Safety Science 87 (2016) 25–37

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Exploring the mechanisms of distraction from in-vehicle technology: The development of the PARRC model

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ARTICLE INFO

Article history:
Received 6 November 2015
Received in revised form 1 March 2016
Accepted 14 March 2016
Available online 21 March 2016

Keywords:
In-vehicle technology
Driver distraction
Grounded theory
Road transport system

ABSTRACT

Technological advances are impacting in-vehicle systems, providing more secondary tasks for drivers to engage with. The adverse impacts of this on driver safety requires further insight to determine the mechanisms involved in distraction and countermeasures to mitigate it. Contemporary approaches highlight the need to move away from individualistic strategies in distraction mitigation, towards a systems perspective that accounts for the road transport system as a whole. This paper applied grounded theory to identify five key factors of distraction and their relationships that were incorporated into the Priority, Adapt, Resource, Regulate, Conflict (PARRC) systems model of driver distraction. Applying this model to a case study suggests how taking a systems perspective to the phenomenon may hold elements within the wider road transport system responsible for distraction incidents. This opens up the potential for countermeasures higher up in the causal chain of events.

1. Introduction

On a clear Sunday morning in September 2012, Victoria McClure was driving on the A4 near Reading, England, when she hit a cyclist, killing him on impact. In a subsequent court investigation it was discovered that 500 m prior to the site of the incident the road was straight which, given the clear visibility of the day, should have allowed Victoria McClure to see the cyclist for approximately 18 s before she hit him if driving at the limit of 60 mph, longer if she was driving slower. The court discovered that prior to the incident she had been interacting with her in-vehicle satellite navigation system, which the court ruled caused her to 'drive blind' for the duration of the 18 s. The lack of skid marks on the road evidence that she failed to spot the cyclist, even at the last minute and perform an emergency brake. The defence argued the cyclist was wearing low visibility clothing that prevented him from being seen but the court convicted Victoria McClure of 'dangerous driving' with 18 months imprisonment (BBC News, 2013). This is an extreme example of the many incidents that occur due to distraction from in-vehicle technology, and it is the focus of much research to actively seek ways to mitigate such events (e.g. Lee et al., 2004; Donmez et al., 2008). One focus within this is to realise the utility of in-vehicle technology while managing the adverse impacts it can have on safety (Lee, 2014; Jamson et al., 2004).

Advances in technology have facilitated a competitive relationship between manufacturers of wireless devices, computers, and automobiles that has helped to propel the implementation of advanced devices such as Intelligent Transport Systems (ITS), e-mail servers and eco-driving systems, into vehicles (Ranney et al., 2000). This satisfies the needs of drivers who are becoming more reliant on the conveniences that wireless technology offer (Dingus et al., 2006). Emphasis by manufacturers on reducing time-to-market has led system developers to implement new technological developments at a rapid pace, without full testing (Leveson, 2011). Hence, developments may align with perceived consumer needs rather than their capabilities and limitations. Legislation on the use of devices and inbuilt technology in vehicles often has to play catch-up, advising on usability after their widespread use, as is the case of handheld mobile phones (e.g. Redelmeier and Tibshirani, 1997). Indeed, Harvey and Stanton (2013) identified task times for operating different in-vehicle devices and showed that entering a destination into the satnav took longer, on average, then the 15-s maximum recommended interaction time (Green, 1999; Society of Automative Engineers, 2002). Contending that the task completed by Victoria McClure should never have been approved for use in the vehicle in the first place. This supports Leveson's (2011) claim that increasingly complex technology is developing faster then techniques employed to respond to their potential safety issues; leaving users exposed to

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http://dx.doi.org/10.1016/j.ssci.2016.03.014
0925-7535/

risk. As increasing levels of death by dangerous driving convictions align with the increased engagement with technology in vehicles (Office for National Statistics, 2013; RAC Report on Motoring, 2013), the safety issues needed to be realised.

The main goal of the driver is, ultimately, to reach the destination safely (Cnossen et al., 2004), with behaviour regulated to achieve this goal (Groeger, 2000). Technology has expanded the potential goals available to drivers, e.g. making a phone call to the person they are due to meet or driving in an eco efficient manner in response to eco-displays (Dogan et al., 2011). The adverse effects of telecommunication devices (McCartt et al., 2006), music systems (Mitsopoulos-Rubens et al., 2011), and email systems (Jamson et al., 2004) on driving performance is well documented. However, increasingly drivers are provided with systems that aim to assist the driver with the driving task for example, ITS, navigation systems and efficiency information systems. Yet, although these technologies aim to enhance and improve the driver's performance they have also been shown to have adverse effects on their safety, as they engage the driver's eyes, mind and hands away from the road and therefore the main driving goal (Harms and Pattern, 2003; Jensen et al., 2010; Kircher et al., 2014). Thus, a fine line exists between devices that assist the driving goal of arriving safely and devices that detract from it. With increasing levels of dangerous driving convictions, this line needs to be clearer to drivers (Cnossen et al., 2004; Dogan et al., 2011).

1.1. Driver distraction from in-vehicle technology: definition and theory

In order to manage the issue, the mechanisms through which distraction occurs need to be recognised and modelled (Young and Salmon, 2012). The study of driver distraction can be dated back over 50 years (Brown et al., 1969). Yet, the complexities of distraction, it's multiple sources and contexts of occurrence, mean that currently no universal definition or model has been achieved (Young et al., 2007; Regan et al., 2009). Several models have been influential however, such as Sheridan's (2004) Control Theory Perspective model which applied control loops to the issue of driver distraction to identify novel aspects of the phenomena. Lee et al.'s (2008) Breakdown in the Multilevel Control Model has also been highly influential and aligns with their definition of driver distraction which has achieved some consensus in the field (e.g. Liang and Lee, 2010; Young and Lenne, 2010; Hosking et al., 2009). They define driver distraction as the: "*diversion of attention away from activities critical for safe driving towards a competing activity*" (Lee et al., 2008:38), although it is not without critique (Regan et al., 2011). It's relevance to distraction from in-vehicle technologies is highlighted here, not only because it captures how technology is encouraging more activities into the vehicle (Walker et al., 2015) but also because it highlights the safety critical impact of engaging with different in-vehicle devices.

Contemporary approaches to driver distraction have uncovered that distraction is not an error in itself but that errors occur as a result of distraction (Stanton and Salmon, 2009), yet the mechanisms through which distraction impacts errors and the wider systemic influences are not known (Young and Salmon, 2012). Over time theories of distraction have switched from considering it as a passive phenomenon that the driver is subjected to, towards a more active process that the driver has control over (Cnossen et al., 2000). Early work simply suggested that distraction is the result of inattention, i.e. a failure to look at the critical aspects of the roadway due to reduced awareness (Dingus et al., 2006). Evidence to support this applied Wickens (2002) Multiple Resource Theory to driver distraction, suggesting that the attentional resources that tasks demand are finite which limits the ability to engage in more then one task sharing the same resources at any one time. Furthermore, Wierwille (1993) highlighted the importance of the visual resource in driving and the need for in-vehicle technologies to utilise other resources such as auditory channels that are less important to the driving task.

Alternative theories that suggest that drivers play a more active role in distraction imply that drivers' structure their performance by adapting their behaviour to be consistent with the demands of the task, predominantly by slowing down to increase headway and time to collision (Noy, 1989; Hockey, 1997; Cnossen et al., 2000). Research showing drivers slowing down when on the phone (Rakauskas et al., 2004) or using navigation aids (Cnossen et al., 2000) supports this. Hockey's (1997) compensatory control theory states that under high demands drivers adapt their behaviour to prioritise their main task, driving, leaving lesser important goals to decline in order to maintain safety. However, there are mixed findings in the field and incidents such as Victoria McClure's suggests drivers do not always prioritise the driving task. It could be proposed that in-vehicle tasks relating to the driving task e.g. navigation aids and ITS, are wrongly prioritised as they are perceived by drivers to enhance the main driving goal (Cnossen et al., 2000), when in reality that are just further distractions. Furthermore, where drivers have a heightened perception of their capabilities while driving they are likely to wrongly believe they can undertake demanding secondary tasks safely (Horrey et al., 2008). Fuller (2000) suggests under some circumstances drivers may be motivated to take on highly demanding tasks that exceed their capability, even though they are aware of the enhanced risk of collision. The perceived value outweighing the potential risk. Indeed many people admit to using mobile phones and other devices while driving despite knowing the associated risks (McCartt et al., 2006; Lerner et al., 2008).

Cnossen et al. (2000) highlights the important differences between approaches that focus on inattention as the cause of distraction and those that focus on the mechanisms drivers use to incorporate the primary and secondary driving task together. Inattention suggests secondary tasks will invariably result in failure to attend to the driving task, having undesirable effects on performance. Whereas theories that suggest a strategic application of attention while driving with a secondary task imply the driver has a more active role, restructuring their performance to manage increased demand (Cnossen et al., 2000). Yet it is unclear what trade-offs drivers make when they decide to engage with technology behind the wheel, what information they are utilising when making their decisions, or the mechanisms through which distraction occurs. It is evident a more cohesive model is required to better understand the issue and present the mechanisms of distraction such that behaviour may be better predicted and effective countermeasures developed. Model development is advantageous to ergonomic research as models enable predictions of behaviour to be made, as well as being a useful means of presenting and advancing research (Moray, 1999). The development of an updated, more cohesive model of driver distraction from in-vehicle technology would therefore be a useful addition to the current literature.

1.2. Driver distraction from in-vehicle technology: approach and countermeasures

The approach to mitigating driver distraction has been inline with theories that place the driver as responsible for their attentional strategy while driving and these have remained relatively unchanged over time (Regan et al., 2011; Young and Salmon, 2015). To date, interventions into driver distraction have focused on regulating the drivers' behaviour with mitigation strategies aimed at educating drivers, and legislation that places the blame solely on the individual (Tingvall et al., 2009). Such is true of Victoria McClure's case, yet this current approach is not considered proactive