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Driving behaviour while self-regulating mobile phone interactions: A human-machine system approach

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ABSTRACT

Mobile phone distracted driving is a recurrent issue in road safety worldwide. Recent research on driving behaviour of distracted drivers suggests that in certain circumstances drivers seem to assume safer behaviours while using a mobile phone. Despite a high volume of research on this topic, self-regulation by mobile phone distracted drivers is not well understood as many driving simulator experiments are designed to impose an equal level of distraction to participants being tested for their driving performance. The aim of this research was to investigate the relationship between self-regulatory secondary task performance and driving. By a driving simulator experiment in which participants were allowed to perform their secondary tasks whenever they feel appropriate, the driving performance of 35 drivers aged 18–29 years was observed under three phone conditions including non-distraction (no phone use), hands-free interactions and visual-manual interactions in the CARRS-Q advanced driving simulator. Drivers' longitudinal and lateral vehicle control observed across various road traffic conditions were then modelled by Generalized Estimation Equations (GEE) with exchangeable correlation structure accounting for heterogeneity resulting from multiple observations from the same driver. Results show that the extent of engagement in the secondary task influence both longitudinal and lateral control of vehicles. Drivers who engaged in a large number of hands-free interactions are found to select lower driving speed. In contrast, longer visual-manual interactions are found to result in higher driving speed among drivers self-regulating their secondary task. Among the road traffic conditions, drivers distracted by their self-regulated secondary tasks are found to select lower speeds along the s-curve compared to straight and motorway segments. In summary, the applied human-machine system approach suggests that road traffic demands play a vital role in both secondary task management and driving performance.

1. Introduction

Driving requires continuous interactions between human operators and system components such as vehicles and road infrastructure. Mobile phone distraction often interrupts this continuous process of driving and increases the risk of crash and injury. In Australia, a hospital-based study found that drivers who use a mobile phone up to 10 minutes before a crash are nearly four times more likely to have a serious crash (McEvoy et al., 2005). In the U.S., the National Highway Traffic Safety Administration (NHTSA) compiled results from numerous naturalistic studies and concluded that (NHTSA, 2016): (i) mobile phone visual-manual interaction tasks (e.g. texting and browsing) while driving increase the risk of crash and safety-critical events, and (ii) other mobile phone interaction tasks (e.g. phone conversation) seem not to be directly associated with the risk of crashes. Similar findings have been reported in recent systematic reviews (Oviedo-Trespalacios et al., 2016) and meta-analyses (Simmons et al., 2016). Nonetheless, cognitive distraction due to mobile phone use remains a significant concern (Lipovac et al., 2017).

Drivers adapt their driving behaviour, intentionally or unintentionally, while performing mobile phone tasks. Until recently, research suggested that drivers could potentially adapt their driving behaviours in a safer direction in order to compensate for any mobile phone related impairment (Oviedo-Trespalacios et al., 2017a,b,c; Wandtner et al., 2016, Choudhary and Velaga, 2017). Lowering one's driving speed is one of the most documented safe behavioural adaptations among mobile phone distracted drivers in simulator experiments (Oviedo-Trespalacios et al., 2017b, Wandtner et al., 2016), self-

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reported questionnaire surveys (Huth and Brusque, 2013, Young and Lenné, 2010), and field observational studies (Fitch et al., 2014, Fitch et al., 2017). Reduced speed can offer safety advantages in terms of crash likelihood or injury severity (see Aarts and Van Schagen (2006) and Choudhary and Velaga (2017)) and, therefore, is often recognised as a risk-minimising driving behaviour. Nonetheless, there is still great uncertainty regarding these sources of self-regulation as frequently reported in the scientific literature. For instance, drivers engaged in mobile phone conversations have been reported to have less lateral lane deviation (Garrison and Williams, 2013, Reimer et al., 2014), but drivers engaged in texting have an increased lane deviation (McKeever et al., 2013, Rudin-Brown et al., 2013). In addition, other studies have reported negligible changes in lateral lane position for either conversations or texting activities (Cao and Liu, 2013, Irwin et al., 2015, Young et al., 2014, Caird et al., 2008). As concluded in a recent comprehensive systematic review of the literature (Oviedo-Trespalacios et al., 2016), research on risk compensatory behavioural adaptations of mobile phone distracted drivers is a largely unexplored phenomenon.

It is important to note that previous research in behavioural adaptation of distracted drivers has confirmed that drivers using a mobile phone modify their driving behaviour as a function of driver characteristics, driving demands, and secondary task demands (Young and Regan, 2013, Oviedo-Trespalacios et al., 2015, Fitch et al., 2017, Choudhary and Velaga, 2017). Personal characteristics such as driving experience, previous experience of multitasking activities, and crash risk perception seem to determine the level of engagement and behavioural changes (Hancox et al., 2013, Oviedo-Trespalacios et al., 2017a,c). Another common result is that the behavioural adaptations of distracted drivers are context-dependent. Drivers using a mobile phone while driving along narrower lanes or roads with high speed limits seem to select a lower driving speed with higher variability and higher lateral acceleration (Liu and Ou et al., 2011). Complex driving situations such as driving along winding roads and driving in heavy traffic are also reported to influence driving speed and lateral lane position variability of mobile phone distracted drivers (Tractinsky et al., 2013, Oviedo-Trespalacios et al., 2017a). Other authors such as Atchley and Chan (2011) have reported that distracted drivers could increase their vigilance even when driving in less stimulating environments. Lastly, differences in the mobile phone task seem to trigger different compensatory strategies, e.g. visual intensive tasks compared with hands-free conversations are typically recognised as more complex and, therefore, drivers might modify their behaviour further (or in diverse ways) depending on the task (Oviedo-Trespalacios et al., 2017c). As a result, in this research special attention is given to the impact of self-regulatory secondary tasks, personal characteristics, and road traffic conditions on mobile phone distracted driving performance.

Theoretical models such as the human-machine systems framework for mobile phone distracted driving proposed by Oviedo-Trespalacios et al. (2016) (based on the work of Cacciabue (2004) and Degani (1996)) concur that behavioural adaptation is a two-way phenomenon. This means that both driving and mobile phone tasks are closely related in that the mobile phone task is benefited if driving performance decreases and vice versa. This is quite logical given that the mobile phone and vehicle are competing simultaneously for the driver's cognitive and physical resources. While numerous studies have reported that the use of mobile phones impairs driving behaviour such as reaction time (Haque and Washington, 2014), car following (Saifuzzaman et al., 2015a) and braking performance (Haque et al., 2016), the opposite has also been observed, i.e. that driving behaviour impairs performance of mobile phone tasks. For example, Becic et al. (2010) reported that mobile phone conversations while driving have lower conversation quality as measured in terms of speech comprehension, language encoding and language production. In addition, the driving task has also been reported to impair texting performance via an increase in accuracy errors (Alosco et al., 2012) and response times (He et al., 2014). Nonetheless, the relationship between driving performance and secondary task performance has not been studied simultaneously. In order to address this research gap in the literature, this study proposes a novel experiment where the relationship between secondary task performance (texting and talking on a mobile phone) and driving performance is analysed. As a result, an in-depth understanding of the human-machine interactions in mobile phone distracted driving will be achieved.

1.1. Specific aim

The aim of this paper is to investigate the effects of a self-regulated secondary task on the driving performance of mobile phone distracted drivers, while considering driver characteristics, road traffic conditions, and secondary task demands. A driving simulator experiment was designed to investigate driving performance when drivers are allowed to determine their own tempo for engaging in distracted driving. The findings of this research will explore the potential of a human-machine system framework to explain mobile phone distracted driving, and discuss practical implications.

2. Method

This investigation was approved by the Queensland University of Technology Ethics Review Committee (QUT ethics Approval Number 1500001038) and was conducted with explicit consent obtained from each subject.

2.1. Experimental protocol

A driving simulator experiment was designed to investigate the

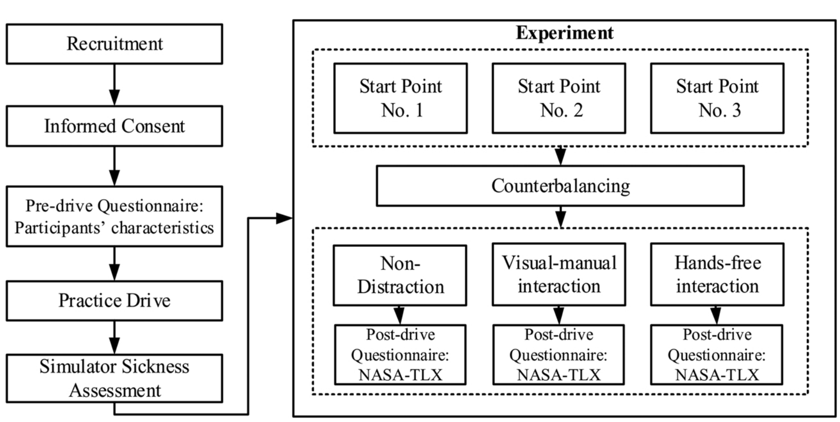

Fig. 1. Experimental protocol.