On-road driving studies to understand why drivers behave as they do at regional rail level crossings

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Abstract

Improving safety at rail level crossings is an important part of both road and rail safety strategies. While low in number, crashes between vehicles and trains at level crossings are catastrophic events typically involving multiple fatalities and serious injuries. Advances in driving assessment methods, such as the provision of on-road instrumented test vehicles with eye and head tracking, provide researchers with the opportunity to further understand driver behaviour at such crossings in ways not previously possible. This paper describes a study conducted to further understand the factors that shape driver behaviour at rail level crossings using instrumented vehicles. Twenty-two participants drove an On-Road Test Vehicle (ORTeV) on a predefined route in regional Victoria with a mix of both active (flashing lights with/without boom barriers) and passively controlled (stop, give way) crossings. Data collected included driving performance data, head checks, and interview data to capture driver strategies. The data from an integrated suite of methods demonstrated clearly how behaviour differs at active and passive level crossings, particularly for inexperienced drivers. For example, the head check data clearly show the reliance and expectancies of inexperienced drivers for active warnings even when approaching passively controlled crossings. These studies provide very novel and unique insights into how level crossing design and warnings shape driver behaviour.

Introduction

The current approach to Rail Level Crossing (RLX) safety

In 2008 there were 58 collisions between trains and vehicles at RLX in Australia, which led to 33 fatalities and serious injuries (Australian Transport Safety Bureau, 2008). Such incidents typically involve road user errors and violations, traumatic injury, and have a significant economic impact on both networks. This is particularly so for heavy vehicle collisions as they have a much greater potential to derail the train.

Our recent review of RLX research highlighted that achieving acceptable levels of performance and safety at RLXs has proven difficult (Edquist et al., 2009), partly because RLXs are not homogeneous. RLXs are typically classified as one of two types: RLXs with active warnings (e.g., flashing red lights), or passive crossings (protected by stop or give way signs). Further, there are differences in the volume of rail and road traffic, the type and speed of traffic, overall RLX geometry, and so on. All of these factors influence fundamental aspects of human performance (including perceptual processes and expectations) that shape road user behaviour and thus the appropriate solution. Across Australia there are approximately 9,400 rail level crossings, with 6,060 passive (60%), 2,650 (30%) active, and 690 (10%) having other forms of control. Current solutions to the problem, such as grade separation and installation of boom gates, provide significant safety improvements but are cost-prohibitive (Wigglesworth & Uber, 1991). The effectiveness of lower cost interventions, such as education campaigns, speed limit reductions, rumble strips, train strobe lightings and in-vehicle warnings remains largely unknown, with the evaluations conducted to date being poorly designed and lacking a sound theoretical underpinning (Edquist et al., 2009).

Key to developing effective RLX crash interventions is an in-depth understanding of the RLX system, including the performance of, and interactions between, its component parts (road users, vehicles, trains, train drivers, infrastructure etc). Although a limited number of models have been developed, currently we do not possess this systemic understanding. The research to date has been driven by an individual road user viewpoint, and therefore does not fully consider the wider RLX system factors that shape road user performance.

Our understanding of RLX system operation and road user behaviour at RLXs is therefore currently limited. The focus of existing research on individual factors is a critical shortfall given the recent theoretical advances within the discipline of Human Factors that emphasise the need to take a systems perspective when evaluating, modelling, and supporting the performance of complex sociotechnical systems. The need to take the entire system, comprising human operators, tools, artefacts, and technologies and the interactions between them as the unit of analysis rather than the individuals working within it has been advocated (Hollnagel, 2001; Walker et al., 2009). While existing theories of human performance (e.g., information processing) and models of driver behaviour provide a solid foundation, a new approach is needed to drive intervention development that recognises broader systemic influences on RLX crashes. Our recent review of level crossing intervention research identified the lack of a systemic model that describes how road users interact with level crossing infrastructure as a major gap in the area. The traditional approach to this issue, while important, has not taken us forward in terms of improving safety for some time as these interventions for road user behaviour and level crossing safety have not been assessed from a true systems perspective.

The human factors approach

The approach we are adopting to reducing RLX trauma involves collection of data to better understand the nature and performance of different RLX systems, and then development of models of RLX system performance using contemporary methods. This involves the use of theoretically underpinned, systems-based methods, including Hierarchical Task Analysis (HTA; Stanton, 2009) and Cognitive Work Analysis (CWA; Jenkins et al., 2008, Vicente, 1999). HTA describes the system *normatively*, in terms of what currently happens, whereas CWA describes the system *formatively*, in terms of what could potentially happen. Following this, the analyses are used to evaluate existing interventions, and to inform the design and specification of novel interventions designed to treat the problem of RLX crashes. The final phase will use advanced driving simulation and on-road methods to test and refine the interventions proposed. An overview of the process is provided in Figure 1.

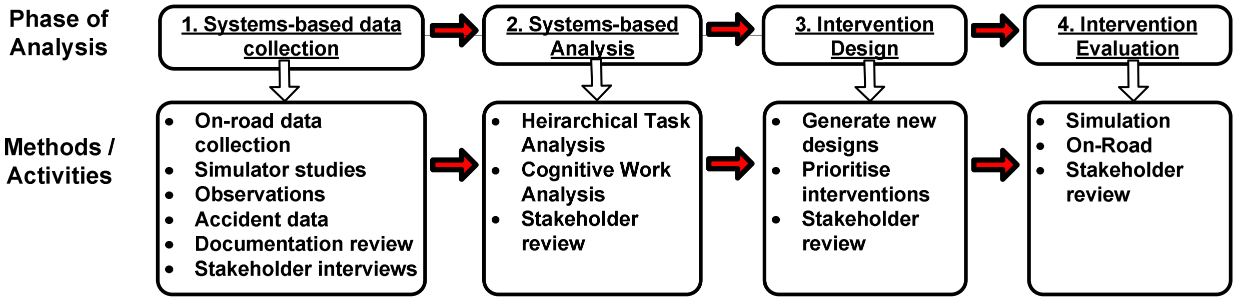

Figure 1. An overview of the human factors-based systems approach to safety research and intervention design.

The application of HTA and CWA in a complementary manner has previously been used for system design and evaluation in other areas such as process control and the military. The outputs from each approach describe the system in a different but complementary manner, which is particularly powerful for system design and evaluation. The development of both models (HTA and CWA) is supported initially by data collected from a range of activities, including observational studies, documentation review, subject-matter interviews, and walkthrough analyses, all of which have previously been used to support previous model development using HTA and CWA (Jenkins et al., 2008; Stanton et al., 2009). The use of driving simulation and on-road methods to study road user behaviour also provides novel insights into the role of the RLX system in shaping behaviour.

In this regard we have already conducted two studies using instrumented vehicles to study driver behaviour at RLX in both regional and metropolitan settings. In addition to the standard suite of vehicle-based and eye-movement measures, measures of driver cognitive process and strategies were also derived via the use of verbal protocol analysis (i.e. think aloud) during the drive, and then post drive 'critical decision method' interviews, which are designed to explore the cognitive processes underpinning task performance and decision making. Data of this type have not previously been collected at RLXs and are required to underpin both the development of the RLX models and future research efforts. This paper reports on some of the visual scanning findings from the first of these on-road studies.

Method

Participants

Twenty-two drivers took part in the study, divided into an experienced driver group (6F & 5M, M_{age} = 45.1 years) and a novice driver group (6F & 5M, M_{age} = 19.3 years). Participants were recruited through local newspapers, notice boards, community groups and word of mouth.

On-road route

The study route was approximately 30km long, situated in Greater Bendigo, a regional centre in Victoria, Australia. Bendigo was selected as it is a region containing both actively and passively controlled RLX. The route encompassed a range of road types, including city streets, residential and suburban streets, highways, gravel and dirt roads. The route included ten RLXs: six active RLXs (five had flashing lights and boom gates, one had flashing lights only) and four passive RLXs (three with stop sign only, one with give way sign only). Participants drove the route using ORTeV, a 2004 Holden Calais equipped to record vehicle and road scene data. Figure 2 provides an example of the active and passive crossings encountered in the study.

On-road test vehicle and measures

ORTeV is an instrumented vehicle equipped to collect two main types of data: vehicle-related and eye tracking data. Vehicle data are acquired from the vehicle network and include: vehicle speed; GPS location; accelerator and brake position; steering wheel angle; lane tracking and headway logging; and primary (windscreen wipers, turn indicators, headlights, etc.) and secondary controls (sat-nav system, entertainment system, etc.). ORTeV is also equipped with seven unobtrusive cameras recording forward and peripheral views spanning 90° each respectively as well as three interior cameras and a rearward-looking camera.

Figure 2. Images for an active (left) and passive (right) RLX in the study route

Eye movements were measured using a head mounted eye tracking system. For the purposes of the current analyses, the primary dependent measure was head checks. Drivers were coded as having executed a head check if their head direction deviated in excess of ±30°, where 0° indicates facing straight ahead. Data from two additional methods was collected but not reported in this paper (verbal protocol analysis and critical decision method interviews).

Results

Each dependent variable was analysed using the Generalised Estimating Equation (GEE) approach. While on average all drivers made a greater number of head checks at passive crossings (stop and give way) than the actively controlled boom barrier crossings, statistically only the give way versus boom barrier comparison reached significance ($\chi^2(1) = 269.6$, $p < 0.001$). Inspection of Table 1 suggests little influence of driver experience on the number of head checks made. Interestingly however, for the active crossing experienced drivers made ~2 checks at boom crossings compared to novice drivers who made on average less than one. While not reported here, the total duration of head checks followed a similar pattern.

Table 1: Mean (±SD) total number of head checks by crossing type and level of driving experience

	Driver Group	
RLX Control	Novice	Experienced
Boom Barrier	0.82 (0.35)	2.0 (0.42)
Stop sign	5.73 (0.83)	5.3 (0.51)
Give way	5.18 (0.403)	5.9 (.50)

While providing an overall viewpoint, as others previously have noted (Ward & Wilde, 1996), when a temporal component of lateral head movements are ignored, it is not possible to assess the significance of the search behaviour. The following discussion presents temporal data.

Table 2: Mean (±SD) points on crossing approach for the first and final head checks by crossing type and level of driving experience

	First Head Check		Last Head Check	
RLX Control	Novice	Experienced	Novice	Experienced
Boom Barrier	105.5 (42.3)	126.8 (40.3)	105.7 (42.3)	74.9 (37.1)
Stop sign	36.7 (35.7)	36.1 (39.2)	7.3 (8.0)	7.4 (4.6)
Give way	182.2 (78.7)	312.9 (95.7)	43.9 (29.9)	38.7 (31.5)

Table 2 presents the points on approach to each crossing type where drivers on average made their first and last head check. Drivers made significantly earlier head checks at give way crossings compared to boom barrier and stop sign controlled crossings ($\chi^2(1) = 4.46$, $p < 0.05$; $\chi^2(1) = 14.15$, $p < 0.001$). The final head checks were made much closer to the stop sign crossing that the give way crossing ($\chi^2(1) = 16.24$, $p < 0.001$), and closer to the give way crossing than the boom barrier crossing ($\chi^2(1) = 19.275$, $p < 0.001$).

Discussion

This paper reports on some of the scanning behaviours of drivers using an instrumented vehicle at regional level crossings, with a focus here on examining how and when drivers visually search for trains on approach to a rail level crossing. While in most instances there were no trains present at the crossing, the results are nonetheless quite revealing. Drivers have greater number of head checks at give way crossings compared to boom barrier crossings.

Interestingly, the total number of head checks made at the passively controlled stop sign and give-way controlled crossing were similar, however analysis of the points at which these head checks occurred reveals some interesting differences. All head checks for the stop sign crossing occurred very rapidly within an approximate 50m area immediately prior to the crossing, whereas the same number of head checks at give way crossings are dispersed over a 200-300m distance. There are at least two potential explanations for this finding. The first relates simply to sight distance. Drivers engage in fewer head checks when visibility is reduced (e.g., Åberg, 1988), and sight distance in our study was larger for the give way crossing than for boom-barriers and the stop sign crossing. Secondly, give way crossings have rumble strips located in advance of the crossing that may in fact be triggering the earlier head checks at give way crossings. To the contrary, it would appear that drivers are focused primarily on speed maintenance and safe braking when approaching stop sign crossings, with all head checks on average occurring within 50m of the crossing itself.

What the data do suggest though is that there are fundamental differences relating to the crossing environment and infrastructure at passively controlled give way and stop sign controlled crossings that shapes driver head check behaviour. These differences relate to the timing of head checks undertaken rather than the total number of head checks. In contrast, the number of head checks conducted at the active boom barrier crossing is much lower than for the passive crossings, with inexperienced drivers making on average only one head check on approach. While reduced sight distance may also play a role here, it is more likely that this finding reflects the ways in which driver experience shapes expectancies and behaviour at level crossings. Data collected from the verbal protocols and post-drive interviews, while not reported in this paper, show the very strong reliance on active warning signals, which contributes to the low level of checking for trains. Our previous research shows that this is particularly the case for novice drivers.

The head check data reported here are novel and highlight the extent to which drivers check for trains when negotiating level crossings in a naturalistic context, and the timing of those checks. A point of note is that almost all of these encounters occurred when there was no train present, and so it remains to be seen how the behaviours reported here would support safe behaviour in the presence of a train. This can be readily done using simulation (Lenné et al., 2011), or in significantly more resource intensive naturalistic driving studies. Head check data, while important, provide only part of the story. The verbal protocol and post-drive interview data are being interrogated to provide insights into how driver situation awareness is influenced by crossing type, and how driving experience might influence this. These analyses will also yield information on the information cues and strategies used by drivers to make decisions at level crossings.

In closing, approaches to safety research and management that take a systems approach are more likely to generate effective interventions. Several authors have called for such approaches to be applied to transport settings. In recognising the need for new approaches to safety in the RLX context, the Victorian road and rail sponsors have partnered with Australian and UK Universities in an exciting four year initiative designed to change the paradigm in RLX safety. The approach we are using initially involves the collection of new data on the ways in which the RLX system shapes road user behaviour. The second component involves a conceptualisation and analysis of the RLX system using methods that are congruent with systems thinking. The use of these outputs to support new intervention design and evaluation are the final components. These outputs will emerge over the next 24 months and it is anticipated they will inform the management of rail level crossing safety in Victoria.

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