From the Bush to the Burbs: a comparison of driver situation awareness at rural and urban railway level crossings

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Abstract

The problem of collisions between road users and trains at rail level crossings (RLXs) remains resistant to current countermeasures. One factor underpinning these collisions is poor Situation Awareness (SA) on behalf of the road user involved (i.e. not being aware of an approaching train). Although this is a potential threat at any RLX, the factors influencing SA may differ depending on whether the RLX is located in a rural or urban road environment. Despite this, there has been no empirical investigation regarding how road user SA might differ across distinct RLX environments. This knowledge is needed to establish the extent to which a uniform approach to RLX design and safety is acceptable. The aim of this paper is to investigate the differences in driver SA at rural versus urban RLXs. We present analyses of driver SA in both rural and urban RLX environments based on two recent on-road studies undertaken in Victoria, Melbourne. The findings demonstrate that driver SA is markedly different at rural and urban RLXs, and also that poor SA regarding approaching trains may be caused by different factors. The implications for RLX design and safety are discussed.

Introduction

Worldwide, the problem of collisions between road users and trains at RLXs remains resistant to current countermeasures. In Australia, between 2000 and 2009, there were 695 collisions between road vehicles and trains at RLXs, resulting in 97 fatalities (Independent Transport Safety Regulator, 2011). Despite various initiatives, in 2011 there were 49 collisions between trains and road vehicles at RLXs in Australia, leading to 33 fatalities (ATSB, 2012).

One of the key issues underpinning these collisions is unintentional non-compliance, whereby road users fail to detect trains and/or warnings or comprehend the meaning of warnings and enter the crossing unaware that a train is approaching. Such incidents are estimated to account for almost half of all RLX crashes in Australia (ATSB, 2002).

Situation Awareness (SA) is a widely used safety-related concept that focuses on how humans maintain an understanding of 'what is going on' in safety critical environments (Endsley, 1995). Research recent has focussed on driver SA as a key factor that lies at the root of unintentional non-compliance (e.g. Salmon, et al, 2013a). Although lack of SA regarding approaching trains is ostensibly a threat at all RLXs regardless of type or location, it is apparent that the factors diminishing SA may differ depending on whether the RLX is located in a rural environment or an urban environment (Salmon et al, 2013b). Although the rural driving environment is typically less complex in nature than urban locations, the low frequency of trains at rural RLXs creates expectancy issues whereby drivers may not expect to encounter trains at them (e.g. Salmon et al, 2013a). As a corollary, they may not look for trains, or in extreme cases may not perceive trains and warnings even when seeing them. This issue is often compounded by the fact that the majority of rural RLXs are 'passive' and do not have so-called 'active' warnings such as boom gates, which provide a highly salient cue when a train is approaching and are known to achieve the best safety performance (e.g. Saccomanno, Park & Fu, 2007). On the other hand, RLXs located in urban environments experience more trains and typically form part of a more complex driving environment and scenario, incorporating higher levels of other traffic such as pedestrians, cyclists, trams, and also a built environment often comprising shops and advertising. This creates the potential for issues such as driver distraction, overload, and inattention. These differences in urban and rural RLX environments suggest that drivers will experience the two forms of RLX differently.

Recent collisions in Australia provide some evidence that there may be fundamentally different issues involved in collisions at rural and urban RLXs. For example, it has been suggested that a primary causal factor in the Kerang tragedy of 2007 in which a loaded semi-trailer truck collided with a passenger train at a rural RLX in northern Victoria, Australia, killing 11 train passengers, was the truck driver's diminished SA which arose from his schema-driven expectancy that a train would not be passing through the crossing (Salmon et al, 2013a). The truck driver in question had not previously experienced a train at the crossing despite having driven the same route on multiple occasions over a seven-year period. In contrast, in their 2008 rail level crossing safety bulletin the Australian Transportation Safety Bureau reported that there have been many instances of trains colliding with vehicles that are effectively trapped on the crossing via a traffic queue or lowered boom gates (ATSB, 2008). The presence of significant traffic queues and/or boom gate controls is more common in urban environments.

These differences in the factors underpinning deficient SA at RLXs raise questions regarding the typically uniform approach to RLX design (regardless of the environment in which they are located). The appropriate design of road environments has been identified as a critical component of supporting road user SA and behaviour (e.g. Salmon et al, 2014; Walker et al, 2013). At RLXs, most efforts to improve safety through the design of more effective warning devices focus on enhancing road user SA regarding the presence of, first, the crossing, and second, the approaching train, regardless of the environment in which the crossing is situated. To date there has been no empirical investigation regarding how road user SA might differ across these distinct RLX environments or on what factors influence attainment of appropriate levels of SA. The extent to which a uniform approach to RLX design is acceptable is therefore unknown. It may be that design solutions should be tailored to suit urban or rural RLX environments.

Previous studies have demonstrated that driver SA differs in different road environments (e.g. intersections versus arterial roads) and across drivers with differing levels of driving experience (Salmon et al, 2013, 2014). The aim of this paper is to take the first steps toward clarifying whether driver SA is different at urban and rural RLX environments. Using data derived from two recent on-road studies of driver behaviour at rail level crossings, this paper presents an analysis of driver SA in both rural and urban rail RLX environments. The aim is to explore the differences in driver SA, both in terms of its development and the resulting situational knowledge, at rural and urban RLXs, with a view to informing the discussion surrounding the design of solutions for both forms of crossing environment.

Assessing situation awareness on the road

Both studies used a network analysis-based approach to describe and assess road user SA whilst negotiating rail level crossings. This approach has previously been used by various researchers during assessments of SA in real world contexts, including on-road studies (e.g. Salmon et al, 2013; Stanton et al, 2007; Walker et al, 2011). The approach involves constructing ‘situation awareness (SA) networks’ using data derived from the Verbal Protocol Analysis (VPA) method. The VPA method involves participants ‘thinking aloud’ as they perform tasks. The resulting verbal transcript is then subjected to a content analysis procedure in which ‘concepts’ and the relationships between them are derived from the text. This process produces an SA network depicting the information or concepts underlying awareness and the relationships between the different concepts. For example, an extract of an SA network is presented in Figure 1. This shows the concepts ‘crossing’, ‘train tracks’, ‘ahead’, ‘flashing lights’ and ‘flashing’ along with the relationships between them; for example the ‘crossing’ has ‘flashing lights’, which are ‘flashing’, the ‘train tracks’ are ‘ahead’ etc. The resulting SA networks enable comparison of SA across different participants, scenarios, and environments (e.g. Salmon et al, 2014; Walker et al, 2011).

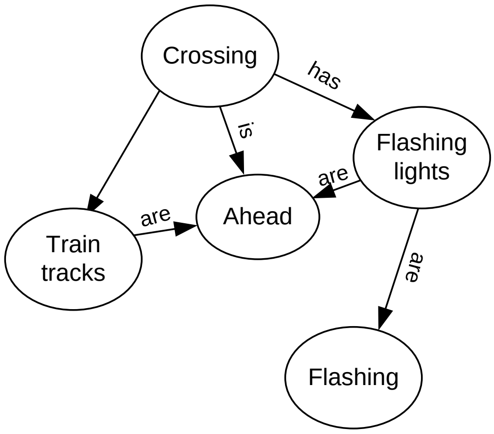

Figure 1. Example rail level crossing driver situation awareness network

Method

Design

Both studies were separate semi-naturalistic on-road studies in which participants drove an instrumented vehicle around a pre-defined route incorporating a series of RLXs. The rural route incorporated ten rail level crossings, whilst the urban route incorporated nine rail level crossings.

Participants

Twenty-two drivers (10 males, 12 females) took part in the rural study. Participants were sorted into an experienced or novice driver group. The experienced driver group (n = 11, Mage = 45.1 years) had an average of 27.3 years solo driving experience (SD = 7.6). The novice driver group (n = 11, Mage = 19.3 years) had an average of 1.6 years solo driving experience (SD = 0.3). Participants were recruited through local newspapers, notice boards, community groups and word of mouth. All participants regularly drove in the study area.

Twenty drivers (10 males, 10 females) took part in the urban study. Participants were sorted into an experienced or novice driver group. The experienced driver group (n = 8, Mage = 35.8 years, age range 29 - 53) had an average of 19.2 years solo driving experience (SD = 9.7). The novice driver group (n = 12, Mage = 20.8 years, age range 18 - 22) had an average of 2.8 years solo driving experience (SD = 0.99). Participants were recruited through local newspapers, notice boards, community groups and word of mouth. All participants regularly drove in the study area.

Materials

The urban study route was approximately 11km long, situated in and around the South East suburbs of Melbourne, Victoria. The route encompassed a range of road types, arterial roads, and residential and suburban streets. Speed limits varied along the route, ranging between 40km/h to 100km/h. The route included nine RLXs. Participants drove the route using the ORTeV, which is a 2004 Holden Calais equipped to record vehicle and road scene data. A Dictaphone was used to record participant verbal protocols.

The rural study route was approximately 30km long, situated in and around Greater Bendigo, Victoria, Australia. The route encompassed a range of road types, including city streets, residential and suburban streets, highways, unmarked roads, gravel and dirt roads. Speed limits varied along the route, ranging between 40km/h to 100km/h. The route included ten RLXs. Participants drove the route using the ORTeV. A Dictaphone was used to record participant verbal protocols.

Participants' verbalisations were transcribed using Microsoft Word. The SA network construction process was undertaken using the Leximancer™ content analysis software.

Procedure

Upon completion of an informed consent form and demographic questionnaire, participants were briefed on the research and its aims, which were expressed broadly as a study of everyday driving. Participants were then given a short VPA training session that incorporated demonstration, practice and feedback, following which they were taken to the ORTeV and told to establish themselves in a comfortable driving position. In the rural study, two observers were present in the vehicle throughout the drive. Participants completed a short practice drive whilst providing a concurrent verbal protocol. At the end of the practice route, participants were informed that the test had begun and that data collection had commenced. On-route, the observer located in the front passenger seat provided directions. Participants provided verbal protocols continuously throughout the drive.

Participants' verbal protocols were transcribed verbatim post drive using Microsoft Word. For data reduction purposes, extracts of each participant's verbal transcript covering the approach to, and negotiation of, each RLX were taken from the overall transcripts based on set points located in the road environment. The verbal transcripts were then analysed using the Leximancer content analysis software in order to create SA networks.

Data analysis

For data analysis, the Leximancer content analysis software was used. Leximancer uses text representations of natural language to interrogate verbal transcripts and identify concepts and the relationships between them. The software does this by using algorithms linked to an in-built thesaurus and by focussing on features within the verbal transcripts such as word proximity, quantity and salience. Initially Leximancer looks for words that frequently appear in the text and then uses a weighting procedure to classify frequently appearing words as concepts. Once a list of concepts is identified Leximancer determines how concepts are related to one another by measuring the co-occurrence of concepts within the text. Leximancer thus automates the content analysis procedure by processing verbal transcript data through five stages: conversion of raw text data, concept identification, thesaurus learning, concept location, and mapping of relationships. The output is a network representing concepts derived from the verbal transcript and the relationships between them reflected within the verbalisations. The Leximancer software has previously been used for SA network construction (e.g. Salmon et al, 2014; Walker et al, 2011) and other studies have found similar outputs when comparing Leximancer and manual analyses of SA (e.g. Grech et al, 2002). Although manual construction of SA networks is more sensitive to differences across participants, the Leximancer tool is especially important to analyses of this kind since it provides a less resource intensive, reliable and repeatable process for constructing situation awareness networks and removes analyst subjectivity during network creation.

Results

The analysis led to the creation of the following four SA networks:

1. Urban RLXs, train approaching, all urban participants;
2. Urban RLXs, no train approaching, all urban participants;
3. Rural RLXs, train approaching, all rural participants; and
4. Rural RLXs, no train approaching, all rural participants.

An additional analysis was undertaken to examine the differences across novice and experienced drivers; however, this analysis is not described in this paper. The four SA networks created provide an overall summary of driver SA in each RLX environment and situation. For example purposes, the no train approaching SA networks for the rural and urban RLXs are presented in Figure 2.

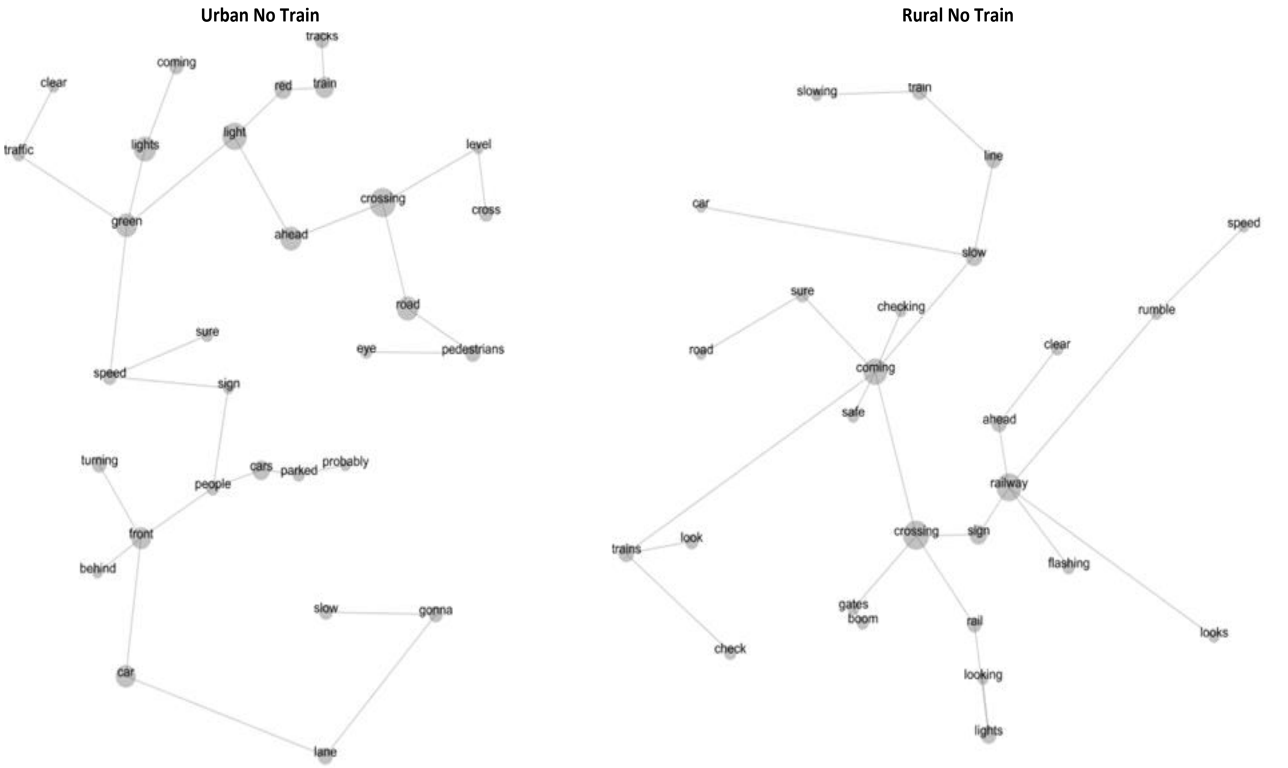

Figure 2. Rural versus Urban no train situation awareness networks

The four networks are presented in tabular form in Table 2. Table 2 shows all of the SA concepts derived from the networks along with shading to show their presence within the SA networks across the four different conditions (urban train coming, urban no train, rural train coming, rural no train).

Table 2. Comparison of concepts across rural and urban RLX environments in train approaching and no train approaching conditions

	Urban train coming	Urban no train	Rural train coming	Rural no train
Railway	■		■	■
Crossing	■	■	■	■
Level		■		
Cross		■		
Gates	■			■
Boom				■
Train	■	■		■
Trains				■
Tracks		■		
Coming	■	■		■
Traffic	■	■		
Lights	■	■	■	
Light		■		
Red	■	■		
Green	■	■		
Clear	■	■		■
Ahead	■	■	■	■
Front	■	■		
Behind	■	■		
Slow	■	■	■	■
Slowing				■
Car	■	■		■
Cars	■	■		
Tram	■			
Moving	■			
Keeping	■			
Pedestrians	■	■		
People	■	■		
Road	■	■		■
Road name	■			
Lane	■	■		
Hand	■			
Turning	■	■		
Sure	■	■		■
Eye		■		
Speed		■		■
Sign		■		■
Parked		■		
Probably		■		
Gonna		■		
Flashing			■	■
Stop			■	
Wait			■	
Move			■	
Forward			■	
No-one			■	
Line				■
Look				■
Looks				
Check				■
Checking				■
Safe				■

Rumble				

Figure 2 and Table 2 show that there were important differences in driver SA across the different RLX environments and scenarios (train approaching versus train not approaching). Overall, for both train approaching and no train approaching conditions, the main differences derived from the presence of concepts related to elements in the urban RLX environment that are not typically present in rural RLX environments. For example, concepts such as 'traffic', 'lights', 'red', 'green', 'tram', 'pedestrians' and 'people' were present in both urban SA networks, but not in the rural networks. In addition, additional driving-related concepts such as 'front', 'behind', 'lane', and 'turning' were present within the urban SA networks but not the rural SA networks. These results point to key differences in driver SA brought about by differences between not only the urban and rural RLX environments themselves, but also by the different nature of the driving task in urban versus rural environments.

Further important differences were present in the train versus no train approaching conditions. When a train was approaching, many of the concepts present only in the urban SA network relate to the surrounding traffic and urban environment. These include concepts such as 'lights', 'red', 'green', 'tram' 'pedestrians', and 'traffic'. Concepts present in the rural SA networks but not in the urban SA networks include 'flashing', 'stop', 'wait', 'move' and 'no-one'. Concepts related to the additional SA requirements associated with urban driving, such as 'behind' were also present in the urban SA networks.

When a train was not approaching the differences between the SA networks relate primarily to the participants' behaviour surrounding checking for an approaching train. For example, the concepts 'check', 'checking' and 'look' are present in the rural SA network but not in the urban SA network. This indicates that checking for train behaviours in urban RLX environments may be limited. Again the concepts present in the urban SA network but not in the rural SA network relate to the surrounding traffic and urban environment and additional SA requirements (e.g. 'traffic', 'behind').

Discussion

The aim of this paper was to use data derived from two on-road studies of driver behaviour at RLXs to identify key differences in driver SA at rural and urban RLXs. From the exploratory analysis presented it is concluded that driver SA at urban and rural RLXs is different, both in terms of the concepts (and therefore information) underpinning it, and the interactions with the environment used to develop it. This is an important conclusion, and brings into question the typically uniform approach to designing RLXs regardless of their location.

This conclusion raises some important questions worthy of discussion. Most important relates to what the differences in driver SA relate to, and whether both forms of RLX environment are currently designed in a manner that supports driver SA or not. Broadly, the analysis suggests that there are three key factors underpinning the differences in driver SA across urban and rural RLX environments that were found in this study: the higher volume, and different forms, of traffic in urban environments, the presence of additional infrastructure in urban environments, and the differences in behaviours related to driving and checking for trains across urban and rural RLX environments. Each issue is discussed below.

More traffic (and more diverse forms of traffic) leads to additional SA requirements

The analysis suggests that the higher volume of traffic in urban RLX environments, along with the presence of different forms of traffic and road users not typically found in rural RLX environments, places additional SA requirements on drivers when approaching RLXs in urban environments. Drivers effectively need to know more about other traffic and road users and their behaviour. In both the train approaching and train not approaching conditions participant SA was focussed on surrounding ‘cars’ and other forms of road user such as ‘pedestrians’ and ‘trams’. In addition, in the urban RLX environments drivers were focussed also on the area ‘behind’ the vehicle, whereas they were not in the rural RLX environments. This was ostensibly down to the presence of other forms of traffic behind the vehicle along the urban route. It is concluded that the higher volume of traffic and presence of different forms of traffic (e.g. pedestrians) in urban RLX environments places additional SA requirements on drivers as they have to be aware of the location and behaviour of other cars and other forms of road user such as pedestrians and also anticipate and respond to their behaviour. These additional SA requirements place an additional cognitive and visual load on the drivers, and could limit the amount of attention that drivers can give to RLXs and their warning devices. In extreme cases (e.g. high traffic situations) this may shift the focus of drivers’ attention away from the RLX.

More infrastructure creates additional SA requirements

Urban RLX environments are typically more complex than rural RLX environments, often being located in built environments such as shopping strips, and experience higher and more diverse levels of traffic. The analysis suggests that this complexity creates additional SA requirements for drivers when negotiating RLXs in urban environments. In the present study these additional requirements included the need to consider traffic lights and their current status (e.g. red or green) and also ‘behind’ the vehicle. Again this additional load on drivers could potentially provide a threat to their maintenance of adequate SA regarding the RLX and approaching trains. This is in line with Caird et al (2002) who found driver distraction to be one of the factors underpinning drivers’ failure to detect RLX signals.

Different environments lead to different SA-related behaviours

The third key difference found appears to be related to the different SA-related behaviours brought about by the nature of the urban and rural SA environments and the resulting differences in the driving task in both environments. For example, when a train was not approaching in the rural RLX environments, participants’ SA was focussed on ‘checking’ for trains, whereas no checking-related SA concepts were found in the urban environments when no train was approaching. This indicates a reliance of drivers in urban environments on the crossing signals to alert them to the presence of a train. This may be due partly to the higher workload placed on drivers in urban RLX environments but also partly due to the fact that it is difficult to check along the tracks for trains in urban RLX environments due to the presence of buildings close to the track area. In rural RLX environments typically drivers can check for trains throughout the approach to the RLX, whereas this is not possible in most of the urban RLX environments studied.

Design implications

Although this study represents a first exploratory step at identifying differences in driver SA when negotiating urban versus rural RLXs, there are some initial implications for RLX design in both environments. First, the additional complexity and load placed on drivers in urban RLX environments suggests that the focus should be on optimising driver workload and attention and not merely on adding more warning signals at the crossing itself. Moreover, driver education and training could emphasise the key SA requirements when negotiating RLXs in urban environments. Both implications suggest that a fundamental change to RLX design may be required, and more importantly that the design of urban road and RLX environments cannot be undertaken in silos; rather, urban road and RLX should be considered and undertaken together as one integrated process. A second implication is that the findings provide further evidence that driver overload is unlikely to play a role in rural RLX crashes. Rather, issues such as expectancy, schema-related errors, distraction and underload represent the key threats to driver compliance at rural RLXs. Rural RLX design should therefore focus on preventing these issues. A key research requirement is therefore to identify the most appropriate design solutions for this purpose.

Study limitations

The data and analysis presented did have some limitations worth noting. First, the analysis was based entirely on participant verbal protocols. Additional data, such as eye fixations and driving performance measures, would confirm some of the verbal protocol content (e.g. participants reporting that they are checking for trains versus participants not mentioning checking behaviours) and enhance the validity of the findings. A separate analysis undertaken by Young et al (Under review) examined the urban study verbal protocol data in conjunction with eye tracking data. Second, although the verbal protocol analysis methodology has a long history use in examining cognitive processes and behaviour in different environments, questions remain over its influence on behaviour during on-road studies. Further research exploring its impact is therefore recommended.

Acknowledgements

This research was funded by an Australian Research Council Linkage Grant (LP100200387) in partnership with Victrack Access, Public Transport Safety Victoria, Transport Accident Commission, VicRoads, Victorian Government Department of Transport and V/Line Passenger Pty Ltd. Professor Salmon's contribution to this research was funded by an Australian National Health and Medical Research Council Post-Doctoral Training Fellowship. Professor Salmon currently holds an Australian Research Council Future Fellowship.

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