The Netherlands
Research School for
Transport, Infrastructure
and Logistics

TRAIL

11th TRAIL Congress
November 2010

INTRODUCTION TO THE CONNECTED CRUISE CONTROL AND RELATED HUMAN FACTORS CONSIDERATIONS

Malte Risto MSc[1], Dr. Marieke Martens[1,2], Dr. Ellen Wilschut[2]
[1]Faculty of Engineering Technology, Centre for Transport Studies,
University of Twente, the Netherlands
[2]Dutch Organisation for Applied Scientific Research – TNO Human Factors, the Netherlands

ABSTRACT

Connected Cruise Control (CCC) is a new approach to driver assistance that avoids some of the problems associated with autonomous driver assistance by advising optimal driver behaviour via a human-machine interface. Yet the characteristics of this advice can have a negative impact on driver distraction and additional task demand. While the system is still under development, an evaluation of system effects is needed to identify potential safety issues at an early stage in the design process. For this reason an introduction to CCC is provided, followed by a discussion of how advice attributes can generate distraction and add task demand. Finally, two human factors constructs are provided that can indicate the effects of systems characteristics on driver performance.

KEYWORDS

Advanced driver assistance systems, ADAS, automation, longitudinal support, lateral support, human factors, Connected Cruise Control, traffic flow, in-vehicle advice.

INTRODUCTION

With rising numbers of commuter and cargo traffic, road demand on motorways in the Netherlands is expected to rise. Especially in rush hours this translates to an increase in traffic density and a decrease in space between cars. Under such conditions traffic can become congested even without artificial bottlenecks (e.g. accident, road maintenance). Studies suggest that human behaviour is a contributor to congestion by causing shockwaves through the disturbance of traffic flow and by facilitating the spreading of shockwaves in upstream direction (Sugiyama et al. 2009).

Several forms of driver behaviour can be fitted into one of the two categories above. For example, drivers in nearly congested traffic tend to change lanes more often under the assumption that the other lane is progressing at a faster pace (Redelmeier & Tibshirani, 2000).

This causes traffic disruptions by breaking manoeuvres of vehicles in the dense target stream. Another example, a driver's inability to avoid small variations in relative speed and following headway can cause fluctuations in traffic flow (Kim et al., 2007, Brackstone, Waterson & McDonald, 2009). These build up in upstream traffic and result in "stop and go" traffic. From an outside perspective the result of strong braking manoeuvres in dense traffic or the mentioned stop and go movements become visible as a waves pattern proceeding in upstream direction. Drivers are able to monitor and react to the state of traffic in close proximity. However in case of upcoming shockwaves they often fail to initiate proper counteractive measures. Cooperative autonomous driver support systems (e.g. Cooperative Adaptive Cruise Control) show the potential to smoothen traffic flow in nearly congested traffic. The underlying idea is to provide upstream vehicles with traffic flow information via vehicle-to-vehicle and vehicle-to-infrastructure communication. Based on this information, vehicles will be able to on the one hand react faster to traffic changes in their close proximity and on the other hand to anticipate the behaviour of downstream traffic and act accordingly.

However, the market introduction of cooperative longitudinal driver support can be expected to progress at a slow pace due to technical, safety reasons. Their deep integration into the cars functionality it will make it cost and time intensive to build them into existing cars. Furthermore, despite the proposed benefits of enhanced driver comfort and traffic stability, a closer look at autonomous driver support can reveal that these systems change the nature of the driving task. This can result in dangerous situations as drivers adapt to their new role in the task. For example, in response to higher levels of automation drivers are kept "out-of-the-loop" because their task changes from actively operating to passively monitoring the vehicle (Bainbridge, 1983). Associated to this phenomenon are different human factors problems such as loss of situation awareness, too high or too low workload, and possible loss of skill (Endsley, 1995; Endsley & Kiris, 1995; Stanton & Young, 1998). In case of system failures, the passive monitor suddenly needs to become an active driver again, requiring a fast response to a dangerous event. It these situations the possibility of human error may increase (Moray, 1986). Although the partial liberation of the driver from the driving task aims to solve problems, it can introduce others, stemming from new forms of driver-system interaction. These often become visible after these systems have been introduced on the market.

The Connected Cruise Control (CCC) project is an EU financed research endeavour, exploring the possibilities to provide traffic state information and support driver decision making in order to improve the flow of nearly congested traffic on a motorway. A functionality of the system is to reduce string instabilities by promoting a constant speed and headway in car following situations. In addition to longitudinal support CCC may also advise the use of a certain driving lane. The given advice is based on traffic models that predict future traffic states based on loop data of current traffic. Therefore it extends the driver's ability to anticipate traffic states several kilometres in front of him and supports his ability to react with appropriate (i.e. advised) changes in driving behaviour.

A novelty of this form of assistance is that it is driver dependent. In other words, it controls the cars behaviour only indirectly, the direct control remains with the driver at all times. Keeping the driver in the loop should eliminate the need for transitions of control between the driver and the system and avoid many problems associated with autonomous driver support. On the other hand CCC introduces its very own set of safety issues that result from the added task for the driver to perceive, comprehend and execute the advice in order for the system to be effective. Earlier studies have shown that ADAS have an effect on the driver's mental workload and situation awareness (Brookhuis, van Driel, Hof & van Arem, 2009; Davidse, Hagenzieker, van Wolffelaar & Brouwer, 2009). These constructs are also related to driving performance and safety; therefore it is interesting to assess how they are affected by the CCC.

Situation awareness is often used to describe how much an operator is aware of what is going on around him or her. It is divided into three phases; the perception and integration of situational information into a holistic image and the prediction of future states (Endsley, 1995). For the evaluation of CCC it would be important to distinguish between awareness of the environment and awareness of the advice. A driver's overly attention to the advice might decrease the awareness of changes in traffic and vice versa. This should be measurable as a reduced awareness of the current state of the traffic situation. Therefore assessing situation awareness should give insights into how drivers manage to distribute their attention between the traffic and the advice and whether the advice is distracting them from paying attention to the traffic.

Furthermore driver workload is determined by task related factors (i.e. the demand from the modal and cognitive load of the driving task and the additional load or distraction from the CCC) and driver related factors (e.g. human capabilities, driver characteristics, driver state).

Within the information processing approach, mental workload has been expressed as the amount of information processing capacity (or the mental effort) that is needed for successful task performance (De Waard, 1996). It can be hypothesized that an increased task demand caused by the advice increases mental effort for the person that tries to keep a certain level of performance, therefore leading to an elevated mental workload. An evaluation of workload should therefore indicate the added demand with CCC advice in contrast to the initial task demand.

Several measures exist for situation awareness and workload (Verwey & Veltman, 1996; De Waard, 1996; Tsang & Vidulich, 2006). However their application and combination depends on the specific questions that a study tries to answer and the methodology being used. An elaborate discussion of their advantages and shortcomings goes beyond the scope of this article. The following text gives an overview of how CCC advice might influence a driver's workload or situation awareness.

Apart from the advice content (the message), other advice attributes (e.g. frequency, modality, timing, order, form, verbosity) determine how efficient this message can be transmitted and how demanding it will be for the driver to comprehend it.

Because the system will find application in nearly congested traffic on a motorway, its update frequency has to be chosen in a way that the advice remains relevant in this constantly changing environment. On the other hand the nature of this situation already puts high cognitive demands on the driver. Every advice that is given will ask additional cognitive resources for attending and processing and executing it.

As a project requirement, the system will be developed as a retrofit nomadic device. This should allow for faster market penetration; on the other hand it restricts the presentation of information and advice to the visual and auditory modalities as these are supported by the in-car interface. Driving is a task predominantly guided by visual input. Constant monitoring of the visual scene is required to prevent the vehicle from going off the road or colliding with obstacles (Mourant & Rockwell, 1972). Therefore increasing the time spent looking at in-vehicle systems will increase the chance of inadequate longitudinal and lateral performance (e.g. Horberry et al., 2006). The load in the auditory modality on the other hand is less severe. Therefore shifting advice presentation to this modality might have a beneficial effect on task demand and driver performance. This assumption is further supported by the multiple-resources model (e.g. Wickens, 1980, 1984). According to the model humans do not have a single information processing resource, but several different pools of mental resources that can be tapped simultaneously. These pools show variations in sensitivity to the nature of the task demand. A hypothesis that can be deduced from the model is that the division of advice over modalities has a beneficial effect on task load. However, Verwey (1996) noted that in concurrent presentation of auditory and verbal messages the auditory may suppress the visual information. Therefore simultaneous presentation of content rich auditory and visual information would not be preferable.

Also the forms of both modalities have implications for the timing and length of the advice presentation. Audio messages are discrete whereas visual displays can be continuously displayed and updated. When audio messages are not correctly timed they rely on the drivers' memory to be able to recall the information at the proper time. Hence when these audio messages are too long a great demand will be put on the working memory. In visual presentation written message should be as short as possible, for example they should not contain more than four information units to avoid too much distraction from the traffic scene (Labiale, 1996). In the visual modality icons and animations can be used for the fast presentation of a complex message. On the other hand, these icons should be recognizable to avoid extended glancing times and elevated workload needed to decode the message from the picture.

Is has been stated earlier that advice will be given concerning speed, headway and driving lane. If the system needs to give advice on more than one category at the same time, the order of presentation becomes important. If several advices are presented simultaneously the driver may feel obligated to absorb and process a lot of information resulting in a sudden increase of workload. Also he would have to make the decision which advice to follow first. Alternatively advice could be presented one after another. Here the amount of information that the driver has to attend at a certain point is smaller. Now the difficulty is with the designer to decide how long a certain advice should be shown. The time needed to perceive, process and execute the first advice can deem the second advice irrelevant.

CONCLUSION

In this article we introduced the Connected Cruise Control, a driver support system based on speed, headway and lane advice. Further we examined how advice characteristics can influence the level of distraction and additional task demand, and identified human factors constructs (i.e. situation awareness and workload) that may be sensitive to these changes. Both constructs can also be applied to denote safety issues that are the result of driver-system interaction.

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