Journal of Psychology & Psychotherapy

Short Communication Open Access

Psychology and the Automated Vehicle

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For many reasons, there is a significant effort being applied to developing automated transport systems. One persuasive reason is that more than 90% of all road collisions have human error as a contributory factor and, for the vast majority, it is the sole cause. Automation may reduce the impact of human error on road crashes since, unlike human drivers, the systems responsible for detecting and avoiding hazards are not subject to fatigue, distraction or impairment by alcohol and drugs.

The SAE [1] J3016 taxonomy of vehicle automated driving systems described six levels of automation. Starting from level 0, in which none of the control operations of the driving task are automated; through to level 5, in which the vehicle is capable of all aspects of the driving task and no driver is necessary.

There are some significant psychological challenges to overcome in the introduction of automated control systems to road vehicles. Firstly, it will be many years before vehicles are available that can undertake all driving on all roads and in all environmental conditions (SAE level 5). Consequently, until such vehicles are available and widespread, drivers will need to become accustomed to vehicles that are responsible for a subset of the driving task. This might be high levels of automation on specific roads (e.g. highways – SAE level 2-4) or low levels of automation at all times (e.g. autonomous emergency braking – SAE level 1). For the former, drivers must understand the process of handing control to the vehicle automation systems and then control being returned to the driver at some later point in time. With reference to aviation but considering broader interactions between humans and machines, Parasuraman et al. [2] identified four areas of human performance that are influenced by automation and have relevance to this process of transition between human and system control of a vehicle. This paper describes how their work relates to road vehicles classified at SAE levels 2-4 in which active control of the vehicle may shift between automation systems and the driver.

Firstly, increased mental workload caused by clumsy automation. By reducing the input necessary for the human driver for safe control of the vehicle, these levels of automation should reduce driver workload and make the driving experience more comfortable. However, if the control systems for automation are difficult to understand or engage, it could result in mental workload being increased by automation. Wiener referred to this as 'clumsy' automation. In a driving situation, it is therefore important that the automation systems are designed in such a way that their operation is intuitive and system status is evident.

Secondly, situation awareness – Parasuraman et al. [2] assert that automation of decision-making functions may reduce the operator's awareness of system status and of dynamic features of the operating environment. Also, if an automation system consistently and repeatedly selects and executes decision choices in a dynamic environment, the human operator may not be able to sustain a mental representation of the information sources in the environment because the operator is not actively engaged in evaluating the information sources leading to a decision. It is therefore likely that automation of the driving task will reduce drivers' awareness of their environment. Studies have shown that drivers may take as long as forty seconds to regain sufficient situation awareness to resume control following a takeover request in a SAE level 3 automated driving situation [3]. This has ramifications for what can be expected of a driver if they are required to resume control and therefore, implications for the capabilities of the automation system whilst the driver achieves the required level of alertness and situation awareness.

Thirdly, complacency – Parasuraman et al. [2] state that if automation is highly but not perfectly reliable in executing decision choices, then the operator may not monitor the automation and its information sources and hence fail to detect the occasional times when the automation fails. This is of particular relevance to SAE level 2 in which the driver is still required to attend to the driving task. In robotics terms, driving could be considered to be a known but unpredictable task. 'Known' in that the rules of the road can be programmed in the vehicle and the routes that the vehicle is able to use can be stored as detailed digital maps. However, it is unpredictable in that one cannot predict the specific environmental conditions, traffic state or pedestrian encounters that might be faced over the course of any journey. As a result, the driving task is infinitely variable and as such, there will be occasions where the automation systems make incorrect decisions. The implications of Parasuraman et al.'s view on complacency is that these errors will be compounded by automation of the task making operators less able to detect when the system is operating in error. Baumann, et al. [4] demonstrated that cognitively and visually demanding tasks interfere with the maintenance of a correct situation model in memory. Similarly, De Winter, et al. [5] showed that both adaptive cruise control and highly automated driving systems caused drivers to demonstrate poorer situation awareness.

Finally, skill degradation – Parasuraman et al. cite a substantial body of work documenting that forgetting and skill decay occur with disuse [6]. If onboard systems are increasingly responsible for safe control of the vehicle, it is possible that human drivers will become less able to respond when required. An example of this from aviation is the crash of Asiana Airlines flight 214 in December 2013. Accident investigators attributed the crash to the pilots becoming over-reliant on the 'auto-land' technology and as a result, insufficiently skilled to land the aircraft safely when this system was not available [7].

The extent to which the driver is required to be alert and attentive to the driving situation during periods of automated control differ between system types. Tesla offer a software update for their Model S vehicle called 'Autopilot' that offers automated driving functionality on highways such that the driver need not interact with steering or pedal controls; however, the Tesla Model S Owner's Manual [8] states: "It is the driver's responsibility to stay alert, drive safely, ensure the vehicle stays

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Received May 19, 2016; **Accepted** July 27, 2016; **Published** August 04, 2016

Citation: Reed N (2016) Psychology and the Automated Vehicle. J Psychol Psychother 6: 273. doi:10.4172/2161-0487.1000273

in the traveling lane, and be in control of the vehicle at all times." As such the vehicle is operating at SAE Level 2. This should be contrasted with the Volvo Drive Me programme, a research study that will provide one hundred members of the public in Gothenburg, Sweden with a vehicle capable of Level 4 automation using the SAE taxonomy. This means that for some parts of journeys on specific roads, drivers will be able to activate an autonomous driving mode that will mean they do not need pay attention to the driving task and can engage in other activities. In technological and regulatory terms, there is a dramatic difference between the two systems. However, to a naïve driver, the experience of using the two systems is very similar. The extent to which we could rely upon drivers to understand and adapt their behaviour to the potential levels of automation that they might experience in different vehicle makes and models is questionable.

Pedestrians will also need to adapt their behaviour to the presence of automated vehicles. In busy urban areas with slow moving traffic, it is not uncommon for intentional or inadvertent non-verbal communication to take place between pedestrians and drivers [9]. In the absence of human drivers, vehicles may need to adopt new forms of communication to indicate their intent to pedestrians. Similarly, pedestrian behaviours may adapt to automated vehicles in the knowledge that, within the capabilities of its braking performance, an automated vehicle will certainly stop for a pedestrian. This may lead to confusion and incidents with a mixed fleet of automated and manually driven vehicles that is likely to exist for many years to come. Nissan (among other manufacturers) are working on highly automated vehicles that use external lighting and messaging to communicate intent to other road users that may help to mitigate this concern [10].

Vehicle automation is a rapidly advancing field in terms of the technologies that are enabling vehicles to gain an understanding of their environment and navigate routes through it. This is leading to a proliferation of driver assistance systems and automated vehicle technologies that may lead to significant changes in the way we are able to achieve mobility in future. However, as with all such significant changes, their psychological effects must also be considered in order to recognise and mitigate any adverse behavioural consequences as a result. The growth of transport and traffic psychology as a discipline means that there are now experienced researchers and robust tools and techniques for study design and analysis that can be applied to support design decisions, aid in testing and validation of systems and monitor/evaluate the performance of vehicle automation from a psychological perspective. That such research is valued by the public and private sector is to be welcomed.

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