Modelling Resilient Future Transportation Systems: Integrating automated and active travel modes

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SUMMARY

Future trends in public mobility highlight the integration of autonomous technologies to our road transportation systems alongside a recent rise in popularity of active travel and micromobility. The interaction between autonomous vehicles and other vulnerable road users is a complex issue. Ongoing work by the authors aims to understand how our road transportation systems can incorporate these future trends, whilst also maintaining safety and resilience by reducing conflict between modes.

KEYWORDS

Resilience, automated driving, cycling, active travel

Introduction

Hoffman and Hancock (2017) define resilience as the "*systemic capacity to change as a result of circumstances that push the system beyond the boundaries of its competence envelope*" (p565-566). The introduction of autonomous vehicles into our road transport systems provides the need for resilience in the face of changing interactions between roads users and the technologies that will alter the tasks and processes required of human operators as well as other road users (Banks et al, 2014; Hancock et al, 2019). Caution is also needed to understand how adaption and emergent behaviour may lead to new sources of failure within future transport systems (Thompson et al, 2020; Millard-Ball, 2018). For example, the enhanced safety benefits of automated vehicles may lead to more risk-taking behaviour by vulnerable road users (Thompson et al, 2020). Therefore, systems need to be designed so that they can facilitate adaption in a safe and reliable way (Read et al, 2015). The system's ability to adapt to perform in new ways in response to new technologies will determine its future resilience.

Work conducted by the authors as part of the REsilient Autonomous SOcio-cyber-physical ageNts (REASON) project within the Trustworthy Autonomous Systems (TAS) program, aims to understand how resilience can be achieved within the interactions between autonomous vehicles and other road users. Initial work within this project has started to develop the resilience engineering approach which encourages the anticipation of possible risks and system failures before they happen, to create foresight, rather than hindsight where safety is neglected leading to negative outcomes (Hollnagel et al 2017). Hollnagel et al (2011) propose that, for systems to be resilient to possible disruptions, we need to be able to *monitor* the system, *anticipate* possible threats, *respond* to critical events that may arise and *learn* from them to prevent them happening again. Foresight of the challenges and risks of integrating autonomous vehicles into current road transport systems offers the opportunity to enhance the resilience of the system with the new technologies, rather than cause it a detriment. Yet, there are limited methods and measures to account for system resilience

(Hoffman & Hancock, 2017). Work within this project applies popular Human Factors methods, that are already well known and have good validity, in new ways to understand how current systems interact, how they fail and where automated technologies can provide positive change.

Predicting future interactions between different road users in a connected and autonomous future is a complex and challenging task. Yet, we can start by reviewing how current interactions take place, what behaviours are observed and what desirable behaviours look like. Taking a real-world scenario encountered on current roadways can enable the specific tasks and interactions that different road users make before reviewing the opportunity for automation and connectivity in future interactions. We take the case of a vehicle overtaking a cyclist on a shared road space. Using real-world verbal protocol data and observations from road safety and human factors experts we model the tasks and interactions between the road users and their environment. This includes insight from drivers and cyclist. Using this data, task analysis methods and operator event sequence diagrams (OESD's) were used to provide a detailed analysis of all tasks and the interactions between road users and their environment to perform the tasks. Conducting a task analysis of the interactions also enabled a review of the possible failures within the system whereby safety may breakdown and accidents and incidents occur i.e. the "*circumstances that push the system beyond the boundaries of its competence envelope*" (Hoffman & Hancock, 2017; p565-566). Methods such as the Systemic Human Error Reduction and Prediction Approach (SHERPA; Embrey, 1986) also provide the framework to review the organisational, equipment, procedural and training measures that can overcome the system failures that are identified. Furthermore, reviewing them as failures rather than errors allows the wider systemic factors that contribute to the behaviours. For example, the regulations and policy in place as well as the manufacturers and infrastructure.

Applying the recommendations from the SHERPA, we developed a future scenario with an automated vehicle overtaking a cyclist. A secondary analysis of this scenario using OESD's and the SHERPA showed the possibility for enhanced resilience with automation and connected technologies through more opportunity for failure recovery and system adaptation. It has highlighted key areas of focus when developing and designing automated vehicles, road infrastructure and connected technologies. It has also identified the value of communication between road user with the opportunity for eHMI and bicycle interactions with connected roadways. Also of central importance is the training and procedural requirements of automated vehicle operation, for other road users to predict and understand automated vehicles behaviour.

Future work will seek to understand the social, ethical and cultural norms that surround the interactions between autonomous vehicles and vulnerable road users, to inform enhanced and resilient communication strategies between road users and their environment.

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