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Driving with intelligent vehicles

Driving behaviour with ACC and the acceptance by individual drivers

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Abstract

This paper presents an overview of the work of a PhD project performed within the research programme "Technology Assessment Automatic Vehicle Guidance" concerning individual driver behaviour and acceptance of Adaptive Cruise Control [1]. It describes and discusses the results of a questionnaire study and two experimental driving simulator studies. It is conlcuded that under certain conditions and limitations Adaptive Cruise Control is a promising technology in traffic.

Keywords Adaptive Cruise Control (ACC), human factors, driving simulator, acceptance.

1 Introduction

The extent to which driver support systems will contribute to increasing traffic safety and efficiency will depend, among other things, on how they affect driving behaviour and how many people are willing to drive with such systems. Drivers have very different preferences and styles of driving, which might again affect the way in which drivers employ the vehicle technology available to suit their driving purpose, motivation and driving style. Individual driver needs and driving styles are therefore the starting point in this research project. It is expected that whenever driver support systems frustrate these needs and driving styles, acceptance of the systems is low and unwanted or even dangerous reactions of drivers may occur.

The main research questions are threefold:

1. What are the effects of driver support systems on driving behaviour?
2. To what extent will driver support systems be accepted by individual drivers?
3. To what extent will driving behaviour and acceptance be determined by individual differences?

In order to answer these questions, a questionnaire study was performed among Dutch car drivers about their judgements on several driver support systems, and their needs and driving styles during different kinds of trip. After that two experiments were performed in the driving simulator at the Centre for Environmental and Traffic Psychology (COV) of the university of Groningen, The Netherlands, in which the effects of different forms of an ACC were tested with groups of subjects who differed in their reported driving styles. The most import results and conclusions will be discussed.

2 Questionnaire study

The questionnaire study investigated drivers' judgements of different driver support systems and their needs and driving styles during different kinds of trips. All three aspects (judgements, needs and driving styles) are considered important for the future developments of driver support systems.
The Needs and Driving Style (NDS) questionnaire that is used for this purpose (described in more detail in [1]) consists of three parts:

- The first part concerns some general data and judgements on four driver support systems: Obstacle Detection, Collision Avoidance, Adaptive Cruise Control, and the Automated Highway.
- The second part concerns the ranking of seven basic needs; Safety, Expediency, Enjoying the surroundings, Kick of driving, Driving relaxed, Driving at your own speed, and doing other things while driving.
- The third part concerns the driving style of the respondent and was based on the Driving Style Questionnaire [2]. Five driving style dimensions are discerned: Speed (made up of items about driving fast and exceeding the speed limit), Deviance (jumping the lights and overtaking on the inside), Carefulness (driving cautiously and adjusting speed to others), Lane-change behaviour (changing lanes often) and Focus (ignoring distractions).

The questionnaire was sent to a sample of 1000 Dutch car drivers, all members of the Dutch automobile association (ANWB). Response rate was 49%, with 60% men and 40% women responding.

The results of the questionnaire show that the respondents see both positive and negative aspects to the four driver support systems. About 50% of the respondents indicates that traffic safety will increase when driver support systems are introduced. Respondents were negative about having taken over control by a system.
With respect to the various needs, the majority of the respondents ranked safety as their most important need during a trip. Driving relaxed was also considered to be very important, whereas expediency and the kick of driving were considered to be very unimportant.
A relationship was found between needs and some of the self reported driving styles, which led to the conclusion that needs and driving styles can be seen as stable traits that can be different between drivers but not very much between trips. That is, drivers don't change their needs and accompanying driving styles when going on different trips like commuter or holiday trips.

This conclusion is used in the experimental studies described in the following sections. An important selection criterion for the subjects participating in the experiments was their self-reported driving style. This gave the opportunity to predict their behaviour and reactions to driving with driver support systems, because we can expect this to be in line with their higher level needs.

3 Driving simulator: ACC on motorways

In this first driving simulator experiment four groups of driver participants, who differed on reported driving styles concerning Speed (high speed = driving fast) and Focus (high focus = the ability to ignore distractions), drove the same motorway route in the driving simulator with and without an ACC system. It was expected that especially these driving styles are important in a driver's reaction to ACC, because of the reduced control drivers will have over speed, and the enhanced susceptibility to distractions when using the system, which will create safety hazards. In the experiment different hypotheses were tested with respect to driving style groups and their reactions to driving with an ACC.

The results show that the driving style 'Speed' was a good predictor of actual driving behaviour, whereas the driving style Focus did not show any effect on actual driving behaviour as measured in the simulator. In general all drivers adapted their behaviour according to expectation, irrespective of their predetermined driving style. They are going to drive faster, with a smaller minimum time headway when driving with an ACC. Also merging manoeuvres were carried out more efficiently. Interaction effects between driving style and behaviour with and without ACC were found on minimum time headway and maximum braking level when drivers had to perform an emergency stop with an ACC. Low speed drivers increase their braking force in this situation much more when driving with an ACC than high speed drivers. Furthermore, minimum time headway adopted by low speed drivers decreased much more with an ACC than it did for the high speed drivers. In their acceptance of ACC the driving style groups differed as well. Only high speed drivers do not appreciate the non-overrulable versions of the ACC, whereas low speed drivers perceive both versions as comfortable and useful.

In the light of the higher speeds, smaller time headways and more efficient merging manoeuvres that were found when participants drove with ACC, the system seems a promising development in terms of capacity and traffic efficiency. Moreover, ACC was assessed favourably with respect to perceived effort, comfort and usefulness.
However, traffic safety is perhaps not served very well by the system as tentatively indicated in this experiment. Although from the collected data no real safety implications could be derived, care is required. Drivers changed their behaviour in ways that might not be beneficial for traffic safety. The participants drove faster and more in the left lane, while swaying more. Accidents did not happen but close following distances certainly occurred more often, which increases accident likelihood [3].

4 Driving simulator: ACC on rural roads

In this second driving simulator experiment two groups of drivers, who differed with respect to reported driving style in terms of speed, drove on a motorway and on a rural road route in the driving simulator. They drove the same routes with a normal car and with an ACC system with adjustable headway settings. In this study hypotheses were tested with respect to Adaptive Cruise Control (ACC) use on two types of roads: motorways and rural roads.

Some specific effects for driving with an ACC on the rural road are found that have to do with the specific traffic situations that occur on these types of road. Overtaking another car for example is especially difficult on these roads. Drivers have to estimate a gap in the oncoming traffic that gives them enough time to accelerate and pass the lead car. The experiment shows that an ACC doesn't help in this difficult situation. On the contrary, overtaking manoeuvres were found to be more dangerous when driving with ACC compared to driving without (i.e. smaller gaps were chosen in opposing traffic). This result can also

be interpreted as the overtaking manoeuvre being performed more efficiently with ACC. However, some participants in the experiment experienced how scary the system's automatic reaction can be, when they 'forgot' to overrule the ACC during the overtaking manoeuvre: at the moment they were driving on the opposite lane, trying to pass the car as quickly as possible, the ACC started braking because the time headway with opposite traffic was too small. This warrants the conclusion that overtaking on the rural road is more dangerous with ACC rather than the conclusion that it is more efficient.

Another traffic situation, specific to rural roads, is the intersection where drivers have to give right of way to traffic coming from the right. In this specific situation the ACC has to be overruled because the sensor of the system doesn't look to the right. All participants in the experiment were explicitly told so, which explains the difference that was found in overruling time between motorways and rural roads. Dictated by this traffic situation drivers pressed the brakes more often when driving on the rural road. When comparing this specific situation driven with and without ACC it was found that drivers pressed the brake pedal later in time than that they released their foot off the gas pedal: they react later to traffic from the right when driving with ACC, an effect that could be caused by reduced activation when the longitudinal driving task is taken over by the ACC system.

Differences in acceptance of ACCs on the two different road types are not found. But in line with the results of the former experiment, driving styles make an important difference in how the ACC is appreciated. Low speed drivers indicate to like the usefulness of the system, whereas high speed drivers emphasise the comfort of the ACC. Both groups have a good acceptance of the system, but for different reasons, which clearly have their background in the different needs of the two groups. All drivers, irrespective of their driving style, appreciate the toggle ACC with adjustable headway settings the most, where they can choose between long and short headway settings. In terms of driving behaviour, the results show that driving with an ACC on the rural road leads to dangerous overtaking behaviour and delayed reactions to traffic from the right.
The conclusion from these findings is that we should be careful with the introduction of ACC's to road types other than the motorway. Drivers will probably use their ACC equally often on both rural roads and on motorways, because of the high acceptance, but behavioural adaptation may seriously deteriorate traffic safety, particularly on the rural road.

4 Conclusions

The research work briefly described in this paper shows that Adaptive Cruise Control seems to be a promising new technology in traffic. That is, under certain conditions and limitations.
In the first place, the experiments clearly demonstrated that driving behaviour with ACC leads to positive effects in terms of traffic efficiency. Driving with ACC reduces speed variability and initial individual differences in driving behaviour on motorways, which harmonizes traffic. On top of this, acceptance results indicate that the headway adopted by the ACC does not influence the preferences of drivers. Even very short headways (0.6 – 1.0 s), which are shown to increase motorway capacity by Minderhoud [4], are accepted very well.
Secondly, a more harmonised traffic pattern can also reduce the number of accidents and thereby increase traffic safety. In addition to increasing traffic efficiency ACC's could therefore also increase traffic safety.

The distinction in driving style between high and low speed drivers was found to be important in the acceptances of ACC. Both driver groups like driving with an ACC, but for different reasons. High speed drivers like the comfort of the system, whereas low speed drivers like the system's usefulness. This finding could be used in marketing strategies. In order to get both driver groups into ACC-cars they should be adressed differently. Most popular in this respect is the ACC where drivers can change their headway setting during driving, i.e. switch between short and longer headways depending on their personal preferences and the current situation. However, when drivers with such a selectable headway switch choose to drive with a headway setting of more than 1.2 s (which they regularly do), the predicted gain in motorway capacity disappears (see [4]). This illustrates the conflict between a driver's need to be in control and the predicted gain in motorway capacity when headway control is taken away. The headway setting of future ACCs should therefore depend on the most important goal that is to be achieved with the system. When the emphasis is on increasing driver comfort (more appealing to high speed drivers) the ACC should be equipped with a driver selectable headway switch ranging from 0.6 to 2.0 s. When the emphasis is on increasing motorway capacity, the ACC should have a fixed headway of 1.2 s or less.

With regard to the effects on traffic safety caution is appropriate.
On motorways the measured higher speeds and smaller headways with ACC are factors known to increase accident likelihood. The importance of speed as a contributory factor to accident liability cannot be overstated; faster drivers are relatively unsafe drivers (French et al, 1993). The categorisation of high and

low speed drivers in looking at traffic safety aspects is therefore an important one. Several studies found a consistent link between self-reported driving speed and accident rates [5], [6]. The fact that ACC does not decrease driving speed of high speed drivers, on the contrary, the first experiment shows that it may *in*crease their driving speed, must therefore be taken as a serious threat for traffic safety.

On roads other than motorways, we should be very careful with the introduction of ACC. Driving behaviour as well as heart rate results indicated that, with respect to traffic safety in specific situations on rural roads, ACC might not serve us particularly well. Dangerous overtaking behaviour and delayed reactions to traffic from the right were found in combination with an elevated heart rate. This clearly indicates that these traffic scenarios get more difficult when driving with ACC, whereas ACC facilitates driving in traffic conditions that were already not too complicated: motorway driving and car following-situations where ACC was originally designed to be used.

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