A self-report study of factors influencing decision-making at rail level crossings: Comparing car drivers, motorcyclists, cyclists and pedestrians

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Abstract

Collisions at rail level crossings (RLXs) represent a major challenge for both road safety and rail safety professionals. RLX collisions are typically high-severity and high-cost, often involving multiple injuries and/or fatalities as well as major disruptions to the transportation network. Most research examining road users' behaviour at RLXs has focused exclusively on drivers and consequently there is little existing knowledge on how other road users make decisions at RLXs. We designed a longitudinal survey to prospectively record interactions at RLXs over a two-week period. The sample included 166 adults residing in metropolitan Melbourne (80%) and regional Victoria (20%), with a mix of car drivers, motorcyclists, bicyclists and pedestrians. Respondents completed the survey daily and provided a detailed account of any encounters with trains and/or activated RLX warnings, with the survey prompts based on a cognitive task analysis methodology. The results reveal that both experiences and behaviour at RLXs differ substantially across different road users. Visual information (e.g., flashing lights) emerged as one of the most influential factors for car drivers and motorcyclists, whereas pedestrians and to a lesser extent cyclists relied more on auditory information (e.g., bells) to alert them to the presence of a train. Pedestrians were also more likely than other road users to speed up and cross the tracks ahead of an approaching train. Overall these results emphasise the importance of designing road systems to support cognition and behaviour across a range of road users, in order to ensure a safe system for all.

Introduction

Collisions at rail level crossings (RLXs) represent a major challenge to the safety and efficiency of rail networks throughout Australia. During the ten year period from July 2002 to June 2012, there were 601 collisions involving vehicles and 92 involving pedestrians at RLXs in Australia (ATSB, 2012). Although RLX collisions are relatively rare compared to other types of road collisions, they are considered a high priority due to their disproportionate impact on society. In particular, RLX collisions have a higher rate of fatalities compared to other types of road crashes (Wigglesworth, 1976) and typically result in massive disruptions to both road and rail networks, incurring an estimated annual cost of approximately $32 million in 1999 (BTRE, 2002).

RLXs are an example of a complex sociotechnical system, requiring interactions between many different categories of road users including train drivers, signal operators, pedestrians, cyclists, motorcyclists, car drivers, truck drivers and other road users (Read et al., 2013). Moreover, RLX collisions are a systems problem in that factors interact across the overall sociotechnical system to shape behaviour at the crossing (Salmon et al., 2013a). As a corollary, it is the interactions between components of the system that are of interest, as opposed to the behaviour of components in isolation (e.g., drivers). Although in recent years there have been increasing efforts to develop safe systems approaches to road safety, a recent literature review found that no previous research had specifically adopted a systems approach in order to examine safety at RLXs (Read et al., 2013). Indeed, there is relatively little research that attempts to understand how different road users behave at RLXs and most existing research focuses exclusively on car drivers (Edquist et al., 2009; Read et al., 2013). As such, there is a need for further research to investigate how different classes of road users interact with RLXs as a system; for example, to understand what types of factors inform individuals' decision-making at RLXs and how individuals could be better supported in order to make safer decisions. Only through this understanding of different road user interactions can "systemic" RLX collision interventions be developed.

Existing research indicates that different road users might interact differently with the RLX system. For example, an increasing body of empirical literature demonstrates that different road users interpret the same situation in quite divergent ways (Salmon et al., 2013b; Walker et al., 2011). In particular, on-road studies indicate that the content of individuals' *situation awareness* or their sense of what is going on around them varies depending on their transportation mode, with some authors suggesting that these differences result in cognitive incompatibilities between different road users (Walker et al., 2011). Motorcyclists appear to be more focused on anticipating potential hazards than car drivers, whereas cyclists in dense traffic may focus more on seeking safe alternative travel routes such as bicycle lanes, service lanes and footpaths (Salmon et al., 2013b). Several studies have also indicated that car drivers and motorcyclists differ in their perception of hazards, particularly in situations involving motorcycles (Crundall et al., 2012, 2013; Shahar et al., 2012). This previous research involved situations where different road users may come into conflict with each other, such as at intersections. At RLXs, the more pressing concern is whether these road users would come into conflict with a train; nevertheless it remains possible that the cognitive inconsistencies observed between road user groups in other contexts could affect their behaviour and decision-making at RLXs. Moreover, it is likely that RLX interventions aimed at one road user group (e.g., drivers) will create emergent issues for other road users.

In addition, there are divergent trends in the number of RLX collisions between vehicles and pedestrians. Most notably, the number of collisions involving vehicles has been declining, whereas the number of collisions involving pedestrians has remained constant (ATSB, 2012). This suggests that recent improvements in the safety of the RLX network (which may be the result of upgrading crossing treatments by adding boom barriers and/or flashing lights) have selectively affected operators of motorised vehicles and other strategies should be sought to improve pedestrian safety.

As part of a wider research program involving the design of holistic RLX solutions for all road users, the current study sought to investigate decision-making at RLXs across four road user groups: car drivers, motorcyclists, cyclists and pedestrians. Truck drivers were not included due to difficulties in recruiting professional drivers for such a time-intensive survey. A prospective diary study was used to collect longitudinal data from individuals throughout metropolitan Melbourne and regional Victoria. The inclusion of urban and regional participants was important to capture data across all key types of RLX warnings. *Active warnings* provide a specific signal to road users that a train is approaching imminently: for example, flashing lights may activate or boom barriers may descend. In contrast, *passive warnings* are static signs that indicate the presence of the crossing itself but do not give any guidance as to whether a train is approaching. Currently in Victoria there are approximately 1,885 road RLXs, less than half of which have active warnings (Public Transport Victoria, 2012). All public road RLXs in metropolitan Melbourne have active warnings, but pedestrian RLXs and road RLXs in regional Victoria often have only passive warnings. The participants all interacted with RLXs regularly and were asked to record their experiences at RLXs on a daily basis for two weeks. The survey focused on understanding how individuals behaved in the presence of a train, which included examining the decision that they made (to stop or proceed before the train) and the specific factors that assisted their decision-making in that situation.

Method

Participants

The sample comprised 166 Victorian residents aged 18-71 years (M = 39.9, SD = 12.9). Most participants resided in metropolitan Melbourne (80%) with a minority in regional Victoria (20%). Table 1 provides brief demographic characteristics by road user group. Most motorcyclists and cyclists were male, reflecting the most typical users of both transportation modes (Austroads, 2011; Haworth, 2012). Participants were recruited through newsletters and local newspapers as well as mailing lists and websites devoted to motorcycle or bicycle riding interest groups. All participants provided written informed consent and were offered AUD$30 payment. The ethical aspects of the research were approved by Monash University Human Research Ethics Committee.

Table 1. Participant demographic characteristics

	Car drivers (n = 50)	Motorcyclists (n = 39)	Cyclists (n = 42)	Pedestrians (n = 35)
Region ***	62% metro	72% metro	98% metro	94% metro
Sex ***	64% female	15% female	31% female	60% female
Mean age (years) **	37.22	46.28	40.95	35.49

** Groups are significantly different, $p < .01$. *** Groups are significantly different, $p < .001$.

Materials and Procedure

Demographic questionnaire

At the commencement of the study participants completed a demographic questionnaire. This included age, sex, place of residence, frequency of use of their nominated mode of transportation and exposure to RLXs. Frequency of mode use was measured as hours per week spent travelling in this mode. Where participants reported that they frequently crossed RLXs using multiple modes of transportation (e.g., cycling and driving), they were asked to nominate which mode they used most frequently at RLXs. Frequency of RLX exposure was measured on a 5-point scale with options for “daily”, “3-4 times per week”, “weekly”, “2-3 times per month”, and “monthly”. Participants met the inclusion criteria for the study if they reported crossing RLXs at least 3-4 times per week on average. Car drivers and motorcyclists were also asked to report years of licensure.

Daily questionnaire

Participants completed a daily exposure questionnaire each day for two weeks. They were asked to report whether they used their nominated mode of transportation that day (e.g., “Did you drive a car?” or “Did you walk outside?”) If so, they were asked to indicate their level of exposure, which was recorded as kilometres travelled for car drivers, motorcyclists and cyclists, and as time spent walking outdoors for pedestrians. They were also asked to report the number and type(s) of RLXs crossed and whether they encountered any trains and/or activated warnings at the RLXs.

For days when participants did encounter a train and/or activated warnings at least once, they were then asked to describe one encounter in detail, with a focus on their decision making process. The questionnaire comprised open-ended and closed-ended questions that served as prompts to recall specific information about the encounter (see Appendix), based on the critical decision method (CDM) cognitive task analysis interview technique (Klein et al., 1989). CDM has been used to model naturalistic decision-making in settings including medical decision-making (Galanter & Patel, 2005), workplace accidents (Salmon et al., 2011) and emergency responses (Mendonça, 2007). Although CDM was primarily developed to investigate critical incidents, it has also been successfully applied to assess decision-making in driving using written questionnaires (Walker et al., 2009). For each encounter, participants were asked to describe the type of RLX, its location and the decision made (i.e., stop, slow down, proceed at same speed, speed up). Pedestrians and cyclists were asked to specify whether the RLX was located on a road, next to a road, or on a footpath.

Survey administration

Participants completed the survey either online or on paper. In the online mode, participants first completed a demographic questionnaire and then completed a daily exposure questionnaire via the website SurveyGizmo. In the paper mode, participants were mailed the demographic questionnaire together with 14 copies of the daily exposure questionnaire and a reply-paid envelope.

Data analysis

Responses to closed-ended questions were analysed using chi-square with an alpha level of .05. Because analysis of the full survey is beyond the scope of the current paper, only the results for three prompts are presented: cue identification, information integration and influencing factors. These prompts reflect the most important categories of information regarding participant's interaction with and decision making at the RLX.

Results

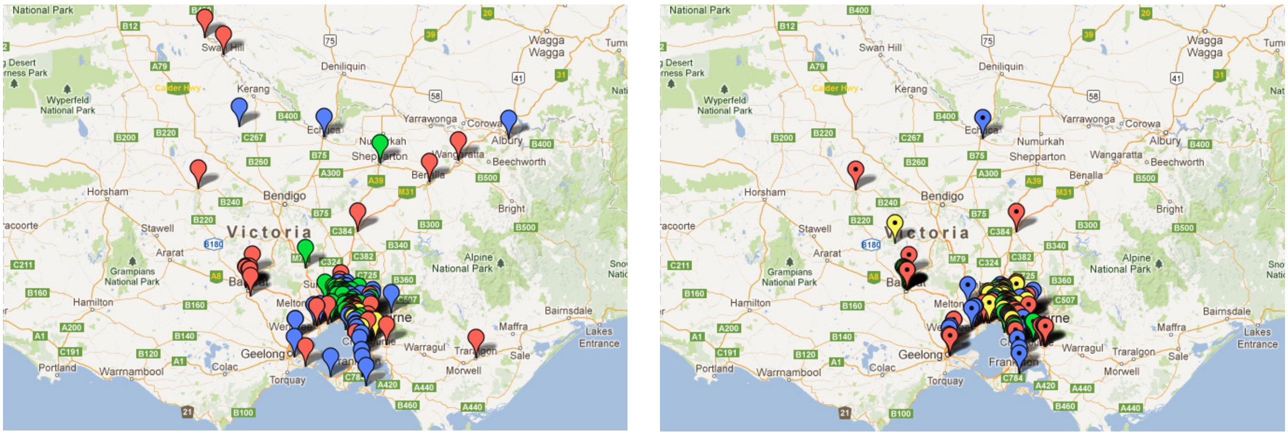
Exposure and Experience

Participants' self-reported average weekly exposure, as measured by their time spent travelling in the nominated transportation mode, was 9.2 hours per week (SD = 5.4) and did not differ significantly between road user groups, $F(3, 161) = 2.24$, $p = .085$, $\eta_p^2 = .040$.

Years of licensure did not vary between motorcyclists and car drivers, $t(79.4) = 0.22$, $p = .825$, $r = .025$. Most motorcyclists (95%) were on their full licence, with 5% on a learner's permit and none on a probationary licence. Similarly, 90% of car drivers reported that they were on a full licence, with 10% on a probationary licence (8% P2, 2% P1) and none on a learner's permit.

Most participants (60%) reported that they crossed RLXs daily. Frequency of RLX exposure did not differ between road user groups, $\chi^2(6) = 10.25$, $p = .115$, although car drivers were nonsignificantly more likely to cross RLXs daily (74%) compared to the other road user groups (52-56%).

Figure 1. Maps of participants' locations of residence (left) and locations of encounters with trains and/or activated rail level crossings (right)



Note. Red indicates car drivers, blue indicates motorcyclists, green indicates cyclists and yellow indicates pedestrians.

Rail Level Crossing Encounters

There were a total of 457 RLX encounters involving an approaching train and/or activated warnings reported in detail by 140 participants. All pedestrians (*n* = 35, 144 encounters), 84% of car drivers (*n* = 42; 135 encounters), 79% of motorcyclists (*n* = 31; 88 encounters) and 76% cyclists (*n* = 32; 90 encounters) reported at least one train encounter during the two-week study period. Most encounters occurred in metropolitan Melbourne (see Fig. 1), which is unsurprising given that the frequency of trains is much higher in metropolitan Melbourne compared to in regional Victoria.

Type of crossing

All encounters reported by motorcyclists and nearly all of those reported by car drivers (99%) occurred at RLXs with active warnings; most had both flashing lights and boom barriers, with a minority having flashing lights only (motorcyclists: 2%; car drivers: 1%). Only one driver reported an encounter with a train at a stop-controlled passive RLX.

Cyclists also reported that the majority of their train encounters (78.5%) occurred at road crossings with boom barriers and flashing lights, with the remaining 21% occurring at pedestrian crossings. These included active pedestrian crossings (e.g., controlled by automatic gates) next to a road (7.5%), active pedestrian crossings not next to a road (11%) and passive pedestrian crossings not next to a road (3%).

The majority of pedestrian encounters (81%) occurred at active pedestrian crossings that were next to a road, 6% occurred at active crossings not next to a road, 8% occurred at passive crossings not next to a road, 1% occurred at passive crossings next to a road. In 4% of encounters the pedestrian reported that they crossed via the road crossing, rather than using a pedestrian crossing.

Decision made

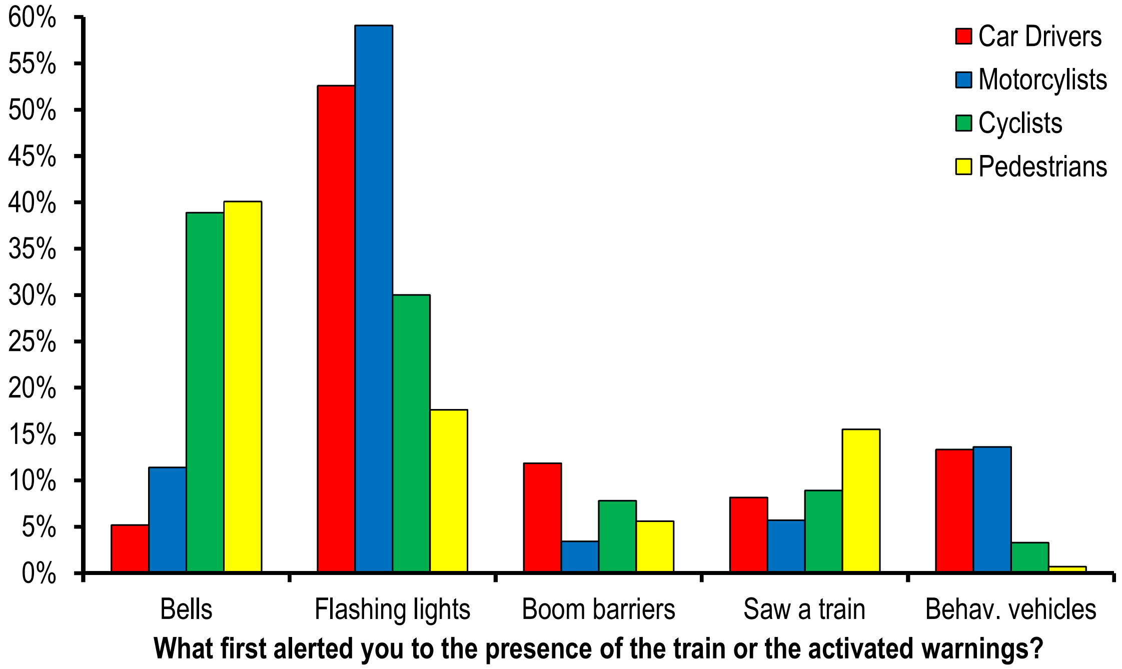
The decisions made at RLXs varied significantly between road user groups, $\chi^2(3) = 40.39$, $p < .0005$. In all groups, most participants opted to stop completely at the crossing (drivers 89%; motorcyclists 85%; cyclists 80%; pedestrians 73%). However, pedestrians were significantly more likely than other road users to speed up in order to cross before the train (drivers 2%; motorcyclists 3%; cyclists 2%; pedestrians 17%). A minority of road users indicated that they slowed down (drivers 7%; motorcyclists 8%; cyclists 11%; pedestrians 4%) or proceeded through the crossing without changing speed (drivers 2%; motorcyclists 3%; cyclists 7%; pedestrians 4%).

Cue identification

Participants were required to report the cue that first alerted them to the presence of a train and/or the activated warnings, with 11 cues reported: advisory signs leading up to the crossing; painted road markings leading up to the crossing; signs at the railway crossing; bells; flashing lights; boom barriers; seeing a train; hearing a train; pedestrian barriers or gates; behaviour of pedestrians or cyclists; and behaviour of other vehicles. Six cues were endorsed by fewer than 4% of respondents and were not analysed further. Overall the most commonly-reported cues were flashing lights (40%), bells (25%), seeing a train (10%), behaviour of other vehicles (8%) and boom barriers (7%).

The relative importance of cue type varied significantly between road user groups. As shown in Fig. 2, motorised road users relied more on the visual cues of flashing lights, $\chi^2(3) = 57.20$, $p < .0005$, and the behaviour of other vehicles, $\chi^2(3) = 23.63$, $p < .0005$. In contrast, non-motorised road users were more likely to use the sound of bells ringing as a cue, $\chi^2(3) = 63.42$, $p < .0005$. There were no between-groups differences in the cues of seeing a train or boom barriers.

Figure 2. Differences in cue identification across road user groups

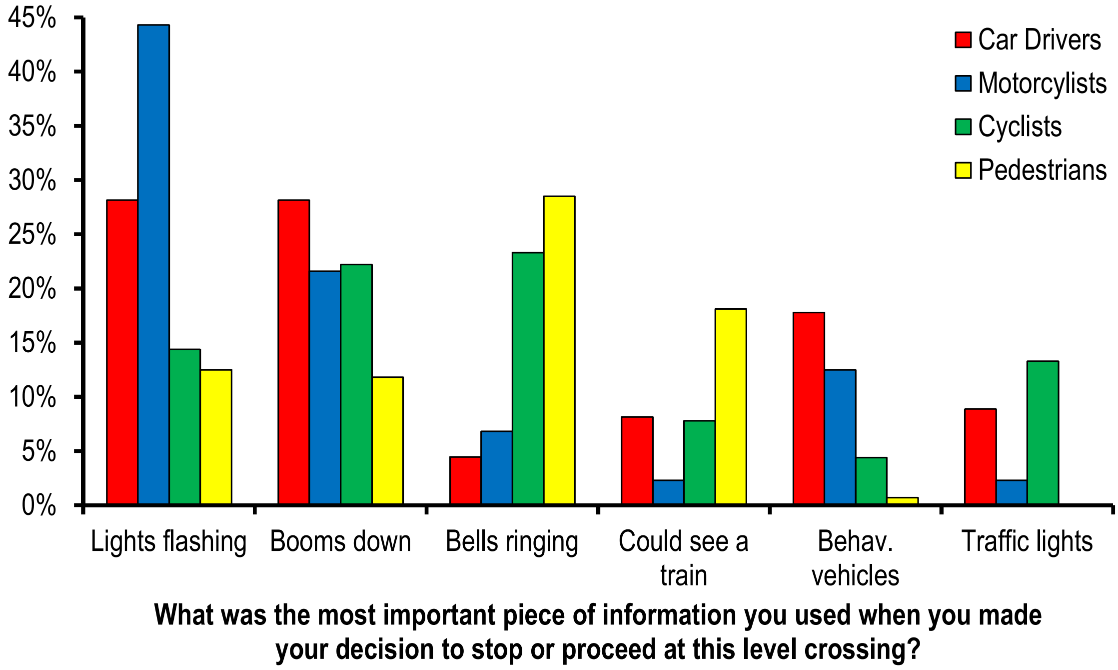


Information integration

Information integration refers to the most important piece of information used to make the decision to stop, slow down or proceed at the RLX. Options included: signs at the RLX; advance warning signs; painted road markings; lights were flashing; lights were not flashing; booms were down/descending; booms were up/ascending; bells were ringing; bells were not ringing; sight distance along tracks; seeing a train; not seeing a train; hearing a train; not hearing a train; behaviour of other vehicles; behaviour of cyclists or pedestrians; traffic lights; length of time signals had been activated; pedestrian gates were open/opening; pedestrian gates were closed/closing; and other. Of these options, 13 were endorsed by fewer than 4% of participants. Overall, the most important information reported was the lights flashing (25%), booms down/ descending (21%), bells ringing (16%), seeing a train (9%), behaviour of other vehicles (9%) and traffic lights (6%).

Again, the importance of different of information varied between groups (see Fig. 3). Although lights flashing emerged as the most important information overall, this was largely due to the fact that motorcyclists relied on flashing lights more than other road users, $\chi^2(3) = 36.52$, $p < .0005$. Car drivers were the most likely to nominate the booms being down/descending, $\chi^2(3) = 11.66$, $p = .009$, and the behaviour of other vehicles, $\chi^2(3) = 29.46$, $p < .0005$, as the most important information used in their decision. Traffic lights were more commonly reported as the most important information by cyclists and car drivers, compared to motorcyclists and pedestrians, $\chi^2(3) = 22.43$, $p < .0005$. Pedestrians and cyclists were more likely than other road users to nominate the bells ringing as their most important piece of information, $\chi^2(3) = 38.65$, $p < .0005$. Pedestrians were the most likely to nominate seeing a train as the most important information, $\chi^2(3) = 17.51$, $p = .001$.

Figure 3. Differences in information integration across road user groups



Influencing factors

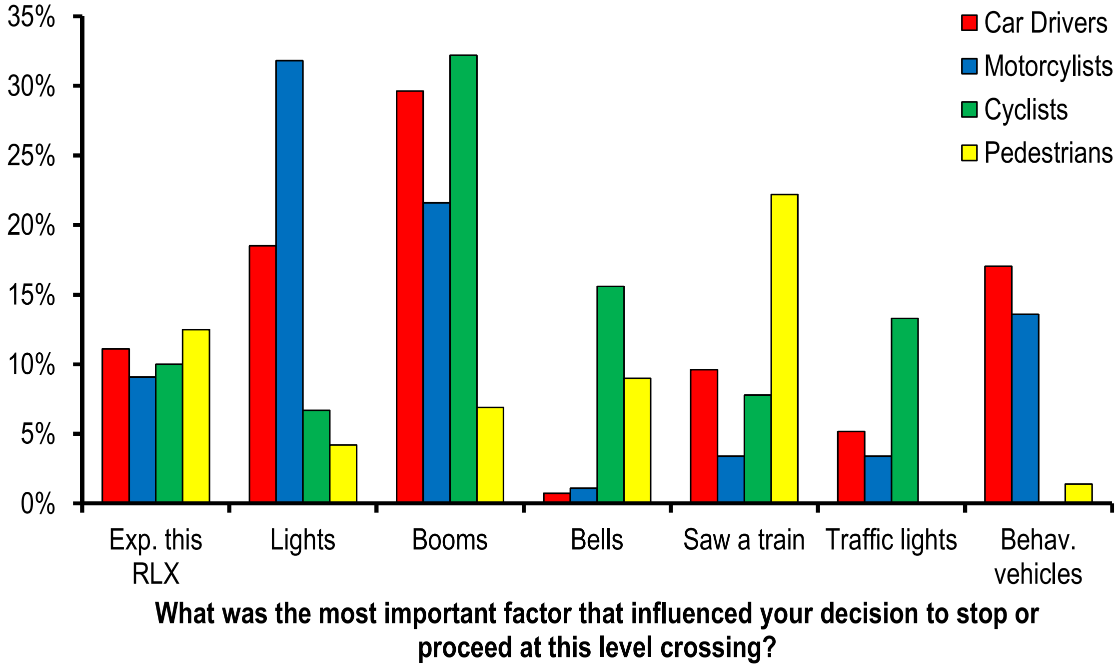
Influencing factors refers to the various factors that influenced the participant's decision to stop, slow down or proceed at the crossing. In some cases these factors may directly relate to specific pieces of information such as flashing lights or boom gates, but in other cases they may be more general factors such as time pressure or prior experience with RLXs.

The influencing factors reported by participants were: presence or operation of boom barriers (56%); presence or operation of bells (47%); experience with this crossing (44%); presence or operation of flashing lights (41%); experience at other crossings (27%); behaviour of other vehicles (27%); seeing a train (27%); traffic lights (16%); signs at the crossing (14%); hearing a train (13%); presence or operation of pedestrian gates (9%); sight distance along the tracks (8%); weather (8%); not seeing a train (6%); road condition (6%); concerned about what other people would think (6%); concerned about being fined for traffic violations (6%); behaviour of pedestrians or cyclists (6%); time pressure (5%); not hearing a train (4%); and the condition of the train tracks (3%).

Of these 21 factors, three (road condition, tracks condition, not hearing a train) were not nominated as the most important factor by any participants and 11 were nominated as most important by fewer than 4% of participants. The factors reported as being the overall most important factors influencing participants' decisions at RLXs were: presence or operation of boom barriers (23%); presence or operation of flashing lights (15%); seeing a train (11%); experience at this crossing (11%); behaviour of other vehicles (8%); presence or operation of bells (7%); and traffic lights (5%).

Prior experience at this crossing was the only factor that did not differ in terms of its relative importance across road user groups (see Fig. 4). The presence of boom barriers was more important to cyclists and car drivers than motorcyclists or pedestrians, $\chi^2(3) = 28.75$, $p < .0005$. The presence of flashing lights was again more important to motorcyclists than other road users, especially non-motorised road users, $\chi^2(3) = 40.55$, $p < .0005$. Motorised road users were more likely than non-motorised road users to report behaviour of other vehicles as the most influential factor, $\chi^2(3) = 35.15$, $p < .0005$. In contrast, non-motorised users were more likely than motorised road users to report the presence of bells as most important, $\chi^2(3) = 25.03$, $p < .0005$. Pedestrians were the most likely to report seeing a train as the most influential factor, $\chi^2(3) = 23.12$, $p < .0005$, while cyclists were the most likely to report traffic lights as the most influential factor, $\chi^2(3) = 21.18$, $p < .0005$.

Figure 4. Differences in influencing factors across road user groups



Although there are similar patterns between the results for information integration and influencing factors, motorcyclists were the only group for which the most important piece of information was also the factor that most influenced their decision (i.e., flashing lights at the crossing). For car drivers, boom barriers were reported equally as often as flashing lights as the most important piece of information, but the boom barriers being down or descending was reported more frequently as the most important factor influencing their decision making at the crossing. Similarly, cyclists most commonly reported the bells ringing as the most important piece of information used to make their decision, but the boom barriers being down or descending was the most important factor that influenced their decision. Finally, pedestrians most frequently reported the bells ringing as the most important piece of information they used, but the sight of a train was more often the most important factor that influenced their decision.

Discussion

RLXs are a complex sociotechnical system in which many different forms of user interact with the road, rail and crossing environment. The current study compared how different types of road users interact with the RLX system and make decisions when the warnings are activated and/or a train is present. A number of important findings emerged from the analysis.

First, the results indicate that most road users make safe decisions in the presence of a train or activated warnings, but that pedestrians are significantly more likely than other road users to cross the tracks in front of a train. This could be, in part, because pedestrians have the ability to do this even when they are at active crossings; it is physically much easier for a pedestrian to circumvent the gates than it is for a car driver to go around boom barriers, for example. It is worth noting that nearly all of the encounters involving motorists occurred at RLXs with boom barriers, whereas a substantial proportion of pedestrian encounters occurred at passive RLXs. As such, it is possible that other road users may show a stronger inclination to cross in front of a train when they are at passive crossings and their path is unimpeded by boom barriers or other vehicles.

Second, the analysis confirms the notion that different road users experience and interact with RLXs differently. Substantial differences were found in the types of information used by the different road users and the factors that are most influential in their decision making processes at RLXs. Visual cues and information, such as flashing lights or the booms descending, were more informative for car drivers and motorcyclists, whereas cyclists and pedestrians were more likely to use auditory information from the bells ringing. Cyclists also used a range of visual information, including the lights and booms, but for pedestrians the predominant source of visual information was the sight of a train itself. Whilst these findings are important for understanding road user behaviour generally at RLXs, the key implication is that a single RLX intervention designed to solve the problem of RLX collisions across road user types may not be sufficient. Rather, the findings indicate that an integrated suite of solutions is likely to be more appropriate and should be tailored to cater for all users of RLXs.

Third, the findings suggest that decision making at RLXs, regardless of road user type, is a function of both the physical crossing environment (e.g., flashing lights, boom gates) and the road user's experience of the crossing in question. This confirms the findings from other research which suggest that expectancy and past experience are key factors in RLX collisions (e.g., Salmon et al., 2013a). An important implication of this finding is that it suggests that modifications to the physical RLX environment alone (e.g., addition of new warnings) will not necessarily prevent RLX collisions and in particular, interventions designed to shape road users expectancy are required.

The current research was limited to frequent RLX users who were car drivers, motorcyclists, cyclists or pedestrians. The omission of truck drivers from the participant sample is notable given the occurrence of a number of high-profile fatal RLX crashes involving heavy vehicles in Victoria during recent years. This omission was due to recruitment difficulties; it proved considerably more difficult to recruit professional drivers for such a time-intensive longitudinal study. As such, further research is planned to examine truck driver behaviour at RLXs, using slightly different methodology that will be more acceptable to this population. In addition, the current study only examined how road users behave in the presence of a train or activated warnings at an RLX, which provides great insight into how road users determine that a train is present. As a complement to this, additional research from the broader project has been designed to assess the converse, which is how road users detect that a train is not present or approaching at an RLX. Overall, the current study provides much-needed preliminary data that can assist both researchers and practitioners in the road and rail safety domains to develop safer and more effective RLX systems.

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Appendix. List of CDM probes/survey questions used

Probe	**Question**	**Answer type**
Incident description	Please describe the situation when you approached the rail level crossing.	Open-ended
	Describe how you knew whether a train was approaching.	Open-ended
	Describe what you did at the rail level crossing and why you did it.	Open-ended
Goal specification	What were your specific goals when you approached this level crossing?	Open-ended
Assessment	What were the conditions at the time of this rail level crossing encounter?	Closed-ended; multiple options allowed
Cue identification	What first alerted you to the presence of the train or the activated warnings?	Closed-ended; one option allowed
Situation awareness	What information did you use when you made your decision to stop or proceed at this level crossing?	Closed-ended; multiple options allowed
Information integration	What was the most important piece of information you used when you made your decision to stop or proceed at this level crossing?	Closed-ended; one option allowed
Situation assessment	Was there any other information that would have been useful when making your decision to stop or proceed at this level crossing?	Combined closed- and open-ended
Influencing factors	What factors influenced your decision to stop or proceed at this level crossing?	Closed-ended; multiple options allowed
	What was the most important factor that influenced your decision to stop or proceed at this level crossing?	Closed-ended; one option allowed
Decision making	How much time pressure was involved in making your decision to stop or proceed at this level crossing?	Closed-ended; one option allowed
Mental models	Did you think about the potential consequences of your decision to stop or proceed before you made it?	Closed-ended; one option allowed
Experience	What previous experience or knowledge did you use when you made your decision?	Closed-ended; multiple options allowed
Conceptual	Are there any situations in which your decision would have turned out differently?	Combined closed- and open-ended