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Causes, consequences and countermeasures to driver fatigue in the rail industry: The train driver perspective

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Abstract

Fatigue is an important workplace risk management issue. Within the rail industry, the passing of a stop signal (signal passed at danger; SPAD) is considered to be one of the most major safety breaches which can occur. Train drivers are very aware of the negative consequences associated with a SPAD. Therefore, SPADs provide a practical and applied safety relevant context within which to structure a discussion on fatigue. Focus groups discussing contributing factors to SPADs were undertaken at eight passenger rail organisations across Australia and New Zealand (n = 28 drivers). Data relating to fatigue was extracted and inductively analysed identifying three themes: causes, consequences, and countermeasures (to fatigue). Drivers experienced negative consequences of fatigue, despite existing countermeasures to mitigate it. Organisational culture was a barrier to effective fatigue management. A fatigue assessment tool consistently informed rostering, however, shift swapping was commonplace and often unregulated, reducing any potential positive impact. In discussing fatigue countermeasure strategies, drivers talked interchangeably about mitigating task related fatigue (e.g. increasing cognitive load) and sleepiness (e.g. caffeine). Ensuring the concepts of fatigue and sleepiness are properly understood has the potential to maximise safety.

Keywords train driving, rail safety, sleep, fatigue

1 Introduction

Fatigue is an important and unique issue for workplace risk management, influenced by both work-related and non work-related factors (Gander *et al.* 2011). Although the implications for fatigue in transport are well documented, there is a deficit of fatigue research in rail compared with road and aviation (Phillips 2014, Anund *et al.* 2015). In the US for example, the risk of a human factors accident is elevated 11-65 percent above chance by exposure to fatigue, and the economic cost of an accident when an employee is fatigued is ~\$1.5M compared to \$400k in the absence of it (Gertler, DiFiore & Raslear, 2012).

As with many other forms of passenger transportation, rail safety relies on the actions and vigilance of one individual to safely transport passengers. However, the actions and vigilance of that individual do not occur in isolation. Instead they are highly influenced and shaped by the sociotechnical system within which the driver operates. For example, management decisions such as the length of work shifts impact a driver's alertness and ability to maintain vigilance. Furthermore, vehicle dynamics also contribute to drivers' actions. In comparison to other land-based transport modes (e.g. road) train manoeuvrability is restricted. The weight, forward momentum and stopping distances of a train require drivers to perform actions well in advance of a desired response. For example, when approaching a speed change, a train driver would typically brake much earlier than when they see the sign. Within Australia and New Zealand there is minimal automation of train driving operations, thus safe driving relies on prior route knowledge, in order for action to be taken before seeing the specific hazard (Naweed *et al.* 2013).

Train driving requires high levels of mental effort and maintained concentration over long periods (Phillips and Sagberg 2010), but the task is also interspersed with similarly long but highly monotonous sections of track with minimal driver input. Such task features represent a high risk for fatigue as the monotonous sections required sustained vigilance, which does not allow for recovery (Dunn and Williamson 2012), thereby lowering alertness and reducing the ability to react (Larue *et al.* 2011). Furthermore, train drivers are shift workers, which create additional implications for

fatigue resulting from sleep loss and disrupted sleep pattern (Åkerstedt 1991). Within Australia, rail operators are required to have a fatigue safety management programme (National Rail Safety Regulator 2014). A common strategy is to use tools based on biomathematical models to assess fatigue when developing rosters, which give scores to identify if a particular shift pattern is likely to induce excessive fatigue. Rosters with high fatigue scores are avoided. In the US, the Fatigue Avoidance Scheduling Tool (FAST) is used to assess fatigue, and in Australia, Fatigue Audit InterDyne FAID is the commercial assessment tool most commonly used by rail operators. However, the efficacy of such shift modelling systems has been questioned due to a lack of controlled intervention studies (Anund *et al.* 2015).

The aviation industry has published fatigue guidance for pilots, and tips and tools for fatigue and sleep management in the air traffic control environment (e.g. Eurocontrol 2005), some of which are even described as “a little eccentric” (p.3). While rail collision avoidance has much in common with the piloting task in the aviation domain, the driving task itself is a closer parallel to trucking. Both are surface transportation modes and both truck and train drivers are required to control relatively long and heavy, articulated vehicles; in Australia, heavy haul trains in the Pilbara region are routinely more than 3 km in length, whilst country “road trains” comprising a prime mover and three semi-trailers are among the longest trucks in the world. The drivers in each mode are also required to maintain sustained attention for prolonged periods of time, a task known to induce fatigue (Williamson *et al.* 2011). Lastly, both truck and train drivers are subject to shift work and/or long shifts. The subsequent lack of sleep is known to impact on performance. Both time on task fatigue and sleepiness due to lack of sleep have been reported as causal factors for truck crashes. Fatigued truck drivers who have crashed can be described in two distinct groups: those with regular sleep/wake patterns who become fatigued while working, and those with irregular sleep patterns who arrive at work fatigued (Young and Hashemi 1996). The commonalities in shift work between road and rail suggest that train drivers may be subject to the same vulnerabilities. In particular,

reduced period of time between shifts has been shown to reduce the amount of sleep that drivers obtain (Kecklund *et al.* 2003, Kandelaars *et al.* 2005).

Another factor which is likely to influence both train and truck drivers is obstructive sleep apnoea (OSA). This sleep disorder is common in those with a sedentary lifestyle. For truck drivers the presence of OSA is reportedly associated with a 30% increase in crash risk (Howard *et al.* 2004). While similar research has not been identified for train drivers, the prevalence of OSA within the driving population is likely to have an impact on fatigue-related safety critical events.

While inferences can be drawn from the commonalities between road and rail transport, there are some clear differences between the truck and rail industry which can limit the relevance of findings. For example, within Australia the long distance trucking industry is subject to prescriptive maximum driving and shift times. This requires drivers to take regular breaks and not to exceed maximum work hours within a set period. In contrast, the rail industry does not universally mandate such prescriptive rules surrounding hours of service (Anderson *et al.* 2013). Furthermore, not all the countermeasures to fatigue which truck drivers can use are available to train drivers. For example, a recognised effective countermeasure to sleepiness is to stop driving and have a nap (Horne and Reyner 1996). This option is more achievable for truck drivers who have greater control over their journey plan and may be able to pull over in a rest area if needed. Differences between transport modes highlight the importance of considering fatigue within the rail context.

As a ubiquitous rail Work Health & Safety issue, fatigue management is a key topic in Industry Standards and Guidelines. As an example, the Rail Safety and Standards Board (2012) has produced a comprehensive Good Practice Guide, in order to assist the industry in understanding and complying with their duties, and the UK Office of the Rail Regulator (2011) also has a companion guidance document on managing fatigue. The primary role of these documents is to guide how substantive elements of safety management systems are designed and to provide a knowledgebase for specialist functions (e.g. roster designers, trainers). However, they reflect a rail industry that has

differing characteristics to Australia, which has different states and different railways. While the US has railways that are much closer to Australia in both design and operation, like the UK industry guidelines, their documents do not capture any of the non-compliance or “unpublished” strategies that drivers may adopt to manage risk but not report for fear of disciplinary action. These are likely to be idiosyncratic to the specific contexts (i.e. Australian rail), thus to capture this data, and gain a rich understanding of how fatigue risk and sleepiness is actually managed at the end-user level, the driver perspective is needed.

1.1 Using SPADs to structure a discussion on fatigue

One of the largest safety breaches in rail occurs when a train passes a stop signal (signal passed at danger; SPAD) and moves into a section of track where it has no authority. A SPAD is considered to have happened regardless of how far the train has exceeded the signal; this includes completely failing to adhere to the signal as well as overshooting by a metre. The Australian and New Zealand rail industries have both experienced a steady increase in SPAD frequency over the last decade (Naweed *et al.* 2015a), and as a result, there is very heavy industry focus to implement strategies to mitigate SPAD occurrence. This includes national SPAD Mitigation Working Groups (Australasian Railway Association 2016) and annual SPAD conferences and forums (e.g. Metro Trains Melbourne, 2015). Technologies intended to stop the train in the event that the driver is incapacitated, and increase their awareness of signal state and thereby reduce SPAD occurrence already exist. These include the Vigilance System (also known as the “Dead Man”), which requires immediate response (pressing a button) after prolonged inactivity, and the Automatic Warning System (AWS), which requires response to upcoming caution and warning signals. Both of these activities further add to the task load of the driver. All Australian and New Zealand passenger operators use one or both of these systems as prospective SPAD mitigation systems (Naweed 2015a), working on the premise that an alert driver will be able to cancel the alarm, and therefore, reduce SPAD risk. SPADs are a highly taboo topic in the rail industry and a dominant feature in rail-oriented research (Naweed 2015a) but the influence of fatigue on SPADs is under investigated.

Consequently, train drivers are very aware of SPADs as a safety critical event. This provides a specific context within which to evaluate train driver perspective on safety, including fatigue.

In the future, automation in train driving is likely to increase and lead to more hybrid driver-train systems, with corresponding increases in the potential for task-induced fatigue. However, the shift-working model is likely to remain, and continue to cause circadian and sleep pattern interruption (Åkerstedt 1991). Ensuring that fatigue and sleepiness concepts are properly understood could be a first step to informing specific interventions to reduce driver fatigue and sleepiness. Research related to fatigue has examined the effects of work rosters (Howard and Tepas 2001) and used observation and self-report to study the effect of journey times greater than six hours (Gouin *et al.* 2001). However the effects of fatigue and shift rosters on performance in rail is an area that has been identified as still needing research contribution (Wilson and Norris 2005). Recent fatigue-related rail research has shifted its focus to understand sleep quality and quantity in naturalistic settings e.g. (Jay *et al.* 2006, Dorrian *et al.* 2011) or train handling impairment in naturalistic and simulator protocols e.g. (Dorrian *et al.* 2006, Dorrian *et al.* 2007). This research has focused on safe driving performance and demonstrated that fatigued drivers are an economic burden as they have higher rates of fuel consumption.

Little is known about the impact of fatigue on unsafe train driving events such as SPADs but it is likely that fatigued drivers will be at increased risk of a SPAD, particularly if an increase in sleepiness is experienced coinciding with the presence of a signal. For example, it is known that fatigue increases the predisposition of drivers to distraction (Anderson and Horne 2006) and distracted train drivers may for example miss the presence of a stop sign. Fatigue also impairs decision making (Harrison and Horne 2000) which is a vital component of safe train driving. The slow response of a moving train to driver control input means that decisions about stopping must be made early in order to halt a train prior to a stop sign. As a demonstration of this, Torsvall and Åkerstedt (1987) note that when monitoring 11 train drivers using physiological measurements during a one day and one night journey, two drivers failed to act on a signal during night driving.

Closer inspection of the physiological measures for one driver at the time the signal was not responded to demonstrate that the driver's eyes were rolling and electroencephalography (EEG) showed bursts of alpha activity which is a clear sign of sleepiness. This pattern was reported to continue for a period of 20 seconds during which the signal was missed before normal waking EEG and electrooculography (EOG) patterns resumed.

Driver fatigue has the potential to influence SPADs, however, there has been little research specifically focusing on this issue. Furthermore, although the causes of SPADs are a common consideration for rail research, the driver's perspective is rarely sought. To ensure active uptake of any strategies for improving fatigue and SPAD management, it is necessary for them to be acceptable for the end-user. It should also be noted that there is a lack of consistency in how the term fatigue is practically operationalised (Phillips 2015). The situation is further complicated by a lack of quantification of when fatigue and/or sleepiness become safety critical (Van Dongen and Hursh 2010). The current work focuses on train driver's perspective of fatigue and therefore a broad definition was adopted in order to encapsulate any aspect which they felt was of influence to a SPAD, arguably the most safety critical event faced by the rail industry. Fatigue was considered to include the inability to continue or the impairment of performance at an activity because it has been going on too long (Bartley and Chute 1947) as well as sleepiness, a physiological urge to fall asleep resulting from sleep loss or circadian effects (Dement and Carskadon 1982). The aim of the current study was to understand more about fatigue and its relationship with SPADs from the drivers' perspective in order to direct future research. The objectives to achieve this were (1) collect and transcribe focus group discussions with drivers about SPADs (2) use a thematic approach to identify factors associated with fatigue.

2 Method

2.1 Study Design

This paper reports a specialised analysis of existing focus group data, concentrating on the contribution of fatigue to SPADs from the driver's perspective. Fatigue was one-third of the key non-technical human-factors dimensions that were covered in the larger dataset, the others being distraction and time pressure. The overall findings of the focus group (not specific to fatigue) are presented by Naweed (2013) and Naweed et al., (2015a,b).

The data were collected using a qualitative research technique employing standard semi-structured focus group methodology (Kreuger 1994, Morgan 1997) to elicit train drivers' views (i.e. on fatigue and its relationship with SPADs). This was selected over the use of formal epidemiologic survey methods because it: (1) allowed the investigation and analysis of a broader array of possible topics, in this case those that were fatigue-related; (2) provided a semi-structured format for obtaining input directly from the train drivers themselves; and (3) permitted the detection of heretofore unexpected themes, whereas a predefined questionnaire is limited to evaluating those areas explicitly included in the questionnaire. The focus groups process was used as a primer for the Scenario Invention Task (Naweed 2012, 2013, 2015a,b), a creative pen-paper drawing task based on Checkland's (1980) "Rich Pictures" approach to help access knowledge. An example scenario collected during the study is shown in Figure 1. The task, introduced halfway into the overall procedure, articulated this knowledge by externalising drivers' mental representation of SPADs and drawing on their relationship with fatigue. Since Checkland's work, various interpretations of this approach have been validated by other studies as a way of assembling relevant information, capturing relationships and reflecting knowledge (e.g. Aginsky *et al.* 1997).

Eight focus groups were undertaken with train drivers from eight different passenger train operators in Australia and New Zealand. A focus group was facilitated with drivers in each organisation by the same researcher and the aim was to discuss a variety of risk factors that contributed towards SPADs, of which fatigue was a key dimension of consideration. Prior to each

focus group, informal unstructured observations of driving were undertaken in each organisation. Like the US, Australia has a differing states and differing railways, thus the observations were used to gain familiarity with each network, and gain first-hand experience of the signalling convention and various systems used in each environment, and this was subsequently used to inform the protocol.

Figure 1 - Example data from the scenario invention task. Scenario depicts a SPAD occurrence arising from a combination of an inactive AWS system and manifest fatigue.

2.2 Procedure

During each focus group, the researcher posed a series of general questions covering general driving experience, understanding of different types of SPAD, individual perspectives about the equipment used to prevent SPADs, personal approaches for SPAD mitigation, drivers relationship with signals, and broader areas of potential improvement (Naweed 2013, Naweed et al., 2015a). All focus groups were asked two questions about fatigue as part of these general questions: *“How much do you think fatigue contribute towards SPADs?”* and, *“What do you do if you feel fatigued?”*.

During the pen-paper task, probe questions were posed about each SPAD scenario to clarify the sequence of events, relationships with the contributing factors, and understand how they would affect the outcome. A further question was asked associated with fatigue: *“What if the driver was*

fatigued - how would that change the scenario/driver's experience of the event?" This was further supplemented by any additional mention of fatigue in response to other probes, for example: "What if this scenario happened at night? Will that change the features of the scenario, and if so how?" The in-depth discussion that followed identified specific risks and then considered potential mitigating factors, providing a rich data source on train driver's perspective of fatigue and understanding of sleepiness. Table 1 shows an overview of the focus group protocol with example questions. Each focus group lasted approximately 120 minutes.

Table 1 – Overview of the focus group protocol (adapted from Naweed et al., 2015a).

Class of question	Example content	Example question
Ice breakers	General experience, Organisational issues	How does your organisation react to a SPAD?
Prospective causation	Distraction, time pressure, fatigue	How much do you think fatigue contributes to the risk of a SPAD? What do you if you feel fatigued?
Task Influence	Service delivery	How much does the timetable influence the way you drive?
Equipment design	Interface, safety systems	How effective do you think AWS is for preventing a SPAD?
SPAD-scenario generation	Create scenario	Invent a challenging SPAD Scenario
	Probes: Influencing factors	What if the driver was fatigued? How would that change the scenario/driver's experience of the event?
	Probes: Countermeasures	What strategies have you developed to help you stop at a signal?
Broader issues	Areas of improvement	How could a driver be better prepared for a SPAD event?

2.3 Participants

One focus group was conducted per organisation and between three and four drivers participated in each group. Each focus group typically included a new train driver (≤ 1 year experience) and two to three experienced drivers (≥ 10 years' experience). There were 28 participants (26 male; *mean age* = 45.67 years, *SD* = 8.52) in total. Twenty-two participants were from Australia and eight from New Zealand. The majority (78.6%) of participants had ≥ 10 years' train driving experience. Focus groups

were conducted within the organisations to facilitate access and allow scheduling into work rosters, however, participation was voluntary and all participants gave informed written consent. This study was approved by the Central Queensland University ethics committee.

2.4 Data analysis

The dialogue from each focus group was transcribed verbatim, de-identified, and coded in three stages of qualitative thematic data analysis: (1) open coding; (2) axial coding; (3) and selective coding (Auerbach and Silverstein 2003, Saldana 2009). Given the size and richness of the dataset, these three stages of analysis created a more robust process, ensuring all data were captured and considered during analysis.

The first stage (open coding) identified units of information that addressed the research aims. This was facilitated by in-text searches conducted for words related to fatigue, such as “fatigue”, “sleep”, “tired”, “monotonous”, “night”, “FAID.” Dialogue surrounding these words was isolated and sections of relevant text spanned from the first mention of the topic (usually by the researcher) until the first mention of a different topic. Text for analysis was not limited to direct responses to the fatigue questions. In the second stage (axial coding), the researcher organised these units into categories consistent with the research aims and links between categories were sought and subcategories were identified. Each category was considered in relation to sleepiness caused by sleep loss and/or circadian influence and fatigue caused by the nature of the task. In the third stage (selective coding), these categories were classified and divided into meaningful subcategories that resonated with pre-established constructs derived from fatigue risk management theory and the Australian passenger train-driving context and the core themes were subsequently identified. Note that axial coding was a critical step for relating categories and concepts with one another and refining the categories. Analysis was carried out using NVivo (Ver. 10, QSR) software and by two researchers; one researcher carried out the open coding stage and both were involved in the analysis for axial and selective coding.

3 Results

Fatigue was discussed in every focus group. Discussions were initiated by the facilitator in the context of fatigue's contribution towards SPADs. Drivers dialogue often expanded to included suggestions of why they experience fatigue, how fatigue impacted their work and what they did to mitigate its effects. Three overarching themes pertaining to fatigue were identified: (1) causes, (2) consequences, and (3) countermeasures.

3.1 Causes

The causes of driver fatigue are presented in Table 2. Overall 9 subcategories of causes of fatigue were identified.

Table 2 – Causes of driver fatigue

Causes
Difficulty getting to sleep
<i>Hard to sleep on days off</i>
<i>Hard to sleep in the daytime</i>
<i>Family influences sleep</i>
<i>Difficulties maintaining sleep at night</i>
Shift work
<i>Adaptation to new shift times</i>
<i>Individual differences in ability to cope with shifts</i>
<i>Shift work inherently makes you tired</i>
<i>Time of the day</i>
Motivation of drivers to engage in excess work when fatigued
<i>Need the money</i>
<i>You should phone in sick if fatigued but might not if need the money</i>
<i>Shift swapping in a regular pattern suggests a second job</i>
Not providing enough opportunity for recovery
<i>Inadequate time off between shifts</i>
<i>To many shifts in a row</i>
<i>Inadequate breaks between trains</i>
<i>Overtime</i>
Too much for drivers to do
<i>Additional duties increase fatigue (e.g. wheelchair assistance)</i>
<i>Trains stopping at all stations makes you more tired</i>
Freight compared to passenger trains
<i>Predominantly night work</i>
Organisational factors
<i>Lack of routine</i>
<i>Inconsistency in managing shift swapping</i>
<i>Staffing issues</i>

Long shifts

Long driving time

Limitations of the fatigue assessment tool

Fatigue assessment tool doesn't work

New rosters should be tested but not on operational drivers

New rosters are not always better

Poor management decision

*Management doesn't understand the amount of fatigue drivers experience,
many have never been train drivers themselves*

Managers just want the train driven and don't care about fatigue

Managers themselves do not like the fatigue assessment tool.

All but one focus group identified organisational factors which were causing fatigue. In particular, inconsistency in the management of shift swapping was frequently discussed. Despite the common practice for rosters being informed by a fatigue assessment tool, almost all organisations allowed informal shift swapping between drivers, with one driver commenting “you can just do whatever as long as the job runs.” Formal checking of shift swapping against the fatigue assessment tool was only noted in one focus group, during which a driver commented that “you put a form in and they check your fatigue score and length of shift”. Limitations of the fatigue model itself were also identified as a cause of fatigue. Drivers did not believe the model worked. In their opinion, the imposed requirements did not reflect their individual experience of the fatigue resulting from various shift patterns. One driver raised concern that fatigue models present ideas for new rosters but particular shift patterns are not tested before implementation

While fatigue assessment should control for adequate breaks between shifts, participants reported that taking overtime meant there was inadequate time to recover which is not monitored by the employer. For example, one driver commented “They’re not looking at how much time I’m having off to make sure – all they’re concerned about is [...] we need a driver to cover each day off, [Driver 1] will work on his day off [...] they should be monitoring that more closely”.

Some of the difficulties with fatigue were considered to be directly related to shift work. The individual difference in response to shift work was noted. Drivers observed that shifts they personally found fatiguing did not necessarily have the same effect on others.

Six of the eight focus groups discussed lack of recovery time between shifts as a cause of fatigue. One focus group raised concerns that “a lot of jobs are pushed right out to almost 9 hours” resulting in an expansion of actual driving time from 4-5 hours to 6-6.5hours. The motivation for drivers to engage in excess work emerged as an independent factor leading to drivers taking on many shifts. Numerous drivers indicated that they agreed to do overtime, in spite of recognising that they were fatigued, suggesting that the motivation for income eclipsed concerns for safety. In one case it was discussed that managers actively offered overtime to those who needed the money rather than considering fitness for duty.

3.2 Consequences

The consequences arising from driver fatigue are presented in Table 3. Overall, 5 separate categories were identified (SPADs, distraction, cognitive impairment, organisation culture, and trains running late). The primary purpose of the focus groups was to discuss factors which contribute towards SPADs, therefore, it is to be expected that SPADs were recognised as a consequence for fatigue.

Table 3 – Consequences arising from driver fatigue

Consequences
SPADs
<i>Drivers report falling asleep while driving (even if there are two drivers)</i>
<i>Vigilance control test can be passed even when asleep (automated behaviour)</i>
Distraction (including internal)
<i>Worry about driving tired</i>
<i>Fatigue makes distraction worse</i>
Cognitive impairment
<i>Being tired impairs judgement</i>
<i>Inattention – lack of concentration</i>
Reactive organisation culture
<i>Drivers are scared to report fatigue as it will result in a medical assessment</i>
<i>If drivers have a SPAD they won't say if they didn't get much sleep before</i>
Trains running late
<i>Drivers reprioritising goals – driving slower when fatigued</i>

Five groups demonstrated strong insight into their fatigue reporting both distraction and cognitive impairments as specific problems which result from fatigue.

Most participants were aware of the dangers of driving when fatigued, yet half of the groups had discussions about a reactive culture resulting from the presence of fatigue. Participants stressed that any mention of the word “fatigue” was considered taboo, and a highly reactive organisational culture of fear had developed around the issue. Under these circumstances, the participants from these groups said they were fearful of reporting fatigue to managers. For example:

“Driver 1: And if you report that you’re sort of like fatigued and if you do that a couple of times then they’re sending you for a medical, basically. It triggers a medical, so you know?”

Driver 2: They don’t realise actually, we can get tired doing shifts – they don’t realise it.”

Overall, participants were aware that fatigue had negative safety consequences, including SPADs. One participant recounted a time that he himself had fallen asleep while driving in a previous job, “I’ve woken up coming down through [Location X] one day [on a] train looked over my [co-driver] and we’re both asleep”.

3.3 Countermeasures

The countermeasures used to manage driver fatigue or mitigate its effects are presented in Table 4. Overall, 2 categories were identified (managing fatigue prior to work and when experiencing fatigue during work activities); each of these had two sub categories with further layers of sub-coding. While drivers were asked to specifically consider SPADs, the dialogue broadened to include approaches beyond those explicitly related to SPADs once they started to discuss fatigue mitigation..

Table 4 – Countermeasures to driver fatigue

Countermeasures	
For managing fatigue-prior to experiencing fatigue	<p>Suggestion to use preferential roster system <i>Drivers should be able to choose the shifts they want</i></p> <p>Adequate employer fatigue management <i>Some employers do not provide enough recovery time between shifts</i></p> <p>System regulation</p> <p>Education <i>Training courses about sleep for new drivers</i></p> <p>Fatigue management <i>Fatigue is managed centrally through fatigue scores from the roster</i></p>
	<p>Shift management <i>I can choose a good shift for me</i> <i>Day shifts are busier than evening shifts</i></p> <p>Sleep management <i>Planned split sleep to fit with shift pattern</i> <i>Get a good night's sleep before work</i></p> <p>Self-regulation</p> <p>Environment regulation <i>Don't use the heater as this puts you to sleep</i> <i>Don't listen to music as this puts you to sleep</i></p> <p>Attitudinal factors <i>I don't get sleepy</i> <i>I have gotten used to shift work</i></p>
When experiencing fatigue during work activities	<p>Biomechanical <i>Stand up</i> <i>Kneel on seat</i></p> <p>Biochemical <i>Drink energy drinks</i> <i>Drink coffee</i> <i>Smoke</i> <i>Drink water</i></p> <p>During train driving</p> <p>Environmental regulation <i>Cold air (via air conditioner)</i> <i>Talk to people (e.g. train guard)</i> <i>Splash water on face</i></p> <p>Goal prioritisation <i>Drive slower if tired</i> <i>Fatigue management is more important than time tables</i></p>
	<p>Biomechanical <i>Go for a walk at the station</i> <i>Get some (fresh) air by walking at the station</i></p> <p>Before or after train driving</p> <p>Restricted sleep recovery <i>Have a power nap at the station</i></p> <p>Unrestricted sleep recovery <i>Phone in sick when fatigued</i></p>

All focus groups discussed countermeasures. Factors which were pre-emptive countermeasures employed prior to the point of actually experiencing fatigue formed two distinct groups: system regulation, which were formal strategies put in place by the organisation, and self-regulation which were instigated by individuals and encompassed formal strategies recommended by the organisation and informal strategies employed by the drivers themselves. Self-regulation was discussed by more focus groups (six) than system regulation (four), hinting at a culture where drivers managed their own fatigue in addition to any reliance they had on organisational control. One participant felt that they did not have to worry about managing their fatigue on the basis of the perception that fatigue was being centrally regulated, meaning that if the roster said there was no fatigue risk, then it was fine.

When participants were asked what they would do if they felt fatigued, the largest range of countermeasures were situated at the time of actually experiencing fatigue and implemented while driving. This included physically changing position, consuming alerting substances, and manipulating the environment. For example, one driver commented, “another good thing I do, actually stand up and drive and you’re not supposed to, but it’s that or [a SPAD]...” When talking about coffee one driver commented “I don’t normally drink coffee, only when I’m on shifts [at 4am] I’ll have a coffee [...] and that will do the desired effect to keep me awake.” In contrast, talking to people was a preference reported by one driver “I like people [in the cab]. It keeps me focussed, I’m able to have a talk and do the job where if I’m on my own I think a lot and you start staring, you know, you get fatigued a bit”. One participant reported reprioritising their goals by driving at a slower speed when tired: “To me, after the fourth train, if I’ve got to do another train and I’m tired, guess what? The old speed limit comes down because, fatigue management is better than running a ‘stick’” (i.e. a stop signal).

Before or after driving the train, countermeasures were predominantly implemented while the train was stopped at stations. For example one driver reported, “... give the Guard two bells on a

platform and go and walk up, say hello to him and walk back.” For one participant at station, countermeasures included taking a “powernap.” Participants in three focus groups discussed the longer-term strategy to phone in sick when fatigued, although, drivers said they would not report “fatigue” as the actual reason because of the organisational culture around fatigue.

4 Discussion

The current study demonstrates that train drivers perceive fatigue to be associated with SPAD risk. Drivers were asked to discuss SPAD scenarios in each focus group and fatigue was unanimously perceived as a potential contributor. This topic of fatigue was either independently mentioned by the drivers or if not, raised by the facilitator. Consistent with the aims of the study SPADs were used as a central focus for discussions, not only because they represented an important safety issue within the rail industry, but also because they were a topic which all drivers would be familiar with. Providing a safety critical event as a focal point allowed drivers to consider fatigue within a specific context. It emerged that, both the “SPAD” and the “fatigue” rhetoric in the Australian and New Zealand rail industries are taboo and underpinned by fear, evidencing issues with organisational culture that is industry wide. The fear culture associated with these issues is not specific to Australia and can have the effect of creating a negative safety culture that impedes the development of a good reporting culture. A number of the presiding views held by drivers raised concerns (e.g. the belief that fatigue is centrally regulated), which had the effect of driving problems and counterintuitive thinking within the driving culture. Given that the data were contextualised on the risks and mitigating factors around SPADs, corresponding findings were concentrated around causes and countermeasures to fatigue. However, whilst the purpose of the focus groups was to discuss any factors that contributed to SPADs, substantial amounts of information could be identified specifically about fatigue. This directly supports the observation of Torsvall and Akerstedt (1987) who noted two train drivers failing to respond to signals while showing physiological signs of sleep. In many cases conversation about the consequences of fatigue expanded beyond the specific occurrence of SPADs, demonstrating implications for working practice more generally. Drivers could identify a range of

situational factors which led them to become fatigued and sleepy and employed a range of strategies for managing both.

4.1 Causes

Inconsistent management of shift swapping was the most commonly discussed cause of fatigue. Having a casual approach to shift swapping undermines the fatigue model within the assessment tool; that is it does not matter how good the assessment tool is if it is not being updated with when drivers are actually working. The culture of shift swapping also creates a contradictory message to drivers (i.e. the fatigue assessment tool is important and must be followed but shifts can be swapped). This may have influenced the perception that managers do not believe the fatigue assessment tool works.

Even if the ideal shift model were followed, drivers demonstrated a lack in confidence of the shift modelling software believing this to be one cause of fatigue. This problem is not unique to Australian rail; for example, good practice around shift swapping feature in UK fatigue guidelines (Rail Safety and Standards Board, 2012) as a factor that should be considered when assessing fatigue risks. This is achieved by gaining feedback from staff on how shift swapping is controlled and by determining how much control staff has over shifts that are worked (p. 33). The problem is however, also not unique to rail; universally, there is a deficit of controlled intervention studies on shift systems (Anund *et al.* 2015). Therefore the scientific basis for any schedule recommendation is limited. A further limitation is that the rosters themselves are designed around the minimum and maximum break times between shifts, but the amount of actual sleep obtained can never be controlled, which is a known limitation of fatigue modelling (Darwent *et al.* 2015). For example, the current study identified that social life, friends, and family pressures influence sleep, which are all factors outside of organisational control. Within aviation, guidelines suggest that employees should plan their personal schedules to preserve regular sleep patterns even on days off (Eurocontrol 2005). In contrast, the culture of shift swapping is a fatigue causal factor and for the most part, within

organisational control. It may be most appropriate to prioritise future strategies to reduce fatigue towards those causal factors within organisational control.

The length of rail industry shifts has been a topic of recent discussion within Australia (Anderson *et al.* 2013, Dawson 2013). The data showed large inconsistencies between Australian states, with many states allowing industry self-regulation of fatigue management which do not impose a maximum shift length, whilst others impose strict work/rest guidelines. The identified concern for a 9h work time adds weight to the argument that 12h work shift may be excessive. The strong evidence for human performance deterioration when working more than 12 hours is recognised by the UK Office of Rail Regulation (2011). This information is provided in UK guidance documents for use by the rail industry. Positively it appears that even without mandated maximum shift length regulation, no focus group reported problem >12h shifts, the recommended shift duration limit (Anderson *et al.* 2013). In part the ability to cope with shift work is also influenced by individual differences. This was noted by drivers who observed that some people were better able to cope with particular shifts than others. This is not surprising, as there is inter-individual variability in response to sleep loss (Van Dongen *et al.* 2007). This topic was also apparent in countermeasures where drivers from three focus groups reported purposely swapping shifts to create a shift pattern that they felt to be less fatiguing for them.

In addition to the shifts themselves, drivers also considered lack of recovery time between shifts to be a cause of fatigue. Previous rail research has demonstrated that significantly more sleep is obtained following longer (48h+) breaks than shorter breaks (Kandelaars *et al.* 2005). The authors posit that the extended break allows workers more time with family and friends without sacrificing their sleep. Similarly, this is recognised in UK rail guidance where the problems of consecutive shifts are highlighted (Office of the Rail Regulation 2011). The data revealed a culture of unmonitored overtime, exacerbating the problem of inadequate time to recover. At the extreme, one focus group discussed being able to work up to 13 days in every 14. This practice directly contradicts research

recommendations which note that these type of “compressed work periods” should be avoided (Kecklund *et al.* 2003).

4.2 Consequences

Several groups showed good insight into fatigue consequences including distraction and cognitive impairment. Recognising the interaction between fatigue and distraction is particularly important given that distraction is considered by drivers to be the leading SPAD risk (Naweed 2013). The aggregate consequence of fatigue and distraction has previously been demonstrated in car driving (Anderson and Horne 2006) but no similar empirical data is available for rail. Furthermore, cognitive impairment is recognised as a consequence of sleep deprivation, particularly in regards to decision making (Harrison and Horne 2000) so it is understandable that participants indicated they were experiencing these consequences. It may be beneficial for formal guidelines to identify the impact of fatigue on performance. For example, within aviation, European guidelines inform employees that fatigue increases reaction time, reduces attention, diminishes memory and results in withdrawn mood (Eurocontrol 2005).

For drivers one of the most feared practical outcomes of reporting fatigue was for managers to require a mandatory medical assessment. A medical assessment was perceived as a threat to job security. Despite concern that managers may send them for a medical, participants did not talk about sleep disorders as a reason for fatigue. This may represent a lack of understanding of the prevalence and potential consequences of sleep disorders. Participants also reported fatigue implications for SPADs to be underreported because if a SPAD did occur, they would not be willing to tell an investigator that they had had little sleep. The culture of not wanting to be seen as fatigued, or even mentioning the word for fear of its personal implication is a concern as it would likely lead to drivers not reporting genuine problems. Guidelines for the UK rail industry suggest that good practice in fatigue management includes encouraging employees to talk about their fatigue and what causes it both with each other and managers (Rail Safety and Standards Board, 2012). Instilling

an open culture on the issue of fatigue is likely to facilitate early identification before it becomes a safety critical issue.

Only one participant in the current study reported having fallen asleep while driving. However, it is likely that other drivers may have had micro sleeps while driving as objective polysomnography recordings of train drivers at work has demonstrated that sleep episodes frequently occur (Torsvall and Åkerstedt 1987).

4.3 Countermeasures

The very existence of a consequences theme points to potential failures in current fatigue countermeasures. Given the subjective and nuanced nature of the countermeasures identified in the studies and the lack of previous research revealing these kinds of data, these findings were largely specific to the Australian rail context. There was evidence of a reporting culture hindered by perceptions of diffused mutual responsibility in that some drivers reported not having to manage their own fatigue because they considered it to be managed by their employer. In practice however, fatigue management relies on individual investment and even the best shift pattern will not reduce fatigue if drivers do not take the opportunity to sleep during their time off work. Education about sleep for new drivers was also brought up. This is a common approach by rail authorities, is recommended practice (Kecklund *et al.* 2003) and may help drivers take ownership of their fatigue. However, there is little to no evidence about its effectiveness for train drivers (Anund *et al.* 2015). An alternative approach would be for the organisation to invoke some countermeasures to assist drivers, for example installing bright lights and encouraging napping if appropriate. These countermeasures have previously been suggested by the aviation industry (Eurocontrol, 2005). Additionally, industry guidelines from the UK suggest regularly reviewing countermeasures to fatigue whenever there is significant change to circumstance e.g. change to workload or fatigue being identified as a causal factor for an incident (UK Office of the Rail Regulator 2011).

The countermeasures suggested by drivers include some items that will successfully counteract sleepiness (e.g. coffee) and some that will not (e.g. talking to people). The consumption of coffee and energy drinks is effective at reducing sleepiness because of the caffeine content. Caffeine consumption has been demonstrated as an effective way of counteracting sleepiness (Schweitzer *et al.* 2006), though frequent use can result in a build-up of tolerance (Evans and Griffiths 1992). There was no suggestion that participants were educated by their organisation in the use of stimulants (e.g. to only use when needed) to overcome the body getting used to them and lowering the effects. In contrast, talking to people will not mitigate sleepiness, but could help reduce fatigue induced from time-on-task, as small increases in cognitive load have been shown to reduce fatigue (Dunn and Williamson 2012). The data also revealed “personal” strategies that while considered to be effective, impacted other safe working rules and regulations, such as standing up while driving in cabs designed for seated driving, and inviting other rail workers/people into the cab, both of which are generally prohibited and may migrate fatigue risk to other areas (e.g. distraction). These practices and perspectives do not appear to have been reported in the literature from other rail contexts, but are not likely to be generalisable outside Australia.

The current work suggests that there are some rigid thoughts within the rail industry about fatigue, sleep and safety, but also confusion and conflict around terminology. This becomes important when considering appropriate mitigation strategies because effective strategies need to match the problem. Factors identified in the current work related to both sleepiness and fatigue which may be considered two distinct concepts requiring different management approaches. For example, fatigue associated with monotony lowers alertness, reducing the ability to react (Larue *et al.* 2011). Monotony related fatigue due to time on task can be mitigated by small increases in cognitive demand, such as an interactive cognitive task (Dunn and Williamson 2012). However, if a driver was experiencing fatigue due to sleepiness, caffeine has been demonstrated as an effective countermeasure (Schweitzer *et al.* 2006). The confusion within terminology is also apparent in rail industries outside of Australia, for example guidance provided by the RSSB in the UK defines fatigue

to result from factors related to fatigue e.g. heavy workload but also to result from inadequate sleep (Rail Safety and Standards Board, 2012). Readdressing the understanding of fatigue and sleepiness may be beneficial for the rail industry more broadly, not only in Australia.

It is apparent from this study that drivers consider fatigue to encompass a wide range of experiences. However, the intended focus of the word “fatigue” from the rail industry is often on sleep, as is apparent in a rail regulator safety bulletin section about fatigue:

"Investigating fatigue factors requires thorough examination of individual circumstances [...]

This should include detailed consideration of factors associated with roster patterns, commute times, sleep patterns, sleep deficits [...] Investigators should ascertain if there are procedures in place to risk-manage fatigued drivers and encourage drivers to self-declare if they have not received enough sleep" (Independent Transport Safety Regulator 2011, p.15).

This raises the question of how the term “fatigue” is being interpreted and if this is important?

Within a clinical environment, clear distinction is made between sleepiness and fatigue (Shen *et al.* 2006). Where sleepiness is caused by insufficient sleep and fatigue includes sleepiness as a symptom but expands to wider physical and psychosocial impairment. In contrast there is greater tendency to use the word fatigue within transport industries as a way of encompassing aspects of sleepiness (Phillips 2015). This is despite guidance from leading authorities, such as the US Federal Railroad Administration who state that fatigue in the rail industry is “largely a function of sleep and circadian rhythms” (Gertler *et al.* 2012). It should also be noted that the situation is further complicated by a lack of quantification of when fatigue and/or sleepiness becomes safety critical (Van Dongen and Hursh 2010).

5 Conclusion and Directions for Future Research

This study provides new insight into fatigue within the context of SPADs for passenger rail operations as it is one of the first to consider the drivers’ perspective. There is consistent evidence that fatigue increases the risk of safety critical events in road transport (see Williamson *et al.* 2011 for a review).

Comparatively, fatigue in the rail industry is under investigated (Phillips 2014, Anund *et al.* 2015). Despite the implementation of existing standard fatigue countermeasures (e.g. technology interventions, fatigue assessment tools), the theme of fatigue consequences highlights limitations. The current findings demonstrate that fatigue is considered to be a problem by train drivers, and one that has a bearing on the incidence of SPADs, a major rail safety failure mode. Similarities between truck and train driving mean that findings from existing studies on some causes and countermeasures to fatigue can be inferred e.g. the impact of shift work (Åkerstedt 1991) and monotony (Larue *et al.* 2011), and the benefits of caffeine as a countermeasure (Horne and Reyner 1996). However, future research within the specific rail context is essential because of the key differences between road and rail transport. For example, the vehicle related limitations of a train mean that stopping decisions must be made much earlier than for road vehicles, and it is known that fatigue impairs decision making (Harrison and Horne 2000). In addition, the restriction of travel on tracks creates a barrier to enacting some countermeasures which have been demonstrated to be effective for road transport, such as pulling over for a nap (Horne and Reyner 1996), making these less accessible to train than truck drivers.

The strongest barrier to effective fatigue management appears to be the organisational culture, for example the benefits of fatigue assessment tools for roster development are limited if shift swapping is unregulated and a reactive fear-based organisational culture around fatigue reporting will limit identification of the true implications of fatigue. Future research is required to both undertake controlled intervention studies on shift systems (Anund *et al.* 2015) but also to consider how such shift systems should be best integrated within a workplace culture. Future research should also consider the relative significance of contextual differences to ensure it is generalisable outside of Australia.

It is acknowledged that findings arise from drivers' explanations surrounding fatigue and opinions of the causal agents and while this reveals richness within the data, they are also a limitation of the study. This view point is restricted by the drivers' nuanced views and awareness of

this issue. For example, the UK rail industry recognises commuting time as a cause of fatigue (Rail Safety and Standards Board, 2012), but this was not mentioned by the drivers in the current study. Similarly, some important aspects from the scientific literature, such as sleep disorders, have been overlooked and are not considered within the results. There is also some miss-match between drivers perspective on causes of fatigue compared to the literature. Specifically, drivers reported that having too much to do caused fatigue. However, the literature demonstrates that having too little to do is a greater causal factor of fatigue (Dunn and Williamson 2012). The presence of this particular fatigue cause is likely to have been influenced by recent policy changes within Australian rail, which have reduced the number of Guards on trains. The resultant increase in workload happened in the months prior to the focus groups being conducted. It is possible that increased workload would not be stated as a cause of fatigue if the focus groups were to be repeated, because drivers may now be more accustomed to their increased duties.

A further limitation is the small sample size of drivers who participated in the focus groups. On average there were 3 to 4 participants per focus groups and comparisons between organisations was limited. Recruiting emphasis was placed on trying to represent every rail passenger organisation within Australia and New Zealand rather than on overall participant numbers, which strengthened the representativeness of findings across this region, however, limiting the number of drivers. Having considered a rich account of the driver's perspective, future research should engage with all organisational levels and representatives from the entire system to consider how organisations as a whole approach fatigue management. This is important because fatigue management is a shared responsibility between employer and employee. For example, from the current work 'inconsistency in managing shift swapping' is influenced by drivers asking to swap shifts as much as it is employers failing to manage swaps.

In the future, train driving is likely to become more automated and the potential for task-induced fatigue will increase. At the same time, the shift work basis is likely to remain, and continue to cause sleepiness resulting from circadian and sleep pattern interruption (Åkerstedt 1991).

Ensuring that fatigue and sleepiness concepts are properly understood could be a first step to informing specific interventions to reduce driver fatigue and sleepiness.

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