Risk Factors Moderating Driving-related Distraction & Inattention in the Natural Rail Environment

Anjum Naweed and Sophia Rainbird [1, 2]

[1]Central Queensland University, Australia

[2]Cooperative Research Centre for Rail Innovation, Australia

Abstract

The signal passed at danger (SPAD) is the rail equivalent of crashes and near-crashes in road. SPADs continue to impact collision risk on railways, despite the prevalence of technology-based countermeasures. This study explored the contribution of task-related distraction and inattention on SPAD-risk. A qualitative methodology was used to collect data from 28 train drivers in eight passenger rail organisations operating in Australia and New Zealand. The approach included focus groups and a scenario Invention Task to determine specific risks and identify amelioration strategies, effectively charactering the experience of distraction and inattention for the driver. Thematic analysis identified four factors that contributed to SPAD-risk. All were task-related, and associated with self-regulatory disconnects in service delivery and in the driver-signal dynamic. Manifest distraction channelled through the factors by assigning primacy to non-safety critical driving goals. The findings are presented in a multifactorial model of distraction linking the risks with mechanisms that induced attentional shift. Three interrelating strategies for ameliorating these SPAD-risk factors were also identified. These were to prioritise goals, remain focused, and remember signal states. The paper conceptualises the driver distraction-inattention relationship in the rail context and considers the taxonomic implications of some subtle yet significant distinctions.

Introduction

Train driving is a complex task underpinned by a highly specialised skill-set unique to railway collision avoidance (Naweed, 2013). Trains can take a very long time to stop and the information required to drive is not always readily observable. In conventional rail networks with trackside signalling, train drivers must acquire a detailed knowledge of their routes, and know all track speeds and signal positions in order to navigate (Branton, 1979). Considerable expertise is required to navigate railways and train drivers are often involved with predicting future states, even in moments of low observable workload. The cognition required by train drivers is recognised in applied attention theory and situation awareness literature (Endsley, 1995; Wickens & Hollands, 2000). This body of literature theorises that the need to sustain attention and maintain route knowledge increases the susceptibility for cognitive disturbance. For example, loss of information from working memory may occur from time on task or displacement by new competing data (Stanton & Walker, 2011). Thus, train drivers are vulnerable to distraction and/or inattentiveness, and a number of critical safe working failure modes can result from these disturbances.

The signal passed at danger (SPAD) is arguably *the* most safety critical rail operational failure mode. This occurs when a train goes through a stop signal into a section of unauthorised track presenting crash and/or collision risk. Whilst SPADs often occur from technical issues, driver distraction and inattention is frequently attributed to human-error related SPADs (Edkins & Pollock, 1997). Various technologies are used to mitigate SPAD-risk. These include perception-action devices and operator-initiated memory aids aiming to support the driver's awareness of signal state (GK/RT0091, 1997), and automatic warning/train protection systems which stop the train if it passes a signal or speed violates line speed parameters (Fenner, 2002; McLeod, Walker, & Moray, 2005; Simpson, 1994). However, the design of these systems has been criticised (Cullen, 2000) and under some conditions, they may offer little guarantee (Edkins & Pollock, 1997). In Australia, this is evidenced by SPAD statistics that continue to rise (ATSB, 2012).

In this paper, the preliminary findings of a SPAD study in the Australasian rail industry are discussed, with specific reference to four themes identified as SPAD-risk factors for driver task-related distraction - sighting restrictions, time pressure, station dwells, and controller interactions. Three cognitive strategies implemented by rail-drivers to ameliorate these SPAD risk factors are also identified. SPAD risk factors and mitigating strategies are a response to distraction that may occur when assigning primacy to non-safety critical driving goals. Consequently, these SPAD risk factors and mitigating strategies must be developed within the context of driver distraction and inattention field and driver distraction taxonomies.

The issue of driver distraction and inattention has not received as much attention in the rail context as it has done in road. Based on road research, distraction has been defined as the 'diversion of attention away from activities critical for safe driving toward a competing activity' (Lee, Young, & Regan, 2009, pp. 34). The implication is distraction gives rise to inattention, though there is some conceptual disagreement on this issue. One view holds that a competing activity (event, person, object) is needed to trigger distraction for inattention to happen (Treat, 1980) and these are typically exogenous to (the mind of) the driver (Hoel, Jaffard, & Van Elsande, 2010). The other view is that distraction is a subset of inattention (Stutts et al., 2005), and inattentiveness can occur without being distracted (Pettit, Burnett, & Stevens, 2005). Recent research has begun exploring the relationship between inattention and distraction instead of the differences. Regan et al. (2011) have developed a taxonomy where distraction exists on a separate level (i.e. as a form of attention), and manifest distraction is defined as the 'diversion of attention away from activities critical for safe driving toward a competing activity, which may result in insufficient or no attention to activities critical for safe driving' (pp. 1776). Thus, research has begun to classify distraction in terms of driving-activity relatedness.

In the rail context, activities that compete for attention can be task-related (e.g. responding to an in-cab warning) or non-task related (e.g. socialising on a smartphone). Industry-led research has studied SPAD mitigation from exogenous distractors with no relation to the task, such as mobile phones (RSSB, 2010). Task-related study has concentrated on sighting constraints such as signal visibility and action/performance failures such as cab ergonomics (e.g. Lowe & Turner, 2005). Similarly, rail research in the endogenous distractors space has focused on non-task related thoughts (RSSB, 2008). Although emotional distraction (e.g. anxiety resulting from running late) and cognitive distraction (e.g. boredom stemming from monotonous work) has been examined (see Dunn & Williamson, 2011; RSSB, 2008), rail research has yet to examine the distraction-inattention relationship when attention is diverted by task-related thoughts, and to determine the impact of this on SPAD-risk. The pressure to perform for example, is a task-related cognitive distractor that may allocate attention to one part of the task whilst drawing it away from another (Lewis & Linder, 1997). In the context of road research, this sits with a point from the road domain that the driver could be covertly 'engaged in what is considered the wrong aspect of the driving task at the time in question' (Hancock, Mouloua, & Sender, 2008, pp. 25).

In driver distraction taxonomies, the pressure to perform aligns closest with 'misprioritised attention', that is when the driver focuses on one aspect of driving to the exclusion of another, both of which are equally (or near-equally) critical for safe driving (Regan et al., 2011). The example given in the taxonomy is merging into road traffic and missing a lead vehicle. Given the complexity of train driving, the dynamism of the rail environment, and the paradox of managing safety with performance, it is difficult to define how train drivers should distribute and divert their attention between multiple activities all construed as 'critical.' Human error in certain SPAD modes may involve a variety of factors that impact the ability to self-regulate, but very little is known about the strategies train drivers use to ameliorate the risk of distraction and inattention during driving. Whilst the utility of some interventions has been explored (e.g. Risk Triggered Commentary, RSSB, 2008), little has been published on personal strategies drivers use to manage SPAD-risk. Identifying these strategies may assist in the development of effective countermeasures to SPAD-risk, help inform the relationship between distraction and inattention in collision avoidance, and test how road-based taxonomies of driver distraction and inattention relate to the rail context.

Aims & Objective

This study aimed to identify key SPAD-risk factors, as perceived by train drivers, and research the strategies used to ameliorate them. The objective of the study was to use the findings to develop a conceptual model of distraction-based SPAD-risk, and by developing knowledge of amelioration strategies, offer taxonomic contributions in the form of subtle yet significant distinctions for driver distraction and inattention in rail.

Methods

Design

Focus groups were conducted in 8 rail organisations in Australia and New Zealand. Cab rides were undertaken at each organisation prior to the focus groups to familiarise with the rail networks. The 8 groups were designed to collect views of SPAD causation and the strategies used to ameliorate risk. Table 1 categorises the questions in the protocol.

The core of the methodology was a scenario Invention Task that placed drivers into a (simulated) SPAD scenario to trigger situational insights. The technique was designed using the principles of the Critical Decision Method (scenario retelling, timeline verification, decision point identification) (Klein, Calderwood, & MacGregor, 1989) but generated pictorial data aiming to externalise the participants' mental representations and knowledge. Sketch elements (e.g. cartoons, symbols) have been used to collect information, relationships, and encapsulate situational connections in similar approaches (Monk & Howard, 1998). Figure 1 shows example study data. Studies comparing the accuracy of pictorial data against knowledge have demonstrated high reliability (Aginsky, Harris, Rensink, & Beusmans, 1997).

Table 1 Overview of focus group protocol

Class of question	Content	Example
General experience	Background, organisational issues	*How does your organisation react to a SPAD?*
Impression of SPAD categorisation	Management, SPAD classifications	*What are your views on the different categories of SPAD?*
Prospective causation	Fatigue, awareness, distraction	*What sort of things would you consider to be distracting during driving?*
Task influence	Service delivery, sustained attention	*How much do you think fatigue contributes to the risk of a SPAD?*
Equipment design	Cab environment, safety systems	*Does your train have any special equipment to help you stop at signals?*
SPAD-risk mitigation	Personalised countermeasures	*What strategies have you developed or used to help you stop at red signals?*
Scenario design, analysis	SPAD-scenario Invention Task	*Invent a scenario and driving conditions that may result in a SPAD…*
Broader issues	Areas for improvement	*How could a driver be better prepared for a SPAD event?*

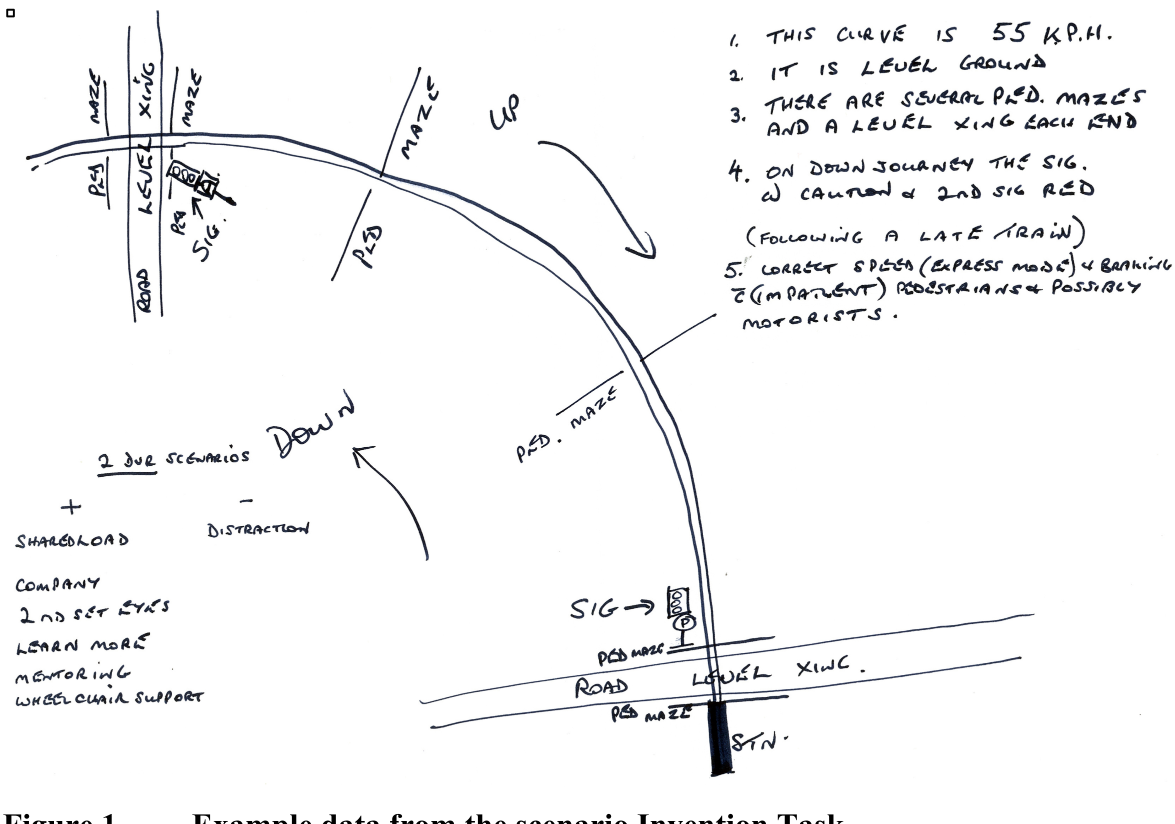

Figure 1 Example data from the scenario Invention Task

Using an approach that articulated beyond discourse gained access to experiential knowledge, typically difficult to elicit (Shadbolt, 2005). Versions of the Invention Task have been used in rail research before, for example to study how train driver route knowledge is encoded (e.g. Naweed & Balakrishnan, 2012). Train drivers use forward-thinking and future state prediction to operate the train. The Invention Task drew on the same type of cognition and required drivers to speculate how a SPAD could occur based on a set of driving conditions. The following excerpt from this study supports this contention:

> [Train drivers] are expected to do what I call 'crystal ball-gazing.' You're expected to make a decision on something that's going to happen up there, which is only a guess, it's only a judgment, it's all the mathematics come into your head, spat out in an outcome.

Participants and Recruitment

A total of 28 drivers participated (male = 26; female =2). The average age was 45.67 (SD = 8.52; median 48; mode 53; range 24 to 58). Twenty-two participants had more than ten years train driving experience. Middle-management level contacts provided access, distributed information articles (e.g. Naweed, 2012), and rostered attendance. Focus groups aimed to be representative, but were logistically driven; variables included experience, SPAD history, and other roles[1]. Table 2 shows the composition of participants in the 8 focus groups.

Table 2 Composition of Focus Groups

	No. of people	Gender		Age range (y)			Driving experience (y)		
		M	F	24-34	35-44	45+	0-5	5-10	>10
1	3	3	0			3			3
2	4	3	0			4	1		3
3	3	3	0		1	2	2		1
4	3	2	1	1	1	1	1	1	1
5	4	4	0		2	2		1	3
6	3	3	0	1		2		1	2
7	3	2	1		1	2		2	1
8	5	5	0	1	3	1	1	1	3

Organisational Profile

Taken together, the participating organisations comprised all passenger rail operators in the trans-Tasman region. Five were metropolitan but three also provided regional services. Half used train guards and the other half did not, thus these drivers performed train guard duties (e.g. wheelchair assistance, station announcements, platform work) in addition to driving. The use of automatic safety systems and in-cab memory aids varied. Three organisations used automatic train protection/warning systems; four used trip mechanisms (activated on contact); one had no automatic safety systems. None of the

[1] Position on organisational SPAD committee (which advised signal placement and/or relocation)

organisations used in-cab technologies that previewed the route, thus, train driving was performed with basic state features (e.g. speedometer) and traditional navigational parameters (i.e. in-depth knowledge of the route and its signalling system) (Naweed, Hockey, & Clarke, 2013).

Ethical Considerations

Data were de-identified and idiosyncratic comments were not reported. Participants were not required to answer questions they felt uncomfortable with and upsetting topics (e.g. fatalities) were avoided. Cab rides received prior approval. The study met the requirements of the ethics committee of CQUniversity (approval no: H12/03-033).

Procedure

Focus groups lasted 120 minutes. For the Invention Task, participants were asked to "invent a scenario and driving conditions that may result in a SPAD for even the most experienced of drivers." This could come from specific SPAD experience (with SPADs) or general experience (what a SPAD event could involve). Participants worked individually and were invited to use drawing conventions that were unconstrained and created on A3 paper with felt-tip pens. Once invented, participants were asked to "imagine being in the scenario," and "highlight and record the key areas of interest." This included significant decision points, shifts in situation assessment, anomalies, and violated expectations. Participants were then asked to "write down the strategies or changes" they would adopt to mitigate their SPAD and each participant walked through their scenario in the vernacular with the rest of the group. Each scenario was repeated back to the participant to verify the timeline, identify gaps, ambiguous cues, or conceptual leaps. The group then reviewed each scenario. This involved discussion of causation, driving challenges, and operational disturbances.

Data Analysis

Thirty SPAD scenarios[2] and eight focus group transcripts were systematically analysed by the authors with the aid of NVivo, a qualitative data analysis software tool for organising, searching, and coding data. Data within the transcripts included verbal elaborations of the pictorial data. Themes and conceptual groupings were drawn from phrases, comments and features of the transcripts, which grounded findings in the data (Huberman & Miles, 1994). The initial findings of this inductive coding technique were then refined into overarching groupings and discussed by the researchers, allowing them to agree on coding definitions. Risk factors were identified and described as they emerged from the analysis. A preliminary identification of strategies used to ameliorate the identified risks was carried out, with further investigation to occur in the next phase of analysis.

The drawings themselves were analysed separately and compared against the verbal elaborations through a process of data triangulation, or 'cross-data validity check', to determine consistency (Patton, 2002:248). This process allowed for further refining. Although conventions were unconstrained, participants tended to create topographical drawings (using *x-y* or *x-y-z* coordination). Drawings were analysed using a scheme that captured SPAD causation in each scenario. The process involved defining the driving challenges, establishing operational disturbances, causation factors, and

[2] Although 28 drivers participated in the study, two generated an additional scenario

classifying the scenario. The analytical framework was developed for the study. Path analyses are commonly used to explore rail accident data (e.g. Stanton & Walker, 2011). Figure 2 presents the coding and categorisation scheme with example codes.

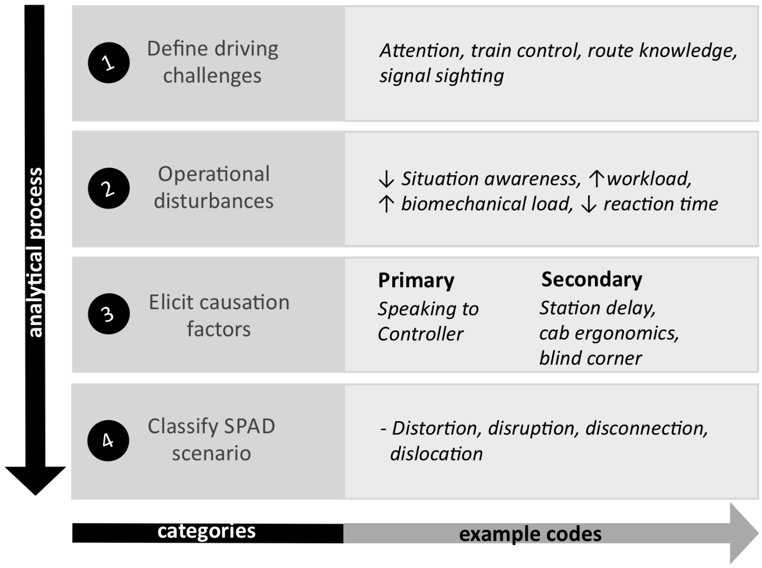

Figure 2 Coding and categorisation process for scenario drawings

For scenario classification (step 4), four discrete codes were developed to describe how driving goals were impacted and attention from activities critical for safe driving was diverted. These were: Distortion, where distraction arose from deformation in driving goals (e.g. assigning urgency to activity/goal not critical for safe driving); Disruption, where manifest distraction arose from a new and competing activity that disrupted the driving task (e.g. a call from the controller); Disconnection, where distraction appeared to manifest from a broken link or gap in working memory though the physical driving task remained uninterrupted (e.g. forgetting the colour aspect of the previous signal); and Dislocation, where inattention and distraction arose from a separation of a fundamental driving cue and/or a replacement of one cue with another (e.g. forgetting the location of a signal; misreading one signal for another signal). These codes were subsequently checked against definitions in Regan *et al.*'s (2011) taxonomy to determine how well they applied, and identify any important distinctions substantive to the rail context.

The findings were repacked into a cohesive model of explanation to illustrate the factors contributing to SPAD-risk, and describe their relationship with distraction and inattention. These data were presented to a reference group comprised of subject matter experts (e.g. risk and safety managers) at the participating organisations, as a means of verifying and validating the findings.

Results

Intrinsic Risk Factors for Train Driving

Sighting restrictions

Sighting restrictions featured in 80% of scenarios. Restricted visibility was a normative feature and driver training was considered to compensate for this limitation: "when you're pulling into stations or you're thinking about what's ahead of you, you're using your landmarks to tell you where you are and how you have to react." The (qualified) train driver had the requisite skill/knowledge to regulate speed for information outside the visual field. Sighting issues were depicted with high and low infrastructure densities and causation pathways varied in complexity. The issue was illustrated in the Invention Task with blind-corners (obscured by bridges, trees, etc.). The threat of a SPAD was expressed through inattentive driving and distraction from the immediate task. More often than not, this arose from operating under high workload conditions where attention was divided over competing activities (e.g. Figure 1).

Some scenarios showed a pre-loaded state of distraction, "Just before the platform there is a level crossing that is often breached by passengers, boom's down, lights going […] cyclists will ride through the damned thing." The resulting anxiety disconnected the driver from their attention, safe working needs and route knowledge, "If [drivers] don't essentially train [themselves] to switch-off to some of those outside distractions, those outside distractions really do eat at your attention." There was also an over-reliance on default driving states and expectations for clear signal aspects. This increased risk acceptance, "If you've seen something happen 99 times, you expect it the 100th time," "We've devalued the yellow." Sighting restrictions were a factor that under many circumstances, amplified SPAD-risk and in combination with other elements, elevated a high emotional response (i.e. anxiety) and risk acceptance.

Time pressure

Time pressure featured in 60% of scenarios. Although time keeping was a goal, "Your job is to get the train in on time," time pressure was experienced as a distraction, "[There is] a push for, you know, it's got to be on time, on time, on time…" Scenario pathways included several elements that evoked task-related distraction from time pressure, "There was a focus on quick turn around of [the] train due to timetable running late." Time pressure disconnected the train driver from their route knowledge (i.e. a signal is around the bend) and their awareness of the aspect (i.e. the signal is set to danger), but it also distorted service delivery by emphasising performance:

> [The driver] might be thinking about the time and so that's distracted you from the actual route knowledge that you have – you should be looking at that, you know you've got to keep going around there until you can see the signal.
>
> If you're running late coming down the hill, the other [train's] waiting there and if you're running late and your crossing's late, it makes the whole line late, so some drivers will, you know, they'll see the yellow, the next one's going to be yellow, and they think, I'll just go for it.

Time pressure raised the issue of multi-tasking and inattention for critical tasks, but also the issue of distraction from service delivery. For example, whilst a number of scenarios demonstrated a focus on time recovery, it was also linked with incoming explanations for delay. This elevated performance anxiety (they want to know why I'm running late) and created a psychological and biomechanical disadvantage (attentional and physical load diverted to a non-critical task). Time pressure attracted breaches of safeworking (answering calls in unsafe working conditions), "When you push [time keeping] and make that the focus of everything that you do all of the time, whether you like it or not, it's what starts to dominate people's thought process." Thus, with time pressure, the majority of attention was directed to a competing activity, leaving residual levels for critical driving tasks (i.e. safe working, train operation) and the cognitive processes needed to support them (route knowledge, situation awareness).

Station dwelling

Station dwelling featured in 50% of scenarios. The point of departure (at stations) was considered high-risk from the perspective of distraction. Whilst station stopping is a normative rail domain feature, dwelling was subjective, signified by the perception of needing to wait longer than necessary. Dwell-time was built into timetabling design but any increases were anxiety inducing. Extended dwells bred concern for accumulated time delay and increased perceptions of inordinate station dwelling for future stations. Numerous disturbances for distraction and inattention were depicted, including passenger activity and fault-finding scenarios, but the scenario of dwelling with nothing to do but wait was also distracting, "Keep the caution up in the top of your head [when at the station] as opposed to filtering it out with all the other rubbish that goes on…"

A common outcome was to misread the signal either from checking the wrong signal, or by omitting signal checks altogether (i.e. a false start), "Spark driver[3] closes doors and departs not looking at red signal and almost side swipes express passenger train." The station dwell dislocated the driver's attention from the primary task and their safe working requirement. Inattention from station dwelling arose primarily from disengagement with actual driving, giving rise to the process of distraction and reducing situation awareness. Sighting restrictions and time pressure exploited a dwell and disconnected the driver from their signal dynamic:

> The train is running late, the driver changes ends quickly, the station staff make announcement 'train will be departing,' the level crossing booms are down and the driver sees they are down, doesn't check signal properly, takes off…

Station dwelling regulated competing task activities and shared a relationship with other factors. Station arrival and departure was affected by variables like time-of-day effects and peak running. Other examples of human error in and around station stopping included overshoots (stopping beyond the end of the platform) and overruns (missing the station altogether). While SPAD-risk from station dwelling was caused by time pressure, high anxiety and/or high workload, inattention and disengagement also attracted error from schema-based responses:

> Automatic announcements are in your ear telling you it's time to go, the time is telling you it's time to go, the guard is telling you it's time to go, the book tells you it's time to go…

Controller interactions

The speculation that driver distraction originated from controller interaction featured in 26% of scenarios. Typically, drivers called controllers[4] to alert signal anomalies or query train running, whilst controllers called drivers to query delay, "[Control] wants to know why you lost four minutes in that section." The length of delay prompting a call varied - some organisations were said to initiate them after a single minute's delay. This aspect of the task was perceived to be risky and distracting, particularly where there was

---

[3] 'Spark driver' is a colloquial reference to the driver of an electric train
[4] Note the term 'controller' varies. Those who interact with train drivers during driving and/or control train movements are also called dispatchers and signallers in different countries.

a culture of accountability, "[Control] is constantly asking 'why are you late driver?' and that wears you down after a while." Explanations for time delay were considered unnecessary and easily deduced without a call (e.g. following a late train, peak-time running, temporary speed restriction) and in a number of scenarios, risk from controller interactions converged with risk from sighting restrictions and time pressure:

> [The driver is] always going to end up late into [this particular station] because it's just the way it is. [Control] give you one minute to get passengers off and then you're running late and they want a 'please explain driver.'
>
> So [the driver] is talking to the [controller] saying whatever information he had to relate, still powering, came around the bend which was obscured by a lot of vegetation…

In some scenarios, driver-initiated calls were part of the SPAD-causal pathway. In these cases, the driver operated in a pre-anxious, inattentive, and highly distracted state, and a call to the controller was used to ameliorate additional anxiety and preempt incoming calls, "Driver contacts and communicates with NCO[5], while talking driver has a SPAD." Often, delay-related controller interactions had the effect of distorting the task by emphasising time keeping, when service delivery was already distorted from station dwells. Thus, much like time pressure and sighting restrictions, the risk from station dwelling bore a relationship with controller interactions "[Control] will ask you if you're sitting at a platform for too long, when are you going to move?"

Novel events

An important code in the SPAD-scenarios was 'novel event.' This reflected a peculiar, uncommon, and/or unexpected occurrence that could be task or non-task-related, and converged with other risk factors to divert attention, distract the driver, and elevate risk. Examples of this were: a danger aspect that did not clear (and match expectations); a door fault that elevated workload and prolonged the station dwell; a train that stopped beside a signal in a manner that rendered it invisible to the driver. Whilst the intrinsic risk factors dominated the scenarios and produced a SPAD-outcome, a novel event contributed to driver distraction and inattention, and ostensibly elevated SPAD-risk.

Summary

Four themes emerged as intrinsic SPAD-risk factors: (1) sighting restrictions; (2) time pressure; (3) station dwells; and (4) controller interactions. In each case, inattentiveness gave rise to distraction by distorting, disrupting, disconnecting and/or dislocating attention from activities critical for safety (in some cases, all four were 'activated'). These relationships and impacting processes are conceptualised in the multifactorial model of task-related distraction shown in Figure 3.

The data revealed clear links and interconnections between all of the factors shown in the model. Importantly, these risk factors had the capacity to converge to elevate SPAD likelihood, thus this was a focal point of the model, and framed within the context of the driver-signal dynamic and service delivery for each factor. The novel event was conceptualised as an external factor, which intensified the experience of distraction and inattention when present. This model was qualitatively derived, thus it is important to note that the physical form and structure found in quantitatively derived

[5] Network Control Officer

models was lacking and limited its power as a complete representation of SPAD-risk. However the purpose of modelling the factors was to illustrate the relationships between these risks and inattention and distraction, not the structure or form itself.

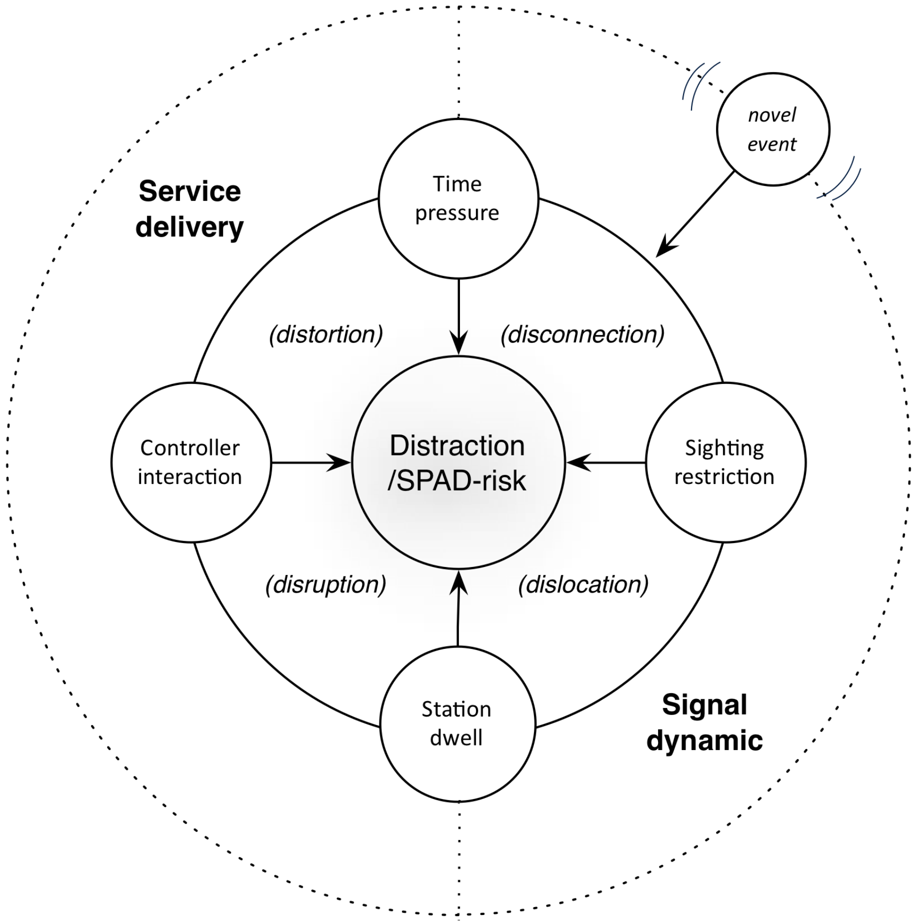

Figure 3 Multi-factorial model of distraction for collision avoidance in rail context conceptualising how inattention and driver distraction may manifest and converge to impact safety critical activities

Risk Amelioration Strategies

An initial analysis of the data identified three main strategies, described by drivers as central to their risk amelioration 'toolbox' to remain focused, safe, and remind them of the task in hand, in effort to address some of the SPAD-risks detailed above.

Prioritising tasks

Task prioritisation was a strategy used to address the risk associated with time pressure and controller interactions. "Concentrating on my train" and "driving the thing safe" meant that at safety critical times disruptions such as calls from the controller could be blocked out: "if they call you up, that's alright. Talk to them when you're prepared to talk to them," "You don't have to report that immediately, do it when it's, you know, safe to do so." Where this prioritisation conflicted with the timetable, more experienced drivers believed their best strategy was to prioritise safety because "it's not about speeding up to get your times back and that, because then all of a sudden you're going to start breaking speed limits and then something can go wrong." Another driver concurred:

> I use whatever time I need to use. I prioritise from the most important thing to the least important. Least important for me is worrying about anything but the signals. Signals and train safety is first everything else comes from thereafter.

Drivers who prioritised were likely to be more experienced drivers who recognised that time delays due to, for example, "picking a wheelchair up" could be reported to train control once it was safe to do so. As a strategy, prioritising shifted pressure away from the conflict of on time running, and allowed drivers to adopt a focus mind-set and concentrate on the task in hand.

Adopting a focused mind-set

Having an optimally focused mindset was reportedly a vital feature of train drivers' risk amelioration strategies, and was used to overcome sighting restrictions and distractions during station dwells. In this context, drivers' description of concentration was of being "zeroed in" where they were "one hundred per cent [...] eyes forward and I don't get distracted by anything." Some drivers referred to this state of concentration as a switch and a way of "staying switched on," whilst other drivers referred to concentration as the ability to "switch off" from external distractions or put "blinkers on." This ability to focus is such that, as one driver commented in relation to having another person in the cab:

> They can talk to what they like, but it goes one ear and out the other. They can tell me what their life story – and if somebody said to me "What have we just talked about?" I wouldn't have a clue. It's just, I don't know, I just put my blinkers on because I'm concentrating on what's in front of me.

Drivers referred to accumulated experience as a basis for the ability to remain focused. One driver trainer referred to the ability to remain focused on signals as fundamental to a trainee's skill set. However, whilst adopting a focused mindset is a critical SPAD ameliorating factor, it is only successful if the driver has good recall abilities so that they are cognisant of the status of each signal. One way of ensuring that a focus mindset includes signal recall is to put in place physical, verbal and tangible cues.

Physical, verbal and tangible strategies

Physical, verbal and tangible strategies were used to overcome sighting restrictions and to act as reminders during station dwells. For example, drivers described kneeling or actually standing while driving as a physical reminder that they were driving through a caution zone. Ordinarily seated whist driving, the physical change in the drivers stance was believed to trigger a reminder that something was different, ensuring they would not forget they were approaching a stop signal. In some stations, departing signals were either not located on platforms or could be obscured by the train's position. This meant that during a station dwell, the driver relied on their memory of the preceding signal to inform the appropriate approach. Thus, a physical change was commonly adopted to ensure signal recall. For instance, a driver commented about the difficulty remembering a caution signal during a station dwell, "You're thinking about your next speed board and all that sort of thing, so I now stand up whenever I leave a platform on a caution, I'm standing up. And that's my memory."

A strategy of verbalising the status of a signal was common amongst drivers. One driver explained that calling the signal committed it to memory faster than visual cues. Calling out each signal three times reportedly aided them to remain focused and ensured the signal status was committed to memory. Trainee and new drivers reported this strategy as “the way I was taught how to drive and do all the recommended things like calling out signals.” Another driver described how this strategy not only aided signal recall, but also interrupted the internal dialogue of task-unrelated thoughts, therefore allowing them to regain focus: “I will verbalise it and that’s to control my own brain chatter.” The underlying principles of verbalisation were consistent with the risk triggered commentary approach (RSSB, 2008), though the nature of what was said differed, “Whenever I go through a caution I always whistle ‘Mellow Yellow’.”

Objects were also used as reminder aids to remember signal status. For instance, drivers spoke of holding a pen, or a bottle in their hand when going past a caution signal. Other drivers wrapped an elastic band round their wrists, or placed keys or other objects on the dashboard. At stations, one driver would pull the cab’s blind down so that on leaving the station, they knew that the signal was at stop or caution.

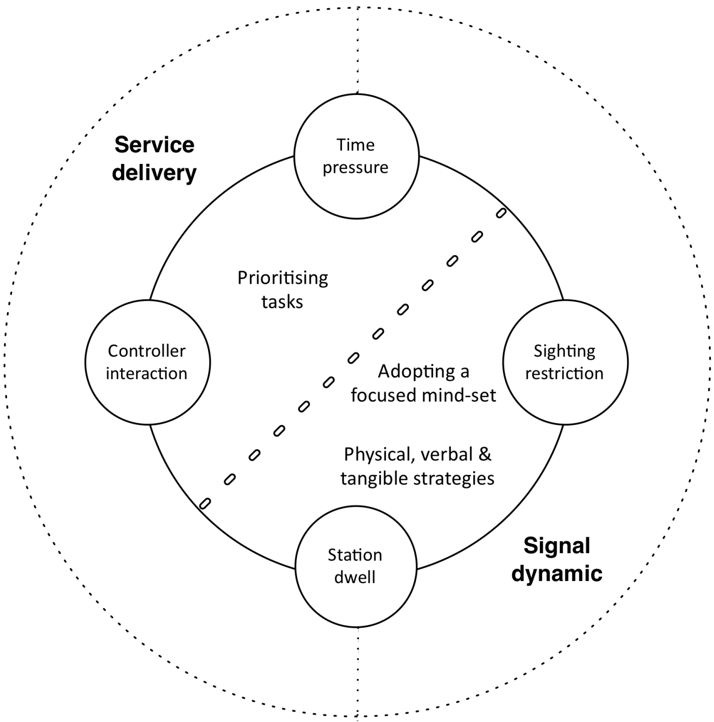

Figure 4 Relationship between risk factors and amelioration strategies

Summary

Taken together, these strategies were put in place to remain focused, safe, and remind drivers of the task in hand. These strategies were applied in different combinations in varying contexts and workload pressures. Consequently, these are strategies rather than countermeasures, in that they are context specific and individually tailored to achieve safe driving, and may or may not be successfully operationalised. These strategies are difficult to synthesise into driving rulebooks because they are endogenously informed and often involve deviating from prescribed procedures. However, knowledge of these strategies can inform the development of countermeasures to address SPAD-risk factors. Figure 4 conceptualises the relationships between risk and risk strategies that were found to ameliorate SPAD-risk for the identified risk factors. It is expected that further analysis of this data will help build this conceptualisation.

Discussion

The study revealed four themes as SPAD-risk factors for task-related distraction. These were sighting restrictions, time pressure, station dwells, and controller interactions. These factors reflected profound difficulty with self-regulation during train driving, and when converged, increased the experience of distraction and the likelihood of a SPAD outcome. The main cognitive strategies implemented to ameliorate these risks were prioritising tasks, adopting a focused mind-set, and invoking physical, verbal and tangible cues. This paper intends to further research and thinking of driver distraction and inattention in the rail context and in similar collision avoidance modes more generally, not in terms of differentiating the two processes, but advancing a better understanding of the relationship they share. To that end, this discussion will consider the implication of the study and its findings on substantive taxonomies.

The terms that were devised during the coding process were used to describe the way that the risk factors gave rise to distraction, but also how they impacted on task goals. They are not intended to replace or substitute the terminology in other taxonomies. Regan *et al.'s* (2011) taxonomy was developed in the context of crash and near-crash incidents in the road sector but despite this, the types of inattention displayed in the study data were captured by one or more definitions in the taxonomy. In many cases, the scenarios chronicled SPAD-risk challenges concomitant with task-related Driver Diverted Attention; that is there were difficulties assigning attentional primacy to activities critical for safe driving from task-related sources. This was particularly the case when the inattention and distraction relationship was coded using Distortion and Disruption. The codes Disconnection and Dislocation and their relationship with distraction and inattention were more complex, as both codes also reflected how the change in task focus impacted on task goals. While elements of other types of inattention applied in varying degrees to some scenarios (e.g. neglected, cursory attention), all types of distraction observed in the data were primed by preoccupation with another task. However, there were also some subtle but significant distinctions that suggested a need for better representation within the taxonomy, especially when the driver was engaged with entirely the wrong task from the safety critical perspective.

For instance, time keeping was a goal-directed activity and though time pressure emerged as a risk, it was also a baseline constant in the workplace of a passenger train driver. This was illustrated by the amelioration strategy to prioritise tasks in order to address risk, even though train drivers might not always be able to address time pressure through prioritisation, as the demands of time may occasionally outweigh safety. This was illustrated by chronic neglectfulness in that some activities critical for safe working (i.e. defensive driving through caution zones) may have been (voluntarily or involuntarily) neglected via over-familiarity with the stopping pattern or expectation for a signal aspect. Alternatively, it also reflected a cursory attentive behaviour, where activities critical for safe working were gradually relegated to residual attention. In either case, driver attention was skewed through internal and/or external task-related emphasis of another goal (i.e. time), to the point at which drivers diverted their attention from activities critical for safe driving to often breach safe working (e.g. calling the controller to explain delay when unsafe to so).

Thus, in a number of scenarios, inattention arose from a voluntary or involuntary diversion of attention away from activities critical for safe driving toward a competing driving-related activity that happened to be less safety-critical. On Regan *et al.'s* taxonomy, the closest definition for this type of distraction is misprioritised attention, but time keeping is a key performance indicator, not safety critical, and inattention was not so much *di*verted as *sub*verted. The subtle distinction here is that whilst the driver may be engaged in what is considered to be the wrong task, not all drivers would necessarily consider this to be the case if it was a domain normative.

Thus in the rail context, misprioritised inattention could be better described as 'misappropriated' through a form of task subversion, that is the shift in attention has a subversive (as well as divertive) property. Consequently, this may force voluntary or involuntary neglect and/or cursory attention during train driving, as defined by Regan *et al.*, implying that these types of inattention could also exist on different levels, or that misappropriated attention gives way to these types of inattention. It is important to note that inattentive behaviours may also be interrelated, and one form of attention may give rise to another, for instance in some scenarios, neglectful attention resulted in cursory checks. Figure 5 illustrates the potential driver misappropriation pathway of inattention, in the taxonomic style adopted by Regan and colleagues (2011). Note that the figure recognises the existence of multiple streams of driver inattention such as Restricted Attention, Diverted Attention, and so on (depicted as DI_1, DI_2, etc.).

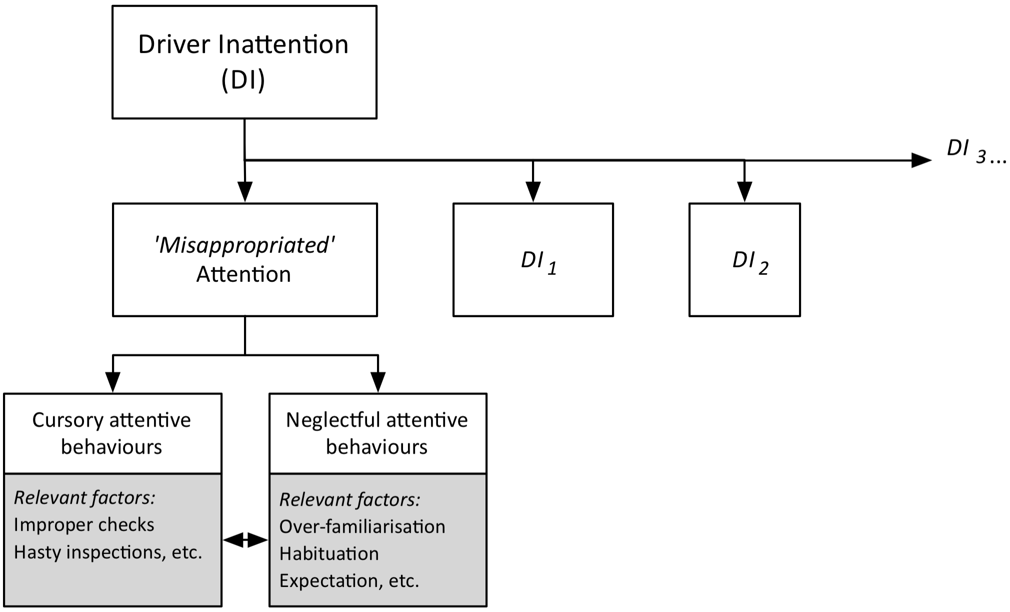

Figure 5 Diagram illustrating the potential misappropriation pathway for driver distraction and inattention within the rail context

A working definition for 'Misappropriated attention' in the context of the study findings may be: 'inattention which arises from the voluntary or involuntary subversion of attention away from activities critical for safe driving toward a competing driving-related activity that has little or non-safety critical significance.' The findings of this study, though based on untested relationships, advocate further thinking in the way the categories of inattention have been distilled. Figure 5 illustrates a small aspect of inattention from a different industry, but based on study data, highlights what may need to be looked at, and provides a good starting point to explore this issue further and more broadly. The findings in this study, while largely consistent with the definitions in existing driver distraction taxonomies, draw attention to an important systems thinking and phenomenological distinction. This relates to the voluntary and involuntary nature of distraction that occurs through misprioritised attention, and whether misprioritisation is an accurate enough description for a branch of inattention when goals that vary in their safety criticality are being mismanaged at a higher level.

Conclusion

This study used a novel data collection methodology to collect situational insight into the SPAD failure mode in passenger rail. Key risk factors were time pressure, station dwelling, sighting restrictions, and controller interactions. Driver distraction emerged under certain conditions in the context of service delivery and the driver-signal dynamic, and growing anxiety, multi-tasking load, and/or disengagement from three or more of the factors were found to intensify distraction and increase the likelihood of a SPAD. The study identified compelling relationships between several factors, and personal amelioration strategies, however consideration is needed for potential solutions to this problem, and the hypothesised relationships associated with the factors need to be tested. The driver distraction and inattention taxonomy referenced in this study was designed and exemplified largely in the context of the road sector, thus a more thorough comparison of the content with crash, incident and SPAD data in the rail domain is recommended. However, investigation of this issue in other road mass transit systems analogous to rail is advised (e.g. buses, trams, trucks, taxis, light rail) to determine if the same sort of risk factors are present.

Acknowledgements

The authors are grateful to the CRC for Rail innovation (established and supported under the Australian Government's Cooperative Research Centres program) for funding this research. This paper reports results from Project No. R2.116 'SPAD-risk Management & Mitigation.' The authors are thankful to the train drivers that took part in the study and gratefully acknowledge the assistance of rail organisations in Auckland, Wellington, Queensland, New South Wales, Victoria, South Australia, and Western Australia.

References

Aginsky, V., Harris, C., Rensink, R., et al. (1997). Two strategies for learning a route in a driving simulator. *Journal of Environmental Psychology,* 17: 317-331.

ATSB, 2012. Australian Rail Safety Occurrence Data 1 January 2002 to 31 December 2011. ATSB

Branton, P. (1979). Investigations into the skills of train-driving. *Ergonomics,* 22: 155-164.

Cullen, W. D., 2000. The Ladbroke Grove Rail Enquiry: Part 1. HMSO

Dunn, N., and Williamson, A. (2011). Monotony in the rail industry: The role of task demand in mitigating monotony-related effects on performance. *Ergonomics Australia – HFESA 2011 Conference Edition*: 38.

Edkins, G. D., and Pollock, C. M. (1997). The influence of sustained attention on railway accidents. *Accident Analysis & Prevention,* 29: 533-539.

Endsley, M. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors,* 37: 32-64.

Fenner, D. (2002). Train protection. *IEE Review,* 48: 29-33.

Hancock, P. A., Mouloua, M., and Sender, J. W. 2008. On the philosophical foundations of the distracted driver and driving distraction., in *Driver Distraction: Theory, Effects & Mitigation*, edited by M. A. Regan, J. D. Lee & K. L. Young. Boca Raton: FL: CRC Press: 11-30.

Hoel, J., Jaffard, M., and Van Elsande, P. 2010. *Attentional competition between tasks and its implications.* Presented at the European Conference on Human Centred Design for Intelligent Transport Systems (29-30 April), Berlin, Germany,

Huberman, M. A., and Miles, M. B. 1994. Data management and analysis methods, in *Handbook of qualitative research*, edited by N. K. Denzin & Y. S. Lincoln. Thousand Oaks: Sage: 209-219.

Klein, G. A., Calderwood, R., and MacGregor, D. (1989). Critical decision method for eliciting knowledge. *IEEE Transactions on Systems, Man, and Cybernetics,* 19: 462-472.

Lee, J. D., Young, K. L., and Regan, M. A. 2009. Defining driver distraction, in *Driver Distracton: Theory, Effects, and Mitigation*, edited by M. A. Regan, J. D. Lee & K. L. Young. Boca Raton: FL: CRC Press: 31-41.

Lewis, B. P., and Linder, D. E. (1997). Thinking about Choking? Attentional Processes and Paradoxical Performance. *Personality and Social Psychology Bulletin,* 23: 937-944.

Lowe, E., and Turner, C. 2005. A human factors SPADs checklist, in *Rail Human Factors: Supporting the Integrated Railway*, edited by J. R. WIlson, B. Norris, T. Clarke & A. Mills. Cornwall: UK: Ashgate: 182-188.

McLeod, R. W., Walker, G. H., and Moray, N. (2005). Analysing and modelling train driver performance. *Applied Ergonomics,* 36: 671-680.

Monk, A., and Howard, S. (1998). The rich picture: A tool for reasoning about work context. *interactions,* 5: 21-30.

Naweed, A. (2012, June). Driving past the danger signal. *Rail Express, 2,* 12-14.

Naweed, A. (2013). Investigations into the skills of modern and traditional train driving. *Applied Ergonomics,* 10.1016/j.apergo.2013.06.006,

Naweed, A., and Balakrishnan, G. (2012). Perceptions and experiences of simulators as a training tool in transport: The case of the Australian rail industry. *Road & Transport Research Journal,* 21: 77-85.

Naweed, A., Hockey, G. R. J., and Clarke, S. D. (2013). Designing simulator tools for rail research: The case study of a train driving microworld. *Applied Ergonomics,* 44: 445-454.

Patton, M. Q. 2002. *Qualitative Research & Evaluation Methods*: SAGE Publications.

Pettit, M., Burnett, G., and Stevens, A. 2005. *Defining driver distraction.* Presented at the In: Proceedings of the 12th ITS World Congress, San Francisco: USA, 2005.

Regan, M. A., Hallett, C., and Gordon, C. P. (2011). Driver distraction and driver inattention: Definition, relationship and taxonomy. *Accident Analysis & Prevention,* 43: 1771-1781.

RSSB, 2008. Good practice guide on cognitive and individual risk factors. RS/232 Issue 1.

RSSB, 2010. Development of a train driver education programme on mobile phone risk. T904.

Shadbolt, N. 2005. Eliciting expertise, in *Evaluation of human work*, edited by J.R. Wilson & E. Corlett. Boca Raton: Florida: CRC Press: 185-218.

Simpson, A. 1994. A formal specification of an automatic train protection system, edited by M. Naftalin, T. Denvir & M. Bertran. Springer: 602-617.

Stanton, N. A., and Walker, G. H. (2011). Exploring the psychological factors involved in the Ladbroke Grove rail accident. *Accident Analysis & Prevention,* 43: 1117-1127.

Stutts, J., Feaganes, J., Reinfurt, D., et al. (2005). Driver's exposure to distractions in their natural driving environment. *Accident Analysis & Prevention,* 37: 1093-1101.

Treat, J. R. (1980). A study of precrash factors involved in traffic accidents. *The HSRI review,* 10,

Wickens, C., and Hollands, J. 2000. *Engineering Psychology and Human Performance (3rd Edition)*. Upper Saddle River, NJ: Prentice-Hall.