Is partially automated driving, a bad idea? Observations from an on-road study

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The automation of longitudinal and lateral control has enabled drivers to become "hands and feet free" but they are required to remain in an active monitoring state with a requirement to resume manual control if required. This represents the single largest allocation of system function problem with vehicle automation as the literature suggests that humans are notoriously inefficient at completing prolonged monitoring tasks. To further explore whether partially automated driving solutions can appropriately support the driver in completing their new monitoring role, video observations were collected as part of an on-road study using a Tesla Model S being operated in Autopilot mode. A thematic analysis of video data suggests that drivers are not being properly supported in adhering to their new monitoring responsibilities and instead demonstrate behaviour indicative of complacency and over- trust. These attributes may encourage drivers to take more risks whilst out on the road.

Highlights:

- On-road study using a Tesla Model S operated in Autopilot mode
- Thematic analysis of driver behaviour highlights the impact of autonomous functionality on driver behaviour
- Findings reveal evidence of mode error, complacency and over- trust

Keywords: automated driving; driver role; level of automation; partial automation; mode transitions; transitions of control

Introduction

'Integrated Cruise Assist' (Robert Bosch GmbH , 2015), 'Autopilot' (Tesla Motors, 2016a), 'Distronic Plus with Steering Assist' (Mercedes-Benz, 2013) and 'Intellisafe Autopilot' (Volvo Cars, 2016) are just some examples of automated driving features emerging into the marketplace that offer an enhanced level of automated driving functionality. According to the National Highway Traffic and Safety Administration (NHTSA, 2013), these systems use a combined function approach. This means that both longitudinal and lateral aspects of driving are automated simultaneously. More enhanced systems can also automate some of the traditional decision-making tasks of the driver (e.g. Walker et al, 2001, 2016). These systems can be seen as a form of ‘driver-initiated automation’ whereby command and control supposedly remains within the drivers grasp (Banks & Stanton, 2016). Theoretically, these systems enable the driver to become hands and feet free but not necessarily ‘mind free’ (Banks et al, 2014). Additional monitoring demands placed upon the driver in using such systems is a consequence of the fact that the driver is expected to be ready and prepared to act as a fall-back if the vehicle approaches the limits of its Operational Design Domain (ODD; SAE J3016, 2016). This essentially represents the Society of Automotive Engineers (SAE) Level 2 description of automated driving systems. Table 1 outlines the allocation of system function (i.e. responsibilities) of the driver and automated driving systems at each level of automation according to SAE. Acknowledgement of these roles and responsibilities is important as it helps to identify system limits and functional boundaries of system operation.

Table 1. Allocation of system function at different levels of automation based on SAE J3016 framework

Level of Automation	**Longitudinal and Lateral Control**	**Monitoring of the Environment**	**Operational & Tactical Tasks**	**Strategic Tasks**	**Examples**
0 – No Automation	D	D	D	D	Warnings e.g. Blind Spot Information Systems
1 – Driver Assistance	D / A	D	D	D	Adaptive Cruise Control
2 – Partial Automation	A	D	D	D	Tesla Autopilot Mercedes Distronic Plus
3 – Conditional Automation	A	A	D	D / A	Audi A7 (prototype)
4 – High Automation	A	A	A	D / A	Toyota Highway Teammate (concept)
5 – Full Automation	A	A	A	A	Google Self-Driving Car

Key: D = Driver; A = Automation; D/A = both driver and automation

The role of the driver throughout automation has however been a contentious issue. This is because SAE and other automation taxonomies (e.g. NHTSA, 2013; Gasser & Westoff, 2012) do not formerly outline what the driver can and can not do under varying levels of autonomy.

The role of the driver therefore is often left open to interpretation. Recently Banks & Stanton (2017) discussed the varying roles of the driver within an automated driving system. A Driver Driving (DD) for example, would be responsible for completing basic, operational, tactical and strategic tasks of driving (Michon, 1985; Walker et al, 2015). The Driver Not Driving (DND) in contrast, would relinquish full control of these tasks to an automated subsystem. Whilst a transition between DD and DND may be appropriate for some driving modes, there is a risk that this transition may also occur at lower levels of the automation despite countermeasures being put in place. During the intermediate levels of automation, Banks & Stanton (2017) suggest that the driver should assume a monitoring role (e.g. Driver Monitor; DM). For SAE Level 2 systems, it is vital that driver mode transitions are only made between DD and DM (and vice versa) to ensure that system safety can be appropriately maintained. A transition between DD and DND is considered to be problematic at Level 2 because automated systems are not capable of functioning during all possible driving modes (Norman, 1990). However, the perception of increased reliability, leads drivers to become more complacent in system operation and it may mean that they do not monitor the system as closely as they should (Molloy & Parasuraman, 1996; Parasuraman et al, 1993). Reductions in awareness may increase the occurrence of mode errors (Sarter & Woods, 1995) and automation surprises (Sarter et al, 1997) in situations whereby the automated system is unable to cope with its current environment. Thus, we may begin to see the emergence of the DND role at lower ends of the automation taxonomy.

"Driver error" was identified as the probable cause of a fatal incident involving a Tesla Model S being operated in Autopilot mode in Florida, 2016 (National Highway Traffic & Safety Administration, 2017). Since then, more evidence has surfaced that suggests there is a major discrepancy in the design philosophies underpinning automobile automation innovation. Despite issues relating to sustained attention, fatigue, trust, reduced situation awareness, decreased response times, cognitive overload and underload that have been consistently highlighted as problems within human-computer interaction (e.g. Dozza, 2012; Molloy & Parasuraman, 1996; Stanton et al, 1997), partial automation is reliant on humans completing a sustained monitoring task. To explore whether or not enhanced Level 2 systems can appropriately support the additional monitoring responsibilities of the driver, a thematic analysis of video data captured during a previous study by Eriksson et al, (2017) was conducted. This study made use of a Tesla Model S, being operated in Autopilot mode, on the open road. Video cameras were used to capture additional data relating to the nature of control mode transitions between manual and automated driving. The purpose of the following analysis was to highlight the impact of autonomous functionality upon driver behaviour and identify specific areas that could be indicative of compromised system safety. To date, very few studies have assessed natural driving behaviours in an on road setting with enhanced SAE Level 2 systems. Some notable exceptions include Banks & Stanton (2015; 2016), Naujoks et al. (2016), Endsley (2017) and Stapel et al. (2017). However, previous investigations have typically been limited to closed-loop circuits (Eriksson, 2017).

Method

Participants

Twelve participants between the ages of 20 and 49 years (*M* = 32.33, *SD* = 10.98) were recruited to take part in this study. They had an average 14.58 (*SD* = 11.13) years driving experience, an average of approximately 10.000-20.000 kilometre driving distance per year (3 reported lower driving distance, and 1 reported a higher value) and all had experience in using Advanced Driver Assistance Systems such as Adaptive Cruise Control and Lane Keeping Assist. The study complied with the British Psychological Society's Code of Ethics and had been approved by the University of Southampton Ethics Research and Governance Office (ERGO: 19151).

Experimental Design and Procedure

Upon providing informed consent, participants were invited to drive along public roads and highways (B4100, M40, M42) within Warwickshire in a right hand drive Tesla Model S P90 equipped with the Autopilot version 7.x software. Drivers were reminded that they were responsible for safe operation of the vehicle regardless of its mode (manual or automated) in line with recent amendments to the Vienna Convention of Road Traffic (United Nations, 1968) and were also advised to adhere to the Highway Code throughout the journey (Department for Transport, 2015). Drivers were not actively encouraged to remove their hands from the steering wheel at any time but were encouraged to drive in a manner they felt comfortable. They were further told that this exercise was not a test of their driving ability. To support them in remaining aware of the vehicles internal Human Machine Interface (HMI), a qualified safety driver was present in the passenger seat throughout the duration of the study. The safety driver was responsible for prompting participants to regain manual control of the vehicle if they failed to respond to the automated warnings, or, pressing the emergency stop button on the centre display if they felt that the safety of the vehicle occupants or other road users was at risk.

Participants were given a brief introduction into the functionality and controls of the Tesla Autopilot system. This included ways in which the Autopilot system could be overridden as well as the meaning of images displayed on the internal HMI (in line with the Model S Owner's Manual, Tesla Motors, 2016b). No further training was provided given that new vehicle customers are not offered additional training in relation to the use of automated vehicle subsystems at point of sale. The researchers felt that this introduction to the Autopilot feature was sufficient.

Throughout the duration of the drive (approximately 40 minutes), video and audio recordings were captured using Racelogic video VBOX equipment. This comprised of four synchronised cameras; 2 facing the driver HMI (control stork, and instrument cluster), 1 road facing camera, and 1 attached centrally to the glass roof behind the driver and passenger seats. The duration of the drive was deemed to be representative of an approximate one-way commute the National Travel Survey (Department for Transport; DfT, 2017) shows that the average daily commute is 30 minutes.

Data reduction and thematic analysis

The video data was subjected to a thematic analysis using a data-driven approach. The final coding scheme consisted of four main themes (see Table 2). These categories were chosen as they serve to highlight potential issues within the driver-vehicle-world interaction patterns for enhanced SAE Level 2 systems such as Tesla's Autopilot. Two videos were selected at random and subjected to further analysis by a secondary coder using the same coding scheme. Inter-rater reliability was calculated and scored above 90% agreement (Lombard et al. 2002; Marques and McCall, 2005).

Table 2. Coding scheme and descriptions used to analyse video data along with frequency counts

Theme	Sub-theme	Description	Frequency	Number of participants
Occurrence of system warnings	'Hold steering wheel'	Visual message presented on HMI	20	11
	Escalating 'Hold steering wheel'	Sounding of an auditory warning accompanying visual display	7	5
	'Collision warning' / AEB warning	Visual indicator presented on HMI combined with an auditory warning. HMI begins to flash as 'threat' gets closer	1	1
	'Take over immediately'	Visual message presented on HMI combined with an auditory warning. Is used when ODD limits have been exceeded.	2	2
Testing the boundaries of ODD		Drivers intentionally test the limits of automated functionality	2	2
Mode confusion		Drivers say that the system is in one mode when it is actually in another	5	4
Engagement in non-driving related secondary tasks		Any activity that is not associated with the driving task (e.g. drinking coffee)	3	2

Results

The following section discusses each key theme in turn;

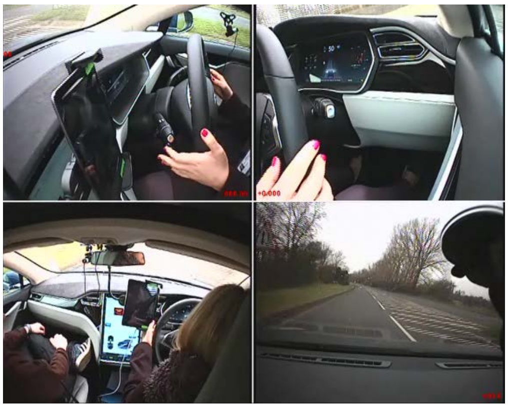
Occurrence of system warnings

It is clear that the most prominent theme occurring throughout the study was the presentation of system warnings, specifically the 'Hold steering wheel' visual warning within the HMI. This suggests that prolonged "hands free" driving (over 60 seconds) was observed for the majority of participants on more than one occasion. Only one participant remained exclusively "hands on" regardless of whether Autopilot was engaged or not. For the remainder of participants, they spent at least one or more occasion driving "hands free" for 60 seconds. Note, that the visual warning at the time of study only became active following 60 seconds of driver inactivity.

Seven of these warnings escalated further - an auditory tone was signalled 15 seconds after the initial visual warning. At this stage, drivers would have been "hands free" for over 75 seconds. This represents a substantial time period that could enable non-driving related secondary tasks to be completed. If this were to occur, drivers would find themselves being in the role of DND (Banks & Stanton, 2017) – something that could have disastrous consequences in the event of ODD limits being reached or system malfunction. The fatal Tesla incident in May 2016 for example, was attributed to a prolonged period of distracted driving (NHTSA, 2017).

Whilst the frequency of system warnings could be argued to be fairly small considering the length of the experimental journeys (equating to 21.75 minutes of "hands free" out of approximately 8 hours of driving, we must reiterate that this data was collected as part of Eriksson et als' (2017)study investigating user-paced transfer of control. Participants were therefore prompted to relinquish and resume control at certain points throughout the drive – an acknowledged weakness of this analysis. Even so, these more naturalistic periods of automated driving signal that a) all but one driver spent at least one part of their journey completely "hands free" b) the initial visual warning associated with inappropriate use of the system was not salient enough to get the drivers attention and c) the escalation in warning, via the use of an auditory tone, did prompt drivers in most cases to put their hands back on the wheel. However, the observations made in this study also suggest that the auditory tone could have potential to create confusion or startle effects (Sarter et al, 1997). For example, the storyboard presented in Figure 1 clearly shows that as soon as the Autopilot was engaged, the participant became completely "hands-free". The driver appeared at ease and appeared to be engaged in monitoring activities external to the vehicle. After 60 seconds, a visual warning was presented in the HMI that instructed them to place their hands back on the wheel. This went completely unnoticed for 15 seconds before an auditory tone was sounded. At this point, the driver appeared confused signalling the occurrence of a mode confusion (Sarter et al, 1997). The ability of the driver to respond in this situation was weakened as their awareness surrounding system state was compromised. This is because they failed to monitor the status of the internal HMI during this period of driving. This therefore represents an inherent paradox within the design of enhanced Level 2 systems. Whilst awareness of the external environment may be improved with the addition of Autopilot, reductions in in-vehicle glances may lead to less awareness relating to system status. In this instance, the safety driver had to prompt the driver to look at the internal HMI and instructed them to place their hands back on the wheel in order to cope with the situation. An additional 2 seconds passed before the driver did this. In total then, this participant spent 77 seconds completely "hands free". Whilst it is possible that improved familiarity with the system would limit the occurrence of mode confusion and startle effects (Sarter et al, 1997), the single case study conducted by Endsley (2017) indicates that even with experience, such performance decrements may still occur, despite familiarity with the associated human factors issues pertinent in vehicle automation. This is likely to be partly attributable to the continued updates being made to the system that deliver subtle changes to system operation. What is of greatest concern however, is the occurrence of mode confusions despite the driver being alert and well-motivated to remain in control of the vehicle.

1. Autopilot engaged – Driver immediately becomes “hands free”



2. Visual warning appears on HMI 60 seconds later instructing driver to “hold the steering wheel”. Driver remains “hands free”

3. Auditory tone issued 15 seconds later. Driver remains “hands free”

4. Driver places hands back onto the steering wheel 2 seconds later following prompts from safety driver

|Figure 1. Evidence of an extended period (77 seconds) of “hands free” driving despite visual and auditory warnings

It is important to note, that like many other vehicles, the Tesla Model S is also equipped with collision warning systems. These are designed to alert the driver to potential hazards within the road environment. Whilst it was not anticipated that any collision warnings would occur during this study, the thematic analysis reveals that a single collision warning was documented. The storyboard presented in Figure 2 shows the circumstances surrounding this situation. The Tesla was being driven in Autopilot mode at the time but the driver remained ‘hands on’. The car ahead was stationary in a right hand turn lane. Whilst for a manual driver this would not be deemed as a hazardous situation, the Autopilot detected this as a threat and activated a combined auditory and visual alert. The driver was already in a position to regain control of the vehicle and quickly overrode the Autopilot. Interestingly, for the remainder of this drive, the driver did not reactivate the Autopilot feature instead choosing to drive the vehicle manually. It seems likely that such an incident could challenge the developing working mental models of system functionality. Here is a clear example of dissonance between what the driver would normally do and what the system actually did. These types of ‘false alarm’ have the potential to negatively impact upon the development of trust in system operation (e.g. Johnson et al, 2004). If these false alarms continue to happen, drivers may choose not use the system at all (Parasuraman & Riley, 1997).

1. Autopilot detects hazard ahead. Auditory warning sounds and visual indicator is displayed on HMI (highlighted by red box) 	2. Area immediately in front of host vehicle representation in HMI turns red and begins to flash. Driver has overridden Autopilot and vehicle is now in manual mode 

|Figure 2. Storyboard showing events surrounding the activation of a collision warning

Testing the boundaries of ODD

The intentional testing of Autopilots ODD boundaries was observed twice throughout the study. This demonstrates that humans have a natural curiosity to test system limits despite strict instruction to remain in control of the vehicle. Figure 3 presents a storyboard example of the events surrounding one situation in which a participant tested the Autopilots ODD boundaries. In this example, the driver attempted to leave the carriageway whilst in Autopilot mode. Whilst they demonstrated strong monitoring behaviour and kept their hands hovering by the steering wheel poised to regain control, they were clearly engaging in risky behaviour. What is more, the driver failed to realise that a small torque input had actually deactivated the Autopilot feature and their hands remained hovering over the steering wheel despite being in manual mode. This is therefore indicative of a mode confusion as the driver thought the vehicle was in Autopilot mode when actually it was in Manual mode. With the vehicle failing to leave the carriageway as desired, the driver placed their hands fully back on the wheel whilst paradoxically stating;

“Don’t worry, I had a handle on it”

completely unaware of their error.

1. Tesla in Autopilot mode. Driver signals to leave carriageway and asks “will it do it?” Hands hover by steering wheel 	2. Driver deactivates Autopilot by making a small input 
3. Deactivation goes unnoticed and driver is clearly observed to be “hands free” 	4. Vehicle does not leave the carriageway so driver places hands on wheel and states “don’t worry, I had a handle on it” 

Figure 3. Evidence of a driver testing the ODD boundaries of Tesla’s Autopilot

Mode confusion

All of the mode confusions that were observed within this study were based upon the driver failing to understand what mode the vehicle was driving in (i.e. thinking that Autopilot was engaged when actually it was not). In the storyboard example presented in Figure 4, the driver attempted to engage Autopilot using the control stork indicators. The driver then released their grip from the steering wheel because they thought the Autopilot feature was engaged despite the HMI indicating otherwise. Upon closer inspection of the internal HMI, the driver quickly realised their mistake and regained control of the steering wheel. If we think of this in terms of the changing driver role, the intention was that the driver would go from active operator (i.e. DD) to monitor (i.e. DM). However, the driver quickly realised that this control transition had not been successful and resumed back to the DD role. Other causes of mode confusion within this study were inadvertent torque inputs (i.e. the driver did not realise they had deactivated Autopilot), failure to properly engage Autopilot in the first instance, and misunderstanding of the internal HMI – perhaps indicative of a system transparency issue (e.g. Banks & Stanton, 2016). The occurrence of mode confusion suggests that overall system safety could be compromised during such instances, especially if drivers believe they are in automated mode when actually, they are not.

1. Driver attempts to engage Autopilot using control stork

2. Driver releases hands from the steering wheel despite HMI indicating manual mode

Figure 4. Storyboard indicating a failure to engage Autopilot

Engagement in non-driving related secondary tasks

Whilst only a small number of examples for engagement in non-driving related secondary tasks were evident within the data, it is clear that Tesla's Autopilot may indeed encourage 'risky' behaviour for some individuals. In the storyboard presented in Figure 5, the vehicle was driving in Autopilot mode. The driver proceeded to drink coffee for approximately 11 seconds whilst completely "hands off". Whilst the duration of the task is relatively short, the driver's posture suggested that they were not attending to the road environment in any capacity. Whilst the driver may have felt it was safe to engage in this non-driving related secondary task due to the carriageway being clear of other traffic, a sudden change within the roadway ahead could have prompted an emergency take over request. In terms of driver roles, this would represent a sudden control transition taking the driver from a DND to a DD (Banks & Stanton, 2017). This could result in a 'startle' effect (Sarter et al, 1997), resulting in a DD being ill-prepared to regain control. Of course, drinking coffee could be seen as an arbitrary example of a non-driving related secondary task, especially as drivers of manual vehicles may be guilty of doing the same. However, the key difference between manual and automated driving is that the driver can become "hands free" and therefore may not be in as good a position to quickly resume control.

There were other instances whereby the same driver was also trying to engage the Experimenter in conversation that led to a shift in body posture (i.e. the driver turned around for a few seconds). This differed from similar situations in manual driving as the driver did not make any glances back to the road environment and their gaze was firmly fixed to the rear of the vehicle. Overall system safety could be deemed as compromised as the driver was not attending to the otherwise dynamically changing environment ahead of them.

It is clear then that the role of DND poses a real risk to overall system safety, even for SAE Level 2 systems. This is a pertinent research finding as it adds to the growing body of literature that shows that drivers are at risk of becoming disengaged from the driving task, both for momentary and prolonged periods during automated phases of driving (e.g. Cabrall et al, 2016; Endsley, 2017; Heikoop et al, 2017; Kyriakidis et al, 2017). The role of the driver is likely to shift throughout the duration of a journey between DD, DM and DND (Banks & Stanton, 2017). Whilst there have been a number of recommendations put forward to help improve the design of SAE Level 2 systems (e.g. Banks & Stanton, 2015; Endsley, 2017), there needs to be a better balance between the risks associated with automation misuse and the pursuit of improved driver experience.

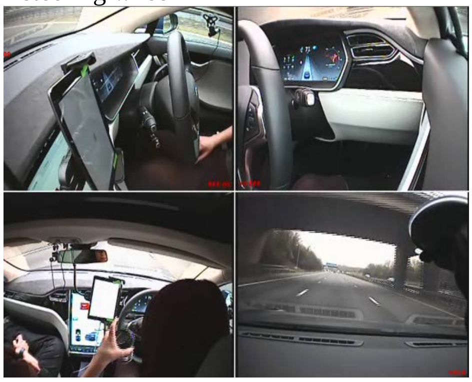
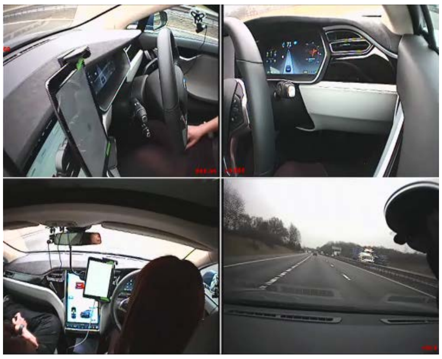
1. Driver engages Autopilot 	2. Driver picks up coffee cup. No hands on the steering wheel 
3. Driver begins to drink coffee for 8 seconds. Remains “hands off” 	4. Driver puts coffee cup down 3 seconds later. Remains “hands off” 

Figure 5. Evidence that a driver transitioned to the role of DND during Autopilot mode

Discussion

Our study shows that the engagement of Autopilot led *most* drivers to assume the role of a DM. However, potential performance issues were highlighted via a thematic analysis of video data. If we consider that the purpose of Eriksson et al’s (2017) study was to investigate how drivers pace the control transition process following a non-urgent request to resume control, drivers were encouraged and motivated to remain in an active monitoring state. Our findings suggest that on the whole, drivers were happy to become completely “hands and feet free” and only placed their hands back on the wheel as a result of system warnings. With the literature suggesting that prolonged exposure to highly automated driving conditions can lead to significant driver disengagement (Stanton et al, 1997; Young and Stanton, 2002; Saxby et al, 2007), it seems reasonable to assume that drivers could easily engage in a non-driving related secondary task that could distract them from their DM role. Inappropriate levels of trust represent an enduring challenge for system designers (Walker et al, 2016). With one driver exclaiming “it is so easy to get used to this”, it is clear that the intermediate phases of automation may be plagued by an underlying 'trust problem' that heavily influences their performance on the vigilance task associated with the DM role. This is a difficult issue to address, especially when we consider that in order for automated features to become commercially viable, they must be accurate, reliable, predictable and dependable (e.g. Eriksson & Stanton, 2017; Donmez et al, 2006). It is these factors after all that contribute to the development of trust. If a system behaves in a consistent and reliable manner for prolonged periods, the user of that system can become complacent in its operation (e.g. Parasuraman et al, 1993; Lee & See, 2004; Hollnagel & Woods, 2005) and may not respond appropriately when required (e.g. Stanton et al, 1997; Hancock, 2013). Inappropriate levels of trust in automation have therefore created new pathways for driver error to occur (Stanton and Salmon, 2009; Walker et al, 2015). In terms of driving automation, a driver may not monitor the system as closely as is warranted due to the perception of high system reliability. This lapse in performance should not however be seen as "driver error" – instead it signals a much larger "design error" whereby the sociotechnical system fails (Chapanis, 1999; Stanton and Baber, 2002). This stems from the viewpoint that the driver *and* automated systems must coordinate their behaviour in order to maintain effective performance (e.g. Stanton et al, 2006; Salmon et al, 2009, 2016; Eriksson & Stanton, 2017).

Banks et al, (2014) showed how cognitive functions can be distributed between drivers and automation in contemporary Level 2 vehicle systems. Human drivers and automated vehicles possess differing types of awareness about the ambient traffic situations (Stanton et al, 2017). Human drivers understand much more about the motivations and potential actions of other drivers (Walker et al,2015) whilst automated systems can possess much more accurate metrical information about kinematics such as range and rate change to other vehicles (Young et al, 2007; Stanton & Salmon 2009). Automated systems have the potential to enhance driver situation awareness but at the same time, humans are notoriously bad at completing sustained monitoring tasks. Decay in performance is highly likely (Stanton, 2015). With this in mind the authors of this paper argue that a shift in attitude is required to ensure that the role of the driver within automated driving systems is protected. Tesla, along with other vehicle manufacturers, have designed vehicles that can essentially drive themselves most of the time but still require a human driver to monitor its performance and intervene when necessary. This design ethos has led to a situation in which humans are bound to fail and so "driver error" becomes an inevitable outcome (Stanton & Baber, 2002). Systems designers have created an impossible task (Stanton, 2015) – one that requires the driver to remain vigilant for extended periods. The literature openly reports that humans are poor at doing this (e.g. Molloy & Parasuraman, 1996). With this in mind, whilst strategies to help improve Level 2 systems could be explored, it seems more appropriate at this time to accept that the DD and DND roles are the only two viable options that can fully protect the role of the human within automated driving systems. This in turn means that *either* the human driver should remain in control of longitudinal and/or lateral aspects of control (i.e. one or the other) or they are removed entirely from the control-feedback loop (essentially moving straight to SAE 4). In the latter instance, this places increased pressure on systems designers to ensure that their systems are both reliable and failsafe before being commercialised (Kalra & Paddock, 2016). Using the driver as the last line of defence is arguably a poor solution for addressing the shortcomings in the design and implementation of SAE Level 2 and 3 automation.

Evaluation and future research

It is important to acknowledge that there were a number of practical constraints that limited the feasibility of data collection in this study. These were primarily concerned with the availability of the test vehicle and hence culminated with the recruitment of a small sample and limited drive durations (approximately 40 minutes). However, the authors argue that despite these limitations, worrisome behaviour was still observed. This is an important finding because if behaviours like these can be demonstrated following relatively short exposure to enhanced Level 2 systems, it is likely that these behaviours will be further exaggerated with increased exposure. Even so, future research should adopt a longitudinal approach, with a larger sample size, whereby the same participants are exposed to the same journey multiple times to test this hypothesis. This will also enable a deeper analysis of emergent behaviour during enhanced Level 2 driving.

The addition of eye tracking would also further complement the data as it would enable analysts to properly assess the visual behaviour of drivers and could be used to infer levels driver distraction and inattention resulting from automation implementation (e.g. Merat et al. 2014). For example, eye tracking data would be able to confirm “where” drivers were looking when the Autopilot initiated the ‘hold steering wheel’ warning on the internal HMI.

Overall, despite its limitations, this study offers a unique insight into real-world driver behaviour using enhanced Level 2 systems. This adds to the growing body of literature relating to on-road driver behaviour within the driving automation domain (e.g. Banks & Stanton, 2015, 2016; Eriksson et al. 2017; Endsley, 2017; Naujoks et al. 2016; Stapel et al. 2017).

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