Applied Ergonomics 67 (2018) 125–132

Contents lists available at ScienceDirect

Applied Ergonomics

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

Mind the gap: Drivers underestimate the impact of the behaviour of other traffic on their workload

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ARTICLE INFO

Article history:
Received 4 December 2016
Received in revised form
8 September 2017
Accepted 19 September 2017

Keywords:
Driving
Workload
Lane change
Secondary task
Demand

ABSTRACT

This study examines the effect of traffic demand on driver workload by varying a range of characteristics of traffic behaviour, in particular focusing on the influence of a lane change performed by a neighbouring vehicle. To examine drivers' ability to manage their own workload in these traffic situations, a self-initiated, surrogate mobile phone task was presented to them, to coincide with changes in traffic demand. Results showed that whilst participants delayed the initiation of the task when the lane change was performed in close proximity to them, the delay was insufficient to mitigate the effects of the increased workload, leading to task errors. This was attributed to driver's willingness to engage in secondary tasks, even though their (self-reported) workload had not returned to baseline levels. The minimum workload recovery period was calculated as being 12 s after the onset of the adjacent vehicle's manoeuvre, and this has implications for the design of workload managers.

1. Introduction

Drivers spend a significant amount of time interacting with the surrounding traffic; the amount of traffic not only influences the visual demand imposed on drivers but also to some degree the behaviour of the drivers themselves (Zaidel, 1992). The traffic environment represents an important and commonly experienced social space that constitutes individuals with varying driving behaviour traits, who interact with one another within a set of written and unwritten rules. Driving culture and hence traffic safety culture is represented by these collective behaviours of other drivers, creating a direct interaction and impact on an individual driver (Ward and Özkan, 2014). For an individual driver, their skills and experience play important roles in structuring expectations, enabling them to formulate hypotheses about the adjustment that other road users may force them to make (Saad et al., 1999). Wilde (1976) provides an extensive review of social interaction patterns, which places various social factors in perspective and discusses how they interact with other factors in driving. For example the presence of other drivers, especially when driving in heavy traffic, may increase demand (e.g. Verwey, 1993, 2000). Other factors include expectations about the behaviour of other road users in terms of obeying rules of the road, and communication between drivers through use of signalling lane changes, as well as the social aspect of invasion of one's personal space, particularly when other drivers follow or pull-in too closely. Through extensive learning and exposure within this rather complex social environment, drivers develop their own expectations for themselves and others following their experience of typical speed, volume, flow and style of traffic within their area. One of those expectations that develops over time is their own desired proximity to other vehicles.

Previous research has found that drivers alter their space preference. For example, in congested conditions, drivers tolerate reduced personal space (Baum and Greenberg, 1975). Traffic congestion and surrounding traffic behaviour alters interpretations and reactions of drivers (for example, increasing driver stress, revenge motivations and aggressions). Fraine et al. (2007) suggested that some drivers identified cutting in and tailgating as a "violation of personal space". With increasing uncertainty in road situations, drivers sample the road ahead more intensely due to increasing driving demand (Senders and Kirstofferson, 1966). To date, little research has examined the temporal fluctuations in workload caused by other traffic, by systematically varying its presence and behaviour. The study reported here attempts to do this, and in addition presents a secondary task to explore how drivers manage their own workload.

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https://doi.org/10.1016/j.apergo.2017.09.012
0003-6870/

Workload can be characterised as a mental construct that relates to attentional demand (Kantowitz, 1987; Wickens, 1992) to explain the inability of human operators to cope with the requirements of a task (Gopher and Browne, 1984). As workload is related to subjective task difficulty and thus related to effort invested, workload measurement can be employed to characterise effort invested in the performance of the task (De Waard, 1996). While drivers do not passively respond to workload demands that are imposed on them (Adams et al., 2005; Raby and Wickens, 1994; Tulga and Sheridan, 1980), and actively manage their own workload by shedding or delaying tasks, they sometimes fail in choosing an appropriate workload level suitable for themselves. Drivers are often viewed as active operators, who are not only capable of assessing their own momentary load but also play an active role in the initiation and management of distracting in-vehicle activities (Lee and Strayer, 2004). However, some studies have also shown that, despite drivers being aware of increases in demand from the roadway, they still choose to engage in the secondary tasks (Horrey and Lesch, 2009) in these high workload conditions.

Initiating secondary tasks such as the use of a mobile phone during high workload conditions may result in perceptual and decisional impairment due to the division of drivers' attention between different sensory modalities (Brown et al., 1969). Some research shows that hands-free phones are equally as distracting as handheld one (e.g. Hendrick and Switzer, 2007) – the act of being involved in a conversation while driving is distracting and can have a detrimental effect on drivers in demanding situations as it detracts a driver's attention away from the primary task of driving (Strayer et al., 2005). This has been found to be particularly so when the conversation has a visual component; Briggs et al. (2011) report that drivers who were distracted by imagery tasks (such as "a cube has six sides") demonstrated decreased hazard perception and increased response times compared to those engaged in non-imagery task (America has 51 states). Almor (2008) has shown that the act of speaking increases the level of interruption with performing a visual task by as much as four times relative to listening-only conditions. Thus if there is a need to perform a response, perception and decision-making abilities could be critically impaired by drivers having to switch their attention between eyes and ears (Spence et al., 2001).

Studies have showed that, even though using a hands-free mobile phone during driving increases subjective workload (Parkes et al., 1993; Alm and Nilsson, 1994) and heart rate (Brookhuis et al., 1991), drivers are not dissuaded from engaging in a series of in-vehicle activities even in challenging and traffic-heavy driving situations (Lerner and Boyd, 2005). Similarly, a questionnaire survey conducted by Lansdown (2012) found that over 30% of surveyed drivers used a hands-free mobile phone during a typical week and would still attempt to use it despite being aware it was distracting. Kidd et al. (2016) have recently published data that suggests that drivers modulate their secondary task activities based on the perceived roadway or driving demand. However, they did not measure demand specifically, and only implied it from the road layout. Due to the seemingly high motivation of drivers to use a mobile phone while driving, this study explores fluctuations in driver workload and performance in a dynamic, simulated environment whereby the surrounding traffic interacted naturalistically with the participant. Might they underestimate their own workload level in dual-task conditions and thus not choose to delay their response to answering a mobile phone call in high workload conditions?

2. Method

The first aim of the study was to quantify the influence of the varying types of lane changes performed by a neighbouring vehicle on driver workload using subjective workload ratings. Secondly, we explored whether drivers would modify or regulate their behaviour to reduce task demand by delaying engagement in a secondary task.

2.1. Apparatus

The experiment was carried out using a high-fidelity simulator with an eight degrees of freedom motion base at the University of Leeds. Participants drove in a 2005 Jaguar S-type vehicle housed within a dome, with the projection system providing a total horizontal field of view of 250° and vertical field of view of 45°. LCD panels are built into the Jaguar's wing mirrors to provide the two additional rear views to allow participants to experience the surrounding traffic to the left and right of the vehicle. The vehicle has all of its basic controls and dashboard instrumentation fully operational (see Fig. 1).

Vocal responses to the secondary task were collected manually via a voice recorder (Sony ICD-200X Digital Voice Recorded attached to a Griffin Lapel Microphone). Data were then processed using the Praat audio playback program with sound spectral analysis capability allowing the identification of the sound stimulus and speech response and thus the vocal reaction time measured to +1/-1 ms accuracy.

2.2. Experimental design

A standard three-lane motorway (speed limit of 112 km/h) was simulated with occasions of adjacent vehicles (either from the slow or the fast lane) pulling in front of the participants. Participants were instructed to drive in the middle lane; vehicles in the slow lane were programmed to maintain 60mph (96 km/h) and fast lane vehicles travelled at 70mph (112 km/h). The lane changes performed by the neighbouring vehicles were manipulated by Lane Change Proximity (5, 10, 15, 20, 25 or 30 m in front of the participant), Lane Origin of the vehicle (Slow or Fast Lane) and Indicator Use (On or Off). When indicators were used, they were activated approximately 1.9s before crossing the lane divider. To ensure that the indicator was visible, the respective vehicle was always ahead of the participant vehicle before starting the lane change manoeuvre. The adjacent vehicle was programmed to pull in at a certain distance measured as the gap (LC_p, in metres) between the participant vehicle and the cutting-in vehicle as shown in Fig. 2.

Participants were required to complete three drives each lasting

Fig. 1. University of leeds driving simulator.