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User-related assessment of a Driver Assistance System for Continuous Support – A field trial

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ABSTRACT

A Driver Assistance System for Continuous Support continuously evaluates the status of the host vehicle as well as the surrounding traffic based on information from on-board sensors. When the system detects a hazard, it issues a warning to the driver, depending on the degree of the hazard. The effects of this system on driver behaviour and acceptance were evaluated in a field trial carried out in 2013. Twenty-four drivers took part in test drives with a within-subject design along a 53 km test route containing motorway and rural-road sections. Driving data was logged and the test drivers were observed by means of an in-car observation method (Wiener Fahrprobe); in this case by two observers in the car along with the driver. Questionnaires were used to assess the drivers' comprehension of and reaction to the system. The system was successful in affecting driver behaviour in terms of lower speed when negotiating curves. Positive effects were found in the form of better speed adaptation to the situation during driving with the system activated. Also, lane choice and lane change improved with the system on. When it came to speed limit compliance, driving speed in general and longitudinal and lateral positioning, no effects could be found. No major differences were found regarding distance to the vehicle in front, overtaking manoeuvres, stopping behaviour at intersections, driving against yellow at traffic lights and interaction behaviour with other road users while driving with or without the system. On the negative side, it was noted that only during driving with the system activated did the test drivers make turns at intersections at too high speeds. In addition, more errors associated with dangerous distance to the side were observed with the system activated. In terms of the emotional state of the driver, the only difference found was that the drivers felt an increase in irritation. Regarding subjective workload, the drivers only assessed one item, i.e. whether their performance decreased statistically significantly while driving with the system. The test drivers were of the opinion that the system was useful, and that it would enhance safety especially in overtaking manoeuvres on motorways. The blind-spot warning was found especially useful in the overtaking process. The drivers appreciated the fact that the system did not give information all the time.

1. Introduction

1.1. Background

Newly developed Advanced Driver Assistance Systems (ADAS) offer the possibility of avoiding crash risks by supporting the driver to keep safe longitudinal and lateral positions in all situations. By issuing timely warnings when critical safety

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situations emerge, these systems should contribute to a reduction in the number of accidents related to inappropriate speeds, too short headways, and unintentional or uninformed lane change, but only if the driver uses the system in the way it was designed to be used, follows its recommendations and does not compensate for safety improvements by driving faster or less attentively.

Among the first indications of unexpected behaviour from car drivers was the finding by Aschenbrenner, Biehl, and Wurm (1992, 1993) that drivers of cars equipped with ABS (anti-lock braking system) drove with lower safety margins than drivers of cars without ABS. Moreover, other studies, investigating the effects of speed support, found (besides positive expected effects in situations the system was designed for) tendencies for negative behavioural effects in the form of increased approach and turning speeds at intersections, deteriorated behaviour in interactions with other road users (Persson, Towliat, Almqvist, Risser, & Magdeburg, 1993) and shorter time gaps in car-following (Várhelyi & Mäkinen, 2001).

The phenomenon of "behavioural adaptation" was defined by an OECD scientific expert group (OECD, 1990) as "those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change". On the basis of a review of a large number of empirical studies, the expert group concluded that "...behavioural adaptation to road safety programmes does occur although not consistently". It was also stated that the magnitude and direction of the effect could not be precisely specified. The reviewed studies suggested that behavioural adaptation generally did not eliminate safety gains from measures, but tended to reduce the size of the expected effects. Behavioural adaptation can, in practice, appear in many different driving manoeuvres: in change of speed, change of following distance, way and frequency of overtaking, way and frequency of lane changing, late braking, change of level of attention, etc. (Draskoczy, 1994). In hypothesising and testing behavioural adaptation, it is important to take into consideration the fact that it is an effect which usually occurs after a familiarisation period, and does not appear immediately after the driving context is changed (Draskoczy, 1994).

Mechanisms that can lead to behavioural adaptation with regard to a system like ADAS are "delegation of responsibility", "behaviour diffusion", and "compensatory behaviour". Carsten (1993) describes "delegation of responsibility" as follows: "Studies had shown that in situations people consider uncontrollable, they want to know who is 'responsible' for certain events. If other, generally more powerful, people assume responsibility, it is not unusual to delegate responsibility to them. This delegation of responsibility can lead to behaviour which is potentially more risky, e.g. in emergency situations where those at risk should make their own decisions". In the case of vehicle-based systems for driver support, the driver might delegate the responsibility to the system. A driver supported by an ADAS is able to devote more attention to other driving tasks. On the other hand, he might become over-reliant on the system. For example, the driver might rely on the system always issuing a warning in critical situations. "Behaviour diffusion" might occur in situations where drivers are not supported by the system, e.g. when driving outside the areas covered by the system, driving non-equipped vehicles or when the system fails (Carsten, 1994). In these cases, drivers who become totally reliant on the system might have difficulty keeping themselves "in-the-loop". The notion of "compensatory behaviour" has its origin in the "risk compensation" theory of Wilde (1994) (the notion that road users will use up some of the margin afforded by safety improvements by, for example, driving faster), and the "risk homeostasis" theory of Wilde (1994) (the notion that road users seek to keep their risk constant).

The key issues with ADAS, in addition to the technical questions, i.e. how to transfer safety critical information to the driver in a timely way via the most suitable HMI (Human Machine Interaction) channels, are how such systems work in real traffic and how drivers react when driving with such systems (behavioural effects in the short and long term, mental workload and acceptance). Such driver reactions contribute decisively to the safety outcome of any system, and real-life field studies are necessary to enable a safety assessment of the systems.

A review of earlier research (Várhelyi, Adell, & Alonso, 2006) reveals that providing the driver with relevant and timely information is of utmost importance, allowing the driver sufficient time to understand and react to the situation. Various modes (visual, auditory or haptic) may be used to inform and warn the driver and support him/her to maintain safe speed, and safe longitudinal and lateral position.

A real life study investigating the effects of an active accelerator pedal (AAP), i.e., a speed limit support system with haptic feedback, on driver behaviour (Hjälmdahl & Várhelyi, 2004a) found expected positive effects of the system. Drivers showed better speed limit compliance, slightly increased headway, improved behaviour towards other road users and more correct yielding behaviour at pedestrian crossings. However, there also were signs of negative behavioural modifications in the form of drivers forgetting to adapt their speed to the speed limit or the prevailing traffic situation when they were not supported by the AAP.

The AIDE (Adaptive Integrated Driver-vehicle interfacE) project looked at interaction with some IVT (in-vehicle-technology) systems such as Cruise Control (CC) and Speed Limiter (SL). The results showed that some drivers did not like to use some system functions, like changing to the previous target speed or activating the kick-down-function on the SL, due to a feeling of loss of control. Regarding attention and vigilance, participants had different opinions, as some stated that these systems could have the advantage of directing more attention to the driving environment while others thought that CC and SL required more attention (Saad et al., 2006).

Investigating the effects of a Driver Assistance System for keeping Safe Speed and Safe Distance in a field trial, Adell, Várhelyi, Dalla Fontana, and D'alessandro (2010) found positive effects in terms of fewer alarm situations, shorter alarm lengths, shorter reaction times, increased headway and better interactions with vulnerable road users at intersections. However, on the negative side, the number of centre line crossings increased, there was worse facilitating behaviour with regard to other drivers and harder braking at traffic lights.