Skill Decay, Distraction and Driver Stress

A SUMMARY REPORT

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Introduction

Internationally there is growing recognition that work-related road traffic crashes resulting in injury or death are a significant public health problem. Professional drivers constitute the most exposed workforce to occupational traffic crashes, which represent a third part of the traffic casualties worldwide (EU-OSHA, 2019), and a high economic and health burden for governments, organisations, and workers (World Health Organization, 2019). The work-related Road Safety Task Group in the UK estimated that 25% of all road traffic crashes involve someone driving in a work-related capacity (Bomel, 2004). Furthermore, traffic crashes comprise the largest category of work-related deaths, accounting for 25–60% of these fatalities (Boufous and Williamson, 2006).

Road traffic crashes have a significant adverse effect on organisations in many ways, including operational efficiency, reputational, financial, and human costs. The driving for work context is complex and dynamic, involving different entities and decision makers. Not only do at-work drivers have to safely operate within the vehicle, traffic, and road environment, but they also must perform specific tasks. Driving is a complex skill that is acquired, but not mastered, through instruction and practice. Safe driving depends on the transfer of what is learned under these restricted conditions to a wider range of circumstances not encountered during training. Driving skill is a combination of competences that are learned during driving training and consolidated through on-road driving exposure. Driving a vehicle combines many sub-tasks such as control, guidance, and navigation. Skills-based training focuses on safely navigating and controlling the vehicle, including speed control, lateral placement control, hazard detection etc.

In 2022 Travis Perkins plc commissioned three literature reviews to understand the evidence-base pertaining to skill fade and the effects of stress and distraction on driving performance. This report is a summary of the findings.

Methodology

Using broad, sensitivity-enhancing search criteria, a systematic database search was conducted in December 2022 for skill fade and in February 2023 for distraction limited to the study title and abstract. The reviews began with a list of search terms that were entered into academic databases called PubMed, Embase, Medline and PsychINFO. Based on the search results the initial search terms were refined, and the main search conducted to source peer reviewed journal publications and restricted to English. The PRISMA guidelines (Moher, Liberati, Tatzlaff, Altman & PRISMA Group, 2009) were adhered to throughout the systematic process of searching, identifying, and evaluating literature across a broad range of transport-related research for skill decay and distraction. For stress, a critical review of key papers was conducted. Where it was not possible to retrieve the full text of a publication, it was excluded. Other forms of literature, such as grey literature (e.g., conference presentations and theses), unpublished literature, literature with no quantitative data, animal and clinical studies were excluded. Literature published in peer-reviewed journals were included without restriction if they could be sourced.

Skill decay

To identify publications on the retention of gross motor skills in the context of transport of operating machinery the following search term was used.

"Skill* AND (retain* OR retention OR deterior* OR fade OR decay OR practise OR loss) AND (car OR vehicle OR HGV OR heavy goods vehicle OR LGV OR crane* OR forklift* OR earth mov* OR police OR paramedic OR ambulance OR fire appliance OR coastguard OR motorcycl* OR e-stooter* OR escooter OR bus OR minibus OR coach OR military OR canal OR ferry OR tanker OR crane OR ship OR construction OR fire appliance OR aircraft OR aeroplane OR crash OR accident OR hazard perception OR training)"

Distraction

To identify a wide range of studies related to distracted driving the search term was "Driv* AND Distract*" with 1331 papers returned. Further refinement restricted the search to literature reviews, systematic reviews, and meta-analyses.

The quality of the evidence was assessed (e.g., was the research design sound, adequately evaluated, which variables were monitored, length of the evaluation, and whether they made robust conclusions). Included in the review were studies across different operational and transport contexts.

A preliminary look at skill decay studies revealed that there is a wealth of information about how skills fade in military, industrial and aviation contexts, but virtually none have been published specifically about how driving skills may fade. Therefore, recommendations contained in this report must be based upon knowledge gleaned from other related skills to identify learnings that are likely to transfer to the driving-related context. Transport-related skills are therefore reviewed, e.g. aviation. Like driving, flying is largely a psychomotor process, with social and emotional components. Like drivers, pilots must attend to relevant cues both inside and outside their immediate surroundings, recognize such cues when they occur, decide upon appropriate responses to those cues, and respond accordingly. As with flying, safe driving for passing a typical driving test of any kind requires psychomotor skills to be well learned during initial training.

For distraction, eleven systematic literature reviews and meta-analyses were returned in the literature search that fit the criteria described. Each paper has been reviewed to (1) describe research in the field pertaining to driver distraction and (2) evaluate the published work for strengths and weaknesses. These key papers included a review of over 800 studies published between 1969 and 2021 which would have been beyond the scope of this report to review individually. The approach adopted here is to understand the main findings in the academic literature on the topic of driver distraction with reference to the key studies.

Stress

The literature review was undertaken in three stages. Firstly, broad search terms were used to search the title and abstract limited to the English language between January 2000 and January 2023. The database searches were conducted using PubMed, Embase, Medline and PsychINFO in January 2023. Search terms were limited to (Stress* and Driv*) and (work or professional or occupational or commercial including taxi drivers and other workers who drive on-the-job) to identify publications on driver stress and driving performance at work. The quality of the evidence was assessed (e.g., was the research design sound, adequately evaluated, what variables were measured etc.) Further supplementary, highly focused searches were conducted to investigate the impact of life stress on driving performance.

A preliminary look at the evidence in a range of different academic databases shows that there is a wealth of information about stress with thousands of research papers. It was therefore necessary to focus on specific research questions to ensure that the review focuses on the extent to which occupational and personal stress impacts on long and short-haul truck driver crash risk. The literature review undertaken had two purposes: (1) to thoroughly describe previous research in the field pertaining to driver stress and driving performance and (2) to identify published work for managing driver stress.

Skill Decay: Summary Findings

The implications of loss of skill are significant for operational safety for all transport modes. The summary findings from the literature review on skill decay aims to investigate the evidence that driving skills may decay over time. The studies were reviewed to identify how, when and what aspects of driving skills may fade. Evidence-based countermeasures are then presented to identify ways in which driving skills can be improved after periods of driving inactivity.

Driving Skill Acquisition

Military research has a 60-year history of studying the long-term retention of skills, the balance between effectiveness and efficiency in training, and the prediction of when and what type of refreshers will benefit retention of specific skills. Much of this work has involved individual skills in laboratory or applied settings. For almost 40 years, the view of Fitts and Posner (1967) has dominated thinking on skill acquisition. Figure 1 graphically represents that skilled behaviours are the result of progress through three distinct phases. In the first 'cognitive' phase, where the beginning performer is attempting to understand the task, performance is slow, deliberate and error prone. Here, working memory load is high, largely because performance depends on the learner's ability to rehearse the declarative facts. By the second 'associative' stage, actions are represented in working memory and performance is more accurate, gross errors are eliminated and patterns or sequences of performance elements are beginning to emerge. In the final 'autonomous' stage, task performance is reliable, efficient, fluent, less likely to break down under stress and largely impervious to distraction. The third stage relies on generalisation, discrimination and strengthening to tune performance, permitting fast performance with a degree of virtuosity. For experienced drivers, skilled behaviour is carried out with little or no conscious thought and acquired through prolonged and intensive practice across many years.

The relationship between driving practice and skill development can be described best by a power function (Groeger, 2000). According to this function, the gain from driving practice becomes increasingly less. Commercial truck drivers' self-reported driving skill compared with their actual driving performance suggest that they tend to overestimate their driving skills (Stavrinos et al, 2016).

Figure 1: Fitts and Posner's Stages of Learning

According to Michon, the driving task consists of three hierarchical levels of skills and control (Michon, 1985). At the top level (the *strategic* level) the general planning of the trip is executed (e.g., decisions on where to go and how to go there, whether an automated function should be used etc). At the middle level (the *tactical* level) decisions are made regarding manoeuvring control related to the present circumstances (e.g., selecting speed, avoiding obstacles, turning, overtaking). Finally, at the lowest level (the *operational level*) the continuous control of the vehicle is performed (e.g., steering, braking, accelerating). In uncertain or novel situations, driving is a top-down, conscious activity that involves the use of higher-order skills such as planning, decision making, and judgement. In top-down control, the strategic, tactical, and operational aspects of driving described by Michon are up-regulated or down-regulated to adjust safety buffers (e.g., speed, following distance, lane choice) and reduce errors when driving. In familiar and unchallenging situations, however, driving is a bottom-up activity that requires very little attention and becomes almost automated (a proceduralized, overlearned task performance).

The three levels of behaviour in Rasmussen's (1987) model map closely with the three hierarchical levels of driving performance in the Michon model. According to Rasmussen, driving is controlled by skill-based, rule-based, and knowledge-based behaviours. The skill-based behaviour involves the use of automated sequences that ensure smooth driving processes, such as pressing on the accelerator to increase speed and braking to reduce speed. Rule-based behaviour refers to the use of common driving principles (''rules''), such as changing gears and slowing down when approaching or turning at an intersection. Knowledge-based behaviour occurs in situations when the driver's own driving experience makes the most sense, such as the knowledge that driving during snow or in dense fog incurs a higher risk of crashing.

Psychomotor Skill Decay

Skill decay refers to the loss of performance that occurs in the absence of practice (Arthur Jr et al., 1998). In the absence of rehearsal, productions or pattern-action associations that form the basis of skilled performance degrade and/or are less accessible, resulting in errors and/or an increase in response latency over time (Seow et al, 2021). When degradation in performance is observed it is likely to be due to interference from a newly acquired skill rather than actual degradation of the skill (Poldrack et al, 2005).

The organisation of gear changing is an example of the effects of extensive practice on the acquisition of a sequential psychomotor skill. Gear changing is composed of several different actions (e.g., accelerator release, depress clutch, etc.), and various elements are learned in a progressive way to form the entire action. Assume there are seven elements in the entire sequence and that these are first each controlled by a separate motor program. With some practice, the first two components might come to be controlled as a single unit, the next three might compose another unit, and the last two could compose a third. Finally, with considerable experience, the entire sequence might be controlled as a single unit (Schmidt and Lee, 1999).

A retention interval is the time between a training course and recertification or refresher training, or between training on how to operate a new type of vehicle and the occurrence of an actual situation requiring the new type of vehicle to be operated. The retention interval has been studied to allow for temporary effects of practice (e.g., fatigue or motivational factors) to dissipate. Generally, the longer the delay between acquisition and retrieval, the greater the opportunity for interference and forgetting. In general, long retention intervals should produce worse performance than short retention intervals.

Most studies on skill retention have been limited to relatively short intervals. Intervals of 6 months or longer has received virtually no attention in the academic literature. One study looking at skill decay after one year of no practice amongst pilots returning to training, found that they performed with great variability (Wick et al, 1986). They used an equation to predict the number of flight hours that would be required to refresh piloting skills. They predicted that 17 hours of flight training for experience relative to inexperienced students would be needed to regain skills.

As with driving a truck, instrument flying relies on psychomotor skills or “hand-eye” coordination. Skills are developed to scan instruments and manipulate flight controls. Mengelkoch, Adams, and Gainer (1971) conducted a study with trainee pilots learning basic instrument flying skills. After acquiring the skills, the researchers stopped their flying activity altogether, and then tested them after 4 months for retention of the skills. The researchers found that when these skills were initially well learned, they were surprisingly resistant to forgetting, even after 4 months of inactivity. Although motor responses may deteriorate, brief intermittent practice in the aircraft or on a training device is usually sufficient to regain them.

Cognitive Skill Decay

Pilot errors due to decision-making tend to be associated with more serious outcomes than errors involving psychomotor skills (O'Hare et al, 1994). Cognitive skills have been found to have a greater rate of decay than psychomotor skills in the absence of practice amongst pilots (Vlasblom et al, 2020). This distinction is explained as differences in the level of automaticity or the extent to which psychomotor skills are practised and proceduralized in memory. Childs and Spears (1986) found that correctly identifying cues and classifying situations proved difficult for participants after a long flight absence. Mengelkoch et al (1971) found that after 4 months of inactivity, pilots’ cognitive skills had significantly deteriorated and replicated by Schendel et al (1978). Whilst handling skills need to be well learned first, then practiced occasionally, cognitive skills, regardless of how well they are initially learned, must be practiced more often. Pilots can wait almost 2 years without flying and still operate under visual flight rules with no passengers aboard. If they want to exercise the privileges of operating under the more cognitively demanding instrument flight rules, 6 months of inactivity is the limit.

Childs, et *al.* (1983) investigated relatively inexperienced private pilots, many of whom had not flown for several months, who underwent an objective retention flight check two years following their certification. Analysis indicated that cognitive/procedural types of errors occurred with alarming frequency during the retention check and pilots often were unaware such errors had been made. Each pilot failed to acknowledge at least one air-traffic control instruction at some point during the flight check, and 70% of the pilots used improper entry procedures for one or more of the stall manoeuvres. These errors serve to illustrate the role of cognitive/procedural elements in decay of flight skill. While it is not possible to isolate the "mental" error from the "control" error, flight skills deteriorate, in part, because pilots forget or confuse task requirements, or they experience decrements in cognitive monitoring over extended periods of time out of the cockpit. Loss of proficiency may occur because pilots undergo a decline in recognizing and organising the cues that are necessary for safe and efficient flight.

Perhaps these findings from the aviation industry are transferable to driving a land-based vehicle, in which the expectation may be that psychomotor skills remain relatively intact but cognitively demanding situations in built-up road environments may be challenging for someone that has not had the opportunity to refresh cognitive skills. The cognitive skills that may have faded include driver decision making in complex situations and hazard perception.

Inactive drivers after licensure are quite common in Singapore due to the high cost of car ownership. Upahita et al (2019) investigated the effect of driving inactivity on hazard perception in a simulated driving environment. Response time to a hazard and its constituent components (lag time, time to fixation and perception-response time) were measured. Active drivers were found to respond faster to hazards than inactive drivers. In a similar study, (Upahita et al, 2018) a different sample of four groups including active drivers, newly licenced novice drivers, inactive drivers that had never driven after gaining a driving license, and a group of learner drivers drove through a stretch of expressway under free-flow conditions, and lane positioning control was monitored. It is found that without on-road driving exposure, lane positioning control may deteriorate after about 3 months of inactivity. Driving training to acquire a driving license seemed to play only a small role in preparing drivers for hazard mitigation with on-road driving exposure strengthening skills in mitigating hazards.

Skill Decay Countermeasures

- Refresher Training - After initial training, refresher training or practice should be implemented at approximate 3-week intervals if there has been no opportunity to drive at all during this interval (Driskell et al, 1992).
- Overlearning - Routinely used skills like driving receive considerable practice beyond the level of initial competence, referred to as overlearning. Skill retention is increased skill by 100% from overlearning in a meta-analysis of 88 studies (Driskell et al, 1992). Overlearning is somewhat stronger for cognitive than psychomotor tasks.
- Feedback - the provision of high-quality and timely performance feedback, access to expert performers and instructors, and goal setting facilitates incremental skill improvements (Ericsson and Poole, 2016).
- Situational Assessment Skills - Cognitive rehearsal improves assessed via situational awareness skills, the ability to extract key features from the environment to develop a mental model of the traffic and road environment (Driskell et al, 1994).
- Distributed Vs Massed Practice - Distributed, spaced practice (e.g., training sessions once a week) is more effective for long-term skill retention than massed practice (e.g., training sessions for 5 consecutive days) (Pashler et al, 2007).
- Switching Tasks - skill acquisition is improved using “contextual interference” which involves switching between different types of learning task within a given training period, instead of repeating a single task type (Broadbent et al, 2017).
- Context Dependent Training - Two-day training courses can significantly improve drivers’ vehicle manoeuvring skills and vehicle control when cornering (Petersen et al, 2008) and changing lanes (Petersen and Barrett, 2009).
- Hazard Perception Training - Improves the ability to detect or anticipate potential hazards and can improve hazard perception test results (Boufous et al, 2011) without increasing driver confidence or risk-taking propensity (Horswill et al, 2021)
- Commentary Driver Training - Commentary training has been found to lead to improved hazard perception test scores, increased horizontal scanning during driving and greater speed reductions when approaching hazards. Trainees provide and/or receive detailed verbal commentary on a driving scene while driving (Crundall et al, 2010) or watching video clips (Chapman et al, 2002; Isler et al, 2009).

- Expert Commentary Driving - Expert commentary on a drive shown via video clips allows drivers to watch videos with expert comments. Only eight minutes of commentary videos can improve novice drivers' hazard perception (Castro et al, 2016). Compared with young novice drivers who received expert commentary training and those who did not receive training, significant improvements in visual search were found (Zhang et al, 2022).

Distraction: Summary Findings

A commonly accepted definition of distraction states that "Distraction involves a diversion of attention from driving, because the driver is temporarily focused on an object, person, task, or event not related to driving, which reduces the driver's awareness, decision-making, and/or performance, leading to an increased risk of corrective actions, near-crashes or crashes". A large and expanding body of research has found that engaging in distracting activities negatively effects driving performance in many ways. These degradations due to visual, manual, or cognitive sources have been shown to translate into an increased risk of crash involvement. Driver distraction is detrimental to drivers' decision-making processes, particularly when performing complex or unexpected driving tasks and manoeuvres. When crashes do occur, they are often caused by drivers failing to look at the right thing at the right time. Even if they look in the right direction, the cognitive demands of a competing activity can interfere with detecting safety-critical changes. Drivers may become distracted at more dangerous times e.g., at junctions, when driving too fast, when driving in heavy traffic, when driving tired or in a bad mood and when driving in bad weather etc.

Of those who die in road traffic crashes, inattention has been cited as either the most dangerous error drivers can make or the second most dangerous (Craft and Preslopsky, 2009). It has been estimated that anywhere between 16% and 80% of traffic crashes are directly or indirectly attributable to driver distraction (Dingus et al, 2006; NHTSA, 2010). Estimates indicate that secondary task distraction is a contributing factor in up to 23% of crashes and near-crashes (Klauer et al, 2006) and extended glances to external sources of distraction have been found to increase crash risk by an odds ratio of 7.1 (Dingus et al, 2016). Horrey and Wickens (2007) found that over 80% of the crashes in their study were attributable to drivers glancing inside the vehicle for longer than 1.6 s. Klauer et al. (2006) also found in a naturalistic driving study that glances of more than 2 s inside the vehicle increased the odds of crashing by three times. In an in-depth examination of 474 crashes, Staubach (2009) found that a significant number of crossroads, lane departure and same direction crashes were the result of errors caused by the driver being distracted. Sandin (2009) found that distraction contributed to a range of errors occurring at intersections including missing a sign or traffic signal, misjudging the timing of amber lights, and failure to see other vehicles. Ismaeel et al (2020) conducted a study of 163 car drivers across 5 European countries including the UK and in-vehicle cameras were used to observe behaviour at intersections. The results showed that for 1630 intersections coded, approximately half of the intersections and one-quarter of the total observation time contained a secondary task interaction. These findings show that secondary task engagement is common and frequent occurrence at junctions where a large proportion of crashes take place. Some drivers may be reluctant to undertake secondary activities under challenging driving scenarios (e.g., Funkhouser and Sayer, 2012) whereas others may have an inaccurate perception of risk and/or overinflated view about their driving skills.

Driving (primary task) while performing a secondary task (e.g., using a mobile phone) has been a major focus of road safety research. Drivers can be distracted not only due to holding conversations on the phone but also due to other mobile phone related activities, including using the internet, sending, and receiving emails, and texting. Mobile phone distractions can be categorised as cognitive, visual, and manual. The driver might engage with the device and manually input a response, leaving one hand on the steering wheel, and thus decreasing physical control of the vehicle. Further cognitive demand is exerted in responding to the content of the message. An incoming text message also attracts the driver's visual attention by the screen lighting up, often accompanied by an audio cue, both of which compete for the already limited attentional resources. Drivers using mobile phones may miss up to 50% of available visual information (Strayer et al, 2006). Smartphone and tablet activities are more distracting because they are more cognitively engaging and are performed over longer periods of time (Strayer, et al 2006).

Distraction generally leads drivers to take their eyes and mind off the road when doing more than one thing at a time and relatively brief glances away from the road can increase brake reaction time and reduce the ability to spot and respond to hazards (Horrey and Divekar, 2016). Secondary cognitive tasks such as holding a conversation on a mobile phone can also alter drivers' visual scanning patterns and less frequent checking of rear-view and side mirrors and vehicle instruments. Internal imagery can distract from hazard detection (Briggs et al, 2016) resulting in attention being withdrawn from the processing of relevant information and information retrieval errors. Several studies have found that drivers may not react to or recall an object or event even if they have visually fixated on it (attentional blindness).

Distraction and Driving for Work

Professional drivers are more exposed to greater risk as they drive for long periods of time and as a daily routine. Salminen and Lähdeniemi (2002) showed that people who are driving for work were more likely to be distracted by thinking about work, be in a hurry, be tired, and be using a mobile phone. In one study (Engelberg et al, 2015) about a third of employed adults felt obligated to take work-related calls while driving. Distraction has been attributed to 70% of truck crashes (European Commission, 2015). Hammond et al (2019) used in-vehicle data recorders to identify safety-critical events such as crashes, near-crashes, crash-relevant conflicts, and unintentional lane deviations. Results show that 40% of truck crashes had some kind of distracting behaviour. These included electronic secondary tasks by truck drivers such as the use of a dispatching device, calculators, and mobile phones.

An analysis of naturalistic driving videos among fleet services drivers for errors and distracting behaviours occurring in the 6 seconds before crash impact revealed insight into fleet driver behaviour (Harland et al, 2016). Of the 229 crashes analyzed, 101 (44%) were rear-end and 128 (56%) were angle crashes. Drivers in rear-end crashes were over three times more likely to being distracted than those in angle crashes. Over 95% of rear-end crashes involved inadequate surveillance compared to only 52% of angle crashes. Almost 65% of rear-end crashes involved a potentially distracting driver behaviour, whereas less than 40% of angle crashes involved these behaviours. On average, drivers spent 4.4 s with their eyes off the road while operating or manipulating their mobile phone.

There are notable age and experience differences in secondary task engagement. Although younger drivers are found to be more inclined than older drivers to engage in phone tasks during driving, their performance is found to be less affected by the phone use (Oviedo-Trespalacios et al, 2016). Impaired visual perception and responses are the main reasons behind the degraded driving performance of older drivers. However, professional drivers can better maintain the lateral position compared to young drivers (Wu et al, 2016). Chan et al (2010) found that inexperienced drivers performed less safely than did experienced drivers. Both studies also found that there was no significant difference between the groups in terms of total time spent on the task. This means that experienced drivers took smaller but more frequent glances inside the car than younger inexperienced drivers. Drivers generally increase their safety margins to reduce the increased risk of performing a secondary task but, younger drivers have reduced safety margins compared to older and middle-aged drivers.

Below is a summary for each of the key papers reviewing distraction research of relevance for this review.

A Meta Analysis of Mobile Phone use (Horrey and Wickens, 2007)

In a meta-analysis, Horrey and Wickens (2007) reported that the costs associated with mobile phone use while driving are primarily due to response time to critical road hazards or stimuli. The costs associated with lane-keeping or tracking performance are much smaller and these tasks may depend on separate resources. Lane keeping may be a skill that is relatively automatic and psychomotor, whereas responding to road events or stimuli may be primarily cognitive because drivers must not only detect critical objects but also select an appropriate course of action. The magnitude of the reaction time effect of mobile phone use was relatively small (an average delay of 130ms). Crashes are often caused by “worst-case” performers under “worst-case” circumstances, and at the tail end of the distribution reaction time delay can be expected to be considerably longer. The meta-analysis suggests that costs in driving performance are equivalent across hands-free and handheld phones, suggesting that the larger part of these costs is attributable to the cognitive aspects of conversation and not to the manual aspects of holding the phone. Conversation tasks showed greater costs in driving performance than did information-processing tasks attributable to the greater “engagement” associated with actual conversations. The costs of engagement may be more pronounced when the conversation is intense such as when managers call to find out why the driver is delayed.

Driver distraction and Driving Errors (Young and Salmon, 2012)

Driver distraction contribute to errors by affecting cognitive processes such as perception, planning, decision making, and situation awareness, as well as by interfering with vehicle control tasks. The authors suggest there are four ways in which distraction leads to driver error.

1. Distraction disrupts natural driving performance variation leading to action errors.
2. Distraction disrupts visual scanning behaviour and situation awareness leading to observation errors.
3. Distraction disrupts cognitive processing leading to information encoding and retrieval errors.
4. Distraction disrupts decision making leading to cognitive and decision-making errors.

Systematic Review and Meta-analyses of Distracted Driving (Ferdinand et al, 2014)

Ferdinand et al (2014) reviewed 350 papers reporting results from secondary tasks and driving performance. Most studies did not differentiate between age groups and almost half the analyses were conducted in the United States. Almost half of the studies collected data in real-world or naturalistic settings, and just over half of the studies were conducted in simulated driving environments. Most studies analysed the use of mobile phones as the secondary task. Almost 80% reported a statistically significant detrimental relationship between secondary tasks and driving performance with crashes being the most explored outcome variable.

Multiple Driver Distractions (Lansdown et al, 2015)

This systematic review of multiple driver distractions presents two key findings. Systematic classification of distracting tasks with respect to driving is challenging, and engagement with Multiple-Additional-to-Driving (MAD) tasks is almost universally detrimental to driving performance. Cognitive overload due to MAD tasks can be expected as increasingly automated vehicles move towards greater complexity. Drivers are especially prone to distraction when allocating attention to more than one task at a time and believe that we comprehend everything available to our eyes and frequently fail to maintain an appropriate attentional focus or resist distractions from other sources. Attention-grabbing stimuli from inside and/or outside the vehicle lead to MAD tasks requiring greater multi-modality, more task switching and extended interactions, conflicts are more likely to occur from various information processing bottlenecks.

Mobile Phone Use in Naturalistic Driving (Simmons et al, 2016)

Simmons et al (2016) performed a meta-analysis of naturalistic studies on the use of mobile phones on distraction to harmonise some of the studies that show discordant findings. For example, Hickman and Hanowski (2012) report that the odds of a safety-critical event occurring while texting and driving are 163.59 times greater than when not texting, while Fitch et al (2013) report that the odds are only 1.73 times greater and not statistically significant. Simmons et al (2016) found that using a held device while driving, showed a significant increase in SCE risk odds ratio of 4.04 but variability between studies limit the interpretation of this finding.

Voice Recognition Systems and Visual Manual Tasks (Simmons et al, 2017)

Multiple Resource Theory (MRT) predicts that separate visual and auditory inputs permit easier task sharing, whereas dual-task interference worsens when two simultaneous tasks compete for the same input modality (Wickens et al, 2013). Voice-recognition systems are expected to minimize diversion of the driver's eyes from the roadway because interactions can be completed using verbal inputs. There is a prevalent view amongst vehicle manufacturers that voice-recognition (V-R) systems may decrease the visual-manual (V-M) demands of a wide range of in-vehicle system and smartphone interactions. The degree that V-R systems integrated into vehicles or available in mobile phone applications affect driver distraction is investigated in this study using a comprehensive meta-analysis of experimental studies. Compared to baseline, driving while interacting with a V-R system is associated with increases in reaction time and lane positioning, and decreases in detection. When V-M systems were compared to V-R systems, drivers had slightly better performance with the latter system on reaction time, lane positioning and headway. Although V-R systems have some driving performance advantages over V-M systems, they have a distraction cost relative to driving without any system at all.

Distraction Types and Performance Measures (Atchley et al, 2017)

Atchley's systematic review revealed a range of different distractions that have been investigated for effects on driving performance. The researchers categorised and defined these distraction sources as talking, text messaging, manual tasks, visual distractions, cognitive distractions, auditory distractions. Performance measures were also defined as lateral manual control, longitudinal control, speed, headway, crashes, vision and attention, cognitive workload, cognitive measures and conversational measures.

Passengers and Driver Distraction (Theofilatos et al, 2018)

Passenger interaction requires extra amounts of mental workload and cognitive functions and can slow reaction times to events for both the time to mentally register the effect and the time to physically react to it (Stutts et al, 2001). This review and meta-analysis of findings regarding the effect of conversation with passengers on road safety outcomes estimated that passenger interaction related crashes are associated with 3.55% of total crashes reported, while the percentage is 3.85% when teens and children are excluded. Conversations appear to induce heightened mental workload and impose varying levels of distraction on drivers.

Neural correlates of secondary task performance (Pamiero et al, 2019)

Neuroimaging techniques have been used in simulated driving and multitasking showing the brain systems that are mostly active when performing a secondary task. Palmiero et al (2019) reported brain activations associated with driving performance decrements when a secondary task is added with a significant shift in activations from the posterior to the anterior cerebral regions. There was also greater recruitment of frontal areas occurs during simulated distracted driving and seems to be consistent across studies. The greater involvement of frontal areas during distracted driving might reflect a competition for limited resources and attentional reallocation. In particular, the prefrontal cortex plays a key role on goal-directed stimulus selection and response as a top–down attention control, coordination of temporal order for task interference and mapping concurrent sensory information for motor behaviour. During a secondary task, attentional resources are re-directed away from visual or motor processing, and some of the neural programs can lead to crash involvement, even if driving behaviour is not explicitly affected. The results suggest that attention and arousal at the neural level are affected earlier than observed behavioural measures. Performing a secondary task may absorbs attentional resources primarily at the neural level, making driving unconscious, as if the driver is on autopilot.

The Brain and Distracted Driving (Haghani et al, 2021)

In their review of 85 studies, Haghani et al (2021) reported that neural correlates of distracted driving constitute a great portion of the studies, and neuro-cognitive effects of having conversations while driving were highlighted. Differences in brain activity modulated by the sentiment of the conversation or whether the conversation is in a person’s native, or second language has been investigated. Some of the key papers reported in Haghani et al (2021) suggest that holding a conversation whilst driving affects spatial attention and may interfere with tasks such as reversing. Just et al, (2008) observed that with the addition of the sentence comprehension task, brain activation in the parietal and superior extrastriate decreased while the activity in the temporal and prefrontal language areas increased. They concluded that while the driving and language comprehension tasks largely draw on non-overlapping cortical areas, the introduction of the secondary task significantly decreases the activity of brain areas associated with spatial processing during driving. Sasai et al (2016) studied brain activity in a simulated driving listening paradigm where drivers engaged in either an integrated task (i.e., listening to the GPS) or a split task (i.e., listening to a radio) as fMRI data was collected showing that a driver’s brain may functionally split into two separate driving and listening systems when the listening task is unrelated to the driving task, but not when the two tasks are integrated. Baldwin et al (2017) collected EEG brain signals and self-reported distraction reports on recurring monotonous simulated freeway driving in a simulator. They observed that the frequency of mind wandering was high among drivers.

Route Familiarity and Distraction (Intini et al, 2019)

Habituation on familiar routes means that drivers may fail to notice recent road changes such as roadworks, especially on easy routes and driving conditions, the mind can be unconsciously occupied by non-driving-related thoughts or ‘‘mind wandering”. Drivers’ adaptation to overly familiar routes is associated with choosing higher speeds and being less focused on driving tasks (Burdett et al, 2018; Yanko and Spalek, 2014). Speed has consistently been found to increase over time with route familiarity (Colonna et al, 2016) and may be related to a typical trade-off between safety (more risks) and mobility (shorter travel time), especially for work related driving in which there may be some perceived benefit in getting deliveries done quickly. Charlton and Starkey (2011) highlighted that mindless driving was more likely to occur the more participants became accustomed to driving scenarios. However, whilst driving became more efficient with increased experience and automaticity, detection capability decreased. Studies investigating driving behaviour on familiar routes have reported high levels of engagement in distracted driving activities (Wu and Xu, 2018); increases in reaction times (Yanko and Spalek, 2013) and decreases in glance duration for road signs (Martens and Fox, 2007); traffic violations and greater deviations of lateral positions than unfamiliar drivers (Colonna et al, 2016). Two studies (Baldock et al, 2005; Intini et al, 2018) revealed an over-involvement of route-familiar drivers in rear-end crashes that may be explained due to possible greater tendency to adopt shorter headways (Yanko and Spalek, 2013) or to brake at shorter distances from an intersection (Wu and Xu, 2018).

Distraction Countermeasures

Interventions that aim to reduce distracted driving are varied. Strategies range from technological to behavioural. Some key evidence-based interventions are presented below.

- Classroom-based Distraction Training - An intervention for 1-hour called 'Just Drive' class delivered by driving safety experts targeted businesses and organisations. Results showed significant increases in distraction related knowledge after the training and in the three-month follow-up survey (Hill et al, 2020).
- Self-Regulation Training - Self-regulation is when drivers adjust their behaviours in accordance with changes in demand situations and this mitigates the effects of distraction. When experiencing a loss of awareness or focus on the driving task, self-regulatory strategies can be employed to sustain attention and included both cognitive and behavioural strategies (Wells and Matthews, 1996).
- Distraction Training at Intersections - Intersections represent almost 60% of the total number of injury crashes in the UK (Simon et al, 2009) and distraction is prevalent at junctions. Distraction training on the additional demands at junctions is recommended.
- Advanced Driver Assistance Systems (ADAS) - ADAS automate elements of the driving task providing warnings, while others automatically intervene in the control of the vehicle. There is a lag between the current literature and the most recent forms of new vehicle technology. Even if these systems improve driver performance, they may not always improve driving safety as drivers may over rely on the automation and engage in secondary tasks. The most effective technology may be that which monitors driver state and driving behaviour and helps attend to the roadway and recognize unsafe behaviour (Donmez et al, 2007).
- Reversing cameras – ADAS using reversing cameras aim to assist the driver to avoid pedestrians and cyclists to the rear of the vehicle. However, researchers report they are relatively ineffective in avoiding collisions (Kidd et al, 2015; Rudin-Brown et al, 2012; Keall et al, 2017).
- Vulnerable Road User Training - Crashes between trucks and VRUs originate from the combination of visual attention lapses/slips (e. g., distraction, visual scanning mismatches, temporal blind spots), reduced visibility of the VRU (e.g., spatial blind spots), and expectation mismatches (e.g., expectation about the truck driver or VRU behaviour). The most frequent cause of the collision involved either the driver or the pedestrian not looking properly during a reversing manoeuvre (Fildes et al, 2014). Behavioural training is recommended for improving VRU safety.
- Work-based Educational Campaign - An educational campaign about the dangers of distracted driving was evaluated by observing the incidence of distracted driving the incidence of distracted near the entrance of the staff parking area. The campaign included interventional points in the cafeteria for 1 week on the risks of texting and driving, an educational video, informative brochures and "Don't text and drive" signs. The incidence of distracted driving at baseline was 11.8% showing a 32% reduction post intervention, which remained low even at 6-month follow-up (Joseph et al, 2016).
- Mindfulness Training - Mindfulness promotes greater situation awareness of the driving environment, enhancing concentration, and assisting drivers to maintain selective and sustained attention (Kass et al, 2011).

Stress: Summary Findings

The results of the review have been organised into themes emerging from the literature. Each theme is presented under a subheading and a corpus of evidence identifies research findings from this literature.

Driver Stress and Driving Performance

Driving for work means that drivers are particularly prone to adverse stress and fatigue reactions (Matthews, 2002; Desmond and Matthews, 2009: Öz et al, 2010; Bergomi et al, 2017) and this can impact on driving behaviour in several ways. Stress has a detrimental effect on cognitive functioning, such as inhibiting appropriate decision-making, directing attention towards processing the emotion, and impeding goal-directed choices by reducing self-control (Maier et al, 2015). The impact of stress on driving performance are therefore mediated by behaviours including cognitive lapses, errors, and intentional traffic violations (Westerman and Haigney, 2000). Truck drivers often experience symptoms of driver stress such as worry, irritation, and anxiety. Öz et al (2010) found that professional drivers are more prone to stress reactions in traffic and to commit risky traffic behaviours compared with non-professional drivers. Shatnell et al (2010) reported that 12% of the truck drivers felt stressed and anxious. The transactional *model of stress* has also been applied to the driving context and tested in dozens of studies (Dorn, 2021). Here, driver stress vulnerability relates to cognitive processes of appraisal and coping (Matthews et al, 1998) and explains that demands may exceed perceived capability or resources. The transactional model states that the way in which an individual appraises the situation and copes with the stressor has an impact on their stress response (Dorn, 2021). This helps explain why two employees might experience the same stressors and yet respond differently. For truck drivers, stress factors are associated with performance impairments primarily in underload conditions (Matthews and Desmond, 1998). Occupational stressors also contribute to driver stress with decreased vigilance as drivers become less able to focus on the driving task and crash risk is increased (Legree et al, 2003).

Driver Stress and Distraction

The relationship between anxiety and task performance has been demonstrated consistently in the academic literature (Shi et al, 2019), several studies have also directly extended this to the driving task. Anxiety negatively predicts driving ability via: (1) the number of attentional lapses in a driving task (Wong et al, 2015); (2) prolonged attentional focus on stimuli (Gotardi et al, 2019); (3) more task irrelevant attentional processing (Metz et al, 2017) and (4) less micro-regulation of both speed and lateral positioning (Lemercier et al, 2014). Stress and worry have a negative effect on both task related processing and attention capacity during the driving task and weaken the person's capacity to inhibit processing initiated by distracting stimuli (Eysenck and Derakshan, 2011).

However, whilst tangible forms of distraction (e.g., mobile phone use) demonstrate a straightforward impact towards attentional capacity when driving, cognitive factors processing emotions are much more complex and considerably more difficult to identify. Attention to the driving task is inhibited by internalised thought processes, such as worry and stress, because such content occupies the processing of working memory. It is also likely that emotional factors such as driver stress when driving for work may impact on brain activations and lead to greater levels of distraction for some driver compared with others. For example, carrying out an emotional conversation task (different questions presented using a neutral or angry speech tone) showed that angry emotional tone enhanced the right fronto-parietal networks and yielded dampening of the left frontal activity as compared to neural emotional tone (Hsieh et al, 2010). Dampening of the left frontal activity may be implicated in poor driver decision making.

Occupational Stress and Effects on Driver Behaviour

Occupational stress is linked to decreased job satisfaction, reduced efficiency and performance, physical depletion and fatigue, absenteeism, and turnover (Cushway et al, 1996) but studies have also found that occupational stress is a risk factor for driving performance. Many studies have reported the link between occupational stress and fatigue, distracted driving, speeding, number of moving violation tickets received in the previous 12 months and work-related crashes (Bunn et al, 2005; 2009; 2012; 2013; Apostolopoulos et al, 2010; Sabbagh-Ehrlich et al, 2005; Cartwright et al, 1996). Early research on stress for commercial drivers has pointed to workload as the main causal factor with large elevations of blood pressure and stress hormones (Evans et al, 1987). Workload has been defined in terms of role overload and conflicting demands on the driver. Increased workload has been associated with increased exhaustion after work, difficulties in unwinding after work, problems in coping with demands at home, and recreational use of free time. Rydstedt and Johansson (1998) in an 18-month longitudinal study of commercial vehicle drivers found that changes in workload were strongly associated with perceived effort to carry out tasks as well as with fatigue spill over from work to leisure time and home life. Occupational stress also affects the quality of sleep (Kecklund and Åkerstedt, 2004). Shorter work hours have been associated with reduced stress and better sleep health (Hege et al, 2015), and improving sleep health has been associated with improved stress responses and lower stress levels (Ebrahimi et al, 2015; Krueger et al, 2007). Professional drivers have a very high prevalence of sleep disorders and complaints of poor sleep. In a cross-sectional study involving a wide sample of truck drivers, Garbarino et al, (2016) observed that participants experienced a sleep debt of two or more hours (24.3% prevalence rate), Obstructive Sleep Apnoea (25.4%), and excessive daytime sleepiness (13.4%). The competing demands of a busy work pattern, poor scheduling, and night shifts can lead to bad sleep habits that cause sleep debt and consequent daytime sleepiness (Braeckman et al, 2010). Guglielmi et al (2018) found that both suspected OSA and perception of low sleep quality were associated with psychological distress.

Management Practises and Safety Culture

Shared attitudes, values, norms, ideas, beliefs, and behaviours at work impact upon employees' exposure to risk while at work and can be seen as the safety culture of the organisation (Guldenmund, 2000). Management practices include management concern for employee well-being; adequacy of training; provision of safety equipment, quality of safety management systems and communication; and employee involvement in workplace health and safety (Neal et al, 2000). Safety climate risk factors identify how truck drivers can be influenced by the pressures, beliefs, instructions, and safety policies of the company in which they work and how this can influence their driving behaviours (Zohar, 2010; Brady et al, 2009). Studies have identified that organisational culture is the strongest predictor of work-related stress (Strahan et al, 2008) and significantly predict several driver safety-related behaviours including traffic violations, driver error, driving while distracted and pre-trip vehicle maintenance (Wills et al, 2006). Morrow and Crum (2004) reported that perceptions that trucking company employees held of management safety practices were predictive of driving fatigue and fatigue-related near misses.

In an industry with a shortage of skilled drivers, poor health status and a consequential high absenteeism, and low profit margins, employers may place excessive demands on drivers. Most of the existing studies of commercial truck driver safety have focused on the demands of driving a truck from an occupational perspective and how stress at work impacts on performance. Occupational stress is a term used to describe stress that originates from the work environment and is different to life stresses. Full-time professional drivers are exposed to a range of stressors, and these can vary according to the type of vehicle being driven and the nature of the work. Occupational stress can spill over into home life, especially if shift patterns are not optimal, resulting in poorer health and work performance (Evans et al, 1999). Driving trucks can be socially isolating and requires heightened alertness to deal with inconsiderate road users who may miscalculate the operational capabilities of a large vehicle. Dealing with difficult customers is also a known stressor of driving a truck for work.

Professional Driver Health and Coping

Multi-level chronic stressors experienced by truck drivers often induce detrimental behavioural and psychosocial responses that significantly contribute to their excessive health and safety disparities. Truck drivers are more likely to be physically inactive and to have disrupted sleep cycles and higher levels of stress (Angeles et al, 2014; Apostolopoulos, 2010; Bigelow et al, 2012; Sieber et al, 2014). Coping behaviours for dealing with stress amongst truck drivers compared with other professions include unhealthy eating, smoking, and drug/alcohol use (Apostolopoulos et al, 2013; Williams et al, 2017; Shattell et al, 2010). These coping responses reduce the physiological capability of truck drivers to handle stress in the long-term and lead to health problems including immune system dysfunction, cardiovascular disease, and diabetes. Further, these stressors can lead to emotional exhaustion and burnout (Williams et al, 2017). Prolonged stress is also associated with strokes, and gastrointestinal diseases (Tse et al, 2006). Of the numerous studies performed in various countries on cardiovascular disease and professional driving over a span of almost three decades, nearly all have shown an excess risk of cardiovascular disease among professional drivers. Stress has been linked with cancer, coronary heart disease/stroke, accidents, and poor mental health. Commercial drivers are therefore plagued with high rates of disease often attributed directly to the nature of the job (Bigelow et al, 2012; Lemke et al, 2015) including an increased risk of psychological and musculoskeletal disorders compared to the general population (Apostolopoulos et al, 2010). The mechanisms for the link between health status and the demands of driving a truck have been considered both indirect, through effects of stress on health behaviours (e.g., poor diet and smoking), and direct (e.g., biological changes including neuroendocrine changes and adaptations) (Aronsson and Rissler, 1998). There is a bi-directional relationship between poor health behaviours and stress. In other words, stress can lead to poor health and poor health can also be stressful. The nature of the work and coping responses leads to an increased risk of metabolic syndrome and insulin resistance, disturbances of blood coagulation, and the disruption of immune responses developing (Belkic et al, 1998). Relative to the general population, truck drivers are a vulnerable group as evidenced by a range of poorer health outcomes. Jovanovic et al (1998) reported that drivers with cardiovascular disease were twice as likely to have an accident and be at fault than were healthy drivers. Hakkanen and Summala (2001) investigated over 300 fatal two-vehicle trailer-truck crashes and found that the probability of being principally responsible for a crash increased by a factor of 3.5 if the driver had a chronic illness. In other studies, diabetic heavy goods vehicle drivers were more likely to have a crash than were nondiabetic HGV drivers (Dionne et al, 1995; Laberge-Nadeau et al, 2000).

Need for recovery after work reflects the extent to which workers feel they cannot adequately recover from work-related stress and fatigue after a working day, and this mediates the relationship between exposure to stressful working conditions and the development of psychosomatic health problems in the longer term. Repeated insufficient recovery after a working period therefore can be seen as the take-off of a vicious circle where extra effort must be exerted at the beginning of every new working day to rebalance the suboptimal psychophysiological state and to prevent performance breakdown (Sluiter et al, 1999). The consequential effects of repeated insufficient recovery leads to a cumulative health deterioration and can result in long-term sickness absence. de Croon et al (2003) in a study of over 1000 truck drivers over 2 years found that high baseline need for recovery after work was associated with an increased risk for subsequent sickness absence after adjustment for age, previous sickness absence, marital status, educational level, and company size. They concluded that a high need for recovery after work increases the risk of subsequent sickness absence that is not explained by relevant (non-) work-related factors.

Time Pressure and Scheduling

Time pressure has been identified as a causal factor for risk taking in a survey of 9475 drivers (McKenna, 2005). Those who claim that they frequently exceed speed limits also report that time pressure plays a significant role in their choice of speed behaviours. Time pressure is often seen as a cause of negative emotional reactions and, in the case of chronicity, a source of stress (Szollos, 2009). A French study found that time constraints, time uncertainty and goal importance are causal factors for time pressure and chronically present amongst in professional drivers. Truck drivers have an increased exposure to traffic congestion and time pressure combined with long hours spent driving, a common factor in driver stress (van der Beek et al, 1995; Vivolvi et al, 1993). Many researchers support the assumption that saving time and energy is the most prevalent reason for performing traffic violations under time pressure (Lawton et al, 1997; Salminen and Lahdeniemi, 2002). Forward (2006) pointed out that drivers who committed speeding violations reported perceived gains (i.e., getting to the destination faster) rather than perceived negative outcomes such as traffic crashes. Time pressure predicts aggression, irritability, frustration, and negative mood (Matthews, 2002). For the loading and unloading of cargo, less experienced truck drivers have an increased likelihood of suffering with stress in situations involving time pressure compared with experienced drivers (Apostolopoulos et al, 2013; Beilock, 2003).

Driving for work risk factors include long hours, tight delivery schedule with some form of job performance or delivery targets to achieve (Stevenson et al, 2010; Hanowski et al, 2007, 2009; Chen and Chen, 2011; Khorashadi et al, 2005). Between 36% and 71% of drivers have reported tight schedules and pressure to deliver on-time as factors for stress and unsafe driving (Apostolopoulos et al, 2016). Long schedules also increase the risk of fatigue and crash involvement as seen in U.S. 1,564 truck driver crash data (Jovanis et al, 2011). Driving time was a statistically significant predictor of crash risk with increasing crash odds as driving time increased from hour 5 through to hour 11 and driving breaks reduced crash risk.

Work Family Conflict

Ample evidence supports the detrimental effect of work-family conflict on various work, non-work, and health-related outcomes (Amstad et al, 2011). Work-family conflict is an inter-role stress that results from incompatible demands from work and family domains. According to the conservation of resources theory (Holmgreen et al, 2017), such inter-role conflict leads to stress because personal resources (e.g., time and energy) are lost in the process of juggling both work and family roles, resulting in a negative state that can lead to petulance, fatigue, physiological tension, and negative emotions. Even though interest in the work-family domain is not new, the potential impact of work-family conflict on road safety has been largely ignored. However, Turgeman-Lupo and Biron (2017) demonstrated that work-family conflict leads to increased unsafe commuting behaviours, and Shukri et al (2021) found that work-family conflict predicts dangerous driving behaviours. Individuals with higher work-family conflict experience self-regulation breakdown because holding multiple roles may require them to use their resources to regulate and suppress emotions other than managing the limited time and energy. Such situations may, in turn, impair the motivation to adopt safety measures whilst driving.

Life Stressors

Everyday critical life events that naturally happen to many individuals at certain times during their lives are not unexpected. These life events include, marriage, childbirth, divorce, death of parents, retirement etc. Nonnormative life events, such as accidents, or loss of loved ones, may be less frequent or not happen at all. Losing a loved one in consequence of a terminal illness can be a very stressful experience. Psychiatrists Holmes and Rahe (1967) examined over 5000 patient’s medical records to determine whether stressful events cause illnesses. Patients ranked a list of 43 life events based on a relative score leading to the development of the Social Readjustment Rating Scale (SRRS). Many validation studies have subsequently supported the scale and subsequent studies suggests that a change in life requires an effort to adapt and then an effort to regain stability leading to a depleted immune system. Driver stress may be reciprocally related to stress in other domains including domestic life. For example, Norris et al (2000) found that financial difficulties were associated with higher crash risk. Early work has focused on personal life stress factors beginning with work by Brenner and Selzer (1969) who conducted an in-depth analysis of 96 drivers that had been killed in crashes that they were responsible for. Drivers had experienced significant social stress during the 12-month period preceding the fatal accident compared with a matched control group and were estimated to be five times as likely to cause a fatal crash as drivers without such stress. It is likely that drivers become preoccupied by thoughts about stressful encounters and situations and that rumination and worry affect driving performance by distracting them from safe driving. McMurray (1970) examined the driving records over a seven-year period for 410 drivers who had been involved in divorce proceedings. She found that crash involvement and traffic violations were significantly higher for the divorced drivers than for the wider driving population. The percentage of participants involved in crashes and traffic violations steadily rose in the six months immediately prior to filing for divorce, reached a peak within three months after filing, then declined. It is suggested that during such a period of personal turmoil, psychological strain due to life stress has a significant impact on safety behind the wheel. Lagarde et al (2004) used retrospective self-report data from a sample of French drivers to examine serious motor vehicle crash involvement over a seven-year period and found participants who had been involved in marital separation or divorce within the year prior to the crash were more than four times more likely to be at-fault than other drivers. Similarly, Legree et al (2003) used retrospective self-reports to examine antecedents to road crashes over the previous five years. They also found that heightened stress due to life events was related to at-fault status.

PTSD and Effects on Driving Performance

Chronic stress can lead to post-traumatic stress disorder (PTSD) which is an anxiety disorder caused by very stressful, frightening, or distressing events. PTSD is marked by intrusive symptoms related to the trauma, negative alterations in cognitions or mood, difficulties experiencing positive emotions and alterations in arousal and reactivity (e.g., difficulty concentrating or sleeping, irritability). PTSD symptoms are often severe and persistent enough to have a significant impact on the person's day-to-day life. PTSD can develop immediately after someone experiences a disturbing event, or it can occur weeks, months or even years later. PTSD is estimated to affect about 1 in every 3 people who have a traumatic experience. Any situation that a person finds traumatic can cause PTSD. The theory of sustained activation (Knardahl et al, 1985), states that the psychophysiological activation response enables the individual to react successfully during a stressful situation. In the short term, the activation response is considered adaptive. In the longer term, however, health problems may appear when the elevation of this psychophysiological response is prolonged. This prolonged response is labelled sustained activation. Sustained activation results from the chronic exposure to fluctuating or heightened neural or neuroendocrine response resulting from repeated or chronic environmental challenge that an individual reacts to as being particularly stressful. Repeated exposure can lead to pathophysiological consequences that include an increased risk for the incidence of cardiovascular disease (Seeman et al, 1997) suppressed cellular immunity (Cohen et al, 1991), and an increased likelihood of chronic musculoskeletal tension (a risk factor for musculoskeletal health problems) (McEwan, 1998).

Several studies have explored the relationship between PTSD and emotions experienced while driving. Feelings of anger and irritability as well as risk-taking and hypervigilance behaviours is one of the main emotions that may increase the risk of being involved in a crash. Typically, driving in an aggressive manner (Possis et al, 2014). According to both Whipple et al (2016) and Zinzow et al (2013), individuals with PTSD reported higher levels of anxiety and/or hyperarousal while driving relative to healthy controls. Tessier et al (2017) showed that individuals with PTSD endorsed greater anger and were less likely to employ coping self-instructions while driving as compared to those without PTSD. Drivers who were suspected to have PTSD have reported more crashes (Saberi et al, 2013). Sayer et al (2010) showed that veterans whose friends and family had noticed their engaging in aggressive or dangerous driving were four times as likely to screen positive for PTSD. Several studies have identified that PTSD symptom severity is related to aggressive driving behaviours (Baker et al 2014; Clapp et al 2014; 2019). For example, Kuhn et al (2010) and Strom et al (2012) found that greater PTSD symptom severity was associated with more frequent verbal outbursts or angry hand gestures at others while driving, tailgating, intentionally cutting off, chasing other drivers, and/or intentionally driving a vehicle into another object. Similar findings were reported by Van Voorhees et al (2018), who found that individuals with PTSD were more likely to endorse driving aggressively and experience road rage and higher rates of self-reported speeding (Fear et al, 2008; Classen et al, 2011). In a large study, Hoggatt et al (2015) showed that greater PTSD symptom severity was associated with higher rates of passing drivers on the right, crossing an intersection during a red light, ignoring speed limits early or late in the day, and underestimation of the speed of an oncoming vehicle. Classen et al (2011) noted that individuals with PTSD committed more adjustment-to-stimuli errors relative to controls. Both Lew et al (2011) and Mairean (2020) determined PTSD was linked to more frequent lapses in attention while driving, near-misses, and other unintentional errors that may endanger other road users. Driving errors are usually made without conscious awareness of the mistake and PTSD is associated with increased odds of making mistakes behind the wheel.

Mind-Wandering and Driving

Mind-wandering is defined as task unrelated thought and occurs when individuals consciously focus on stimuli or events unrelated to the task. Mind wandering occurs most frequently in situations associated with low attentional demands including familiar commutes and monotonous motorways (Berthié et al, 2015). Drivers may be especially prone to mind wandering when they are thinking about a life stressor. Rumination can lead to negative cognitive biases (Lavender and Watkins, 2004) and can be a risk factor for stress and emotional disorders such as depression. Rumination is also a predictor of PTSD for road traffic crash survivors (Heron-Delaney et al, 2013). According to Matthews (2002) worry leads to cognitive interference and compared with other driver groups, truck drivers have a higher level of intruding thoughts about personal concerns, particularly when the task is not demanding. Physiologically, the body cannot differentiate between work-based stress and stress resulting from personal life events. When work-based stress is experienced, it can act as a trigger for intrusive thoughts and/or other symptoms of anxiety.

Stress Countermeasures

Driver stress management interventions aim to support drivers who are more vulnerable to stress when driving for work. There are several ways in which various countermeasures may improve stress-related impairments on driving performance and reduce crash risk. Strategies to manage occupational stress can be approached at both the organisational level and the individual level. At the organisational level clarification of roles, job design etc. reduce occupational stress, and at the individual level counselling services, employee assistance programmes and stress management training may also reduce occupational stress. Companies also often benefit from higher levels of performance, improved safety, and lower levels of absenteeism and turnover when implementing stress management interventions. Some key evidence-based interventions are presented below.

- Safety Culture - Organizations in which management commitment to safety is strong, have reported low road traffic crash rates while, such commitment has been found to be characteristically absent in high crash-involved companies in the trucking industry (Arboleda et al, 2003).

- Safety Culture Training - New truck carriers were trained in the applicable regulations and inspections to foster a good safety culture, and their number of crashes were compared to controls from other states. Better performance of the trained carriers versus controls in the first part of the project was seen (Goettee et al, 2015).
- Employee Assistance Programs (EAPs) – EAPs offer individualised counselling to employees to identify effective coping strategies for personal and professional stressors and lead to improved performance and reduced absenteeism (Nunes et al, 2018)
- Group Discussions – Aim to identify problems within the workplace and find solutions reduced crash involvement by more than half (before/after periods of two years) compared with other interventions and a control group (Gregersen et al, 1996).
- Work-related stress management programmes – There are several different approaches to reduce stress using stress management programmes and studies have found this approach to be effective at reducing stress in the workplace (Apostolopoulos et al, 2013; Shattell et al, 2010).
- Driver Stress Management Programmes – Individual coaching interventions aim to promote emotional regulation and reduce feelings of anger and anxiety, leading to reduced rates of hostile driving and better coping strategies (Dorn et al, 2010; Rowden et al, 2011).
- Physical Activity – Increasing physical activity effectively influences stress and psychological states, fatigue, sleep, and health status for professional drivers. Acute exercise may have short-term effects that have an impact on driver behaviour and cognitive performance (e.g., increased alertness) (Taylor and Dorn, 2006). Truck driver health promotion programmes, based on key information needs around health behaviour change that have been implemented in the UK, have resulted in improved health (Varela-Mata et al., 2018).
- Mindfulness Training - Mindfulness promotes greater emotional regulation and can assist in maintaining selective and sustained attention (Kass et al, 2011).

Research Limitations

- Most of the research on skill decay comes from either laboratory-based studies or applications in the aviation industry and the study findings may not transfer to the driving context.
- Many studies use relatively small samples.
- Many interventions use short-term evaluations. Longitudinal comparisons are essential to fully assess the effects of countermeasures over time.
- Few studies have been published about how driving skills may fade. However, for the studies investigating novice driving skills, it can be concluded that driving skills do fade rather quickly after licensure for those that fail to practise.
- Further research on driving skills decay is required, especially in relation to real-world contexts and driving for work.
- Although there is an increase in research around distraction mitigation interventions for young drivers, little has been studied with employee-directed interventions at worksites.
- There is a lack of research investigating commercial drivers' behaviours and how to mitigate the risk of distracted driving.
- There have been very few replications of the studies reported. One of the difficulties of lack of replication is that researchers cannot be certain that the findings reported will be seen in subsequent studies.
- Studies were conducted in regions other than the UK. It is not clear to what extent these findings are transferable to a UK-specific context.
- For some topics, the number of studies available to draw conclusions is scarce
- Substantial differences are reported between studies due to the varieties of methods used (e.g. simulators, secondary tasks, and neuroimaging techniques) making it difficult to draw definitive conclusions.

References

Amstad, F.T., Meier, L.L., Fasel, U., Elfering, A., Semmer, N.K., 2011. A meta-analysis of work–family conflict and various outcomes with a special emphasis on cross-domain versus matching-domain relations. J. Occup. Health Psychol. 16 (2), 151–169.

Angeles, R., McDonough, B., Howard, M., Dolovich, L., Marzanek-Lefebvre, F., Qian, H., Riva, J.J., (2014). Primary health care needs for a priority population: a survey of professional truck drivers. Work 49 (2), 175–181.

Apostolopoulos, Y., Sönmez, S., Shattell, M.M., Belzer, M., (2010). Worksite-induced morbidities among truck drivers in the United States. AAOHN J.: Off. J. Am. Assoc. Occup. Health Nurses 58 (7), 285–296.

Apostolopoulos, Y., Sönmex, S., Shattell, M.M., Gonzales, C., Fehrenbacher, C., (2013). Health survey of U.S. long-haul truck drivers: work environment, physical health, and healthcare access. Work 46 (1), 113–123.

Arboleda, A., Morrow, P.C., Crum, R. and Ii, M.C.S. (2003). Management practices as antecedents of safety culture within the trucking industry: similarities and differences by hierarchical level. Journal of Safety Research, 34, 189–197.

Aronsson G, Rissler A. (1998). Psycho-physiological stress reaction in female and male urban bus drivers. *J. Occup. Health Psychol.* 3:122–29

Atchley, P., Tran, A. V., & Salehinejad, M. A. (2017). Constructing a publicly available distracted driving database and research tool. *Accident Analysis & Prevention*, *99*, 306-311.

Baker, A.S., Litwack, S.D., Clapp, J.D., Beck, J.G., Sloan, D.M., (2014). The driving behavior survey as a measure of behavioral stress responses to MVA-related PTSD. Behav. Ther. 45 (3), 444–453.

Baldock, M. R. J., Long, A. D., Lindsay, V. L. A., & McLean, J. (2005). Rear end crashes. University of Adelaide. Centre for Automotive Safety Research.

Baldwin, C.L., Roberts, D.M., Barragan, D., Lee, J.D., Lerner, N., Higgins, J.S., (2017). Detecting and quantifying mind wandering during simulated driving. Front. Hum. Neurosci. 11 (406).

Beilock, R., (2003). Schedule tightness among tractor-trailer drivers. Traffic Inj. Prev. 4 (2), 105–112.

Belkic K, Emdad R, Theorell T. (1998). Occupational profile and cardiac risk: possible mechanisms and implications for professional drivers. *Int. J. Occup. Med. Environ. Health* 11:37–57

Bergomi, M., et al. (2017). Work-related Stress and Role of Personality in a Sample of Italian Bus Drivers. Work 57(3). 433 – 440.

Berthié, G., Lemercier, C., Paubel, P.V., Cour, M., Fort, A., Galéra, C., Lagarde, E., Gabaude, C., Maury, B., 2015. The restless mind while driving: drivers' thoughts behind the wheel. Accid. Anal. Prev. 76, 159–165.

Boufous, S., Ivers, R., Senserrick, T., Stevenson, M., (2011). Attempts at the practical on- road driving test and the hazard perception test and the risk of traffic crashes in young drivers. Traffic Inj. Prev. 12 (5), 475–482.

Brady, J.E., Baker, S.P., Dimaggio, C., McCarthy, M.L., Rebok, G.W., Li, G., (2009). Effectiveness of mandatory alcohol testing programs in reducing alcohol involvement in fatal motor carrier crashes. Am. J. Epidemiol. 170 (6), 775–782.

Brenner, B., & Selzer, M. L. (1969). Risk of causing a fatal accident associated with alcoholism, psychopathology, and stress: Further analysis of previous data. *Behavioral Science*, *14*(6), 490-495.

Broadbent, D.P., Causer, J., Williams, A.M., Ford, P.R., (2017). The role of error processing in the contextual interference effect during the training of perceptual-cognitive skills. J. Exp. Psychol. Hum. Percept. Perform. 43 (7), 1329–1342.

Bunn, T.L., Slavova, S., Struttmann, T.W., Browning, S.R., (2005). Sleepiness, fatigue and distraction/inattention as factors for fatal versus nonfatal commercial motor vehicle driver injuries. Accid. Anal. Prev. 37, 862–869.

Bunn, T.L., Yu, L., Slavova, S., Bathke, A., (2009). The effects of semi-truck driver age and gender and the presence of passengers on collisions with other vehicles. Traffic Inj. Prev. 10 (3), 266–272.

Bunn, T., Slavova, S., Robertson, M., (2012). Crash and burn? Vehicle, collision, and driver factors that influence motor vehicle collision fires. Accid. Anal. Prev. 47, 140–145.

Bunn, T., Slavova, S., Robertson, M., (2013). Motor vehicle injuries among semi-truck drivers and sleeper berth passengers. J. Saf. Res. 44, 51–55.

Burdett, B. R., Charlton, S. G., & Starkey, N. J. (2018). Inside the commuting driver's wandering mind. Transportation Research Part F: Traffic Psychology and Behaviour, 57, 59–74.

Braekman L, Verpraet R, Van Risseghem M, Pevernagie D, De Bacquer D (2011) Prevalence and correlates of poor sleep quality and daytime sleepiness in Belgian truck drives. Chronobiol Int. 28:126–134.

Cartwright, S., Cooper, C., & Barron, A. (1996). The company car driver; occupational stress as a predictor of motor vehicle accident involvement. Human Relations, 49(2), 195–208.

Castro, C., Ventsislavova, P., García-Fernandez, P., & Crundall, D. (2021). Risky Decision Making and Hazard Prediction are negatively related and could be assessed independently using driving footage. *Psychology Research and Behavior Management, 14*, 857–876.

Chan, E., Pradhan, A. K., Pollatsek, A., Knodler, M. A., & Fisher, D. L. (2010). Are driving simulators effective tools for evaluating novice drivers' hazard anticipation, speed management, and attention maintenance skills? Transportation Research Part F: Traffic Psychology and Behaviour, 13, 343–353.

Chapman, P., Underwood, G., Roberts, K., (2002). Visual search patterns in trained and untrained novice drivers. Transp. Res. Part F Traffic Psychol. Behav. 5, 157–167.

Charlton, S. G., & Starkey, N. J. (2011). Driving without awareness: The effects of practice and automaticity on attention and driving. Transportation Research Part F: Traffic Psychology and Behaviour, 14(6), 456–471.

Chen, F., Chen, S., (2011). Injury severities of truck drivers in single- and multi-vehicle accidents on rural highways. Accid. Anal. Prev. 43 (5), 1677–1688.

Cheng, A.S.K., Ng, T.C.K., Lee, H.C., (2011). A comparison of the hazard perception ability of accident-involved and accident-free motorcycle riders. Accid. Anal. Prev. 43 (4), 1464–1471.

Childs, J. M., & Spears, W. D. (1986). Flight-skill decay and re- current training. Perceptual and Motor Skills, 62, 235–242.

Childs J. M., Spears W. D., and *Prophet,* W. W. (1983) *Private pilot flight skill retention* 8-, 16-, and 24-months *following certification.* Washington, DC: Federal Aviation Administration. (Report No. DOT/FAA/CT-83/34).

Clapp, J.D., Baker, A.S., Litwack, S.D., Sloan, D.M., Beck, J.G., (2014). Properties of the Driving Behavior Survey among individuals with motor vehicle accident-related posttraumatic stress disorder. J. Anxiety Disord. 28 (1), 1–7.

Clapp, J.D., Sloan, D.M., Unger, W., Lee, D.J., Jun, J.J., Litwack, S.D., Beck, J.G., (2019). Problematic driving in former service members: An evaluation of the Driving Behavior Survey in veterans with posttraumatic stress disorder. J. Anxiety Disord. 67, 102134.

Classen, S., Levy, C., Meyer, D.L., Bewernitz, M., Lanford, D.N., Mann, W.C., (2011). Simulated driving performance of combat veterans with mild traumatic brain injury and posttraumatic stress disorder: a pilot study. Am. J. Occup. Ther. 65 (4), 419–427.

Cohen S, Tyrell DAJ, Smith AP. (1991). Psychological stress and susceptibility to the common cold. N Engl J Med; 325:606 – 12.

Colonna, P., Intini, P., Berloco, N., & Ranieri, V. (2016). The influence of memory on driving behaviour: How route familiarity is related to speed choice. An on-road study. Safety Science, 82, 456–468.

Craft, R.H., Preslopsky, B., (2009). Driver distraction and inattention in the USA large truck and national motor vehicle crash causation studies. In: Regan, M.A., Lee, J.D., Victor, T.W. (Eds.), Advances in Research and Countermeasures. Ashgate Publishing, p. 384.

Crundall, D., Andrews, B., van Loon, E., Chapman, P., (2010). Commentary training improves responsiveness to hazards in a driving simulator. Accid. Anal. Prev. 42, 2117–2124.

Cushway, D., Tyler, P. A., & Nolan, P. (1996). Development of a stress scale for mental health professionals. British Journal of Clinical Psychology, 35, 279–295.

Custers, E., (2010). Long-term retention of basic science knowledge: a review study. Adv. Health Sci. Educ. 15 (1), 109–128.

de Croon, E. M., Sluiter, J. K., & Frings-Dresen, M. H. (2003). Need for recovery after work predicts sickness absence: a 2-year prospective cohort study in truck drivers. *Journal of psychosomatic research*, *55*(4), 331-339.

Desmond, P. A., & Matthews, G. (2009). Individual differences in stress and fatigue in two field studies of driving. Transportation Research Part F, 12 (4), 265-276.

Dingus, T.A., Klauer, S.G., Neale, V.L., Petersen, A., Lee, S.E., Sudweeks, J., et al., (2006). The 100-Car Naturalistic Driving Study, Phase II–Results of the 100-Car Field Experiment. NHTSA, Washington, DC, USA.

Dingus, T. A., Guo, F., Lee, S., Antin, J. F., Perez, M., Buchanan-King, M., et al. (2016). Driver crash risk factors and prevalence evaluation using naturalistic driving data. *Proceedings of the National Academy of Sciences, 113*(10), 2636–2641.

Dionne G, Desjardins D, Laberge- Nadeau C, Maag U. (1995). Medical condition, risk exposure and truck drivers' accidents: an analysis with count data regression models. *Accid. Anal. Prev.* 27:295–305

Donmez, B., Boyle, L. N., Lee, J. D., & Scott, G. (2007). Safety implications of providing real-time feedback to distracted drivers. *Accident Analysis and Prevention, 39,* 581–590.

Dorn, L., (2005). Driver Behaviour and Training, vol.2. Ashgate, Aldershot.

Dorn, L., Stephens, L., af Wåhlberg, A. E., & Gandolfi, J. (2010). Development of a self-report measure of bus driver behaviour. Ergonomics, 53, 1420-1433.

Dorn, L. (2021). Driver Stress and Driving Performance. International Encyclopaedia of Transportation, Elsevier.

Driskell, J. E., Willis, R. P., Copper, C. (1992) Effect of overlearning on retention. Journal of Applied Psychology, 77(5), 615-622.

Ebrahimi, M. H., Sadeghi, M., Dehghani, M., & Niiat, K. S. (2015). Sleep habits and road traffic accident risk for Iranian occupational drivers. *International Journal of Occupational Medicine and Environmental Health*, *28*, 305-312.

Engelberg, J. K., Hill, L. L., Rybar, J., & Styer, T. (2015). Distracted driving behaviours related to cell phone use among middle-aged adults. *Journal of Transport & Health, 2*(3), 434–440.

Eysenck, M. W., & Derakshan, N. (2011). New perspectives in attentional control theory. *Personality and Individual Differences*, *50*(7), 955-960.

European Commission (2015). Driver distraction. European Commission, Directorate General for Transport.

Evans, G. W., Palsane, M. N. & Carrere, S. (1987). Type A behavior and occupational stress: A cross-cultural study of blue-collar workers. *Journal* of *Personality and Social Psychology, 52,* 1002-1007.

Evans, G.W., Johansson, G., Rydstedt, L., (1999). Hassles on the job: a study of a job intervention with urban bus drivers. Journal of Organizational Behavior 20, 199–208.

Fear, N.T., Iversen, A.C., Chatterjee, A., Jones, M., Greenberg, N., Hull, L., Rona, R.J., Hotopf, M., Wessely, S., (2008). Risky driving among regular armed forces personnel from the United Kingdom. Am. J. Prev. Med. 35 (3), 230–236.

Ferdinand, A. O., & Menachemi, N. (2014). Associations between driving performance and engaging in secondary tasks: A systematic review. *American journal of public health*, *104*(3), e39-e48.

Fildes, B., Newstead, S., Keall, M., Budd, L., 2014. Camera Effectiveness and Backover Collisions with Pedestrians: a Feasibility Study, Report No. 321. Monash University Accident Research Centre, Melbourne.

Fitch, G.M., Soccolich, S.A., Guo, F., et al., (2013). The impact of handheld and hands-free cell phone use on driving performance and safety-critical event risk. National Highway Traffic Safety Administration, Washington, DC, Report No. DOT HS 811 757.

Fitts, P. M., and Posner, M. I., (1967) Learning and Skilled Performance in Human Performance Belmont CA: Brock-Cole.

Forward, S.E., (2006). The intention to commit driving violations – A qualitative study. Transp. Res. Part F: Traffic Psychol. Behav. 9 (6), 412–426.

Funkhouser, D., Sayer, J., (2012). Naturalistic census of cell phone use. *Transp. Res. Rec. 2321 (1)*, 1–6.

Garbarino S, Durando P, Guglielmi O, Dini G, Bersi F, Fornarino S et al (2016) Sleep apnea, sleep debt and daytime sleepiness are independently associated with road accidents. A cross-sectional study on truck drivers. PLoS One 11: e0166262.

Goettee, D., Spiegel, W., Tarr, R., Campanian, C., & Grill, L. (2015). *Overview of Federal Motor Carrier Safety Administration Safety Training Research for New Entrant Motor Carriers.* Federal Motor Carrier Safety Administration: FMCSA-RRR-13-015.

Gotardi, G. C., Polastri, P. F., Schor, P., Oudejans, R. R., van der Kamp, J., Savelsbergh, G. J., ... & Rodrigues, S. T. (2019). Adverse effects of anxiety on attentional control differ as a function of experience: A simulated driving study. *Applied ergonomics*, *74*, 41-47.

Gregersen, N.-P., Brehmer, B., & Morén, B. (1996). Road safety improvement in large companies: An experimental comparison of different measures. *Accident Analysis and Prevention, 28,* 297-306.

Groeger, J. A. (2000). Understanding driving. Applying cognitive psychology to a complex everyday task. East Sussex: Psychology Press.

Groeger, J. A., & Clegg, B. A. (1997). Automaticity and driving: time to change gear? Traffic and Transport Psychology: Theory and application.

Guglielmi, O., Magnavita, N., & Garbarino, S. (2018). Sleep quality, obstructive sleep apnea, and psychological distress in truck drivers: A cross-sectional study. *Social psychiatry and psychiatric epidemiology*, *53*, 531-536.

Guldenmund, F. W. (2000). The nature of safety culture: A review of theory and research. Safety Science, 34, 215–257.

Hakkanen H, Summala H. (2001). Fatal traffic accidents among trailer truck drivers and accident causes as viewed by other truck drivers. *Accid. Anal. Prev.* 33:187–96.

Haghani, M., Bliemer, M. C., Farooq, B., Kim, I., Li, Z., Oh, C., ... & MacDougall, H. (2021). Applications of brain imaging methods in driving behaviour research. *Accident Analysis & Prevention*, *154*, 106093.

Hammond, R. L., Soccolich, S. A., & Hanowski, R. J. (2019). The impact of driver distraction in tractor-trailers and motorcoach buses. *Accident Analysis & Prevention*, *126*, 10-16.

Hampton, M. E. (2016). Enhanced FAA oversight could reduce hazards associated with increased use of flight deck automation. Washington, DC: US Department of Transportation.

Hanowski, R.J., Hickman, J., Fumero, M.C., Olson, R.L., Dingus, T.A., (2007). The sleep of commercial vehicle drivers under the 2003 hours-of-service regulations. Accid. Anal. Prev. 39, 1140–1145.

Hanowski, R.J., Hickman, J.S., Olson, R.L., Bocanegra, J., (2009). Evaluating the 2003 revised hours-of-service regulations for truck drivers: the impact of time-on-task on critical incident risk. Accid. Anal. Prev. 41 (2), 268–275.

Harland, K. K., Carney, C., & McGehee, D. (2016). Analysis of naturalistic driving videos of fleet services drivers to estimate driver error and potentially distracting behaviors as risk factors for rear-end versus angle crashes. *Traffic injury prevention*, *17*(5), 465-471.

Hege, A., Perko, M., Johnson, A., Yu, C. H., Sönmez, S., & Apostolopoulos, Y. (2015). Surveying the impact of work hours and schedules on commercial motor vehicle driver sleep. *Safety and Health at Work*, *6*, 104-113.

Heron-Delaney, M., Kenardy, J., Charlton, E., & Matsuoka, Y. (2013). A systematic review of predictors of posttraumatic stress disorder (PTSD) for adult road traffic crash survivors. *Injury*, **44**, 1413– 1422.

Hickman, J.S., Hanowski, R.J., (2012). An assessment of commercial motor vehicle driver distraction using naturalistic driving data. *Traffic Inj. Prev. 13 (6)*, 612–619.

Hill, L., Rybar, J., Jahns, J., Lozano, T., & Baird, S. (2020). 'Just Drive': An Employee-Based Intervention to Reduce Distracted Driving. *Journal of community health*, *45*, 370-376.

Hoggatt, K.J., Prescott, M.R., Goldmann, E., Tamburrino, M., Calabrese, J.R., Liberzon, I., Galea, S., (2015). The prevalence and correlates of risky driving behavior among National Guard soldiers. Traffic Inj. Prev. 16 (1), 17–23.

Holmes, T.H.& Rahe, R.H. (1967). The Social Readjustment Rating Scale. *J Psychosom Res*; 11, 213–218.

Holmgreen, L., Tirone, V., Gerhart, J., Hobfoll, S.E., (2017). Conservation of resources theory. In: Cooper, C.L., Quick, J.C. (Eds.), The Handbook of Stress and Health: A Guide to Research and Practice. John Wiley & Sons, Ltd, Chichester, UK, pp. 443–457.

Horrey, W. J., & Divekar, G. (2016). Attention allocation and maintenance in novice and teen drivers. 2016). Handbook of Teen and Novice Drivers: Research, Practice, Policy, and Directions. CRC Press: Boca Raton, FL.

Horrey, W.J., Wickens, C.D., (2007). In-vehicle glance distributions, tails, and model of crash risk. Transportation Research Record 2018, 22–28.

Horswill, M., Hill, A., Silapurem, L., Watson, M. O. (2021). A thousand years of crash experience in three hours: An online hazard perception training course for drivers, Accident Analysis and Prevention, 152, 105969.

Hsieh, L., Seaman, S., & Young, R. (2010, November). Effect of emotional speech tone on driving from lab to road: fMRI and ERP studies. In *Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 22-28).

Intini, P., Berloco, N., Colonna, P., Ranieri, V., & Ryeng, E. (2018). Exploring the relationships between drivers' familiarity and two-lane rural road accidents. A multi-level study. *Accident Analysis and Prevention, 111*, 280–296.

Isler, R.B., Starkey, N.J., Williamson, A.R., (2009). Video-based road commentary training improves hazard perception of young drivers in a dual task. Accid. Anal. Prev. 41, 445–452.

Ismaeel, R., Hibberd, D., Carsten, O., & Jamson, S. (2020). Do drivers self-regulate their engagement in secondary tasks at intersections? An examination based on naturalistic driving data. *Accident Analysis & Prevention*, *137*, 105464.

Joseph, B., Zangbar, B., Bains, S., Kulvatunyou, N., Khalil, M., Mahmoud, D., ... & Rhee, P. (2016). Injury prevention programs against distracted driving: Are they effective? *Traffic injury prevention*, *17*(5), 460-464.

Jovanis, P. P., Wu, K. F., & Chen, C. (2011). Hours of service and driver fatigue: Driver characteristics research (No. FMCSA-RRR-11-018).

Just, M.A., Keller, T.A., Cynkar, J., (2008). A decrease in brain activation associated with driving when listening to someone speak. *Brain Res. 1205*, 70–80.

Kass, S. J., VanWormer, L. A., Mikulas, W. L., Legan, S., & Bumgarner, D. (2011). Effects of mindfulness training on simulated driving: Preliminary results. *Mindfulness*, *2*, 236-241.

Keall, M. D., Fildes, B., & Newstead, S. (2017). Real-world evaluation of the effectiveness of reversing camera and parking sensor technologies in preventing backover pedestrian injuries. *Accident Analysis & Prevention*, *99*, 39-43.

Kecklund, G., & Åkerstedt, T. (2004). Apprehension of the subsequent working day is associated with a low amount of slow wave sleep. *Biological Psychology*, *66*(2), 169–176.

Kidd, D.G., Hagoski, B.K., Tucker, T.G., Chiang, D.P., (2015). The effectiveness of a rear view camera and parking sensor system alone and combined for preventing a collision with an unexpected stationary or moving object. Hum. Factors 57, 689–700.

Khorashadi, A., Niemeier, D., Shankar, V., Mannering, F., (2005). Differences in rural and urban driver-injury severities in accidents involving large-trucks: an exploratory analysis. Accid. Anal. Prev. 37 (5), 910–921.

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). *The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data* (No. DOT HS 810 594). Washington, DC: National Highway Traffic Safety Administration.

Knardahl S, Ursin H. (1985). Sustained activation and the pathophysiology of hypertension and coronary heart disease. In: Orlbeke J, Mulder G, editors. Psychophysiology of cardiovascular control. New York: Plenum, pp. 151–67.

Kuhn, E., Drescher, K., Ruzek, J., Rosen, C., (2010). Aggressive and unsafe driving in male veterans receiving residential treatment for PTSD. J. Trauma. Stress 23 (3), 399–402.

Laberge-Nadeau C, Dionne G, Eke J-M, Hamet P, Desjardins D, et al. (2000). Impact of diabetes on crash risks of truck-permit holders and commercial drivers. *Diabetes Care* 23:612–17.

Lagarde, E., Chastang, J., Gueguen, A., Coeuret-Pellicer, M., Chiron, M., Sylviane, L., (2004). Emotional stress and traffic accidents: the impact of separation and divorce. Epidemiology 15 (6), 762–766.

Lansdown, T. C., Stephens, A. N., & Walker, G. H. (2015). Multiple driver distractions: A systemic transport problem. *Accident Analysis & Prevention*, *74*, 360-367.

Lavender, A., & Watkins, E. (2004). Rumination and future thinking in depression. *British Journal of Clinical Psychology*, 43, 129– 142.

Lawton, R., Parker, D., Manstead, A.S.R., Stradling, S.G., (1997). The role of affect in predicting social behaviors: the case of road traffic violations. J. Appl. Soc. Psychol. 27 (14), 1258–1276.

Legree, P.J., Heffner, T.S., Psotka, J., Martin, D.E., Medsker, G.J., (2003). Traffic crash involvement: experiential driving knowledge and stressful contextual antecedents. Journal of Applied Psychology 88 (1), 15–26.

Lemercier, C., Pêcher, C., Berthié, G., Valéry, B., Vidal, V., Paubel, P. V., ... & Maury, B. (2014). Inattention behind the wheel: How factual internal thoughts impact attentional control while driving. *Safety science*, *62*, 279-285.

Lemke, M., Hege, A., Perko, M., Sönmez, S., Apostolopoulos, Y., (2015). Work patterns, sleeping hours and excess weight in commercial drivers. Occup. Med. 65 (9), 725–731.

Lew, H.L., Kraft, M., Pogoda, T.K., Amick, M.M., Woods, P., Cifu, D.X., (2011). Prevalence and characteristics of driving difficulties in Operation Iraqi Freedom/Operation Enduring Freedom combat returnees. J. Rehabil. Res. Dev. 48 (8), 913.

McEwen BS. (1998). Protective and damaging effects of stress mediators. N Engl J Med; 338:171 – 9.

McKenna, F.P., Horswill, M.S., Alexander, J.L., (2005). Does anticipation training affect drivers' risk taking? J. Exp. Psychol. Appl. 12, 1–10.

McKenna, F. P. (2005). What shall we do about speeding-education? In G. Underwood (Ed.), Traffic and transport psychology (pp. 521–528). Oxford: Elsevier.

McMurray, L. (1970). Emotional stress and driving performance: The effect of divorce. *Behavioral Research in Highway Safety*.

Mairean, C., (2020). Posttraumatic stress symptoms, fear and avoidance of driving, and aberrant driving behaviors. The moderating role of gender. J. Transp. Health 16, 100830.

Matthews, G. (2002). Towards a transactional ergonomics for driver stress and fatigue. Theoretical Issues in Ergonomic Science, 3, 195-211.

Matthews G, Dorn L, Hoyes TW, Davies 91. DR, Glendon AI, Taylor RG. (1998). Driver stress and performance on a driving simulator. *Hum. Factors* 40:136– 49.

Mengelkoch, R. F., Adams, J. A., & Gainer, C. A. (1971). The forgetting of instrument flying skills. *Human Factors*, *13*, 397–405.

Metz, B., Schoemig, N., & Krueger, H. P. (2017). How is driving-related attention in driving with visual secondary tasks controlled? Evidence for top-down attentional control. In *Driver distraction and inattention* (pp. 83-102). CRC Press.

Michon, J. A. (1985). A critical view of driver behavior models: what do we know, what should we do? In *Evans, L., Schwing, R.C. (eds) Human Behavior and Traffic Safety*. Springer, Boston, MA.

Morrow, P., & Crum, M. (2004). Antecedents of fatigue, close calls, and crashes among commercial motor-vehicle drivers. Journal of Safety Research, 35, 59–69.

National Highway Transportation Safety Administration (2010). Traffic safety facts research note: distracted driving 2009. Available at: http://www.distraction. gov/download/research-pdf/Distracted- Driving-2009.pdf.

Neal, A., Griffin, M., & Hart, P. (2000). The impact of organisational climate on safety climate and individual behaviour. Safety Science, 34, 99–109.

Norris, F.H., Matthews, B.A., Raid, J.K., (2000). Characterological, situational, and behavioral risk factors for motor vehicle accidents: a prospective examination. Accident Analysis and Prevention 32, 505–515.

Nunes, A. P., Richmond, M. K., Pampel, F. C., & Wood, R. C. (2018). The effect of employee assistance services on reductions in employee absenteeism. *Journal of Business and Psychology*, *33*, 699-709.

O'Hare, D., Wiggins, M., Batt, R., & Morrison, D. (1994). Cognitive failure analysis for aircraft accident investigation. Ergonomics, 37, 1855– 1869.

Oviedo-Trespalacios, O., Haque, M.M., King, M., Washington, S., (2016). Understanding the impacts of mobile phone distraction on driving performance: a systematic review. *Transp. Res. Part C Emerg. Technol. 72*, 360–380.

Öz, B., Özkan, T., & Lajunen, T. (2010). Professional and non-professional drivers' stress reactions and risky driving. Transportation Research Part F: Traffic Psychology and Behaviour, 13(1), 32-40.

Page, M. J. et al. (2020). The PRISMA statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.

Palmiero, M., Piccardi, L., Boccia, M., Baralla, F., Cordellieri, P., Sgalla, R., ... & Giannini, A. M. (2019). Neural correlates of simulated driving while performing a secondary task: a review. *Frontiers in Psychology*, *10*, 1045.

Pashler, H., Rohrer, D., Cepeda, N.J., Carpenter, S.K., (2007). Enhancing learning and retarding forgetting: choices and consequences. Psychon. Bull. Rev. 14 (2), 187–193.

Petersen, A., Barrett, R., (2009). Postural stability and vehicle kinematics during an evasive lane change manoeuvre: a driver training study. Ergonomics 52, 560– 568.

Petersen, A., Barrett, R., Morrison, S., (2006). Driver-training and emergency brake performance in cars with antilock braking systems. Saf. Sci. 44, 905–917.

Petersen, A., Barrett, R., Morrison, S., (2008). Enhanced postural stability following driver training is associated with positive effects in vehicle kinematics during cornering. Hum. Factors 50, 159–172.

Poldrack, R. A., Sabb, F. W., Foerde, K., Tom, S. M., Asarnow, R. F., Bookheimer, S. Y., & Knowlton, B. J. (2005). The neural correlates of motor skill automaticity. *Journal of Neuroscience*, *25*(22), 5356-5364.

Posner, M. I. (1990). Hierarchical distributed networks in the neuropsychology of selective attention. In A. Cramazza (Ed.), Cognitive neuropsychology and neuro- linguistics (pp. 187e210). Hillsdale, NJ: Lawrence Erlbaum Associates.

Possis, E., Bui, T., Gavian, M., Leskela, J., Linardatos, E., Loughlin, J., Strom, T., (2014). Driving difficulties among military veterans: Clinical needs and current intervention status. Mil. Med. 179 (6), 633–639.

Rasmussen J. (1987). The definition of human error and a taxonomy for technical system design. In: Rasmussen J, Duncan K, Leplat J, eds. New Technology and Human Error. Chichester, UK: Wiley.

Rowden, P., Matthews, G., & Watson, B. et al. (2011). The relative impact of work-related stress, life stress and driving environment stress on driving outcomes. Accident Analysis and Prevention, 43 (4), 1332-1340.

Rudin-Brown, C., Burns, P., Hagen, L., Roberts, S., Scipione, A., 2012. Behavioural adaptation as a consequence of extended use of low-speed backing aids. In: Sullman, M., Dorn, L. (Eds.), Advances in Traffic Psychology. Ashgate, Burlington, VT, pp. 285–294.

Rydstedt, L. W., Johansson, G., & Evans, G. W. (1998). A longitudinal study of workload, health and well-being among male and female urban bus drivers. *Journal of occupational and organizational psychology*, *71*(1), 35-45.

Saberi, H., Abbasian, H., Kashani, M.M., Esfahani, A.N. (2013). Post-traumatic stress disorder: a neglected health concern among commercial motor vehicle drivers. *Int. J. Occup. Environ. Med. (The IJOEM), 4*(4 October), 313-185-394.

Sabbagh-Ehrlich, S., Friedman, L., Richter, E.D., (2005). Working conditions and fatigue in professional truck drivers at Israeli ports. Inj. Prev. 11, 110–114.

Salminen, S., & Lähdeniemi, E. (2002). Risk factors in work-related traffic. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*(1), 77–86.

Sandin, J., (2009). An analysis of common patterns in aggregated causation charts from intersection crashes. *Accident Analysis & Prevention 41 (3)*, 624–632.

Sasai, S., Boly, M., Mensen, A., Tononi, G., (2016). Functional split brain in a driving/ listening paradigm. *Proc. Natl. Acad. Sci. 113 (50)*, 14444–14449.

Sayer, N.A., Noorbaloochi, S., Frazier, P., Carlson, K., Gravely, A., Murdoch, M., (2010). Reintegration problems and treatment interests among Iraq and Afghanistan combat veterans receiving VA medical care. Psychiatric Services 61 (6), 589–597.

Schendel, J. D., Shields, J. L., & Katz, M. S. (1978). *Retention of motor skills: Review* (Technical Paper 313). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Seeman TE, Singer BH, Rowe JW, Horwitz RI, McEwen BS. (1997). Price of adaptation — allostatic load and its health consequences. Arch Intern Med; 157:2259 – 68.

Seow, R. Y. T., Betts, S. A., and Anderson, J. R. (2021). A Decay-Based Account of Learning and Adaptation in Complex Skills. Journal of Experimental Psychology: Learning, Memory, and Cognition. 47(11), 1761–1791.

Shattell, M., Apostolopoulos, Y., Sönmez, S., Griffin, M., (2010). Occupational stressors and the mental health of truckers. Ment. Health Nurs. 31 (9), 561–568.

Shukri, M., Jones, F., Conner, M., 2021. Work-family conflict and dangerous driving behaviours: the mediating role of affect. Stress Health 37 (4), 669–681.

Sieber, W.K., Robinson, C.F., Birdsey, J., Chen, G.X., Hitchcock, E.M., Lincoln, J.E., Sweeney, M.H., (2014). Obesity and other risk factors: the National Survey of U.S. Long-Haul Truck Driver Health and Injury: long-haul Truck Driver Health Risk Factors. Am. J. Ind. Med. 57 (6), 615–626.

Shi, R., Sharpe, L., & Abbott, M. (2019). A meta-analysis of the relationship between anxiety and attentional control. *Clinical psychology review*, *72*, 101754.

Simon, M., Hermitte, T., Page, Y., (2009). Intersection road accident causation: a European view. Proceedings of 21st International Technical Conference on the Enhanced Safety of Vehicles 1–10.

Simmons, S. M., Hicks, A., & Caird, J. K. (2016). Safety-critical event risk associated with cell phone tasks as measured in naturalistic driving studies: A systematic review and meta-analysis. *Accident Analysis & Prevention*, *87*, 161-169.

Simmons, S. M., Caird, J. K., & Steel, P. (2017). A meta-analysis of in-vehicle and nomadic voice-recognition system interaction and driving performance. *Accident Analysis & Prevention*, *106*, 31-43.

Sluiter JK, Van der Beek AJ, Frings-Dresen MHW. (1999). The influence of work characteristics on the need for recovery and experienced health: a study on coach drivers. Ergonomics; 42:573 – 83.

Staubach, M., (2009). Factors correlated with traffic accidents as a basis for evaluating Advanced Driver Assistance Systems. *Accident Analysis & Prevention 41 (5)*, 1025–1033.

Strahan, C., Watson, B., & Lennonb, A. (2008). Can organisational safety climate and occupational stress predict work-related driver fatigue? *Transportation research part F: traffic psychology and behaviour*, *11*(6), 418-426.

Strayer, D. L., Drews, F. A., and Crouch, D. J. (2006). A comparison of the cell phone driver and the drunk driver. *Hum. Factors* 48, 381–391.

Strom, T.Q., Leskela, J., James, L.M., Thuras, P.D., Voller, E., Weigel, R., Yutsis, M., Khaylis, A., Lindberg, J., Holz, K.B., (2012). An exploratory examination of risk-taking behavior and PTSD symptom severity in a veteran sample. Mil. Med. 177 (4), 390–396.

Stutts, J. C., Reinfurt, D. W., Staplin, L., & Rodgman, E. A. (2001). *The role of driver distraction in traffic crashes.* Washington, DC: AAA Foundation of Traffic Safety.

Szollos, A. (2009). Toward a psychology of chronic time pressure: Conceptual and methodological review. Time & Society, 18, 332–350.

Taylor, A. H. & Dorn, L. (2006). Stress, fatigue, health, and risk of road traffic accidents among professional drivers: The contribution of physical inactivity. Annual Reviews of Public Health, *27,* 371-391.

Tessier, J.M., Whipple, E.K., Robinson, K.M., Schultheis, M.T., (2017). Driving-Related Coping Thoughts in Post-9/11 Combat Veterans with and without Comorbid PTSD and TBI. Federal Practitioner 34 (12), 20.

Theofilatos, A., Ziakopoulos, A., Papadimitriou, E., & Yannis, G. (2018). How many crashes are caused by driver interaction with passengers? A meta-analysis approach. *Journal of safety research*, *65*, 11-20.

Tse, J. L. M., Flin, R., & Mearns, K. (2006). Bus driver well-being review: 50 Years of research. Transportation Research Part F – Traffic Psychology and Behaviour, 9, 89–114.

Turgeman-Lupo, K., Biron, M., (2017). Make it to work (and back home) safely: the effect of psychological work stressors on employee behaviour while commuting by car. Eur. *J. Work Organ. Psychol.* 26 (2), 161–170.

Upahita, D. P., Wong, Y. D., & Lum, K. M. (2018). Effect of driving experience and driving inactivity on young driver's hazard mitigation skills. *Transportation research part F: traffic psychology and behaviour*, *59*, 286-297.

Upahita, D. P., Wong, Y. D., & Lum, K. M. (2018). Effect of driving inactivity on driver's lateral positioning control: A driving simulator study. *Transportation research part F: traffic psychology and behaviour*, *58*, 893-905.

van der Beek AJ, Meijman TF, Frings-Dresen MH, Kuiper JI, Kuiper S. (1995). Lorry drivers' work stress evaluated by catecholamines excreted in urine. *Occup. Environ. Med.* 52:464–69

Varela-Mata, V., Caddick, N., King, J.A., Johnson, V., Edwardson, C., Yates, T., Stensel, D.J., Daly, H., Nimmo, M. and Clemes, S. (2018). The Impact of a Novel Structured Health Intervention for Truckers (SHIFT) on physical activity and cardiometabolic risk factors. Journal of Occupational and Environmental Medicine, Vol. 60 No. 4, pp. 368-376.

Van Voorhees, E.E., Moore, D.A., Kimbrel, N.A., Dedert, E.A., Dillon, K.H., Elbogen, E.B., Calhoun, P.S., (2018). Association of posttraumatic stress disorder and traumatic brain injury with aggressive driving in Iraq and Afghanistan combat veterans. Rehabilitation Psychol. 63 (1), 160.

Vivoli G, Bergomi M, Rovesti S, Carrozzi G, Vezzosi A. (1993). Biochemical and haemodynamic indicators of stress in truck drivers. *Ergonomics* 36:1089–97.

Vlasblom, J. I., Pennings, H. J., van der Pal, J., & Oprins, E. A. (2020). Competence retention in safety-critical professions: A systematic literature review. Educational Research Review, 30, 100330.

Wells, A., & Matthews, G. (1996). Modelling cognition in emotional disorder: The S-REF model. *Behaviour research and therapy*, *34*(11-12), 881-888.

Westerman, S. J., & Haigney, D. (2000). Individual differences in driver stress, error and violation. Personality and Individual Differences, 29, 981-998.

Wick, D.T., Millard, S.L., Cross, K.D., (1986). Evaluation of a Revised Individual Ready Reserve (IRR) Aviator Training Program (No. ASI479-058-85). Anacapa Sciences Inc, Fort Rucker AL.

Wickens, C.D., Hollands, J.G., Bansbury, S., Parasuraman, R., (2013). Engineering Psychology and Human Performance, 4th ed. Pearson, Montréal.

Whipple, E.K., Schultheis, M.T., Robinson, K.M. (2016). Preliminary findings of a novel measure of driving behaviors in veterans with comorbid TBI and PTSD. J. Rehabil. Res. Dev. 53 (6), 827–838.

Williams Jr., D.F., Thomas, S.P., Liao-Troth, S., (2017). The truck driver experience: identifying psychological stressors from the voice of the driver. Transport. J. 56 (1), 54–76.

Wills, A., Watson, B., & Biggs, H. (2006). Comparing safety climate factors as predictors of work-related driving behaviour. Journal of Safety Research, 37, 375–383.

Wong, I. Y., Mahar, D., & Titchener, K. (2015). Driven by distraction: Investigating the effects of anxiety on driving performance using the Attentional Control Theory. *Journal of Risk Research*, *18*(10), 1293-1306.

Wu, J., Yan, X., Radwan, E., (2016). Discrepancy analysis of driving performance of taxi drivers and non-professional drivers for red-light running violation and crash avoidance at intersections. *Accid. Anal. Prev. 91*, 1–9.

Wu, J., & Xu, H. (2018). The influence of road familiarity on distracted driving activities and driving operation using naturalistic driving study data. Transportation Research Part F: Traffic Psychology and Behaviour, 52, 75–85.

Yanko, M. R., & Spalek, T. M. (2013). Route familiarity breeds inattention: A driving simulator study. Accident Analysis & Prevention, 57, 80–86.

Young, K. L., & Salmon, P. M. (2012). Examining the relationship between driver distraction and driving errors: A discussion of theory, studies, and methods. *Safety science*, *50*(2), 165-174.

Zhang, W., Wang, Y., Feng, Z., Zhu, C., Cui, J., Hao, W., and Wang, C. (2022). A method to improve the hazard perception of young novice drivers based on Bandura's observational learning theory: Supplement to expert commentary training, Transportation Research Part F: Traffic Psychology and Behaviour, 85, 133-149.

Zinzow, H.M., Brooks, J., Stern, E.B. (2013). Driving-related anxiety in recently deployed service members: Cues, mental health correlates, and help-seeking behavior. *Military Med. 178*(3), e357-e361.

Zohar, D., (2010). Thirty years of safety climate research: reflections and future directions. Accid. Anal. Prev. 42, 1517–1