What Just Happened? Exploring Drivers' Acceptability of Minimal Risk Condition – A Qualitative Driving Simulator Study

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ABSTRACT

Automated vehicles (AVs) are expected to improve road safety by reducing the number of collisions and safety critical events [1,2]. In the event of a failure of the automated driving system (ADS), or if it reaches the limit of its capability, action is required to preserve the safety of the vehicle occupants and other road users. The Society of Automotive Engineers (SAE) [3] highlights the need for the user to assume control in these situations by performing the driving task or placing the vehicle in a safe state, i.e. one in which the risk of a collision is reduced ('minimal risk condition' (MRC)). Should the driver not be available or deemed unable to achieve this (for example, if they are inattentive or distracted by a non driving-related task (NDRT)), the ADS (operating at level 4 or above) must achieve the MRC. MRC is therefore the subject of intense scrutiny, with many automotive manufacturing companies (OEMs) already proposing solutions, for example, by performing a controlled stop of the car at the side of the road (a 'minimal risk manoeuvre' (MRM)). This is arguably an extension of existing advanced emergency braking systems (AEBS) that sense driver inactivity or their lack of an adequate braking response and intervene. However, one of the key differences in a L4-AV is that drivers are "out of the loop" by design (i.e. not driving and engaged in a NDRT), and the MRM may therefore be entirely unexpected. As such, drivers' responses and behaviour are unpredictable. For example, the ADS will likely prohibit driver intervention during the MRM [3], but it is unclear whether the driver would expect or attempt to intervene and what the consequences might be. These factors are likely to influence the acceptability of proposed solutions.

In a medium-fidelity driving simulator, sixteen experienced drivers (10 female, 6 male, 21-65 years old, mean age 31.8, mean driving experience: 12.0yrs with licence, 4.0 hrs/wk driving) undertook three 8-minute drives, each within the same simulated environment created using STISIM Drive software (v3). The driving simulator mimicked an SAE level 4 AV in that it was capable of monitoring the environment and executing both lateral and longitudinal control, thus relieving the driver from primary driving tasks. The MRM was achieved by changing lanes and bringing the vehicle to a stop outside the active traffic lanes (on the "hard shoulder") – a commonly proposed MRC strategy [4]. Lane change trajectories and brake intensity were based on relevant

literature [5,6,7], and vehicle controls were functionally disabled during the MRM. Automation was available only on lane two of a two-lane dual carriageway – representing the operational design domain. The first two drives included routine take-overs. During the third drive, participants were actively engaged in a secondary task – an immersive game on an iPad. This ensured they were "distracted" and subsequently failed the attentiveness assessment made by the 'driver monitoring system' (i.e. the experimenter) immediately prior to the takeover request, thereby initiating the MRM. This was communicated via an HMI located in the centre console and an accompanying spoken warning: "*You are inattentive, a safe stop will begin in 5 seconds*". Participants were made aware of the level 4 capabilities of the vehicle, with regard to routine operation, but were not informed of the MRM or MRC to avoid influencing their instinctive behaviour and responses. The study was video recorded for subsequent analysis. In a post-study interview, participants were asked to elucidate on factors such as: their initial response to the MRM, their understanding of the situation (what just happened?), the role they assumed, and the level of control they had or felt they should have (i.e. should they be able to intervene during the MRM). This paper briefly introduces six themes which emerged through inductive thematic analysis [8] of the transcribed responses to all questions.

1. Reluctance to Relinquish Control. Several participants felt that the intervention was abrupt and 'over the top' (p2,5,12), evoking negative emotions of "anger" and "frustration" (p2,3,14,15) or "panic" and "surprise" (p5,10,13); others referred to the process of the vehicle taking over control as "weird" (p6,12). Some stated that they subsequently felt the need to define and adopt a specific role during the manoeuvre, thus enabling a semblance of 'being in control' (e.g. monitoring the system performance), while others admitted that they waited for the system to instruct them.

2. Loss of Authority and Control. Participants expressed concerns regarding the removal of active control and decision-making authority. Some were frustrated by their inability to 'correct' the inattentiveness assessment ("*I am here and ready to drive*" (p3)), while others (p7) specifically identified that control had been removed without their consent, and therefore expected that it would be reinstated if they actively engaged with the driving task (e.g. pressed a pedal), as might be expected with existing driver assistance systems, such as cruise control. Others expressed the desire to be given a choice in the course of action.

3. Sensemaking. Although participants were initially unsure of what was happening, they were generally forgiving of the experience once they understood that it had been triggered by their lack of attention, and ultimately accepted that it probably represented the best (safest) course of action (p5,9,14). Nevertheless, concerns were expressed regarding the potential disruption it could cause (e.g. delaying their journey) – although this was regarded as an acceptable consequence by some (p4). It was also recognised that manually intervening during the manoeuvre could have a disruptive or deleterious outcome, and this stopped some participants from attempting to do so (p8).

4. Mental Models of System Capability. Drivers' mental models affected the level of trust they placed in the system. Scepticism about AVs generally, translated to distrust in the MRM (p8), although the experience already provided during the routine

drives/handovers also shaped opinion ("*this is the first time it was changing lanes, so I didn't trust the car*" (p9)). For others, the ability of the car to take over control when their own attention lapsed *increased* their trust in the system (p4). The means by which driver attention was assessed was also questioned: "*I just glanced away and it suddenly said oh you're not attentive*" – assumes glance behaviour (p2). Another thought that their attention was determined by hands-on-wheel (p7), resulting in this driver fervently grasping the steering wheel. Others expected that the check involved a more thorough assessment, acknowledging the limitations of human performance ("*maybe ... you think you are alert enough to drive but you are not actually*" (p9)).

5. Perception of Drivers' Capability. Participants were generally in favour of their own abilities to take control, over and above those of the automated system and indeed, other drivers. This was consistently used as justification for their desire (and expectation) to intervene *during* the MRM (p4,6,8,15). Amongst those drivers who perceived the automated system as more capable than a human driver (p3,10,16), participant 3 even so highlighted that the system telling them they were not ready was annoying. Interestingly, several participants were supportive of the system controlling *other* drivers' unsafe behaviour (not necessarily their own!).

6. Situation Assessment. Participants regularly refereed to their own assessment of the driving situation, including factors such as 'complexity'. As such, many recognised that the MRC did not represent *complete safety*, but rather the best ("safest") course of action, under the circumstances. This also influenced their decision to intervene, with participants suggesting that they would more likely intervene if there was "*not much traffic*" (p5), for example. Conversely, others questioned how well the system would have performed had the road situation been more complex (higher density of traffic, different road infrastructure etc.), suggesting that this would ultimately determine their confidence, trust and the acceptability of the system (p11).

The study explored drivers' responses to a level 4 ADS-initiated MRC scenario using a simulated driving experience and follow-up interview, and presents themes that were identified from the interview data. Whilst most drivers ultimately understood the purpose of the MRM and appeared willing to accept it as the safest course of action under the circumstances, there was some initial confusion, resulting in strong emotional reactions, such as surprise and even anger. An interesting irony is that several drivers felt that they should have been consulted regarding the vehicle's intentions and actions – despite them being actively taken out of the control loop immediately prior to the take-over request. This suggests that drivers need to be made aware of the actions and intentions of their vehicle and indeed, *their own limitations* – at all times. In addition, the lack of control – or more precisely the removal of control without drivers' consent, and their inability to resume control partway through the manoeuvre (when some felt they were able to do so), appears to have frustrated drivers and presents a challenge to OEMs. Many of the concerns centred around drivers' preconceived ideas about AVs (i.e. their mental models), which, combined with elevated opinions of their own ability to resume control, suggest the additional need for improved driver training and awareness. Overall, the study highlights several key challenges to overcome before an enforced MRC may be seen as acceptable solution. Future work will aim to validate findings by analysing drivers' behaviour during the study.

References:

[1] Cunningham, M. L., & Regan, M. A. (2017). Driver distraction and inattention in the realm of automated driving. IET Intelligent Transport Systems, 12(6), 407–413. https://doi.org/10.1049/iet-its.2017.0232

[2] Serban, A. C., Poll, E., & Visser, J. (2018). Tactical safety reasoning. A case for autonomous vehicles. IEEE Vehicular Technology Conference, 2018-June, 1–5.

[3] SAE International. (2018). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016_201806. https://doi.org/https://doi.org/10.4271/J3016_201806

[4]Dennis, E. P., Schultz, M., & Wallace, R. (2018). Opportunities to Encourage On-road Connected and Automated Vehicle Testing Recommendations for the Saginaw Region, (May).

[5] Yang, D., Zheng, S., Wen, C., Jin, P. J., & Ran, B. (2018). A dynamic lane-changing trajectory planning model for automated vehicles. Transportation Research Part C: Emerging Technologies, 95(June 2017), 228–247. https://doi.org/10.1016/j.trc.2018.06.007

[6] Large, D. R., Pampel, S., & Burnett, G. (2018). Exploring Drivers ' Visual Behaviour During Take-Over Requests Exploring Drivers ' Visual Behaviour During Take-Over Requests. In International Conference on Driver Distraction and Inattention (DDI2018). Gothenburg, Sweden.

[7] Pampel, S. M., Large, D. R., Burnett, G., Matthias, R., Thompson, S., & Skrypchuk, L. (2018). Getting the driver back into the loop: the quality of manual vehicle control following long and short non-critical transfer-of-control requests: TI:NS. Theoretical Issues in Ergonomics Science, 20(3), 265–283. https://doi.org/10.1080/1463922X.2018.1463412

[8] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa