The different scenarios are based on interventions on top of a baseline scenario. This baseline resembles the starting point from which increasing penetration rates of automated vehicles (AVs) are introduced (Table 1).

CAV Deployment Scenarios								
Type of Vehicle	A	B	C	D	E	F	G	H
Human-Driven Vehicle - passenger vehicle	100%	80%	60%	40%	20%	0%	0%	0%
1st Generation (Cautious) CAV - passenger vehicle	0%	20%	40%	40%	40%	40%	20%	0%
2nd Generation (ambitious) CAV -- passenger vehicle	0%	0%	0%	20%	40%	60%	80%	100%
Human-driven - Freight vehicle	100%	80%	40%	0%	0%	0%	0%	0%
Freight CAV	0%	20%	60%	100%	100%	100%	100%	100%

Table 1: Penetration scenarios for the LEVITATE project.

1.2 This document

One of the main methods used within the LEVITATE project is traffic simulation. Traffic simulation is widely applied to estimate potential impacts of automated vehicles and relies on the mathematical modelling of transport systems. Driver models are used to simulate the different vehicles within the transport system. A more detailed description of the traffic simulation methods used within Levitate can be found in deliverable D3.2 (Elvik, Meyer, Hu, Ralbovsky, Vorwagner & Boghani, 2020).

Within the project several key differences in driving behaviour between AVs and human driven vehicles (HV) are set. Among these differences are a smaller time-headway, smaller reaction times, stricter speed control and less speed and lateral variations for

AVs compared to HVs. These aspects of automated vehicles could be imitated by human drivers, influencing their driving behaviour. In order to investigate the effects of the increasing penetration rate of automated vehicles on the driving behaviour of the other road users and potential needed adjustments to driver behaviour models used in microsimulations a driving simulator study was set up.

This document focusses on the current knowledge relating to social contagion in traffic and automated vehicles and describes the driving simulator study including results and a discussion of the process. Chapter 2 provides background information about human driver models and behavioural adaptation due to social contagion. Chapter 3 describes the study aims and process. Chapter 4 provides results of the performed study and chapter 5 discusses the impacts on further research.

2 Current knowledge

This chapter shortly discusses the current knowledge about human driver models and behavioural adaptation.

The microsimulation platform used within the Levitate project is Aimsun Next. This platform models a defined traffic system by utilizing models of human driver behaviour for each individual vehicle.Impacts of different settings on aspects of the traffic system such as traffic flow and capacity can than ben determined. These driver models are based on data from real-world observations and scientific studies. Different microsimulation platforms might use different models for separate parts of driver behaviour and could use different parameters within these models.

2.1 Human driver models

To model impacts of the introduction of AVs in the traffic system it is important to have valid models of human and automated driving behaviour. Models currently in use have been shown to accurately represent current driving behaviour (AbuAli & Abou-zeid, 2016). Models for the behaviour of the automated vehicles are made by adjusting parameters within the human driver behaviour models to match expected behaviour of AVs. As the Levitate project uses two distinct types of AV, cautious and ambitious, two different models are used. The cautious AVs are more defensive drivers and adopt bigger time-headways. Ambitious AVs on the other hand are expected to more closely represent later models that utilize the advantages of automated systems to adopt smaller time-headways. Deliverable 3.2 describes the differences between the two types of AV in more detail. The models for human driver behaviour remain constant for all the different penetration scenarios.

2.2 Behavioural adaptation

Humans are adaptive creatures, often adjusting their behaviour to the environment. Phenomena like social contagion have been described in many different situations such as crowd behaviour during evacuations (Hasan & Ukkusuri, 2011) and crossing against the light for pedestrians (Pelé, Bellut, Debergue, Gauvin, Jeanneret, Leclere et al., 2017). There is also evidence of social contagion among car drivers as shown by, for example, Arthur (2011) and Gouy, Wiedemann, Stevens, Brunett & Reed (2014). Arthur (2011) found four different groups of drivers, high and low speed drivers with two intermediate groups. The two intermediate groups showed signs of imitation behaviour in that they adjusted their speed to the vehicles driving in their vicinity. Gouy et al. (2014) found contagion effects when driving in close proximity of AVs. Participants adjusted longitudinal control according to the following distance of trucks driving in a platoon next to them, shortening their minimum time-headway when the platoon drove closer together. Connolly & Aberg (1993) found indications that the effect of social contagion is influenced by the number of road users adopting certain behaviours. It is therefore plausible that as the number of AVs increases the contagion effects become more pronounced in human drivers.

However, most studies and human driver models currently do not take behavioural adaptations caused by social contagion due to driving close to AVs into account (Deluka Tibljaš et al., 2018; Karbasi & O'Hern, 2022; Morando et al., 2017; Morando et al., 2018; Rezaei & Caulfield, 2021; Stanek et al., 2018).

3 The study

This chapter provides information about the development and results of the performed study. For a more detailed description see the paper by de Zwart, Kamphuis and Cleij (2022).

3.1 Aim and hypotheses

The aim of the study is to examine potential behavioural adaptation effects for human drivers when driving in close proximity of multiple AVs. We hypothesise that human drivers adapt their driving behaviour to surrounding vehicles. We expect that changes in driving behaviour are visible in time-headway, reaction times at traffic lights and in driving speed. As the penetration rate of AVs increases we expect that participants will adopt behaviour more closely mirroring the behaviour of the surrounding AVs. Originally the goal was also to incorporate the found effects into behavioural models used during the Levitate project. Delays due to Covid-19 made this no longer feasible.

3.2 Setup

The performed study uses a within subjects design where the three conditions (0%, 50%, and 100% AVs) were presented in a random order. A total of 32 participants were recruited online and participants were accepted into the study if they had a driving license for at least 5 years at time of recruitment and had no prior history of simulation or car sickness. Despite the check for known history of simulator sickness a total of 15 participants were unable to finish the full study due to feelings of sickness.

A fixed base driving simulator was used for data collection. Attempts were made to link the driving simulator with the AIMSUN microsimulation software to ensure the exact same behaviour of vehicles in the driving simulator and in the microsimulations. Unfortunately, this approach turned out not to be feasible within the available time. In order to ensure that the driving behaviour of the other traffic in the driving simulator still match as close as possible to the behaviour of those vehicles in the microsimulation a series of adjustments was made to the existing driver behavioural models of the driving simulator. These adjustments result in vehicles that resemble the ambitious AVs used in other parts of the project (Papazikou, Zach, Boghani, Elvik, Tympakianaki, Nogues et al., 2020).
Key differences between the simulated human driven and simulated automated vehicles during the study relate to their following distance and time-headway, their speed control and their reaction times. The automated vehicles adopt smaller time-headways (AV: 0.5s vs HV: 1.1s), stricter speed control (lower variation in AVs) and lower reaction times at stop (AV: 0.1s, HV: 1.2s), at traffic lights (AV: 0.1 vs HV:1.6) and during driving (AV: 0.1s, HV: 0.8s) than the simulated human vehicles. The route for all three drives was chosen in such a way that two predetermined traffic events of interest occurred in each drive. These events were chosen because they put the participant next to other traffic but still allow free choice of speed. The stationary event consisted of the participant being stopped at a traffic light with 2 vehicles in the lane next to the participant (see Fig 1a). The other event consisted of a straight section of road where the participant was

surrounded by other traffic at cruising speed (see Fig 1b). For a more detailed description of the events see the paper by de Zwart, Kamphuis and Cleij (2022).

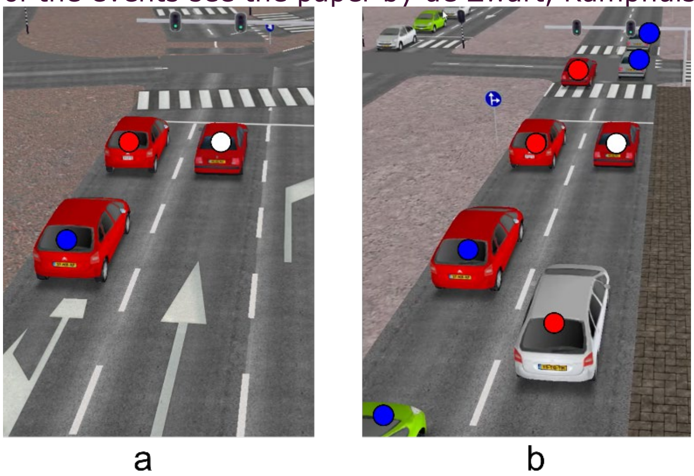

Fig. 1. Events encountered during the test trial in the 50 percent condition (standstill event on the left (a), cruising event on the right (b)). White dot: simulator car, red dot: simulated human vehicle and blue dot: AV. Colours of the vehicles were randomized during the test trials.

3.3 Results

A comparison was made of the driving behaviour of participants during the three different drives. Analysis focussed on several dependent variables that relate to reaction times, lateral and longitudinal control and control of the vehicle.
For the standstill event at the traffic light, several significant effects were found. Participants showed lower reaction times to green light when the vehicles in the neighbouring lane consisted of AVs. In addition to this, participants showed a shorter time until maximum acceleration when next to AVs. In both findings the behaviour of the participants changes to more closely resemble the behaviour of the AVs.
For the cruising condition, participants adopted significantly smaller time-headways and lead distance when surrounding traffic consisted of more AVs. However, the speed difference with the vehicle in front was significantly smaller in the conditions with more AVs present. Mean speed increased as the percentage of AVs increased with participants driving on average below the speed limit during all conditions. speed deviations showed significant reduction when comparing the 0% condition with the 100% condition.

4 Impacts and conclusions

The results of the performed study show several examples of social contagion relating to driving behaviour. Participants show significantly lower time-headways and following distance when driving between traffic consisting of AVs than when driving among simulated human vehicles. These effects show increased potency as the percentage of AVs in traffic increases. These results match what was found in Gouy (2014) where driving next to a platoon resulted in reduced headways in participants. Because human drivers do not posses the same abilities as automated vehicles the shown adaptive behaviour could pose risks and should be taken into consideration when assessing the safety impact of AVs in the traffic system.
However, while following distance decreased so did the speed difference between the participant and the lead vehicle as the percentage of AVs increased. This is likely related to the decrease in speed deviation participants show when AV penetration rate increases. As the speed of AVs is more constant and more predictable this could aide participants in keeping their own speed constant. This matches the findings of Mahdinia, Mohammadnazar, Arvin & Khattak (2021). They found that participants showed more stable traffic flow in the presence of automated vehicles. Some microsimulation software already takes into account effects the lead vehicle can have on the follower vehicle (Olstam & Tapani, 2004). These do however not take into account adjacent vehicles and might not cover the full extent of social contagion on driving behaviour.
When pulling away from a green light participants also showed signs of social contagion. Reaction times, as measured by the first press on the gas pedal, decreased when participants were next to an AV. The time until maximum acceleration also decreased when participants were next to an AV compared to being next to a simulated human vehicle. These results are likely adaptions to the fact that AVs show quicker response to a green light than the human vehicles. These adaptation could influence traffic flow by reducing the time it takes to get going at a traffic light. However, more aggressive acceleration can also be linked to an increased risk of crashes (Scanlon, Sherony & Gabler, 2017).

This study provides insight into possible social contagion effects that are introduced as AVs become more common. While social contagion is not unique to automated vehicles their behaviour is based on assumptions that do not hold for human drivers. Automated vehicles rely on very low reaction times and complete lack of inattention, both of which are not feasible for human drivers.

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