Rail Control and Automation Technology: Transitions within the European Rail Traffic Management System

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Abstract. The European Rail Traffic Management System (ERTMS) is a control and automation system which is being gradually introduced to rail systems across the world. The introduction of ERTMS has meant an increase in the level of automation in train driving. A mixed methods approach was used to investigate transitions on an ERTMS fitted line. Qualitative data was collected as a part of a semi-structured interview study with ERTMS drivers. Quantitative data was collected as part of a larger real world eye-tracking study with ERTMS drivers. The results provide an initial insight into the effect of transitions with ERTMS on train driver behaviour.

Keywords. Automation, train driving, transitions, ERTMS

1. Introduction

Over the years the UK rail system has introduced train protection technologies which provide conflict resolution as they bring trains to an automatic stop if the separation of the trains is violated by passing a signal at danger (Stoop et al 2008) or in some cases if the driver is violating the speed restrictions. However, the introduction of this type of protective automation has not had an impact on the tasks and responsibilities of the driver, as it was designed to mitigate the consequences of a driver passing a signal at danger (SPAD) or exceeding the speed limit.

The European Rail Traffic Management System (ERTMS) is a control and automation system which is being gradually introduced to rail systems across the world. The introduction of ERTMS has meant an increase in the level of automation in train driving, however very little human factors research was conducted around how this new system would affect train driver behaviour. Porter (2002) stated that the problems that could be created by increasing automation in train driving are parallel to the types of problems created by increasing automation in other industries such as nuclear and aviation. The examples given included mode confusion, lack of trust in the system, unclear intentions by the system following an abnormal event, lack of transparency of the system processes and decrease in driver job satisfaction.

Enhanced automation with ERTMS driving will ultimately change the role of the driver. The driver's role will consist of more monitoring tasks and anticipating intervention in case of any disruptions (Stoop et al 2008). In areas of full automation (Automatic Train Operation, ATO) the role of the driver will have even less control and more monitoring tasks. As a consequence, important questions need to be addressed, such as how this will have an impact on driver's cognitive strategies and attention. Additionally, it is important to investigate how transitioning between conventional driving and the different modes of ERTMS will impact driver behaviour.

ERTMS, when in level 2, provides the driver with in-cab signalling, where the movement authority is presented on a planning area on the Driver-Machine Interface

(DMI), as opposed to following movement authorities provided on the track via signals. ERTMS also provides a supervisory automatic protection system via speed profiles on the DMI, which train drivers must adhere to. If the driver overspeeds the system produces auditory and visual alarms, which will eventually be followed by the automatic application of the brakes.

There is a small section of the route in the UK where ERTMS drivers have to transition back to conventional signalling (level NTC-National Train Control), where their movement authority is no longer given on the DMI but on signals out on the track; and the system is no longer monitoring the speeds. Also ERTMS has different modes, which include full supervision (FS, when ERTMS is working under normal conditions, providing full protection) and on sight (OS- when the movement authority allows the train to enter an occupied section of line at a very low supervised speed).

With the introduction of automation and the proposed use of different levels of automation on new signalling schemes, it is crucial to understand how this will effect train driving. The fatal Santiago de Compostela train accident on 23rd July 2013 is an unfortunate example of why it is so crucial, as a transition out of ERTMS level 1 was implicated in the accident report (Puente 2015).

The data collected for this study was from the only ERTMS fitted route in the UK and is providing insight for future routes which will include transitions between sections of conventional driving, ERTMS driving and ATO. This paper will present a data collected in relation to transitions as part of a three-year research project on ERTMS and train driver behaviour; including semi-structured interviews and a real world eye-tracking study.

2. Methods

A mixed methods approach was used to investigate transitions on the ERTMS Cambrian line. Qualitative data was collected as a part of a semi-structured interview study with ERTMS drivers. Quantitative data was collected as part of a larger real world eye-tracking study with ERTMS drivers.

2.1 Semi-Structured Interviews

A semi-structured interview study was conducted with 14 ERTMS drivers lasting approximately one hour (detailed methodology can be found in Buksh et al 2013). As part of this study direct questions were asked relating to transitions, but drivers also discussed transitions in more open ended questions. This paper will only discuss the data collected in relation to transitions.

2.2 Real World Eye-Tracking

An eye-tracking study was conducted in the field on timetables routes using 14 ERTMS drivers (detailed methodology can be found in Naghiyev et al 2014). SMI eye-tracking glasses were used to collect eye movements and the visual scene. Begaze software was used to analyse the eye movements, in particular the number of fixations on predefined areas of interest (AOIs) both inside and outside the cab and their associated fixation durations. The Observer XT software was then used to code the events that occurred in the videos (e.g. alarms, signals, transitions etc.), using a predefined coding scheme. Once all the video had been coded, data profiles were set up to analyse the fixation data for select events, including transitions. Baseline data was analysed for 8 second sections where no other events were occurring. Eight seconds before and after a selected event were also analysed. The time period 8 seconds was selected as it is the signal sighting time used by Network Rail’s Engineering teams.

This paper will only present the transitions between OS and FS, as only 2 participants experienced the level 2 to level NTC transition during the data collection.

3. Results

3.1 Semi-Structured Interview Data

The data emphasised the importance of the positioning of a transition when designing a signalling scheme and considering safety.

“Yeah when you leave Aberystwyth you leave in OS and the next block marker, you are very close to it. If you didn't transition to full supervision you would SPAD it and not stop in time.”

In particular, it was shown to have an impact on the driver’s visual strategy and allocation of attention when transitioning from OS mode to FS mode.

“So I think what you find yourself doing is looking down as you are accelerating, looking for it to change but as you don't have a planning area you have to keep looking up to see where you are in relation to the block marker and to see how close you can let it go.”

Drivers also need to integrate information about the system and their past experiences with that particular transition into their route knowledge to anticipate the events that will occur during a transition. One driver stated,

“And you need to know when you are in SR (staff responsible), when it should transition into OS and then FS (full supervision). You need to know that sort of thing. You need to know a lot more with ERTMS than conventional driving.”

Drivers reported different experiences about transitioning from level 2 to level NTC. Some drivers found that they had to pay more attention to remember where to start braking, the various speed restrictions and the use of different line side signage; whilst other drivers found that they had to pay equal or less attention whilst driving. Participants stated varying degrees to which their visual attention was being shifted from both inside and outside the cab, to predominately outside the cab.

When transitioning from level two to level NTC, drivers’ variations in experiences are shown by the statements below:

“you have to focus really hard on remembering that you now need to brake and slow down for speed restrictions yourself, because you won’t get told to do it.”

“So it’s almost like a switch you have to operate somewhere and then your back into being a proper driver again. And I find that that is quite a big transition and I quite look forward to it actually.”

“No not really. I think it's just relief that it exited it successfully and then I'm quite happy to drive into Shrewsbury. I don't find it a struggle to look at signals.”

“Do you notice any difference when driving from ERTMS to non-ERTMS and vice versa? No”

"Not really. I am just as alert it's just that the signal is outside rather than the screen. The speedometer is still on the DMI."

Some drivers reported that their main challenge from going from ERTMS driving to conventional driving (level NTC) was to monitor speed without the assistance of a system and to switch their monitoring of signals to outside on the track. However, concerns were raised about new drivers using ERTMS without prior experience with conventional driving.

The data indicates that the message that drivers received from the system when they transitioned to level NTC acts as a cue for them to switch their mental models from ERTMS driving to conventional driving. This is also reinforced by the presence of the AWS (automatic warning system), which normally prompts drivers to look outside for the upcoming trackside signal.

A major concern with the introduction of ERTMS driving was its potential impact on drivers' mental workloads. Tasks that a driver must carry out during transitions (such as monitoring if ERTMS has been successfully achieved) could also lead to peaks in workload. In addition, extra events around a transition could cause high mental workload. An example one driver provided was that:

"Again going into Aberystwyth, you have the ABCL at Llanbadarn, but just beyond it you have a marker board for end of authority, so you don't know where to look. And if you're trying to do two things you can't do them both well. Nothing has happened to me there but it could. And in fact it has happened to one of our drivers at Llanbadarn coming out of Aberystwyth. He didn't have the white flashing light but he was so busy looking for the transition to full supervision mode and getting the brake test done and it was all later than normal that he failed to look out for the white light and didn't realise that it was there."

3.2 Eye-Tracking Data

The fixation durations for the baseline data is shown in figure 1 and the fixation durations for the OS to level 2 transition data is shown in figure 2. The data shows that there is a temporary increase in allocation of attention to the message area on the DMI immediately after a transition.

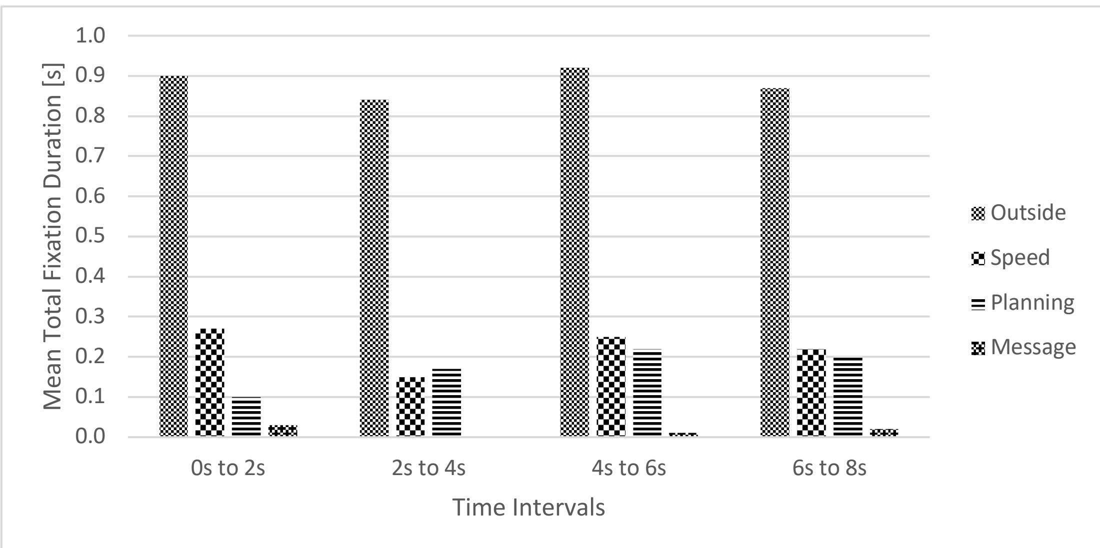

Figure 1: Graph for the fixation durations for the baseline

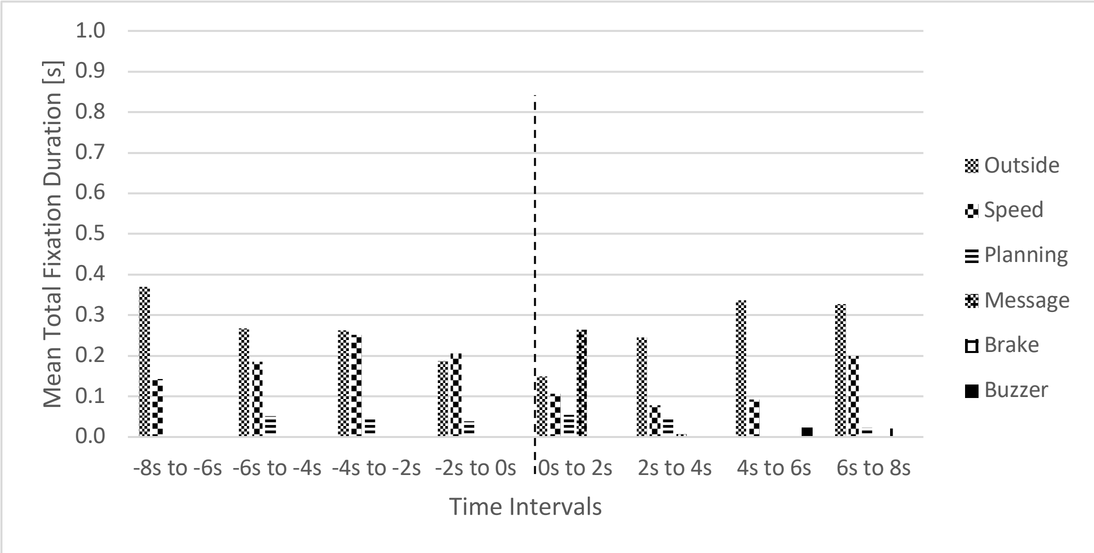

Figure 2: Graph for fixation durations for the OS to level 2 transition

A paired-samples t-test was conducted to compare fixation durations in the baseline (8 seconds) and the 8 seconds prior to the transition. There was no significant difference in the fixation durations at the outside AOI (t(7)= 1.528, p=.17) nor the speed AOI (t(7)=1.573, p=.16) for baseline and prior to entering the transition.

A paired-samples t-test was also conducted to compare the fixation durations in the baseline (8 seconds) and the 8 seconds immediately after the transition. There was no significant difference in the fixation durations at the outside AOI (t(7)= 1.57, p=.16) nor the speed AOI (t(7)=1.29, p=.238) for baseline and immediately after the transition.

4. Discussion and Conclusion

The results provide an initial insight into the effect of transitions with ERTMS on train driver behaviour. In particular, the results highlight the need to carefully design new signalling schemes with no additional tasks around transitions which may increase a driver's workload or cause them to have divided attention. There may be different driving styles emerging which may explain the variations in reporting of allocation of visual attention from transitioning from level 2 to level NTC. The eye-tracking data shows that drivers' attention is shifted to the message area on the DMI immediately after a transition for a very short period of time (when they receive an alert and message which they must acknowledge). However there isn't a significant difference in the allocation of attention to outside the cab or to the speed profile area on the DMI, in comparison to the baseline data.

There is also evidence that driver's mental models and route knowledge have now adapted to include how the system will 'behave' and at what points they will receive alerts or transitions, which is allowing them to anticipate the system's action and be 'proactive' drivers instead of 'reactive' drivers. Potentially the ERTMS has provided another layer to the already existing route knowledge which could in theory adapt how train drivers react or make decisions along the route.

This piece of research provides empirical evidence from a real world study based on one ERTMS fitted route. It would be beneficial to explore transitions and ERTMS further, in particular with ATO, in a simulated environment with additional tasks of varying workload and the test the impact of route designs.

This would further the understanding of mental workload around transitions and help to inform the design of future signalling schemes.

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