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Human factors implications of vehicle automation: current understanding and future directions

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1. Background

Advances in vehicle-based technology are currently progressing at an ever- increasing rate and innovations in this area are no longer restricted to Original Equipment Manufacturers or the automotive industry, with service providers such as Google and a number of research institutes in Europe and North America also offering possibilities for new approaches to mobility (see http://www.driverless-future.com/?page_id=155). The race to test the first fleet of such vehicles on public roads is currently underway, with Volvo Cars announcing the start of its Drive Me project by 2017 (Volvo Cars, 2013) and the UK Government recently encouraging cities to engage in demonstrating trials of such vehicles on public roads from January 2015 (BBC, 2014). However, the homogeneous global implementation of fully autonomous vehicles is unlikely in the near to distant future.

2. Current Issue

This special issue was initiated following a symposium on the human factors of automated vehicles, at the 5th International Conference on Traffic and Transport Psychology in Groningen, the Netherlands, in August 2012. However, following a call for papers, studies not presented at the symposium were also considered for this final version of the Transportation Research Part F journal. Our intention, as much as feasible, was to welcome studies which considered drivers' interaction with more than one vehicle support system, i.e. not solely studies which investigated driver behaviour with either Adaptive Cruise Control (ACC) or Lane Keeping Systems (LKS) in isolation, but empirical work which investigated driver interaction with highly or fully automated vehicles (FAD/HAD). Here, both lateral and longitudinal control of the vehicle is managed by an automated system, as described by NHTSA's levels 2 and 3 (NHTSA, 2013).

The papers included in this special section capture a wide range of findings related to highly or fully automated driving, from drivers' interaction with the system in an individual automated vehicle, to the influence of neighbouring platooned vehicles on driving an unequipped, manually controlled car. The marked change in drivers' role from a car where only ACC is engaged to one which is highly automated is best emphasised by the meta-analysis of 30 studies conducted by de Winter, Happee, Martens, & Stanton (2014). These authors conclude that although a typically lower level of workload is experienced by drivers during highly automated driving, when compared to both ACC and manual driving respectively, drivers engage in more non-driving related tasks during HAD.

Concerns regarding the deleterious effects of increasing automation on performance and situation awareness, when high automation is compared to ACC, are also stressed in the study by Strand, Nilsson, Karlsson, & Nilsson (2014). Using a motion-based driving simulator study, Strand et al. (2014) recorded drivers' response to critical events when automation failure involved varying levels of deceleration failure (partial, moderate and severe). The authors used an innovative measure for potential vehicle collisions, termed the 'point-of-no-return' (PoNR). In contrast to allowing a (virtual) collision and stopping the simulated environment, Strand et al. (2014) measured the point at which driver action was no longer able to avoid a collision, allowing a more comfortable experience for drivers and continued data collection after the PoNR. Increasing levels of automation from partial to high was found to increase the number of PoNRs and reduce minimum time to collision, implying lower situation awareness with increasing automation. Understanding how drivers cope with partial versus complete failures in automation showed mixed results in this study, compared to a previous study conducted by the authors (Nilsson, Strand, Falcone, and Vinter, 2013). Strand et al. (2014) suggest that understanding how drivers cope with automation failure at different levels of automation warrants further research, as well as how results may be affected by increasing experience and interaction with automation.

The matter of driver experience with automation is addressed in the paper by Larsson, Kircher, and Hultgren (2014) who studied drivers' interaction with ACC and ACC plus automatic steering (AS). In line with previous studies (Rudin-Brown & Parker, 2004; Young & Stanton, 2007) Larsson et al. (2014) report slower brake reaction times to a 'cut-in event' for drivers driving with an ACC, compared to those in manual control of the vehicle. Consistent with previous research (Stanton, Young, Walker, Turner, Randle, 2001), Larsson et al. (2014) report that addition of AS to ACC did not affect overall driving performance. However, drivers familiar with an ACC were faster at responding adequately to cut-in events, than those who were experiencing the system for the first time, demonstrating the importance of long term adaptation to technology when evaluating its effects. Larsson et al. (2014) argue that the increased brake reaction time during ACC control is not necessarily a disadvantage of the system, as experienced drivers clearly trust it to perform its task appropriately and only intervene at the last second. However, understanding the interaction between driver age and experience for handling automation warrants further research, as drivers familiar with the ACC in Larsson et al.'s study were older than the inexperienced group.

The use of an automatic steering intervention for avoiding imminent collisions was also the subject of a study conducted by Schieben, Griesche, Hesse, Fricke and Baumann (2014). Investigating the benefit of additional information to steering interventions, Schieben et al. (2014) compared a pure steering intervention manoeuvre, which was initiated at a Time To Collision (TTC) of 2.1 seconds before the obstacle on the road, with one supported by an additional auditory signal (with no information about direction of steering) or a haptic signal illustrating steering direction. The advantage of these steering interventions compared to baseline was confirmed by an observation of more collisions by the group of drivers who had to manually avoid the obstacle. However, results did not show any difference in collision avoidance when pure automatic steering intervention was supported by an auditory or haptic signal, although there was a trend for better performance with a supporting haptic signal which informed drivers of the steering direction. An interesting finding from this study was that drivers tried to interfere with the steering manoeuvre, reducing the possibility for intervention to be 100% effective. The benefit of such systems in avoiding collisions is evident, as they steer around the obstacle. This is potentially safer than drivers' natural reaction to sudden collision events, which is invariably a sharp brake response (Schieben at al., 2014). However, here also, further work is required to understand when and how driver intervention should be prevented in favour of system domination, for example by decoupling the driver from the steering control task (see Heesen, Dziennus, Hesse, Schieben, Brunken, Löper, Kelsch & Baumann, 2014).

Considering drivers' appreciation of the potential benefits of highly or fully automated vehicles was addressed in a study by Payre, Cestac and Delhomme (2014). Data from 421 French drivers were analysed and showed an overall willingness to accept such vehicles by just over 68% of the respondents. This is in contrast to a recent survey conducted on British drivers, which suggests only 18% of drivers appreciate the benefits of such vehicles (Ipsos MORI, 2014). Similar to other polls (Ipsos MORI, 2014), Payre et al. (2014) found men to be more favourable of the concept of FAD than women, as were those with higher driving-related sensation seeking scores. However, the authors argue that high sensation seekers may soon tire of such vehicles, once the novelty of interacting with them has worn off. The potential of FAD was deemed to be particularly useful during highway driving by this group of French respondents, who also saw the benefit of FAD when impaired by drugs, fatigue or alcohol. As outlined above, as the potential for testing the technology for automated vehicles in the field becomes more feasible, further insight into the users' interaction and acceptance of these vehicles becomes more crucial. One important caveat highlighted by Payre et al., (2014) is that understanding the benefits of such vehicles can only really be appreciated upon prolonged contact and handling of the system by drivers, which is currently not possible. It will therefore be interesting to contrast these results with future such surveys as trials for driverless cars become more commonplace in the coming years.

Before that stage is reached, there will be a situation with mixed traffic, i.e. some highly automated vehicles are present on the road amongst other partially automated or manually controlled vehicles. In such circumstances, the short headways maintained by vehicles in a platoon, motivated by a desire to increase road capacity, may also be adapted by drivers operating non-automated vehicles. This assumption was addressed by Gouy, Wiedemann, Stevens, Burnett, and Reed (2014) in a simulator study, which found that participants driving non-automated cars did indeed display platoon behaviour by driving at reduced time headway to lead vehicles. Gouy et al.'s (2014) study stresses the importance of investigating the potentially long period of time when fully automated driving is mixed with manually operated traffic.

Merat, Jamson, Lai, Daly & Carsten (2014), study drivers' ability to successfully resume control from automation after short periods of time, by assessing how quickly drivers re-engage their visual attention back to the road ahead and how well they maintained vehicle lateral position, when compared to periods of manual operation. Looking at the first minute after manual control was transferred back to drivers from automation, management of the vehicle was found to be rather erratic for around the first 10-15 seconds, with around 40 seconds required by drivers before performance stabilised. Merat et al. (2014) argue that there are important implications of this finding for transfer of control to drivers during critical situations and providing the right message to drivers at the correct time and via appropriate Human Machine Interfaces is an important consideration for the automotive industry.

Although perhaps not obviously related to other papers in this special issue, the paper by Schwarz (2014) provides a new and interesting method for Time To Collision (TTC) calculations and also introduces the Time to Closest Approach (TCA), for measuring near misses. Schwartz (2014) argues that the new method for calculating TTC goes beyond what has been used for traditional car following scenarios and may provide valuable understanding in studies of vehicle automation.

Contributions to this special issue focus on a number of important behavioural implications of vehicle automation. They also indicate gaps in knowledge where future efforts should be directed. For example, many simulator studies investigate the effects of drivers' first encounter with automation, while humans are adaptive beings (Jamson & Rudin-Brown, 2013). Therefore, the long-term effects of automation on driver and traffic behaviour and drivers' ability to become familiar with a system and adapt to its operation is largely under researched. Another important topic is that of the interaction between automation and drivers of different age. In an ageing society where the number of people aged over 65 is projected to double between 2010 and 2050 (Lanzieri, 2011), this is an area which deserves further attention, as perception and cognitive performance of drivers gradually but substantially decreases with age (Barberger-Gateau & Fabrigoule, 1997). It can be argued that to maintain mobility automation is likely to be helpful for this and other groups of impaired drivers. However, substantial research is required to ensure support is offered in an optimal manner. Finally, understanding how automated vehicles are received and operated by today's tech-savvy young novice or learner drivers and the implications of this on future mobility and road safety is also of great interest.

In sum, although the current special issue contains a number of robust studies which will no doubt better inform our understanding of this area, studying the human factors, environmental and socio-economic implications of automated vehicles proves to be an exciting space in traffic and transport psychology for the foreseeable future.

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