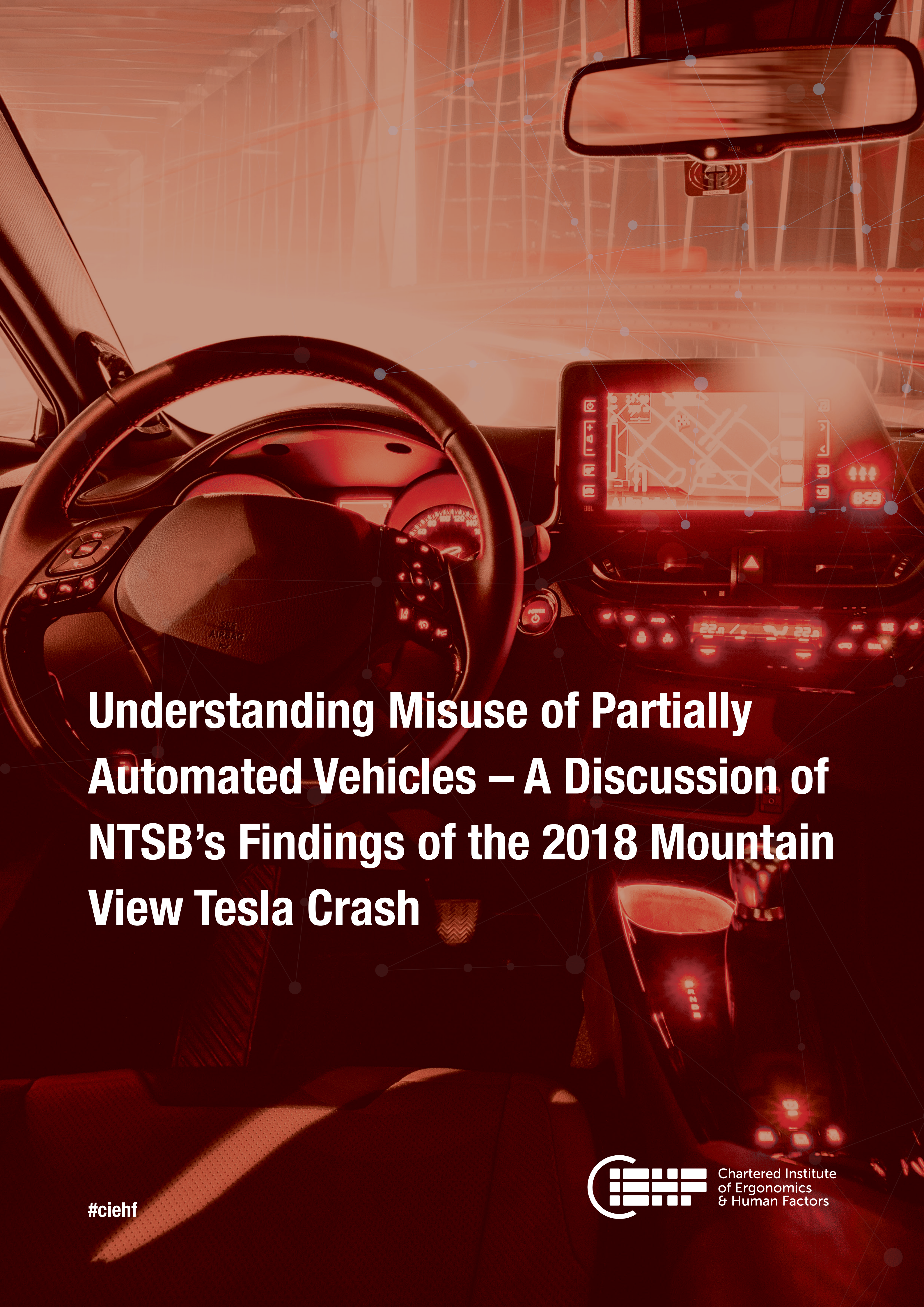

Understanding Misuse of Partially Automated Vehicles – A Discussion of NTSB's Findings of the 2018 Mountain View Tesla Crash

Chartered Institute
of Ergonomics
& Human Factors

#ciehf

Contents

Glossary of terms

CAV	Connected and Autonomous Vehicles
CIEHF	Chartered Institute of Ergonomics and Human Factors
DDT	Dynamic Driving Task
DSM	Driver State Monitoring
HMI	Human Machine Interface
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
ODD	Occupational Design Domain
OEDR	Object and Event Detection and Response
SAE	Society of Automotive Engineers

The Chartered Institute of Ergonomics and Human Factors

An introduction from the CEO

The purpose of this document is to highlight and evidence the benefits of applying a human factors approach to incident investigation and to share a complementary perspective on the events surrounding the Mountain View crash.

Human factors experts are formally trained to design for, and improve, user experience, safety, usability and effectiveness in technology across diverse fields. By evidencing the human aspect of vehicle automation, it is hoped that vehicle manufacturers, policy makers, incident investigators and consumers may become more aware of the role of the "human" in our exciting automated future.

Drawing from expertise across the CIEHF community, this report introduces some of the human factors aspects related to vehicle automation.

The Chartered Institute of Ergonomics & Human Factors (CIEHF) received its Royal Charter in 2014 to recognise the uniqueness and value of the scientific discipline and the pre-eminent role of the Institute in representing both the discipline and the profession in the UK. This includes the protected status of Chartered Ergonomist and Human Factors Specialist with the post-nominal C.ErgHF awarded to practising Registered Members/Fellows who are among a group of world-class professionals. The Institute focuses on integrated human-centred design and thinking to improve life, wellbeing and performance. This involves the disciplines of design, engineering, technology, psychology and physiology.

Dr Noorzaman Rashid

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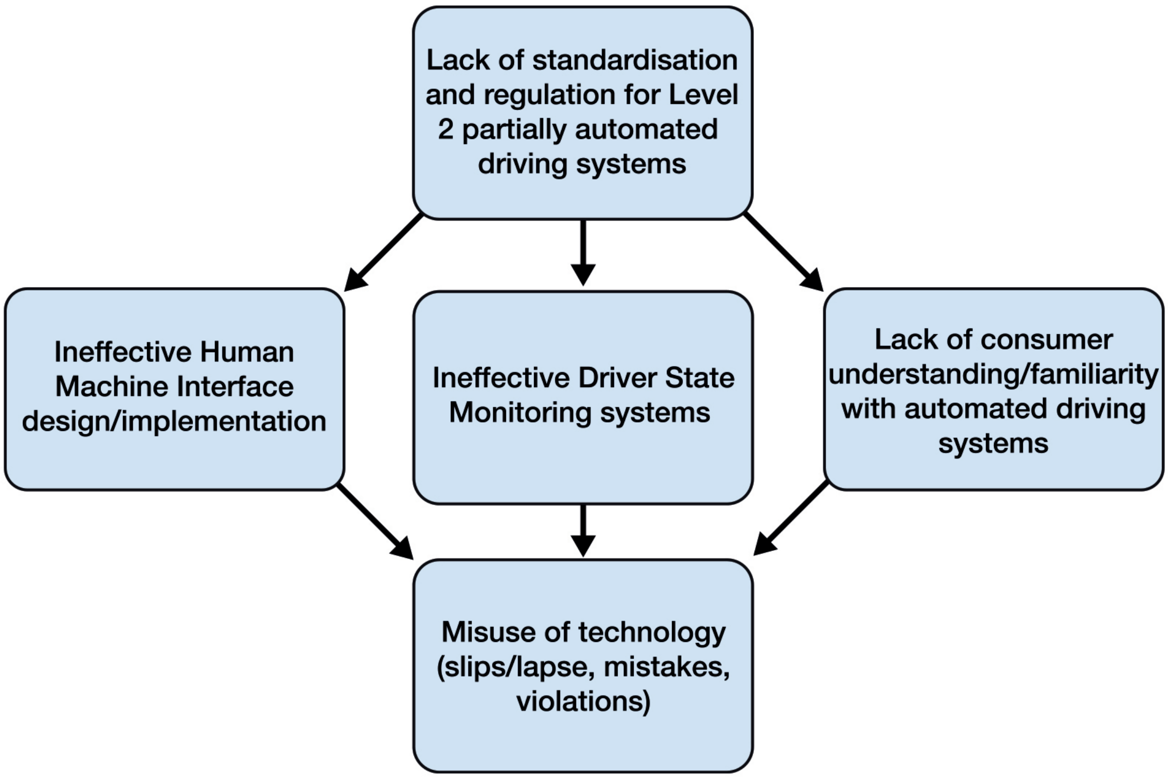
Executive summary

This document discusses a fatal crash from March 23, 2018 involving a Tesla Model X using the partially automated 'Autopilot' function. It provides a critique of the NTSB's report and examines the findings from a human factors perspective to contribute towards an enhanced understanding of the circumstances related to this crash. It concludes with areas for open discussion, recommendations for future investigation and five findings of worthwhile of further consideration.

- We question whether 'driver distraction' is an appropriate classification for a "probable cause" of the crash.
- We disagree that "familiarization with the vehicle" was not a contributing factor related to this crash.
- We question the conclusion that driver qualification was not a contributing factor related to this crash.
- We highlight the need for regulatory bodies to ensure effective driver state monitoring and urge for regulation on minimum requirements for driver state monitoring in partially automated vehicles.
- We highlight the importance of human-machine interface design in a human-machine shared system and urge for regulation on minimum requirements of such systems within partially automated vehicles.

And in doing so we highlight the importance for a human factors perspective of such events.



Introduction

On March 23, 2018 a Tesla ‘Model X’ collided with a damaged and non-operational crash attenuator resulting in the tragic death of the vehicle occupant. In response to this event, the US National Transportation Safety Board (NTSB) released a preliminary report discussing the lead-up to the event as well as conclusions and recommendations for the transport sector and relevant stakeholders. This report is referenced as NTSB/HAR-20/01 Adopted February 25, 2020 (National Transportation Saftey Board, 2018). A productive analysis of this event requires consideration of many new (to the automotive world) factors, due to the complex human-system shared responsibility that is present in partially automated driving. To benefit the NTSB and associated stakeholders, the NTSB report has been critiqued from a human factors perspective and this document identifies some areas for further consideration both within this specific report, and for future investigations involving partially automated driving systems.

The tragic event being discussed ultimately resulted in the loss of life, and we must be sensitive to this point. However, this does not excuse the need for a comprehensive review and critique of the human factors issues that may have contributed to the event. It is hoped that through an honest and productive critique of the conclusions and recommendations proposed by the NTSB, we can positively impact the safety of vehicles and regulation surrounding the safe operation of partially automated vehicles in the future.

As is common with retrospective analyses of incidents, there are numerous complex and contributing factors involved. Many of these were highlighted by the NTSB including: road layouts, crash structures and software dependencies/limitations, as well as Operational Design Domain (ODD). As human factors experts we shall address only the points where we may be most productive, and aim to address some of these human factors considerations within this particular event which have been identified and summarised as:

- Driver Distraction
- Driver Responsibility
- Driver Training
- Human Machine Interface (HMI)
- Driver State Monitoring (DSM)

Background

The Society of Automotive Engineers (SAE) categorise levels of driving automation from L0 to L5 (where 'L' is used as an abbreviation for 'Level'). These levels range from no driving automation (L0) to a full driving automation (L5). A Level 5 vehicle is often referred to as an 'autonomous vehicle'. The SAE provides detailed information on the features and limitations of each level within the report ref: J3016_201806 (SAE International, 2018) and a summary table is presented below:

Level	Name	Narrative definition	*DDT*		*DDT Fallback*	*ODD*
			Sustained lateral and longitudinal vehicle motion control	*OEDR*		
Driver Performs part or all of the DDT						
0	**No Driving Automation**	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems.*	*Driver*	*Driver*	*Driver*	n/a
1	**Driver Assistance**	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control subtask* of the *DDT* (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*	*Driver* and *System*	*Driver*	*Driver*	Limited
2	**Partial Driving Automation**	The *sustained* and *ODD-specific execution* by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and *supervises* the *driving automation system.*	***System***	*Driver*	*Driver*	Limited
***ADS* (*"System"*) performs the entire *DDT* (while engaged)**						
3	**Conditional Driving Automation**	the *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* with the expectation that the *DDT fallback-ready user is receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other vehicle systems, and will respond appropriately.	*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
4	**High Driving Automation**	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT falback* without any expectation that a user will respond to a *request to intervene*	*System*	*System*	***System***	Limited
5	**Full Driving Automation**	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene.*	*System*	*System*	*System*	**Unlimited**

Figure 2 (SAE International, 2018)
'DDT': Dynamic Driving Task.
'OEDR': Object and Event Detection and Response
'ODD': Operational Design Domain

Level 2 (Partial driving automation) has been highlighted in the above figure as this is of most interest to this report where there is common agreement that the Tesla Autopilot system fits the criteria for a Level 2 classification (van Huysduynen, Terken, & Eggen, 2018.)

Recent Tesla vehicles may come equipped with Tesla's 'Autopilot' feature which advertises to "steer, accelerate and brake automatically within its lane" (Tesla, 2020) when activated. This system is classified as a Level 2 system – partial driving automation.

One important aspect of this level is the shared responsibility of the Dynamic Driving Task (DDT) – which is split into the 'sustained lateral and longitudinal vehicle motion control' and the 'Object and Event Detection and Response' (OEDR). This split in driving responsibility is a key feature of this report. The SAE goes on to explain in their definitions the responsibility of the human driver when a L2 system is activated such as when using the 'Tesla Autopilot' system:

Figure 3 A detailed explanation of SAE Level 2 (SAE International, 2018)

Ultimately, when the 'Autopilot' system is engaged, it is the driver who is 'driving' and they are required to monitor both the automated driving system, and the road ahead for any objects or events – responding appropriately and retaking full control where needed. With an understanding of these systems, we can begin to understand some of the background to the road collision on March 23, 2018.

Driver Distraction

The NSTB report identifies that the driver, leading up to the crash, was engaged with a mobile phone game ‘application’. The NTSB reports “driver distraction” linked to this mobile phone use was one of the probable causes of this crash. In this instance we consider this classification of ‘driver distraction’ insufficient for understanding the underlying cause(s) of this event and we believe this classification may limit the ability to further understand other contributing factors related to this crash.

The idea of ‘distraction’ implies diversion of attention away from a primary task to something perhaps unrelated to the primary task. By implication therefore, one must be involved in a primary task in order to be distracted from it. Understanding what this means in a driving context is widely discussed in the literature, one particularly useful source attempts a taxonomy of driver distraction (Regan, Hallett, & Gordon, 2011). Here they discuss the concept of voluntary/involuntary distraction and subsequent voluntary/involuntary diverted attention (p 1778).

In the case of this Tesla crash there appears to be voluntary diversion of attention from the primary driving task; this would be uncommon in a traditional (non-automated) vehicle, but facilitated when using partially automated driving systems even though this might be in violation of system intended use. If the ‘driver’s’ primary task is not driving, designs embedded in the driving task intended to influence human behaviour and nudge attention may be ineffective.

(Pettitt, Burnett, & Stevens, 2005) explore driver distraction and example the concept of internal distraction - that is distraction caused by driver actions. Their work also gives insight on how traditional ‘driver distraction’ terminology relies on ISO definitions which relate to ‘driver performance’ in non-automated vehicles (ISO, 2004). In a partially automated vehicle, the measure of ‘driving performance’ is dissimilar to a non-automated vehicle, and this identifies the need for more thorough understanding of the appropriateness of the term ‘driver distraction’ in instances related to partially-automated vehicles.

Despite the multiple definitions of ‘distraction’ and irrespective of the level of vehicle automation, there are many commonalities between various definitions, in that they mostly describe the momentary diversion of attention away from the primary task. Possibly the most widely used definition of driver distraction (across both academia and industry) is given by the National Highway Traffic Safety Administration (NHTSA) which states:
“Distraction means the diversion of a driver’s attention from activities critical for safe operation and control of a vehicle to a competing activity” (National Highway Traffic Safety Administration, p. 243)

Distraction is considered using the three categories of visual, manual, and cognitive distraction. NHTSA recommend that device-based tasks can be completed using glances of 2 seconds or less, with a total eyes-off-the-road time of 12 seconds or less (NHTSA, 2013).
Considering now the Tesla event, the driver appears to be engaged in their mobile phone game, potentially comprising visual, manual, and cognitive distraction. They also had autopilot engaged, and log data indicated that hands were off the steering wheel for approximately 1/3 of the time since autopilot was instigated. It is possible that there were extended periods (i.e. >12s) prior to the crash when the driver was inattentive to the driving task. The scenario cannot be assumed to

be classified as a delay in receiving information necessary to safely maintain safe driving. Rather, we argue the driver was inattentive to the driving task. Where driver inattention may be defined as: “insufficient or no attention to activities critical for safe driving” (Regan, Hallett, & Gordon, 2011, p. 1780)

The SAE definitions make it quite clear that when the L2 system is active, the driver of the vehicle should have been fully attentive to the road (Object and Event Detection and Response or ‘OEDR’) whilst also supervising the Autopilot system. Tesla also promote this responsibility when for example updating to V8.0 Autopilot software (2017) the information is given “you need to maintain control and responsibility of your vehicle while enjoying the convenience of Autopilot”. In the Mountain View crash, the driver was not adequately performing their OEDR responsibilities and hence neglectful to their responsibility for the dynamic driving task. The lack of action from the driver prior to the collision is a key factor in this event where it may have been possible to avoid this altogether if proper supervision and OEDR responsibilities were undertaken.

Conclusively, we highlight the NSTB’s classification of ‘driver distraction’ would benefit from more precision, where a lack of precision is potentially limiting for further understanding of how to improve the safety of partially automated systems in the future. Working with this proposed reclassification of ‘distraction’ to ‘inattention’, we are now able to look to understand exactly why this driver was inattentive and disregardful to their responsibilities. For this we continue to explore this concept of OEDR and navigate the complexities of this at both a consumer, and system level.

Driver Responsibility; OEDR and System Monitoring

The SAE definition of a Level 2 partially automated driving system is defined as (Figure 2): “The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system” (SAE International, 2018) ‘DDT’: Dynamic Driving Task. ‘OEDR’: Object and Event Detection and Response. ‘ODD’: Operational Design Domain

The definition places the driver as bearing sole responsibility for the sustained completion of the OEDR task. Consequently, this means that the driver must be ready to resume control of the vehicle at any time. Hence there can be no period of time during the partially automated drive, that a driver can disengage from the OEDR task. Further, with a supervisory aspect to the driver’s responsibility, one must assume failures within the automated ‘sustained lateral and longitudinal control’ are possible. From this definition alone, it can be argued that Level 2 automation is unambiguous inasmuch the driver must pay attention at all times, or the system is effectively being misused (intentionally or otherwise).

Whilst the SAE levels of automation might be well-defined within the industry, expectations and responsibilities associated with them are not understood by the general public, including owners of vehicles with such capability. The nuances regarding responsibility for the OEDR, are very much in the expert domain of those who work in the field of ‘connected and autonomous vehicles’ (CAV). There remains a question of education and training for drivers to ensure that they understand what a vehicle is and is not capable of. Training can be administered through multiple conduits including vehicle dealerships, training videos, websites, manuals etc.

However, all of these can be bypassed by the user and there is no regulation for mandating training. Furthermore, certification with one vehicle would not necessarily transfer to another even if classified within the same SAE level.
The vehicle itself provides an opportunity for training and guiding the user through the human-machine interface (HMI). The vehicle's HMI provides the possibility to enable/enhance the safe operation of the vehicle through effective communication to the driver and assuring they are aware of system status and operation parameters. However, there is little evidence of the effectiveness of HMI-based guidance for any manufacturer and a gap in the safety literature is identified.

Despite the relatively clear SAE Level 2 definition placing responsibility on the driver for OEDR and system monitoring, the reality is that its implementation in vehicles is non-standardised, complex, and involves multiple vehicle systems. As the number of manufacturers and vehicles featuring Level 2 capabilities increases, an increasing number of control and engagement interfaces are implemented, resulting in potential confusion of OEDR monitoring responsibilities and HMI feedback. Tesla require continuous contact with the steering wheel and measures torque input during Autopilot operation – providing alerts if no steering wheel input is felt after a time delay. Nissan's ProPilot system relies on a similar steering wheel input to determine attentiveness. GM's super cruise system uses head movement tracking to infer driver attention to the road and Audi's AI traffic jam pilot proposes a combination of head and eye tracking cameras. However, as yet, there is no evidence in the published literature to show the effectiveness of these systems for sustained OEDR assurance for real-world naturalistic conditions.

One well-established paradox of automation is that as any system becomes more proficient at being automated, the incentive for the human operator to maintain attention reduces. Workarounds can be sought when a system is perceived as low-risk even if a violation of training (e.g. wedging open fire doors).   Similarly 'alarm fatigue' results in desensitisation to a familiar warning signal if it is over-used. In the case of vehicle automation, one must expect that, as systems become more reliable, drivers will lose incentive to maintain vigilance, that workarounds might be used (e.g. small steering forces to 'fool' the system), and alarms are likely to be perceived as reducing in urgency the more familiar they become.
In the case of the Mountain View crash, the driver was familiar with the car and the autopilot system, and may have potentially placed more trust in the system than a naïve driver.

Driver Familiarisation

The NTSB report concludes that driver familiarity with the vehicle was not a contributing factor in this crash. This can be challenged inasmuch that the driver may have developed over-trust in the system precisely due to their familiarity with it.

The NTSB report appears to interpret 'familiarity of the system' in a manner such that, from a basic perspective, the driver knew how to operate the system which must be correct given the Autopilot system was manually turned on. The interpretation of 'familiarity' is challenged here, as the driver's experience and cognitive model of the system was based on when it maintained control of the car. Prior to the introduction of level 2 systems, it was not necessary for a driver to be aware of, for example, ODD boundaries of a system because the responsibility of the driver was never in doubt. Therefore, a traditional definition or understanding used to assess a driver's familiarity with the system did not need to include elements that we now understand are important for a partially automated driving system. For the first time in the automotive domain we are faced with new concepts of shared control and the requisite responsibilities of the driver, knowledge of limitations and capabilities of the system. We believe there to be benefit in reviewing the interpretation of 'driver familiarisation' and therefore conclusions on the level of familiarisation.

Misinformation and lack of information with regard to driver education of a partially automated system is particularly important to recognise. Tesla have been criticised for their use of the name 'Autopilot' for their partially automated system. With Munich's Regional Court going as far to ban all future use of Tesla's "Autopilot" and "Full Self Driving" names in Germany (Taylor, 2020), forcing a rebrand to 'autodrive' to protect users from being 'misled' about system capabilities. There is no doubt that this partially automated driving system is an exciting technology, and there is myriad consumer-created content online that many of the same technology-interested owners of such vehicles will undoubtably explore. Consumer YouTube videos and other media outlets frequently demonstrate inappropriate and dangerous driver behaviour as entertainment, but providing misleading information on capability of current automation systems. This is counterproductive to ensuring driver familiarity and correct expectations of automation systems.

The enthusiasm surrounding the current capability of Level 2 technology, and the misinformation this causes, is adding to the risk that drivers over-estimate the vehicle's capabilities, influencing how they interact and engage in their OEDR responsibility. We believe factors related to over-trust and a lack of system understanding to be contributory factors in the Mountain View crash. Furthermore, in this particular case, it is likely that the familiarity of this route to the driver (e.g. daily commute) coupled with the ability of the partially automated system to be 'good enough' to navigate the route up to this point had a cumulative effect on the driver's likelihood to disengage with their OEDR responsibilities, despite the driver's knowledge that the system had previously had sensor issues at this point in the journey. In other words the driver's incorrect mental model of the system capabilities (over trust) seems to have been reinforced by the absence of an emergency/collision, despite an incidence of system uncertainty.

The NTSB report concludes that driver qualification was not a contributing factor. Whilst qualified, it could be argued that training should be mandated, to ensure familiarisation before operating a Level 2 partially automated vehicle. As such, requirements for driver education should be considered by regulatory and licencing agencies as the automotive industry progresses into an increasingly automated future, to ensure that the potential safety benefits are delivered fully.

Human Machine Interface for a Human-Machine Shared Task

Whilst there is precedent for the consideration of training in the future use of automated systems, there remains no standard to educate drivers on the specific capabilities of an implementation of an automated system. Different partially automated systems vary in their capability to read lane markings, for example, or perform to different degrees of success during challenging conditions, such as bright sunlight or rain. With this in mind, there must be a consideration for how drivers can be better educated either prior to and/or during their use of the system.

The SAE (and manufacturers' guidance) place responsibility on the driver for constant supervision of the automated system. But how might one monitor such a system, and does this strict requirement neglect to recognise the complexity and demand on the driver to monitor the system? Studies have found that the cognitive demand during monitoring of a partially automated vehicle is far greater than that of manual driving (Griffin, Young, & Stanton, 2010) (Walker, et al., 2010). Furthermore, a detrimental effect on the quality of driving immediately following a handover can be seen for up to 40 seconds (Merat, et al., 2014). It is unreasonable to expect all drivers to be as fully aware of the capabilities of a system as the engineers who created it. However, Level 2 systems such as the Tesla Autopilot require the driver to supervise the system at all times.
So how might they do this?

The Human-Machine Interface (HMI) serves as the vital conduit between the engineers who design the system and the driver; guiding them into their expected role as a monitor of an automated process. What is or is not presented on the HMI is of critical importance to the safe and appropriate use of a partially automated system. Human factors specialists have been aware of this for some time. Outside of the automotive domain, appropriate communication between a system and the user has long been recognised as one of the key elements of safe automation (Wessel, Altendorf, Schreck, Canpolat, & Flemisch, 2019).

There must be a minimum threshold for HMI effectiveness if a driver is to safely monitor a partiality automated system. Likewise, there must be a minimum threshold for measuring HMI effectiveness if the vehicle is to safely monitor the driver's vigilance to OEDR. Guidance for testing these systems is required. Alerts, alarms, driver notifications and dialogue principles are broadly covered across ISO/TR 16352-2005, ISO 9241-110:2020 and BS EN ISO 15005:2017 showing capability in standardising driver-focused features for traditional non-automated driving. This specific case highlights the urgency to develop these further to cater for partially automated systems as well – providing manufactures the means to incorporate their automated technology safely and in consideration of the human user.

The NTSB identify "timing of alerts and warnings was insufficient to elicit the driver's response" which seems to be an appropriate conclusion. However, there is a lack of consensus in the scientific literature about what type and modality of alerts and warnings are most effective, and there is currently no governance on inclusion of such features, or how to force manufacturers to comply. In the Mountain View crash journey, the driver received "two visual alerts and one auditory alert" due to improper use of the Autopilot system, some time prior to the fatal incident. This highlights that resumption of attention might be short-lived even if achieved. 'Improper use' was determined by the driver not inputting torque to the steering wheel for a predetermined amount of time (3 minutes according to the report – p.15) whilst Autopilot was activated. There were no collision avoidance alerts. In line with the NTSBs conclusion, these alerts did not seem to be enough to encourage appropriate use of the automated system and avoid the crash. Technological innovation in automation of vehicles is progressing faster than standards or regulatory bodies can keep up with, and gives manufacturers a competitive advantage. Regulators must be agile in defining performance requirements for systems and HMI, to ensure effective implementation to enable OEDR and system-monitoring whilst assuring consistency between manufacturers.

Driver State Monitoring

The NTSB identifies that the Tesla system did not provide an effective means of monitoring the driver's level of engagement. A Level 2 vehicle is an example of a shared 'human-machine' responsibility in the automotive world. We understand that during traditional driving, with no automation (Level 0) the driver is responsible for the entire dynamic driving task (DDT) comprising control of the vehicle and the 'object and event detection and response' (OEDR). If the driver cannot perform OEDR, and sustained control of the vehicle they should not operate the vehicle (Figure 4).

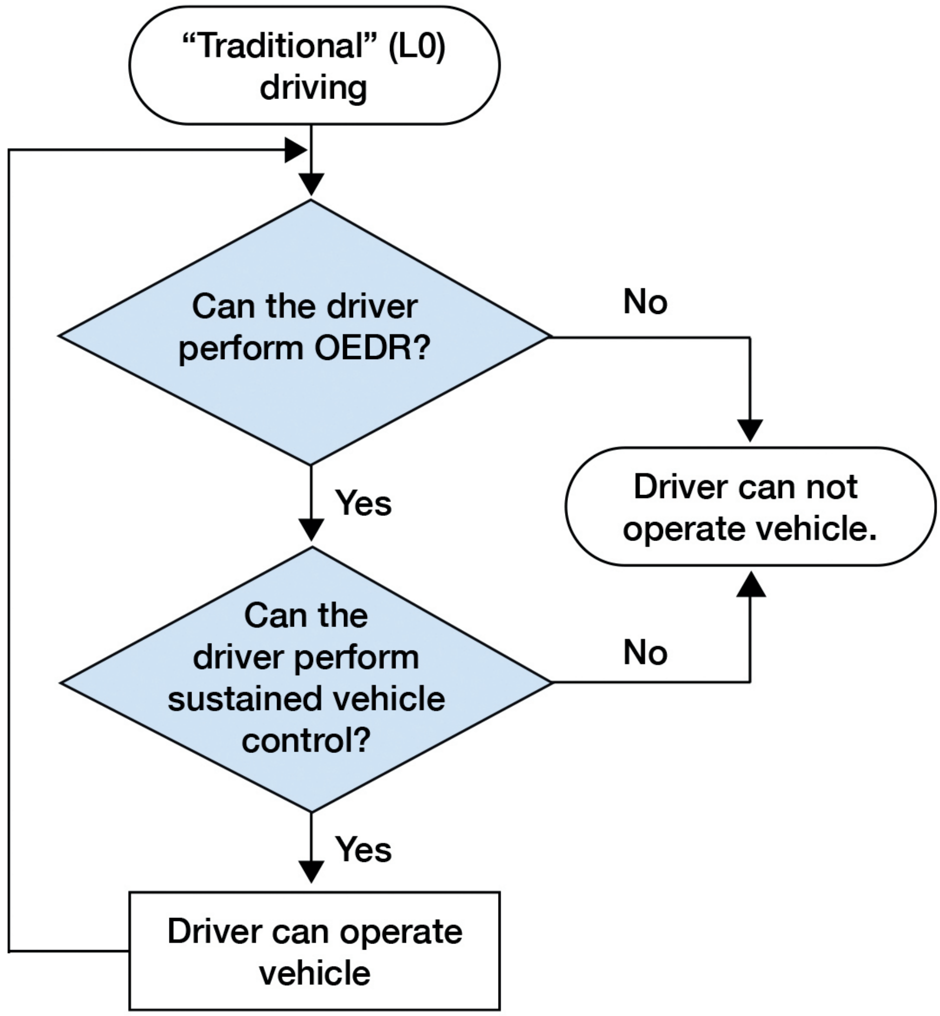


Figure 4 Flow Diagram for L0 (no driving automation)

If a driver is unlicensed, intoxicated, distracted, fatigued or otherwise impaired it is their responsibility to be aware of this and not drive. There is no shared responsibility; all responsibility is with the driver. However, in a partially automated vehicle responsibilities for ensuring safe operation are shared. The driver must monitor the system (through effective HMI) and the driver must also perform the OEDR. It is possible within control loops for an automated vehicle to identify that (for example) a sensor is faulty, or a tyre is flat affecting longitudinal and lateral vehicle control. In this instance the system would identify it is unsafe to operate. However, as the DDT (dynamic driving task) is split between the human and system, it is logically also a requirement of the system to check and ensure the driver is performing the OEDR as is required for a complete system. This is not an inconsiderable task, identifying presence is rather straight forward, but measuring/inferring the visual, manual and cognitive attention of a driver is increasingly complex (considering both technology and algorithm design). If the vehicle cannot assure OEDR is being handled, the level 2 system is incomplete and should not operate. Further to this, with the requirement of the driver to be able to monitor the vehicle's automated system comes a heavy reliance on the vehicle to enable this supervision. This is done through the HMI. The Level 0 (manual control) flow chart can be expanded to illustrate what this split in DDT responsibility may look like (Figure 5).

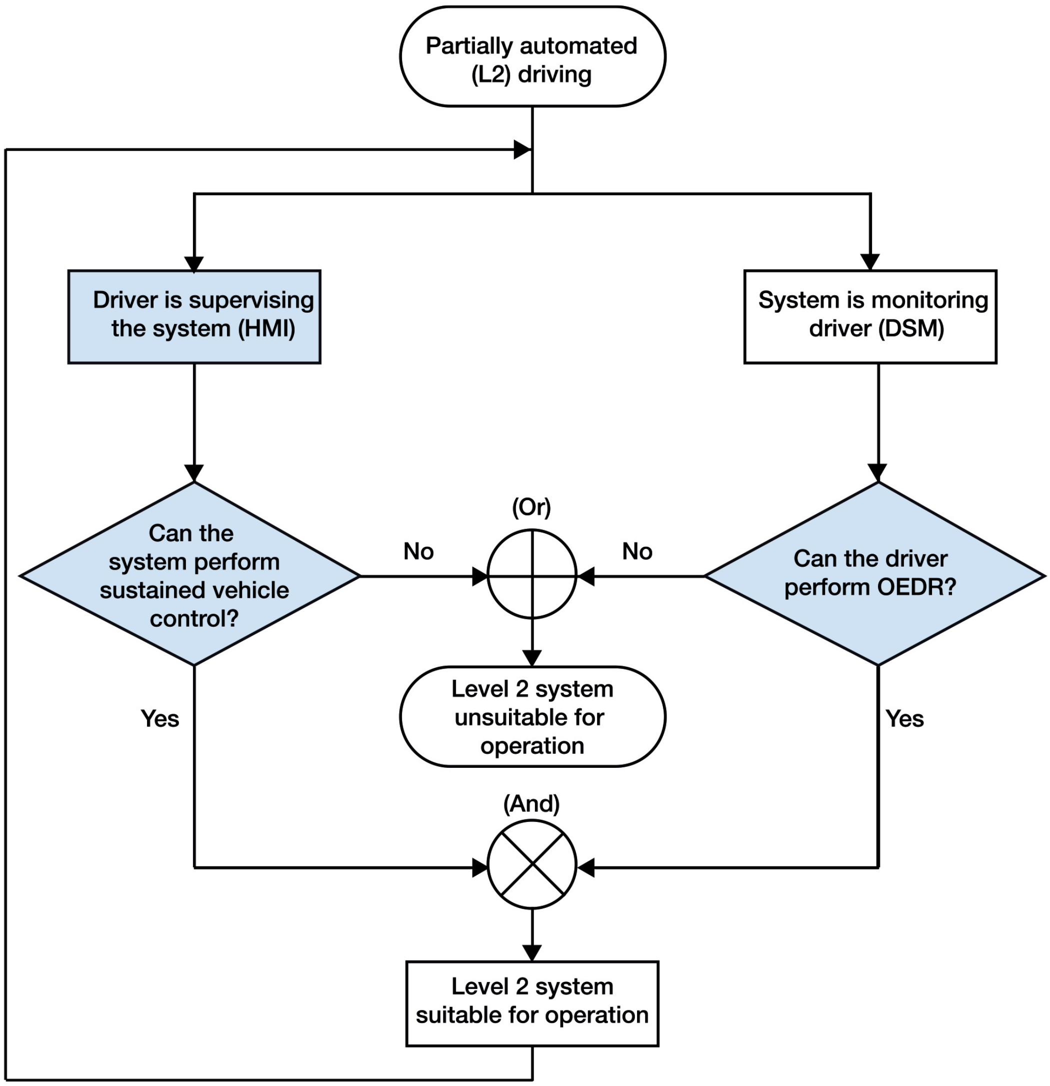


Figure 5 Flow Diagram for l2 (parital driving automation)

As the diagram in Figure 5 demonstrates, there is a reliance on effective HMI in order for the human to supervise the system as required. However, this diagram also shows that the vehicle must be aware if the human is correctly handling the OEDR. This is captioned in the function of 'system is monitoring driver' (e.g. Driver State Monitoring or 'DSM'). Without the ability to monitor the driver, the theoretical system cannot operate as 'half' of the shared system is unaccounted for. This diagram is useful for demonstrating how critical this DSM aspect of a partially automated system is.

We are in agreement with the NTSB that the Tesla system did not provide an effective means of monitoring the drivers level of engagement with the OEDR task. This raises the question whether or not the Tesla 'Autopilot' system should have been operational. We believe that without a proven and robust driver state monitoring system (DSM) a partially automated vehicle should not be able to operate. We also note a lack of regulation and standardisation within this area, which makes compliance for safe system performance unachievable.

Conclusions

The SAE levels of automation have provided an important foundation to categorise new vehicle automation systems and represent a key first step in the move towards automated vehicle technology. However, as we see more varied and diverse solutions being deployed by automobile manufacturers, it has become evident that there is a need to standardise, not only the definitions of the technology, but the way in which it is implemented too. In a partially automated system such as Tesla's Autopilot, there can be no doubt that there is a responsibility on the driver to ensure they use the technology appropriately. However, this responsibility must also be shared and enabled by the manufacturer through careful design and testing of the HMI and DSM systems that aim to promote its safe use. While increased regulation and standardisation represent an important step in developing better and safer partially automated implementations, we believe there is also an onus on review bodies to reconsider effective and critical analysis of accidents such as that presented in NTSB/HAR-20/01 involving vehicles with increasingly complex automation capabilities. We have identified a number of areas that would benefit from further consideration and have discussed the reasons for our contention. If issues such as a lack of familiarity and qualification in using partially automated systems are deemed to be irrelevant in crash scenarios, this sets a precedent of continuing to ignore key human factors effects. In doing so we highlight the need for a human factors perspective in the analysis of such complex systems.

As a summary we map what we consider to be four prevalent human factors considerations which may have led to this event, and may be likely to lead to more accidents in the future:

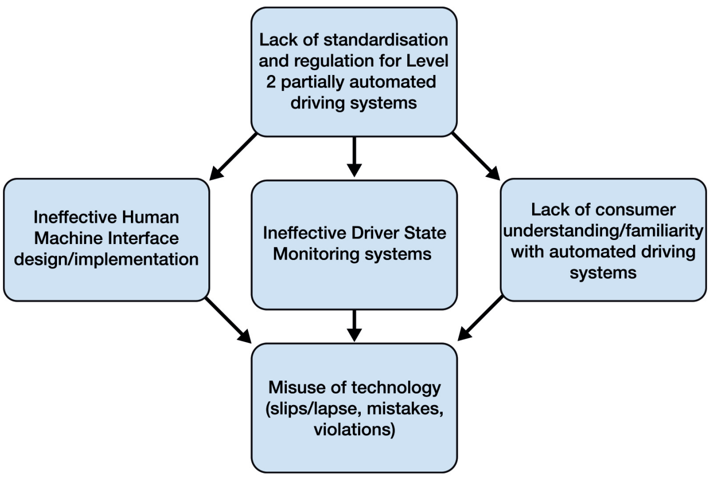


Figure 6 Summary of Findings

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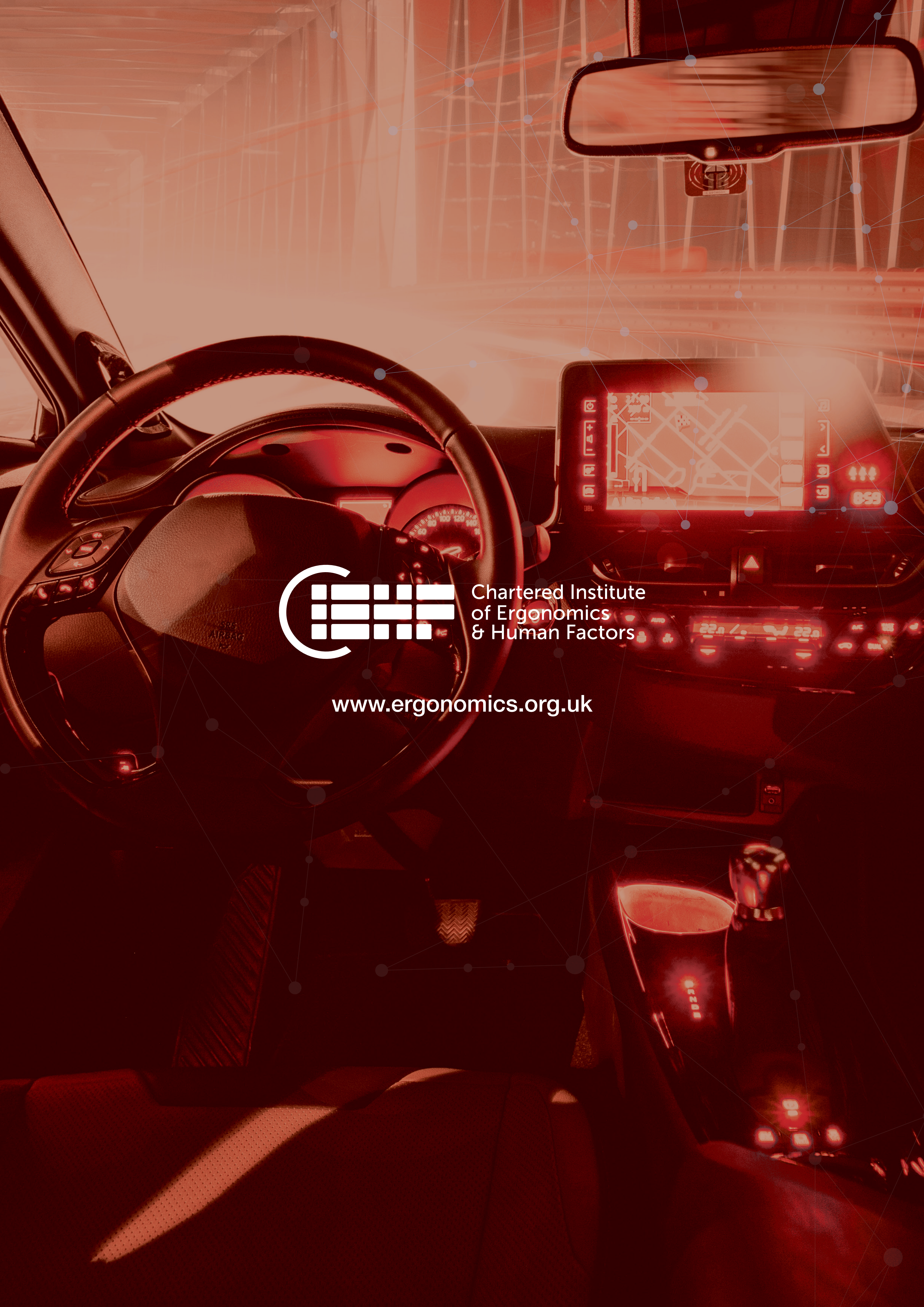

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