An explorative analysis of pedestrian situation awareness at rail level crossings

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Abstract

Pedestrian safety at rail level crossings (RLXs) is a concern for governments and the community. There is sparse published literature, however, that has investigated pedestrian situation awareness when negotiating RLXs. This paper presents the findings from an exploratory study of pedestrian situation awareness at RLXs. Fifteen participants took part in a naturalistic study in which participants walked a pre-defined route in one of three urban environments, each of which incorporated two RLXs. Whilst walking the route participants wore video recording glasses and provided 'think aloud' verbal protocols describing the cognitive processes and decision making underpinning their behaviour. Analysis of the verbal protocols provided during the approach and traversal of the RLX was conducted using content analysis software as well as through manual analysis of the data. The analysis identified that pedestrian situation awareness was most commonly underpinned by concepts such as the 'railway crossing', the 'train' and other 'pedestrians'. Interestingly, concepts such as 'bells', 'flashing lights' and the ‘pedestrian gate' were not prominent. This may reflect that most participants did not encounter the RLX when a train was approaching. However, concepts around checking for the train were prominent suggesting that many pedestrians may not simply rely on automatic warnings, but use their own judgement to make a decision about when it is safe to cross a RLX. Further findings, implications for RLX design, limitations and future research directions will be discussed.

Introduction

Collisions involving pedestrians being struck by trains at rail level crossings (RLXs) are a public safety concern in Australia and internationally. The most recent statistics available show that, in the 10 year period between 2002 and 2011, 92 pedestrians were struck by trains at RLXs in Australia (ATSB, 2012). The majority of these collisions (51) occurred in the state of Victoria, with other states and territories experiencing between zero and 16 collisions over the same time period. In Victoria, collisions between trains and pedestrians at RLXs resulted in 17 fatalities and six serious injuries in the five year period between 2009 and 2013 (TSV, 2014). Further, statistics indicate that reductions in collisions being experienced in relation to motor vehicle-train collisions is not reflected in the pedestrian-train collision rate (ATSB, 2012; Metaxatos & Sririj, 2013; Stefanova et al., 2015). Finally, it has been identified that there is a lack of research into the reasons behind pedestrian-train collisions (e.g. Freeman, Rakotonirainy, Stefanova & McMaster, 2013; Read, Salmon & Lenné, 2013).

Situation awareness, the ability to develop and maintain an understanding of ‘what is going on’, is important to support safe decision making at RLXs (Salmon, Lenné, Young & Walker, 2013). If pedestrians are not aware of important elements in the environment or do not understand the relevance of information and cues, they will be more susceptible to errors or poor decisions. Diminished situation awareness has been implicated in RLX crashes involving drivers (e.g. Office of the Chief Investigator, 2007) and has been emphasised as required to avoid situations of unintentional non-compliance by drivers with RLX warnings (Salmon, Lenné, Young & Walker, 2013). While there is evidence that intentional violations by pedestrians of warnings at RLXs are more prevalent than unintentional errors (Freeman & Rakotonirainy, 2015), situation awareness remains important in cases where pedestrians have chosen to breach the road rules as they may not be aware of important information in the environment which could put them at risk (for example, they may be aware of a train approaching, but not aware that another train is also approaching from the other direction).

While the literature on pedestrian situation awareness and decision making at RLXs is limited, some findings are emerging. Beanland and colleagues (2013) investigated pedestrian, driver, cyclist and motorcyclist decision making at RLXs via a daily survey about RLX encounters, incorporating questions based on the critical decision method probes. Pedestrians most often reported that the bells ringing was their first alert to the presence of a train and that audible warnings were the most important piece of information when deciding whether or not to cross. In addition, pedestrians reported that the sight of a train was the most important factor that influenced their decision to stop or proceed across the RLX. However, for drivers, visual information such as the flashing lights were the most influential factors informing decision making. Compared to other road users (drivers, cyclists, motorcyclists) pedestrians were statistically significantly more likely to report speeding up when the warnings activated to cross before the train arrived at the RLX. These findings reinforce the importance of considering pedestrian decision making at RLXs specifically, rather than relying on findings from studies of drivers.

In another study, the data from Beanland et al.'s (2013) daily survey study were employed to develop decision ladder models to describe and compare decision making processes during compliant and non-compliant encounters with RLXs (Mulvihill, Salmon, Lenné, Beanland & Stanton, 2014). This work compared compliant and non-compliant crossings by pedestrians and found that pedestrians who crossed in a compliant manner were more likely to report having been alerted by the flashing lights than those crossing in a non-compliant manner. Those who crossed in a non-compliant manner were more likely to report they used information about the location of the train in making their decision, suggesting that non-compliant pedestrians go beyond the warnings to gather information regarding the position of the train.

Stefanova and colleagues (2015) conducted focus groups with pedestrians in Brisbane and analysed the factors influencing their decision making based on crossing experiences described by participants. The study found that factors relating to the pedestrian themselves (e.g. their past knowledge and experience) as well as factors associated with the physical environment (e.g. the RLX and station environment), the social environment (e.g. motorised users' behaviour) and the organisational level (e.g. rail traffic planning and procedures which affect train stopping patterns) were influential in determining pedestrian behaviour.

This literature provides an interesting perspective on pedestrian behaviour at RLXs. However, it is notable that the data in all studies was obtained post users negotiating the RLX. An important gap in the literature then is research adopting naturalistic methods to obtain data in-situ whilst pedestrians are engaged in RLX tasks. Using situation awareness as a lens through which to examine pedestrian behaviour enables the use of semi-naturalistic methods, such as concurrent verbal protocols whereby participants 'think aloud' while conducting tasks, to examine cognition at RLXs. Such approaches have previously been applied to understand driver situation awareness at RLXs (e.g. Salmon, Lenné, Young & Walker, 2014) and to investigate pedestrian situation awareness at road intersections (e.g. Salmon, Lenné, Walker, Stanton & Filtness, 2014). However, they have not previously been applied to understand pedestrian situation awareness and decision making at RLXs. The aim of this paper is to explore pedestrian situation awareness at RLXs using semi-naturalistic methods, including concurrent verbal protocols, to identify findings that could be applied to improve pedestrian safety in this context.

Method

Prior to data collection commencing, approval for the research was obtained from the Monash University Human Research Ethics Committee.

Participants

Participants were recruited through a weekly online university newsletter, through pamphlets distributed at local community centres and businesses and via advertisements on social media platforms. Fifteen participants (6 males, 9 females) were recruited to take part in the study (five at each study location). Participants were aged between 19 years and 62 years (M = 34.2 years, SD = 14.2 years).

A paper-based demographic questionnaire was completed by participants. A laptop computer was used to display a training video showing a forward facing view of a pedestrian walking on a footpath in an urban environment to enable the researcher to demonstrate the verbal protocol methodology and enable participants to practice and gain feedback from the researcher.

Three RLX locations in the south-eastern suburbs of Melbourne, Victoria were selected by the researchers and for each, a pre-determined route that incorporated two RLXs (once on each side of the road). The locations were Centre Road in Bentleigh, McKinnon Road in McKinnon and Murrumbeena Road in Murrumbeena. All sites had automatic pedestrian gates and were adjacent to train stations and road RLXs (with flashing lights and boom barriers installed). Figure 1 shows the approach view for one RLX at each study location. The RLX at Bentleigh, in addition to the standard warnings, had red man standing signals for pedestrians (similar to those provided at road crossings but with no green phase, shown in Figure 1 in the deactivated state as no train is approaching).

Centre Road, Bentleigh

McKinnon Road, McKinnon

Murrumbeena Road, Murrumbeena

Figure 1. Images of the approach to three of the RLXs used in the study

The routes were designed to be completed in approximately 20 minutes, given differences in normal walking speeds. Route completion times for Bentleigh were between 10 minutes 35 seconds and 15 minutes 46 seconds; for McKinnon were between 14 minutes 05 seconds and 23 minutes 54 seconds; and for Murrumbeena were between 9 minutes 51 seconds and 15 minutes 05 seconds. All participants wore Imging HD video recording glasses and a microphone and dictaphone to record the forward view and their verbal protocols.

Procedure

Participants met the researcher at a public place near to the study site for which they had been recruited. Participants were provided with an information sheet broadly describing the aims of the research and completed a consent form. Participants were told that the research was investigating pedestrian behaviour in urban environments. Next, participants were provided with instructions on how to provide concurrent verbal protocols and they practised providing concurrent verbal protocols while watching a video recording of a pedestrian's perspective of walking in an urban environment. The researcher provided feedback to the participant regarding the quality of their verbal protocols until it was felt they were able to provide protocols of sufficient quality for the study. Participants were then shown the pre-determined route and asked to memorise it. When participants were comfortable with the verbal protocol procedure and the route the recording equipment was fitted and activated. Participants then negotiated the study route alone whilst providing a continuous verbal protocol. Once participants had completed the route, which was a loop, they met the researcher back at the point of origin.

Data analysis

The verbal protocols were transcribed verbatim using Microsoft Word. The verbal protocols provided by participants relating to the RLX were extracted from the overall dataset. These included verbalisations given on approach to each RLX from either the point at which RLX-related concepts were first mentioned or when the participant had reached the fencing that funnels pedestrians in towards the RLX pedestrian infrastructure. Verbalisations provided during the traverse of the RLX were included in the extracted data set until the participant was at a point where they had exited the RLX. One participant made no verbalisations during the RLX encounters, meaning that the final dataset contained verbalisations from 28 RLX encounters (each of 14 participants traversed two RLXs). In 8 encounters, participants experienced the RLX warnings operate for the approach of a train (a '*train coming*' encounter) and in the remaining 20 the RLX warnings were not activated (a '*no train coming*' encounter). It should be noted that in *no train coming* encounters there may have been a train visible to the participant in the distance).

The verbal protocol data were analysed in two ways. Initially, the text from the transcripts was uploaded into the Leximancer content analysis software which analyses relationships between concepts from an objective perspective using the natural language of the participants. The software uses algorithms to determine the key concepts and their relationships based on position within the text. Secondly, to gain a deeper understanding of the individual concepts and their meaning, the transcripts were reviewed and key concepts coded using NVIVO software. Concepts identified from participants' verbalisations included either references to information in the environment or to actions (physical and cognitive) being undertaken or planned by the participant. For example, the utterance 'Moving over for a pedestrian' was coded as containing an information concept 'pedestrian' and an action concept 'moving over'. Here the natural language of participants was maintained so far as possible, however categorisation was undertaken to classify similar concepts to ensure a coherent data set. For the *train coming* encounters, 267 concepts were identified in the verbal protocols and for the *no train coming* encounters 316 concepts were identified.

Results

Objective analysis

The results from the objective analysis of the data are provided in the concept maps shown in Figures 2 and 3. The figures show concepts mentioned by participants according to the relationships uncovered in the text. The larger the node (circle shown behind the concept name), the more frequent or important the concept was in the text. The shorter the links between nodes, the more closely related the concepts.

Figure 2 shows the concept map for participant verbalisations during *train coming* encounters. It indicates that the concepts 'signal', 'pedestrian', 'crossing', 'train', 'walking' and 'wait' were the most important within the text. The concepts associated with signals (i.e. flashing lights or red man standing signals) are also interesting, with references to looking at signals, checking the signals and having noticed the signal or attention being drawn to them. However, the concept of signal is not linked to the concept of 'train'. It would appear instead that the concepts of 'bells' and the 'gate' were more often associated with the train in pedestrian's situation awareness. Interestingly, the concepts of 'boom' and 'gates' (i.e. boom gates) was relatively frequent in the data, even though boom gates are not intentionally provided as a signal for pedestrians.

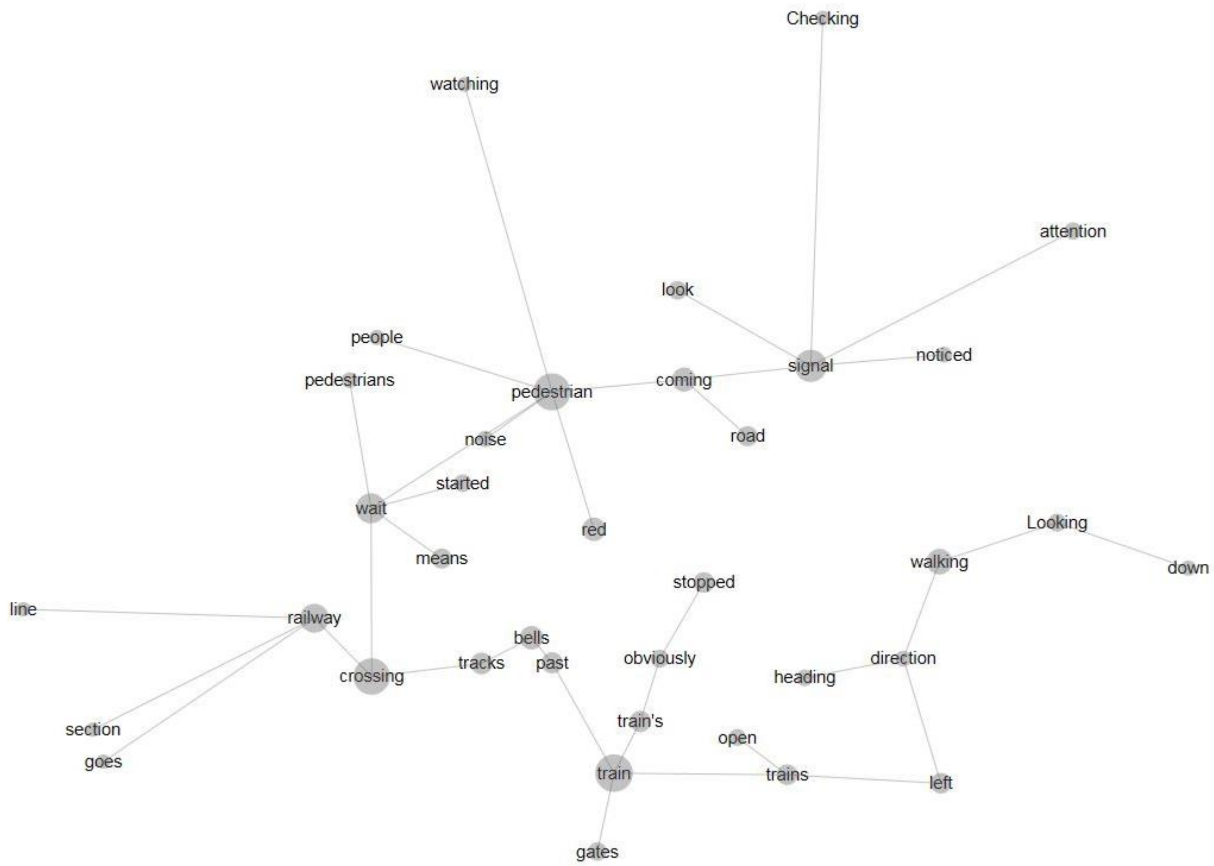

Figure 2. Concept map of pedestrian situation awareness in 'train coming' situations

Figure 3 shows the concept map for data collected during *no train coming* encounters. Here the concepts of 'railway', 'crossing', 'checking', 'check', 'trains' and 'coming' were most important within the verbalisations. In comparison to Figure 2, there appeared to be more uncertainty in this concept map, with concept such as 'probably', 'caution' and 'sure' being present. Further, in both concept maps checking was generally associated with the signals, however in Figure 3 checking is also associated with whether trains are 'coming' and with 'lights'.

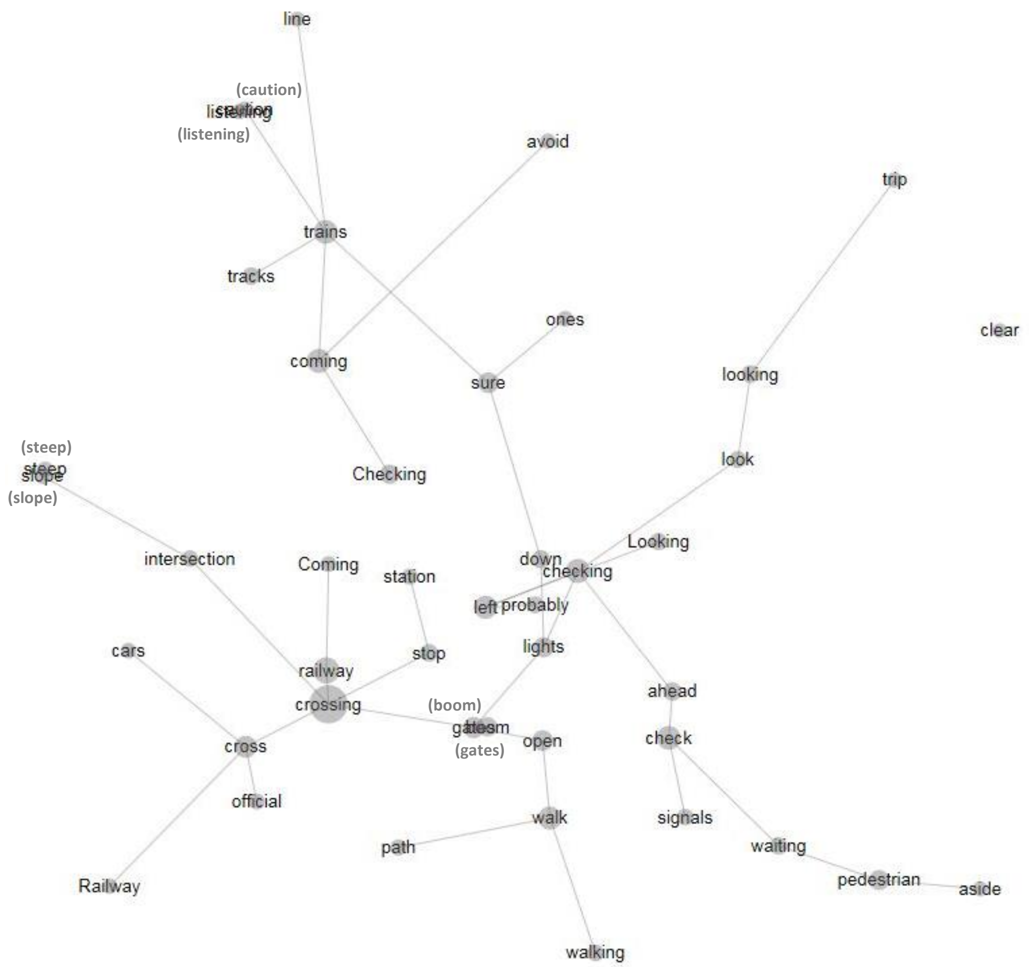

Figure 3. Concept map of pedestrian situation awareness in no train coming situations (text in brackets provided for clarification)

Manual analysis

The results of the manual coding for the key concepts is presented in Table 1 in order of the frequency of the concepts across the verbalisations provided by participants in both *train coming* and *no train coming* conditions. Key concepts were defined as those where there were five or more instances across the total sample. The low percentages show the level of variation present in the concepts identified from the verbal protocols.

Table 1 shows that regardless of whether a train is approaching, participants most often mentioned the train. Secondly, participants mentioned the presence of other pedestrians fairly equally across the conditions. There appears to be some important differences, however, between the verbalisations provided by participants across conditions. For example, for the *no train coming* situation, the concept of 'railway crossing' made up 7.1% of the concepts mentioned, yet it only made up 2.2% of the concepts for the *train coming* condition. Further, participants who did not encounter a train were more likely to mention being 'sure', the 'path', whether it was 'clear' and the 'pedestrian gates'. This is particularly interesting given that the gates are only salient when they close in front of the pedestrian, yet no participant who encountered a train mentioned them.

Overall, the participants appeared to be more concerned with the presence of a train than with the warning signals at the RLX (e.g. boom gates, lights and pedestrian gates). The bells do not appear in Table 1 as they were only present in the verbal protocols four times (all during *train coming* encounters), and as such were not considered to be a key concept.

In relation to participants' verbalisation of their own actions (shown in the second part of Table 1), the most frequent concept overall was 'crossing'. As might be expected, those participants not encountering a train mentioned 'checking' more frequently than those encountering a train. Although there were references to checking made by those in *train coming* situations, this occurred where the train had passed and the participant had mentioned checking for trains as they traversed the RLX. Those in the *train coming* situation were more likely to mentioned 'waiting' although, interestingly, the concept of 'stopping' was mentioned relatively equally across both situations. This reflects that a number of participants stopped at the entry to the RLX and checked for trains, even though the warnings were not activated and gates were open. Overall, the actions describe what might be considered desirable behaviours for pedestrians to engage in when encountering an RLX. For example, checking, looking, stopping, watching and avoiding could all be interpreted as cautious behaviours. There was no mention of hurrying, rushing or trying to beat a train.

Table 1. Concepts from the verbal protocols relating to information in the environment

Concept	Train coming (316 concepts)	No train coming (267 concepts)	Total (583 concepts)
Information in the environment			
Train	7% (N = 22)	7.5% (N = 20)	7.2% (N = 42)
(Other) pedestrian	4.7% (N = 15)	4.5% (N = 12)	4.6% (N = 27)
Railway crossing	2.2% (N = 7)	7.1% (N = 19)	4.5% (N = 26)
Railway tracks	2.8% (N = 9)	5.6% (N = 15)	4.1% (N = 24)
Coming	3.2% (N = 10)	3% (N = 8)	3.1% (N = 18)
Left	1.9% (N = 6)	3.7% (N = 10)	2.7% (N = 16)
Right	1.6% (N = 5)	2.6% (N = 7)	2.1% (N = 12)
Sure	0% (N = 0)	3.7% (N = 10)	1.7% (N = 10)
Path	0% (N = 0)	3.4% (N = 9)	1.5% (N = 9)
Clear	0.3% (N = 1)	2.6% (N = 7)	1.4% (N = 8)
Open	0.9% (N = 3)	1.9% (N = 5)	1.4% (N = 8)
Boom gates	1.3% (N = 4)	1.1% (N = 3)	1.2% (N = 7)
Lights	0.6% (N = 2)	1.9% (N = 5)	1.2% (N = 7)
Road	1.6% (N = 5)	0.7% (N = 2)	1.2% (N = 7)
Signals	1.6% (N = 5)	0.7% (N = 2)	1.2% (N = 7)
Activated	0.6% (N = 2)	1.5% (N = 4)	1% (N = 6)
Car	0.9% (N = 3)	1.1% (N = 3)	1% (N = 6)
Pedestrian gates	0% (N = 0)	1.9% (N = 5)	0.9% (N = 5)
Direction	0.6% (N = 2)	1.1% (N = 3)	0.9% (N = 5)
Own actions			
Crossing	6.6% (N = 21)	7.1% (N = 19)	6.9% (N = 40)
Checking	2.2% (N = 7)	8.6% (N = 23)	5.1% (N = 30)
Waiting	4.7% (N = 15)	1.1% (N = 3)	3.1% (N = 18)
Looking	2.2% (N = 7)	3.7% (N = 10)	2.9% (N = 17)
Walking	2.2% (N = 7)	2.2% (N = 6)	2.2% (N = 13)
Moving over	0% (N = 0)	3.7% (N = 10)	1.7% (N = 10)
Stopping	1.6% (N = 5)	1.9% (N = 5)	1.7% (N = 10)
Watching	1.3% (N = 4)	1.5% (N = 4)	1.4% (N = 8)
Avoiding	0.6% (N = 2)	1.9% (N = 5)	1% (N = 6)

Discussion

The aim of this paper was to explore pedestrian situation awareness at RLXs to identify findings that could be applied to improve pedestrian safety. The findings have provided a number of insights into pedestrian situation awareness and decision making at RLXs. Firstly, participants mentioned the road warnings (e.g. boom barriers / flashing lights) more often than the bells and pedestrian gates. Potentially these visual warnings are more salient in the environment. Further, if the majority of participants can be assumed to be drivers, they may be habituated to look at the road warnings rather than focussing on the pedestrian warnings. While in the situation where the pedestrian RLX footpath is adjacent to the road this strategy is suitable, there may be negative implications for the fewer number of crossings where there is no adjacent roadway and thus just a pedestrian gate and bells, or no gate at all. If individuals have a schema which directs them to search for flashing lights, the absence of lights at stand-alone pedestrian RLXs may lead them to fail to search for trains.

Secondly, it was interesting to note that the bells were mentioned by participants only four times (all during *train coming* encounters). This is in contrast to what might be expected based on the finding of Beanland and colleagues (2013) that auditory information was the most important information used by pedestrians in their decision making. Potentially, this discrepancy relates to the different study designs employed. In the survey study, participants responded to closed-ended questions which prompted them with a list of cues and information that might have influenced their decision making. In the current study, no prompts were given. The audio recordings clearly indicated that the bells were operational on all *train coming* encounters and it is unlikely that participants were not aware of their onset as all took appropriate action to stop at the RLX prior to the gates closing. Potentially, participants in this study were less likely to mention the bells specifically because they were focused on describing visual cues and information and how these were being used for decision making, rather than auditory information which may potentially be less straightforward to verbalise. If pedestrians process the information about the bells in a skill-based or automatic manner, this may be difficult for them to verbalise.

Additionally, many concepts were associated with other pedestrians and the need to move for, or avoid them. This was present in both *train coming* and *no train coming* situations. There are various potential explanations for this. Pedestrians need to negotiate the space on the path with other pedestrians when they are present and this is potentially a more difficult task when many have stopped to wait at the automatic gate and then all enter the RLX at the same time once the gates open. On the other hand, the prominence of pedestrians in the data could be indicative of a propensity for pedestrians to follow other pedestrians and base their behaviour on that of others at the crossing. This requires further investigation as this following behaviour could heighten the risk of a collision when those being followed choose to violate. In some cases the presence of other pedestrians may be distracting. For example, one participant in the study made multiple remarks regarding another pedestrian who was crossing with a dog. The participant was focussed on the dog as they were concerned about its behaviour being unpredictable. Congestion may also be an issue, especially in busy urban environments. Consideration could be given to increasing the width of the pedestrian paths across RLXs (where practicable) or providing better guidance to reinforce social crossing conventions (i.e. providing arrows on the path indicating to keep to the left).

Finally, it is promising that the concept of ‘train’ was shown to have prominence in pedestrians’ situation awareness networks when encountering RLXs. This aligns with the previous finding that the train was the most important factor influencing pedestrian decision making at RLXs (Beanland, Lenné, Salmon & Stanton, 2013). The train is the hazard in this situation and should be the most important consideration. Interestingly, the fact that the train was mentioned more frequently than the risk controls at RLXs (e.g. bells, pedestrian gates, lights and boom barriers) could be interpreted as meaning that less importance is placed on the warnings than on the position of the train itself.

This can be contrasted with previous findings regarding driver situation awareness which have found that there is a focus on the flashing lights and booms (Beanland, Lenné, Salmon & Stanton, 2013) rather than the train. This may be due to pedestrians being physically closer to the tracks with time to slow and check for trains which is more difficult for drivers to achieve due to their speed and the expectation of continued traffic flow when the RLX warnings are not activated. Given that concepts associated with checking, looking, stopping and watching were prominent in the verbal protocols it could be suggested that in contrast to drivers, pedestrians may not simply rely upon the automatic warnings, but use their own judgement to make a decision about when it is safe to cross a RLX. The focus on checking may also be explained by the fact that the RLX warnings operate only when a train is coming and it is unsafe to cross, but provides no information indicating when it is safe to cross. Pedestrians are used to receiving this information at road intersections (i.e. the ‘green man’). Potentially, implementing a similar approach at RLXs would reduce pedestrian workload. However, this may not be desirable as it could also reduce the cautious behaviours identified in this study. Such potential design changes would require further evaluation and testing.

There are some limitations of the study that should be acknowledged. Firstly, this exploratory study utilised a relatively small sample. Further research should use a larger sample to ensure the full range of crossing behaviour is captured and to enable inferential statistics to be applied. Secondly, as a semi-naturalistic study, the study conditions may not be representative of those that are associated with RLX crashes. This was partly intentional to avoid placing participants at increased risk by introducing time pressures or other factors that are associated with collisions. Further research should consider how to capture naturalistic data on pedestrian situation awareness which can capture situational pressures, such as the need to catch a train. Thirdly and finally, our participants may not be representative of pedestrians who are involved in RLX collisions in urban environments in Australia. Unfortunately, there is no published data on the demographics of pedestrians involved in collisions at Australian RLXs. While it has been suggested that adult males are more likely to be involved in RLX collisions (e.g. Edquist, Hughes & Rudin-Brown, 2011; Freeman, Rakotonirainy, Stefanova & McMaster, 2013; Silla & Luoma, 2012), there are suggestions that school children and people with disabilities are disproportionately represented in fatality databases (Freeman, Rakotonirainy, Stefanova & McMaster, 2013). However, such groups were not observed to be more likely to engage in non-compliant behaviours at RLXs. The present study included adult male participants but did not seek to compare their situation awareness with other participants. Future research with a larger sample size could seek to determine if there are any differences in the cues and information used by this group to make decisions at RLXs. In addition, the improved data collection and analysis systems for pedestrian collisions at RLXs is necessary.

Related to the above, participants may not have behaved as they would usually due to social desirability effects related to their behaviour being recorded. Attempts were made to minimise this through not informing pedestrians of the true focus of the study (i.e. the RLX encounter) and having the participants initiate the walk away from the RLX to enable them to become accustomed to the recording prior to reaching the RLX. Social desirability could be addressed in future research through means such as the use of eye tracking.

Overall, these findings add to a growing body of literature around pedestrian situation awareness and decision making at RLXs. Further research is needed in this area of public safety concern to provide additional insights and recommendations to improve RLX safety.

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