Exploring effectiveness of driver attention and alertness monitoring devices for GB railway

Dr Kirsten Huysamen, Paul Leach, Anna Vereker, Dr Claire Coombes, Tom Hyatt, Jasmine Bayliss & Anisha Tailor

Rail Safety and Standards Board

SUMMARY

Seven people died in the Sandilands tram accident in 2006 illustrating the impact loss of driver alertness can have. A study into Signal Passed at Danger (SPADs) revealed that driver alertness and attention were factors in 49% of events. The Rail Safety and Standards Board therefore instigated a study to a) determine what driver attention and alertness monitoring technology would be suitable for GB rail (phase 1) and b) determine the benefits of the technology through a live industry trial (phase 2). The phase 1 evidence indicated that loss of alertness and attention has significant safety consequences, and that driver alertness and attention monitoring technology can help to mitigate this risk. The research recommended that a specific GB rail device is required, and 108 functional requirements were developed. These have been used to procure a device that will be trialled live with three train companies from March 2024 for a year (phase 2). The paper details the phase 1 findings, the phase 2 trial methodology and initial findings from the trial.

KEYWORDS

Fatigue, alertness and attention, distraction, technology, train driving

Introduction

Loss of attention and alertness has a significant impact on safety. The Sandilands tram accident in 2006 illustrates this, where loss of driver alertness was one cause, seven people died and many were injured. A study into SPADs revealed that driver alertness and attention were factors in 49% of events, with an additional 4% of events involving drivers being asleep or incapacitated (Gibson et al., 2018). Evidence suggests that driver attention and alertness monitoring technology, specifically technology that monitors the driver's facial features with a driver-facing camera, can help to reduce this risk (Lenne & Fitzharris, 2016). This technology provides real-time feedback to the driver when behaviours indicative of loss of attention and alertness are detected. Driver alertness and attention monitoring technology has been implemented in sectors such as road transportation (buses, trucks, motor vehicles) and mining (Leach & Basacik, 2021).

Minimal research on this type of technology exists for mainline rail (heavy rail). Within the UK, driver attention and alertness monitoring technology has only been trialled in light rail, specifically at Croydon Trams in response to the Sandilands tram accident. The system alerted the driver in the form of an audible and seat-shaker alarm when visual distraction or a microsleep was detected. Croydon trams found the technology to improve safety, reporting a 75% and 30% reduction in fatigue and visual distraction related events, respectively, and a 300% increase in driver incident reporting (Leach & Basacik, 2021). As such, the Office of Rail and Road (rail regulator) challenged mainline rail (heavy rail), to determine how this technology could be implemented, and the safety benefits it could bring. This was supported by the Rail Accident Investigation Branch (RAIB) investigation into the Kirby buffer stop collision on 13 March 2021, where loss of alertness was identified as a causation factor. RAIB recommended research to be undertaken on the effectiveness of technology to improve the detection and mitigation of train driver loss of attention and alertness (RAIB, 2022).

The Rail Safety and Standards Board instigated this study to: determine what driver attention and alertness monitoring technology would be suitable for GB mainline rail (phase 1) and; determine the benefits of the technology through a live industry trial (phase 2).

Method

Phase 1 built understanding of driver alertness and attention technology (including the indicators used to assess these states). It explored lessons learned from their deployment in different industries and its application to mainline rail. It included:

- Literature reviews to determine a) types of technology, their application and effectiveness, and b) the clinical performance and practicality of psychophysiological and behavioural indicators used to assess loss of alertness and attention.
- Interviews and site visits with organisations who have trialled or implemented similar systems to gather operational learnings and understand policy, process, and competence.
- Workshops with experts in railway engineering, operations and data handling, utilising agreed user personas and journeys to determine how different individuals might interact with the technology and the potential processes that could govern its use.

These research activities led to the development of functional requirements for a GB rail specific train driver alertness and attention monitoring device, as well as a good practice implementation model. Both of which were used to create the phase 2 trial plan and procure the equipment for trial.

Phase 2 comprises of a live trial with three train companies over a twelve-month period, starting from March 2024. Data collected during the trial (including baseline data) will be reviewed and statistically analysed. The trial objectives are to: develop understanding of the causes of loss of attention and alertness; identify opportunities to improve attention and alertness and evaluate the technology's ability to reduce the consequences of loss of attention and alertness events.

Phase 1 Findings

Driver alertness and attention monitoring technology

The phase 1 evidence identified 61 products with the ability to monitor driver attention and alertness. These were categorised into four types:

- Behavioural devices: Monitors the drivers physical features or movements for symptoms of loss of attention or alertness (eye movement, facial feature movements, head position etc.).
- Driving performance devices: Monitors the drivers input to the vehicle or the vehicles behaviour for drowsy or inattentive driving behaviour (steering wheel movement, lane position etc.).
- Physiological devices: Measures physiological signals that have a correlation to loss of attention or alertness (brain activity, ocular activity, electrodermal activity etc.).
- Hybrid devices: A combination of two of the three types described above.

Behavioural devices are non-obtrusive, monitoring the driver via a driver-facing camera and alerting them in real-time if needed. These devices tend to be in a fixed location in the driving environment and require no interaction from the driver to function. Behavioural devices are being trialled in light rail and other transport industries, where some positive results have been observed. For example, a study conducted by Lenne & Fitzharris (2016) reported a significant reduction (93.2%) in fatigue events for truck drivers from three South African heavy fleet companies over a five-month period after the implementation of a driver fatigue monitoring system. An Australian mining company reported a 75% reduction in fatigue events for their heavy vehicle fleet drivers and Croydon Trams a 75% and 30% reduction in fatigue and visual distraction related events for tram drivers, respectively, after the implementation of similar technologies (OpGuard and Guardian systems, respectively) (Leach & Basacik, 2021). These findings suggest behavioural devices to be suitable for mainline rail.

Driving performance devices are non-obtrusive, providing feedback to drivers in real time. However, these devices are more applicable for road driving than train driving as they use measures such as lane deviation and steering wheel movement. The accuracy of these devices in detecting loss of attention and alertness have also been questioned in the literature (Leach & Basacik, 2021). There is some evidence to suggest that physiological devices, specifically those that monitor brain activity, can detect loss of attention and alertness the quickest. Evidence also exists on the accuracy of some of these devices. For example, in a controlled laboratory setting, the SmartCap fatigue algorithm has been shown to have a sensitivity score of 94.75% for detecting sleepiness (Rajaratnam & Howard, 2011). However, these devices can be obtrusive, requiring the driver to wear a device such as headwear. Moreover, each driver would need their own device, take ownership of it and position it correctly on their bodies throughout the duration of their shift. All of which is impractical in a railway setting. There was limited available research on the reliability, validity and implementation of hybrid devices so the advantages and disadvantages of these devices could not be determined.

Psychophysiological and behavioural indicators of loss of attention and alertness

For the purposes of reviewing indicators, attention was defined as 'the behavioural and cognitive process of selectively concentrating on a discrete aspect of information, while ignoring other perceivable information' (Castro, 2009). This included distraction in terms of attention being given to irrelevant stimuli or actions. Alertness focused on the degree of arousal in terms of sleepiness and wakefulness.

The literature identified fifteen psychophysiological and behavioural indicators of loss of attention and alertness. The indicators were assessed and scored (1 to 10) on two dimensions: clinical performance and real-world practicality. None of the indicators achieved a perfect score of 10 for clinical performance and real-world practicality. The indictors that scored above 5 on both dimensions were: Eye closure, eye movement, gaze zone, foveation and pupillometry. In contrast, heart rate, skin resistance, respiration and salivary biomarkers scored below 5 for both clinical performance and real-world practicality. Brain waves was scored as being effective, but impractical.

Eye closure, eye movement, gaze zone, foveation, and pupillometry are all indicators that can be measured by analysing data captured by a camera or sensor. Evidence from the literature suggests that these indicators can measure both alertness and attention, specifically microsleeps and visual distraction, with the exception of eye closure. Eye closure appears the most effective indicator of alertness, but a relatively poor indicator of attention.

Learnings and guidance from operational experience

Eight organisations who have trialled or implemented driver alertness and attention monitoring devices were engaged to gather operational learnings and understand policy, process and competence requirements for implementation.

Operational learning indicates that implementation problems can be mitigated by taking a planned and comprehensive approach to introducing driver alertness and attention monitoring devices.

Organisations highlighted the importance of staff engagement and fostering a fair culture during the introduction and operation of such technology. The development of a fair culture creates a high degree of trust within the organisation and staff feel comfortable discussing situations where they have experienced loss of attention and alertness. The operational learning also suggests that this culture means staff are more likely to perceive the device as being a positive safety intervention.

Using the operational learning, an implementation model for introducing this technology was developed and used to plan the phase 2 live trial. The model sets out the activities organisations undertook to implement the technology and reported as being essential for successful implementation. The implementation model, in Figure 1, presents the recommended order of the tasks to be undertaken when introducing this technology. A summary of each stage is captured in Leach & Tailor (2021). Fostering a fair culture and staff engagement were considered two of the most critical activities and cover all aspects of the model.

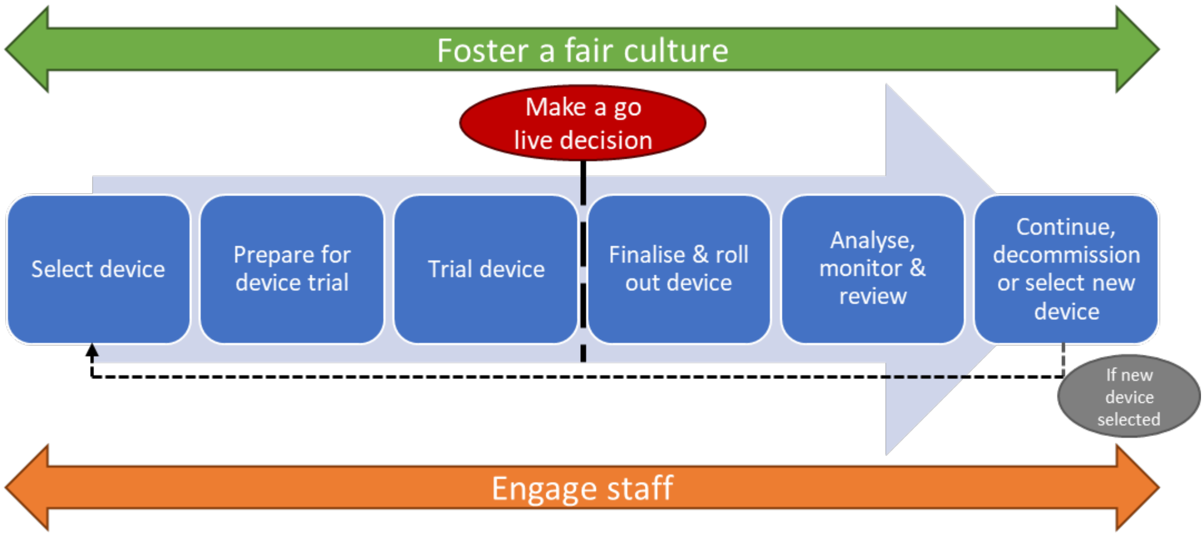

Figure 1: Implementation model for systems that monitor train driver alertness and attention

Developing functional requirements

The phase 1 research activities concluded that a specific device for GB rail was required. Workshops were undertaken to develop functional requirements for a GB rail specific device.

To achieve this, the ways in which different individuals might interact with a driver alertness and attention monitoring device in GB rail was explored with experts in railway engineering, operations and data handling. The potential processes that could govern its use was also explored. User personas and journeys were used to facilitate discussions on the following topic areas:

- Engineering (e.g., technology installation, maintenance and de-commissioning)
- Operation (e.g., start-up activities, calibration, passive monitoring, event detection and alarm, event response)

- Data (e.g., data transmission, analysis, storage and disposal)

The findings from these workshops as well as all learning from the phase 1 research activities were collated, analysed and used to develop the functional requirements. These were divided into 10 high-level requirements (Figure 2). Each high-level requirement consisted of a set of lower-level specific requirements. The lower set of requirements, totalling 108, were prioritised in terms of whether the device 'Must', 'Should' or 'Could' meet that specific requirement. The functional requirements were used by the trial companies to procure the driver alertness and attention device for trial.

High-level functional requirements for a GB rail specific driver alertness and attention monitoring device

- A system that can be fitted, and reliably function, be maintained and recovered from the range of the GB Rail vehicle fleet, without affecting other onboard structures or systems, or the availability of rolling stock for railway operations.
- A system that accurately and reliably monitors attention and/or alertness across a reasonable range of cab environments and driver clothing, behaviours and characteristics.
- A system that does not adversely affect drivers' health, safety, comfort or task performance.
- A system that provides an alarm to the driver when they lose alertness or attention.
- A system that notifies the company if a driver has reached a defined threshold for loss of alertness or attention, when they have received a false alarm, and when the device is faulty, disarmed or has been tampered with.
- A system that can be calibrated or can learn so that its accuracy within the railway context and with individual drivers, and the timeliness of the alarms to the driver and notifications it provides to the company, improve over time.
- A system that provides data on driver loss of alertness and/or attention events, that the organisation can use to better understand and manage these issues.
- A system that collects, stores, transmits and disposes of data in a way that is compatible with the General Data Protection Regulations and railway companies' data transmission and storage facilities, and is future proofed in this respect.
- A system which can be configured so that different users have different permission levels for accessing different types of data (including different permissions to access event notifications vs numbers and text about a particular event vs footage vs a history of one's own events vs a history of anyone's events) vs updating it vs deleting it.
- The supplier to provide documentation and support in managing the introduction of the system into the company.

Figure 2: The ten high-level functional requirements a driver alertness and attention monitoring device need to meet to be considered for the Phase 2 trial

Phase 2 activities for live trial

Technology to be trialled

After a selection process involving consultations and an in-depth analysis of tender documents against the functional requirements, the technology to be trialled was selected. This will:

- Detect microsleeps (loss of alertness) and visual distraction (loss of attention).
- Be camera based with a sensor mounted in the train driving cab to detect behaviours indicating a microsleep or visual distraction.
- Provide both an audible and haptic alarm when detecting a microsleep and a different audible alarm when detecting a distraction event.
- Provide real-time feedback to the driver and organisation to help mitigate the risk of loss of alertness or attention.

Prior to trial implementation, various activities have been undertaken in line with the implementation model displayed in Figure 1 to create the enablers for a successful trial.

Operational procedures

Operational procedures for implementing and operating the device have been developed. This sets out:

- The data management principles: This includes capture, storage and management of data, and the measures taken to ensure driver confidentiality. All in line with legal data protection and trial company requirements.
- The process for responding to activations and system failures: This describes the actions taken by the organisation and driver when 1) the monitoring device detects a true-positive loss of alertness or attention event during the shift, 2) the device generates false-positive activations and 3) the monitoring device experiences a system failure.
- The process for analysing data at an individual and company level: Loss of attention and alertness events can be caused by a combination of factors to do with the organisation and individual, and as such, the trial will apply equal consideration to both. The process details how to identify individual, organisational, job or workplace factors contributing to activations, and the process for developing, implementing and monitoring solutions.

Fair culture policy

Facilitating a fair culture within the three trial companies is a key enabler. As such a fair culture policy has been developed. This policy has been used to develop the procedures described above as well as the overall approach to trial. The fair culture policy sets out principles (Figure 3) with subsequent guidance.

Fair culture principles for trialling a driver alertness and attention monitoring device in GB rail

- Principle 1: We [trial companies] will only use attention and alertness monitoring equipment to help our employees and organisation understand how they can better manage attention and alertness.
- Principle 2: When a loss of attention or alertness event occurs, we will consider equally how the individual can be supported and organisational system improved.
- Principle 3: When a loss of attention or alertness event occurs or an employee reports concerns, they will be treated with respect, trust and dignity, and their report will be treated confidentially.
- Principle 4: Loss of attention and alertness events and early reporting concerns provide us with an opportunity to learn and we will act on these to help us improve how we manage safety.
- Principle 5: Our employees will be provided with information, development and/or support so that they are able to adopt and uphold the principles of a fair culture.
- Principle 6: We will regularly review our use of attention and alertness monitoring equipment to drive continual improvement and ensure the agreed principles of fair culture are being upheld.

Figure 3: The fair culture principles that each trial company will embed in their organisation

To support a fair culture briefing materials and staff communication plans have also been developed with the trial companies.

Hazard identification

Taking a risk-based approach to the fitment and operation of the technology is another enabler in line with GB rail Taking Safe Decisions (Rail Safety and Standards Board, 2019). A comprehensive hazard list for fitting and operating the technology was developed. The list, which is continuously being developed, captures the hazards that could arise during fitment, implementation and operation of the technology. The following steps were performed to create the list:

1. Understanding the system: This was to understand the design and intended use of the technology. The following documents were reviewed: project objectives, phase 1 findings, functional requirements, system specifications (from supplier) and any relevant industry standards and regulations.
2. Identifying potential hazards: This was to identify potential hazards that could arise from implementation. Hazards included, but were not limited to, technical failures, system malfunctions, data privacy concerns, use error and external factors (e.g. weather).

3. Documenting potential hazards and consequences: A comprehensive list of all potential hazards and their consequences were documented. This included potential impacts on driver safety, passenger safety, train operations, and system performance.
4. Reviewing and updating the hazard identification process: This involved refining the process so that all potential hazards had been considered, and that trial companies could develop appropriate mitigation strategies with input from RSSB.

Multiple sources were used to develop the comprehensive hazard list, including the rail industry CHAMOIS list (Gilmartin et al,. 2023), the functional requirements established in phase 1 and HAZID lists from rail organisations. The development process included:

- Backwards hazard identification on the functional requirements. This involved reviewing each requirement to determine whether it was mitigating a safety hazard.
- Reviewing HAZID lists from rail organisations. This was to identify hazards that may arise from the interactions between the new system and existing systems, processes or procedures.
- Gap analysis involving the rail industry CHAMOIS list. This was to identify any additional hazard that were relevant but not yet included to the hazard list.

Trial plan

To assess the trial objectives a trial evaluation plan has been created. Key aspects are described below:

- Three train companies reflecting GB mainline rail (heavy rail) operations are participating in the trial: a long-distance passenger operator, a short distance operator and a freight operator.
- The live trial will take place over a 12-month period. This is considered useful to illustrate any seasonal trends in the data. Preceding this will be a month long 'silent monitoring' period. The data collected during this period, as well as pre-trial survey data and historic fatigue reports and safety event data, will be used as the baseline data for the project.
- The following types of data will be collected in the 'silent monitoring' and live trial periods: monitoring device data, roster data, operational data, fatigue reports and safety event data.
- Pre- and post- trial surveys will be administered to understand perceptions of fatigue reporting, safety culture and behaviours within the trial companies.
- Lessons learned during the implementation period and live trial will be captured.
- Resources have been created for trial companies to use during the trial. The materials enable consistent and standardised data collection and help answer the research objectives of the project. They also assist trial companies with collecting and sharing data with the RSSB, providing the appropriate level of care to the driver, and explore how system issues affecting fatigue and loss of attention can be addressed.
- The data captured will be statistically analysed to identify trends, patterns and insights. The data and analysis techniques are captured in a data analysis plan. Several factors and relationships will be assessed including, but not limited to, the frequency of events per route, time of day, shift type, location on route, weather conditions, sleep quality, occupational health outcomes, hours worked prior to activation etc.

The trial plan was agreed by an independent ethics committee comprised of academics and crossindustry specialists.

Conclusions (so far)

Incidents and studies in rail transport indicate that loss of attention and alertness pose a safety risk and that technology to monitor driver alertness and attention has positive impacts on reducing these events and improve safety.

The phase 1 research activities identified behavioural devices as the most suitable type of device for GB mainline rail (heavy rail). This is because they are the least intrusive measures as they monitor the drivers' physical features or movements for symptoms of loss of attention or alertness using indictors such as eye movement, facial feature movements and head position. Moreover, phase 1 suggests that detecting loss of alertness through micro-sleeps and loss of attention through visual distraction appears to be the most suitable approach for a live trial. Noting that these can still be considered rudimentary measures of complex constructs.

One hundred and eight functional requirements were identified creating a bespoke specification, which in turn led to the procurement of a specific device for trialling in phase 2. The live trial plan is built on key enablers identified in phase 1. The two most important enablers, based on operational learning, is the facilitation of a fair culture and staff engagement.

A fair culture develops trust in the system so that it is used to support the driver in managing attention and alertness, and helps the organisation determine system issues affecting train drivers' attention and alertness. Staff engagement facilitates trust and provides an opportunity for staff and management to discuss potential fears and concerns over the technology and often “myth bust” potential misunderstandings around the technology and how it will be used in an organisation.

The phase 2 trial will provide detailed data sets to help understand the causes of loss of attention and alertness, individual and organisational solutions and the impact alertness and attention monitoring technology can have on reducing these events and improving overall safety.

References

Castro, C. (2009). Human Factors of Visual and Cognitive Performance in Driving. Boca Raton: CRC Press.

Gibson, H., Monk, A., & Walters, S. (2018) Research into human factors causes of signals passed at danger, T1128. London, RSSB.

Gilmartin, B., &, Griffin, D (2023). Common Hazards for the management of industry safety (CHAMOIS), T1194. London, RSSB.

Leach, P., & Basacik, D. (2021). Understanding the functional requirements for train driver attention and alertness monitoring devices: Assessment of indicators and evaluation of technologies. London, RSSB.

Leach, P. & Tailor, A. (2021). Understanding the functional requirements for train driver attention and alertness monitoring devices: Learning from operational experience. London, RSSB.

Lenne, M., & Fitzharris, M. (2016). Real-time feedback reduces the incidence of fatigue events in heavy vehicles. 23rd ITS World Congress Melbourne, Australia.

RAIB. (2002). Rail Accident Report: Buffer stop collision at Kirby, Merseyside. UK, Crown.

Rail Safety and Standards Board. (2019). Taking Safe Decision, Issue 3. London, RSSB.

Rajaratnam, S.M.W. & Howard, M.E. (2011). Evaluation of the SmartCap technology to monitor drowsiness in healthy volunteers exposed to sleep restriction – Relationship between the SmartCap fatigue algorithm and frequent misses on the Osler test. Australia: Monash University.